EXECUTIVE SUMARY

1. INTRODUCTION

The National River Conservation Directorate (NRCD), Ministry of Environment and Forests (MoEF), Government of India (GoI) vide letter no. J11022/1/2010 – NRCD – II dated July 14, 2010 assigned a study to Alternate Hydro Energy Centre (AHEC), IIT Roorkee, for "Assessment of Cumulative Impact of Hydropower Projects in Alaknanda- Bhagirathi Basins".

Keeping in view the terms of reference (ToR) of the assignment the entire work was divided into different subject areas. All team members discussed and brain stormed the methodology to be adopted for carrying out the assignment. An inception report was then prepared and submitted to the MoEF vide letter No. AHEC/C-567/ dated Aug 08, 2010 by the Alternate Hydro Energy Centre (AHEC), Indian Institute of Technology Roorkee, Roorkee.

The data required for different subject areas was identified and various organizations/agencies/Government departments were approached for providing the data. In case the data was not available, primary data was collected to meet the requirements of the project. Regular interactive meetings were subsequently held between the team members to discuss the progress and further follow up action and work as and when required. The physiographic map of Alaknanda and Bhagirathi basin is given at figure ES-1.

2 THE REPORT FORMAT

The report has been organized in two volumes containing twelve chapters and their appendices, as detailed in the table below, in addition to an Executive Summary.

Volume	Chapter No.	Title
I	Chapter 1	Introduction
	Chapter 2	Methodology
	Chapter 3	Remote Sensing and GIS studies
	Chapter 4	Geological Studies
	Chapter 5	Seismological Aspects
	Chapter 6	Water Quality, Biodiversity and River Ecology
	Chapter 7	Hydrological Studies
II	Chapter 8	Hydropower Development
	Chapter 9	Impact on Places of Cultural and Religious Importance
	Chapter 10	Hydropower and Stakeholders
	Chapter 11	Cumulative Impact Analysis - Assessment of HPs on Components of Ecosystem
	Chapter 12	Conclusions and Recommendations

Chapter 1 is devoted to defining objectives of the project and describing the Term of Reference (ToR). Chapter 2 briefly discusses the methodology adopted for carrying out the assignment. Chapter wise findings of all studies and recommendations can be summarized as follows:

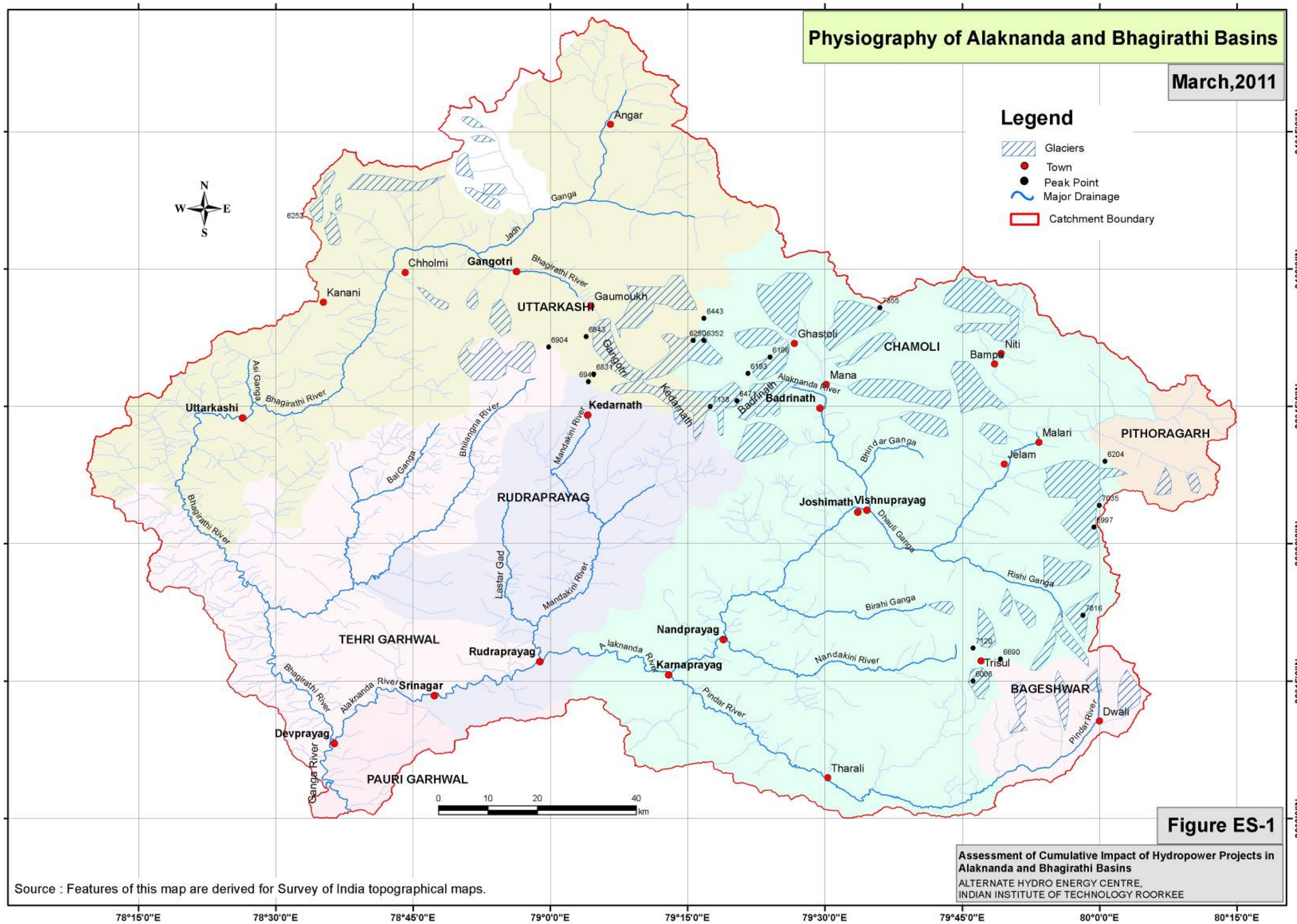


Fig. ES-1: Physiographic map of Alaknanda and Bhagirathi basins

3 REMOTE SENSING AND GIS STUDIES

Remote Sensing (RS) and GIS (Geographical Information System) based analysis has been carried out to provide vital inputs for detailed assessment of cumulative impact of Hydropower Projects in Alaknanda and Bhagirathi basins.

A base map was prepared using topographic maps and satellite images, by including the information about major roads, major rivers, location of major towns and hydropower projects, etc. These maps have been used for various studies as well as for field data collection related with the project. Map showing the forest and protected areas is given at figure ES–2 along with the location of hydropower projects.

The maps prepared using RS and GIS included (a) catchment and sub-catchments of Alaknanda and Bhagirathi basins (b) Drainage map, (c) Soil map and (d) Land cover map etc.

(i) Change detection between the years 2000 and 2009:

Satellite images of year 2000 and 2009 provided extensive information about the land use land cover changes in the span of ten years. A prominent change in this decadal period was the formation of the huge reservoir of Tehri dam. A few other hydropower projects were commissioned before 2009. Forest areas have undergone only marginal changes. However, statistical comparison of land use in 2000 and 2009 could not be made due to constraints of satellite data. Since the satellite data procured was of different seasons (May to October for year 2000 and October for year 2009), comparison should be viewed with this limitation in mind.

(ii) Urban sprawl analysis of (a) Srinagar (b) Tehri (c) Uttarkashi (d) Gopeshwar and (e) Joshimath towns lying in the catchment area was carried out.

(iii) Assessment of land use land cover changes in the vicinity of selected hydropower power project

Area of influence of hydropower projects was delineated along the river on the basis of subjective assessment of the possible impact of HP on the surroundings for the following projects: (a) Bhilangna (b) Maneri Bhali-I and Maneri Bhali-II (c) Alaknanda (d) Tehri Stage-I and Tehri Stage-II (e) Srinagar (f) Rajwakti (g) Phata-Bhyang, and (h) Deval.

On the basis of the experience gained in this study, it is recommended that detailed RS & GIS studies be carried out at periodic intervals (say every 3 to 5 years) to monitor changes and to take appropriate steps to mitigate any future adverse effects of hydropower projects in the area. These are discussed in Chapter 3.

4 GEOLOGICAL STUDIES

Chapter 4 deals with geological studies carried out in the area. Major inferences of geological studies are as follows:

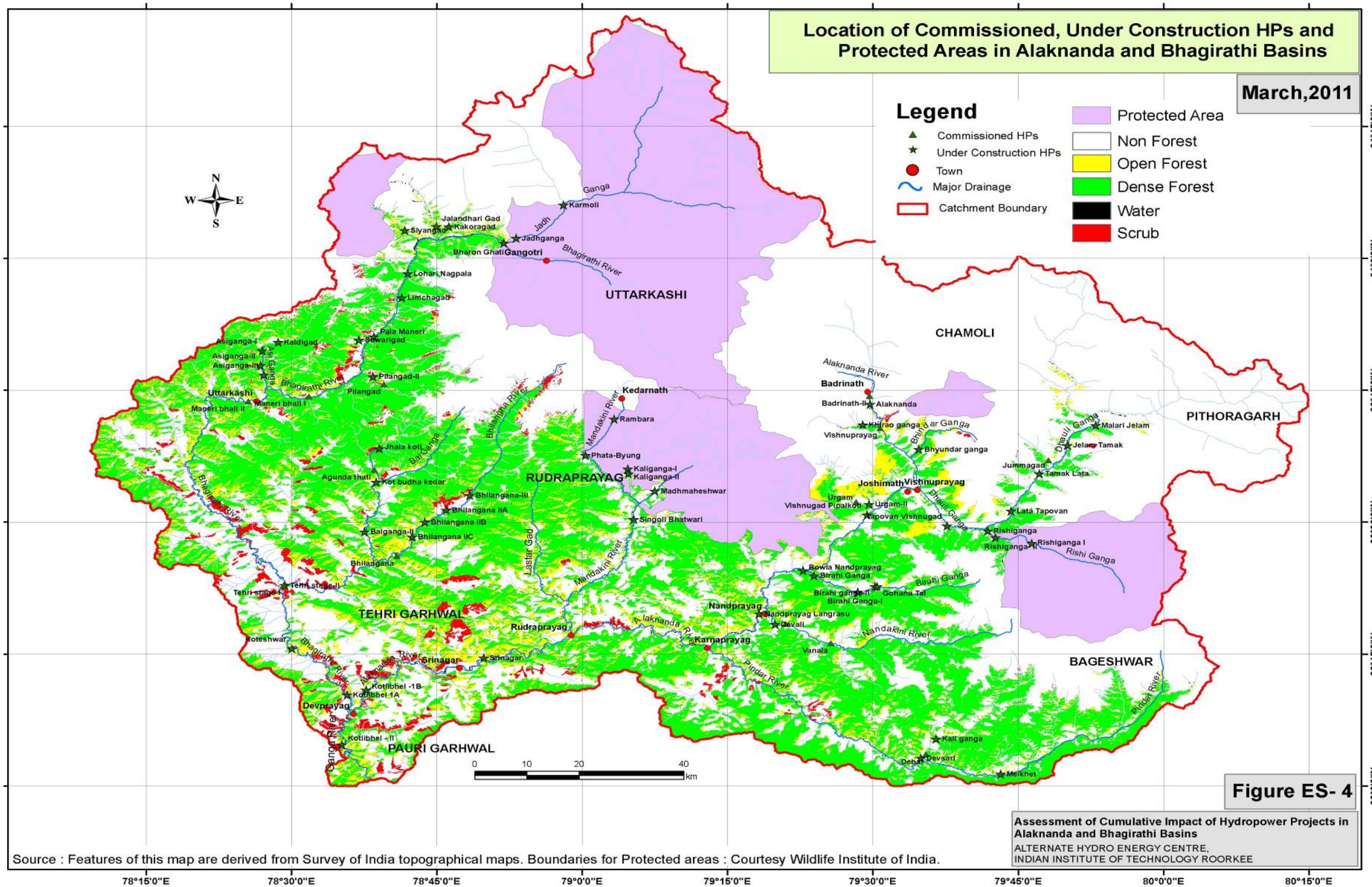


Fig. ES-2: Location of Commissioned, Under Construction hydropower projects and Protected Areas

(i) There is no perceptible impact of HPs on geotectonics of the area, neither individually nor cumulatively.

(ii) The fluvial environment is changed by the construction of dam/barrage into a stagnant, low kinetic energy, relatively deeper water environment just behind (upstream) the dam/barrage and shallow running water downstream. The valley slopes on upstream side are submerged and on downstream side are exposed. This local change in environment may lead to destabilization of critically stable slopes, change in sedimentation pattern and change in the ecosystem. The initial discrete, shallow landslides in the rim area are expected to stabilize in about 5 to 10 years.

(iii) The HPs have only local area effect and shall have no impact on glaciers which have their locales on high altitudes, and far away and upstream of the HPs.

Recommendations on the basis of geological studies carried out in the area can be summarized as follows :

At the planning and execution stages of hydropower projects detailed geo-scientific studies be carried out to identify problematic areas of earth mass failure, and, site-specific, cost effective measures such as plantation on slope, re-grading of slope, shotcreting, grouting, anchoring, retaining and supporting walls, etc. along with proper drainage (surface and subsurface) measures to avoid saturation of earth mass, be taken up. Details of geological studies which should be carried out for each project are discussed in chapter 4.

Alaknanda and Bhagirathi basins witnessed dramatic changes in landform and river valley development in response to climate change in the last about 20,000 years. Available information in the form of pollen studies and archaeological data indicates that humans were living in the area for at least the last 3000 years. Human population increased with time and anthropogenic activity of different types, namely habitation, agriculture, water requirement started having some impact on the nature. Present-day changes taking place in Alaknanda and Bhagirathi basins are partly natural and partly anthropogenic. It is not always easy to assess what fraction of changes can be assigned to human activity. In order to assess the impact of hydropower projects in Alaknanda and Bhagirathi basins, it is important to assess changes caused by natural processes and changes due to other anthropogenic activity in the area. Details of geological studies are discussed in chapter 4.

5 SEISMOLOGICAL ASPECTS

It is imperative that all hydropower projects in Alaknanda and Bhagirathi basins have a firm design so that these can withstand future earthquakes. For this a multi pronged strategy was adopted. Seismological studies pertaining to Alaknanda and Bhagirathi basins had the following objectives:

a. Study of available historical, reported and recorded earthquakes, seismo tectonic models and assessment of cumulative impact of existing, proposed and under construction large hydropower projects in Alaknanda and Bhagirathi basins in terms of seismic design parameters i.e., Deterministic seismic hazard analysis (DSHA).

b. Study the possibility and prediction of Reservoir Induced Seismicity (RIS) associated with Hydropower Projects.
c. Study of pattern of local seismicity on the basis of locally monitored earthquakes.

Seismo tectonics was studied for a wide area, 6°×6°, with each project at its center. The earthquake catalogue containing location, time of occurrence and size of earthquakes (provided by India Meteorological Department, New Delhi), together with tectonic data, as per GSI atlas (2000), was used for this study. The DSHA, i.e., the design part, has been addressed by adopting a set of procedures that are being practiced worldwide and are constrained by present data technology and wisdom. The approach adopted was as follows: seismic design of each project studied was based on local and regional geological conditions, earthquake occurrences and seismo tectonic set up of the region. Structures designed as per recommended design earthquake parameters for this region would generally prevent loss of human life and only repairable damage could occur. Maximum Considered Earthquake (MCE) was evaluated on the basis of above studies using the deterministic approach and the same was recommended for consideration in design of structures, (hydropower projects).

Major findings of seismic studies can be summarized as follows:

(a) Seismic activity within the study area is high and recent earthquakes with maximum magnitude 6.8 have occurred within the Alaknanda and Bhagirathi basins. Noteworthy earthquakes in the region are the Uttarkashi earthquake of October 20, 1991 (M=6.4) and Chamoli earthquake of 27 March 1999 (M=6.8). In view of the prevailing seismicity and seismotectonic models, standard procedures were adopted to estimate ground motions (conservatively) for various project sites for design purpose. It is rational to believe that dams can withstand future earthquakes with the present design.

(b) Deployment of a seismological network around Tehri region since 1994 provided useful information on the pattern of local seismicity in the vicinity of proposed hydropower projects. The region north of the MCT, where most proposed hydropower project sites are located, both along Alakananda and Bhagirathi rivers, exhibit a low level of contemporary local seismicity. No change in the pattern of local seismicity, within 40 km of Tehri dam, has been observed after filling of Tehri reservoir.

(c) The maximum occurrence probabilities estimated for various hydropower project sites falling in Alakhnanda – Bhagirathi basins have values less than that of critical probability. In view of this the cumulative risk of occurrence of reservoir induced earthquakes, as a random event, seems to be very unlikely. Most dam sites in the Garhwal Lesser Himalaya fall in a compressional tectonic environment, and based on available case histories of Bhakra, Mangla, Tarbela and Tehri from the Himalayan region on RIS, it can be concluded that chances of occurrence of reservoir induced seismicity are minimal.

On the basis of seismic studies which have been carried out for the Alaknanda and Bhagirathi basins, the following recommendations are made which may be kept in view while new hydropower projects are constructed in the area.

(a) As geological and seismotectonic conditions are highly variable in the study area no generalized design parameters can be suggested for hydropower projects. Wherever a new hydropower project is planned or established it is recommended that a detailed site specific geological, seismological and seismotectonic study be carried out for evaluation of design earthquake parameters, as is the normal practice.

6 WATER QUALITY, BIODIVERSITY AND RIVER ECOLOGY

In order to assess the impact of hydropower projects and water quality parameters were analyzed. These were for six commissioned HP, 27 under construction and seven proposed HPs including 19 samples for creating baseline water quality data. Based upon the analysis of data it was concluded that only three parameters i.e. DO, BOD and fecal coliform undergo minor change within standard limits of class A quality water. Therefore the impact of hydropower projects on water quality is not significant. These observations are further validated by the analysis of CPCB data of precious year, water quality report on Alaknanda River 2009 and EIA report 2007 of NTPC.

Environmental flows are required for river continuum, maintaining aquatic biodiversity, recharging groundwater, supporting livelihood, maintaining sediment movement and maintaining the integrity of river ecosystems. The major biotic components of Alaknanda-Bhagirtahi basin up to Deoprayag are periphyton, phytoplankton, macrophytes, zooplankton, benthic macroinvertebrates, fish and fish otter. It has been an established fact that these freshwater organisms have specific hydrological requirements for sustaining their life. Some organisms need fast water current, others need moderate, while few organisms may thrive in slow water current. A large number the hydropower projects in different stages of implementation in Alaknanda-Bhagirtahi basin will have adverse impact on natural hydrology (water depth and velocity) of the riverine ecosystems. Therefore, it was necessary to assess hydrological requirements of major aquatic biotic components (macroinvertebrates, fish and fish otter), so that an optimum environmental flow can be set for maintaining biodiversity and integrity of the ecosystem. The entire stretch of the river basin of Alaknanda –Bhagirathi has been divided into three zones/classes –Epirhithron, Metarhithron and Hyporhithron, based on various ecological indicators, fish, water velocity, composition of riverbed substratum, and presence of number of rapids, pools and cascades. Hydrological variation plays a major part in structuring biotic diversity within river ecosystems as it controls key habitat conditions within the river channel and hyporheic zones. On the basis of primary and secondary data related with analysis of natural habitat and various life stages of aquatic organisms, assessment of hydrological requirements have been made. Three flow groups (water velocity > 100 $cm.sec^{-1}$, 50-100 $cm.sec^{-1}$ and 25-50 $cm.sec^{-1}$) of aquatic organisms have been identified, which need minimum hydraulic mean depth of 15cm, 20-30cm and 30-

50cm, respectively, for their survival. Therefore, environmental flows have been recommended based on the hydrological requirements of aquatic organisms. This holistic approach is based on the ecosystem requirement for maintaining its integrity. A map showing the fish zones is given at figure ES-3.

A host of suggestions have been made for maintaining health of the downstream ecosystem/by passed section of the river and restoration of goods and services provided by the ecosystem through protection of the freshwater biodiversity. A comprehensive biological monitoring programme by every project authority under the supervision of an environmental biologist, coordinated by a central agency has been recommended for adaptive management of the aquatic biodiversity and integrity of the downstream river ecosystems of Alaknanda and Bhagirathi basin up to Deoprayag. These are discussed in detail in chapter 6.

7 HYDROLOGY

Most rivers in the study area are perennial and receive flow from surface runoff, snowmelt, and baseflow. The rivers flow through deep incised valleys are carry large sediment. Due to steep slopes and large volumes of flow, most rivers have huge hydropower potential.

Long time series of rainfall and flow data were available at limited sites and these were used to estimate streamflows at required dependabilities at the sites of hydropower projects and places of religious and cultural importance. A line diagram showing the hydropower projects is given at figure ES-4.

7.1 Assessment of Environmental Flow Requirement (EFR)

Increasing withdrawal of water for uses such as hydropower generation, irrigation, domestic and industrial has reduced the flow in vast segments of many rivers. To maintain the rivers and their ecosystems in good health, certain quantity of water should always flow in rivers. The concept of Environmental Flow (EF) has been developed to minimize the impact of large withdrawals on the river ecosystem and the uses to which the river is put. Environmental flows denotes the quantity, timing, duration, frequency and quality of water flows required to sustain freshwater, estuarine, and near share ecosystems and the human livelihoods and well being that depend on them. A number of methods such as Hydrological index method (e.g. Look-up tables, EMC-FDC approach) and Hydraulic habitat analysis, e.g. EMC HMD approach, etc were employed in this study to estimate EFR at various representative project sites and places of religious and cultural locations.

The minimum flow given by World Commission of Dam and 75% of low flow based on Q95 along with the actual minimum required based on Environmental Management Class (EMC)-Hydraulic Mean Depth (HMD) have been presented. Maximum and minimum values from these methods/approaches have been presented as the range environmental flows.

A major handicap in this study is that the measured river cross sections and velocity of flows were available at limited locations. Hence, the interpolated values of these were used to derive the required parameters such as the hydraulic mean depth

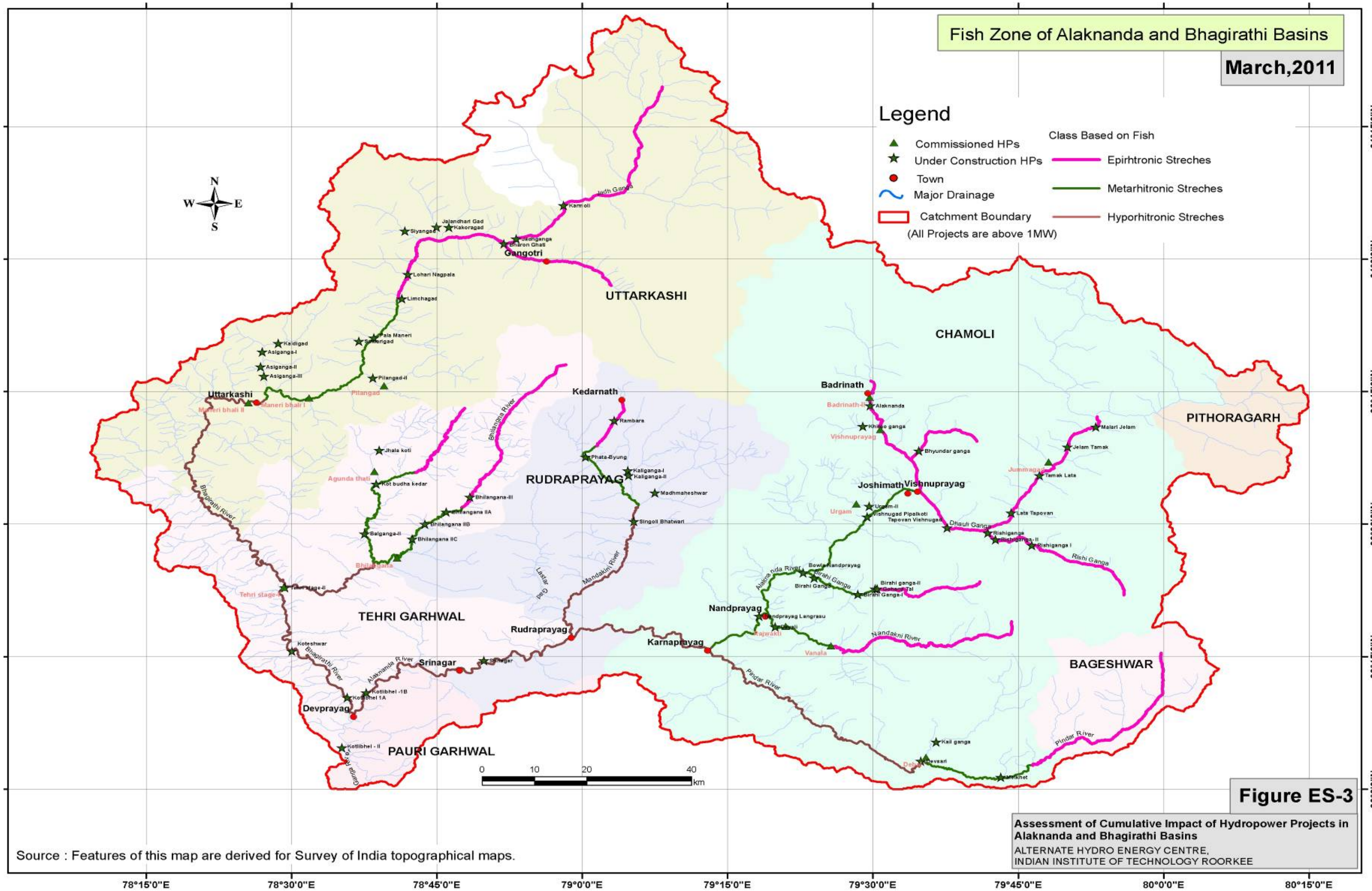


Fig. ES-3: Fish Zone of Alaknanda and Bhagirathi Basins

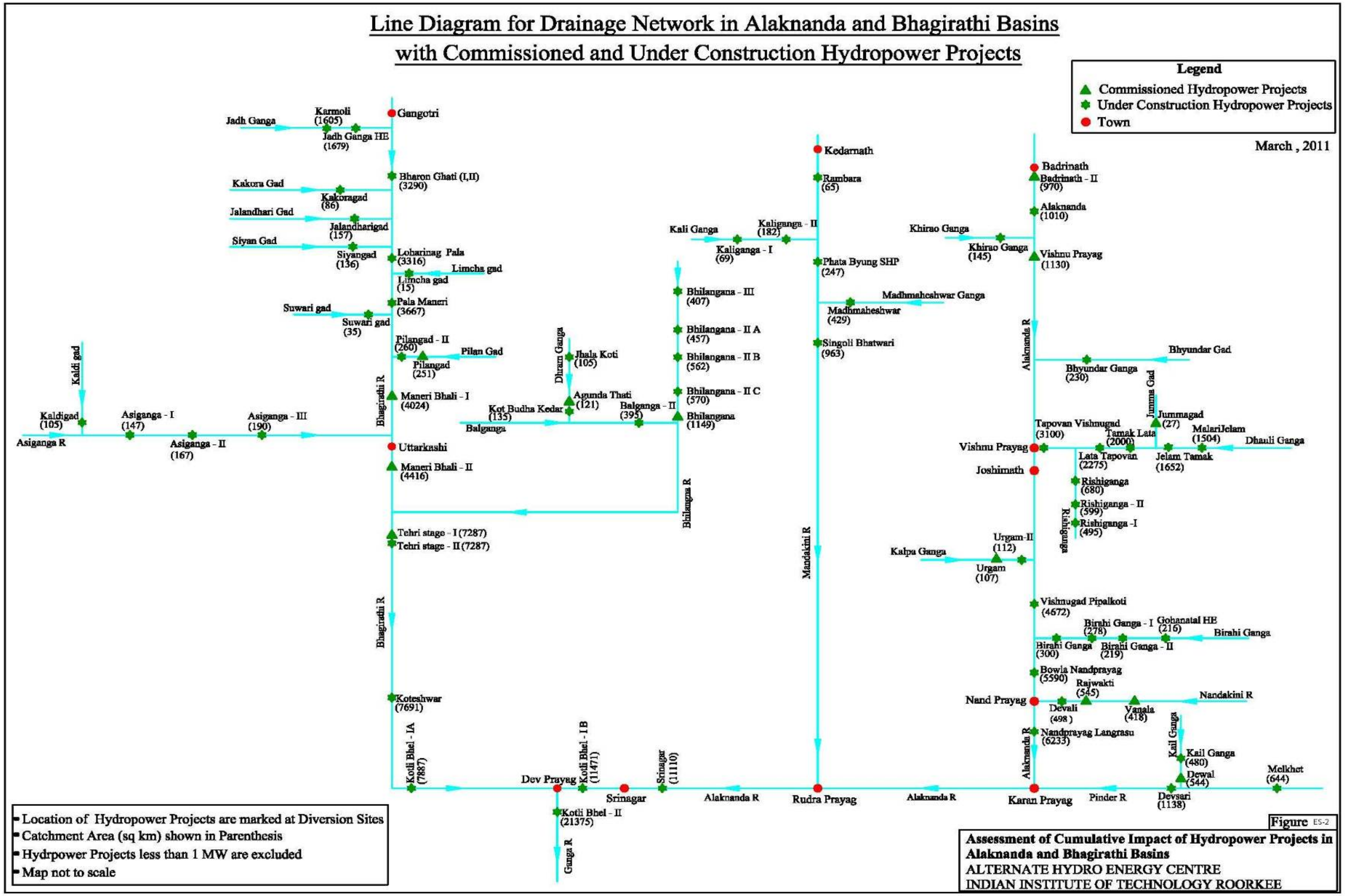


Fig. ES-4: Line Diagram for Drainage Network in Alaknanda and Bhagirathi Basins with hydropower projects at different locations.

Actually, EFR critically depends upon the development stage of the region and what the society expects from the river. There are methods, such as the Building Block Method, which can consider a wide range of indicators as well as the opinion of experts and stakeholders. But these type of methods require much more data, time and manpower and other resources and, therefore, could not be applied in this study. In view of this, the environmental flow values computed in this study may be considered only indicative values.

7.2 Impact on Springs, Drinking Water and Irrigation

Due to limitations of data, ground water modelling and impacts of the projects on springs could not be assessed. A map showing location of major springs and HPs has been prepared. If the area through which the tunnel is laid has springs, they are likely to be impacted. The impact, if any, is always localised. Detailed data should be collected so that this aspect could be studied in future.

i. During tunnelling, ground water or water from springs may seep in to the tunnel unless through prior geological investigations, the springs and the ground water passages are avoided.
ii. In the basins, the main rivers flow in the valley and so are not used for irrigation. The streams and tributaries pass through the catchment and could be available for irrigating agricultural/horticultural fields. The impact of HPs on irrigation is generally positive and localised.
iii. In case of large storage projects, ground water recharge takes place at higher rates and the recharge of springs takes place. The impact is assessed as positive and localised.
iv. With increased availability of ground water, storage of water and recharging of springs, the impact on irrigation is positive.

7.3 Soil Erosion and Sedimentation

i. There is no impact of HPs on soil erosion from the catchment. However, there is impact of soil erosion on the sediment deposit on the bed of the reservoir of a HP.
ii. The reservoirs store water and the sediment settles down at the bottom. Thus the sediment load in the river downstream of the project alters. Thus the impact on sediment is cumulative.
iii. The sediment is transported from the catchment to the rivers and is trapped at the dam. In RoR projects, the bed is flushed and sediment does not pose much problem. In storage based projects, the sediment collects on the bed and causes problems. Higher channel erosion takes place downstream of the project.

Due to HPs, the flow regime alters completely even though the project may reduce stream flow variability. The impact is cumulative as the projects downstream also get affected.

In RoR projects, there is considerable length of the river downstream of the barrage which is bypassed and water is discharged into the river only after the powerhouse. An adverse impact of the HPs is by way of fragmentation of the river which prevents migration of aquatic life across the dam. Barriers prevent migration of fish across the project both ways, i.e., from downstream to upstream and vice versa and has effect on their survival and sustainability. This fragmentation, if unattended can be very harmful for the aquatic life.

8 HYDROPOWER DEVELOPMENT

The State of Uttarakhand since its creation, has been witnessing a sharp increase in energy demand. The State is able to meet only 52 percent of its power needs from its own resources. The State plans to harness hydro-power potential and improves high voltage transmission systems in the State. Uttarakhand has a hydropower potential of the order of 20,000 MW against which only about 3,164 MW has been harnessed.

Legal Framework for water resources development puts water as the state subject. However, inter-state river basins and adjudication of disputes related to waters of inter-state rivers or river valleys are dealt by the central Government. To encourage generation of hydropower, the Government of Uttarakhand (GoU) has formulated and implemented policies (October 2002) with the following broad objectives of creation of conducive conditions for encouraging private sector participation, harnessing water resources in an environment friendly manner, meeting energy demand of the state/country, promotion of the overall development of the region and generation of revenue from hydro resources. The policy for Small Hydro Projects (SHP), up to 25 MW, was later revised in January 2008, to include power projects based on biomass, wind power, solar energy, geothermal power etc. in addition to hydropower.

A capacity of 12,235 MW is under development (at various stages) in state, central and private sector: state sector 2815 MW – 32 projects; Central sector 7302 MW-25 projects; and private sector 2118 MW- 38 projects. Techno-economic clearance needs to be obtained from Central Electricity Authority (CEA) only if the estimated cost of the project exceeds ₹5000 Million (MOU route basis) and ₹25000 Million (if competitive basis) and / or inter-state issues are involved.

Hydropower projects, according to size (installed capacity), are the most frequent form of classification used. Small scale hydropower plants have the same components as large ones. Hydropower projects mainly are run of river (RoR) operating mainly from available flow of the river, storage (Reservoir) and pumped-storage plants.

Water withdrawal and water consumption varies widely. As up and downstream stages require little water, life cycle water use is close to zero for run-of-river hydropower plants. Life-cycle energy payback ratios for well performing hydropower plants reach the highest values of all energy technologies, ranging from 170 to 267 for run-of-river, and from 205 to 280 for reservoirs.

The building of dams/ weirs/ barrages impact fish populations, migrations and other fish movements. Fish ladders and fish lifts can easily but partly restore upstream migration.

Thirteen hydropower sites have been commissioned in the study area till date. Hydropower projects above 1 MW have only been considered in this study. There may be some more sites and those have been excluded. Small hydropower (below 25 MW) sites, which have not been allotted have also not been considered. All allotted sites, i.e. commissioned and under development hydro projects in the area of study have been considered under the study.

Tehri dam is the largest multipurpose project in the study area. Another project in its close vicinity downstream is the Koteshwar HP of 400 MW capacity. Installed capacity of 1422 MW has been developed and 3449 MW (13,620 MU) is under development in Bhagirathi basin as on March 2011. Vishnuprayag project of 400 MW is the first major RoR project commissioned on Alaknanda. Overall, the commissioned hydropower potential of Alaknanda is 429 MW and 3734 MW (15,513 MU) is under development.

Bhagirathi river with a total length of 217 km up to Devprayag, has an average slope of 12.5m per km, whereas Alaknanda river has an average gradient of 15.8m per km in its 224 km length up to Devprayag.

Allotted hydropower projects in both basins indicate that against 13 commissioned hydropower projects with total installed capacity of 1851 MW (7,860 MU), 14 projects of 2,538 MW capacity (10,727 MU) or almost 35% of present capacity are in advanced stage of construction, whereas 42 projects with installed capacity of 4,644 MW (18,516 MU) are at different stages of development. Thus, the present developed hydropower potential is likely to increase by 5 times with the allotted projects (9,033 MW to produce 37,103 MU).

There are 15 projects (2 commissioned, 2 under advance stage of completion, 2 under construction and 9 other stage of development) with storage reservoirs having more than 20 m height (above the river bed level). All of them except Tehri project, basically are run of river with diurnal storage for operating for peak hours during lean flows. A map showing all allotted projects with diversion and submergence of river at figure ES-5.

8.1 River Length Affected:

All types of hydropower development affect rivers. RoR hydro projects in hilly areas divert the water through open or closed channel/tunnel/pipe and use the steep gradient of river, thus reducing the natural discharge in the river in the diverted stretch of the river. On the other hand, storage based hydropower involve a submergence of river stretch. About 31% of the Bhagirathi river length is diverted whereas 39% of the river is submerged. On the other hand, Alaknanda river may have 27% of river length diverted and only 21% submerged. The tributaries of Bhagirathi except Bhilangana do not have any submergence but there is about 53, 19, 40 percent of diversion of Asiganga, Bhilangana and Balganga tributaries.

Analysis of hydropower projects for using river stretch and discharge have been carried out from energy generation point of view and investment on Hydropower. Annual generation per unit of diverted discharge indicating the energy value for diverted quantity of water from the river has been analyzed for all projects. Vishnuprayag project has the highest electricity generation as 32 MU for each cubic m of water against the storage based projects like Kotlibhel 1B and Koteshwar which have the low energy generation from diverted unit discharge as 2.5 MU and 1.8 MU, respectively. Values of annual generation for per m of head available in the river

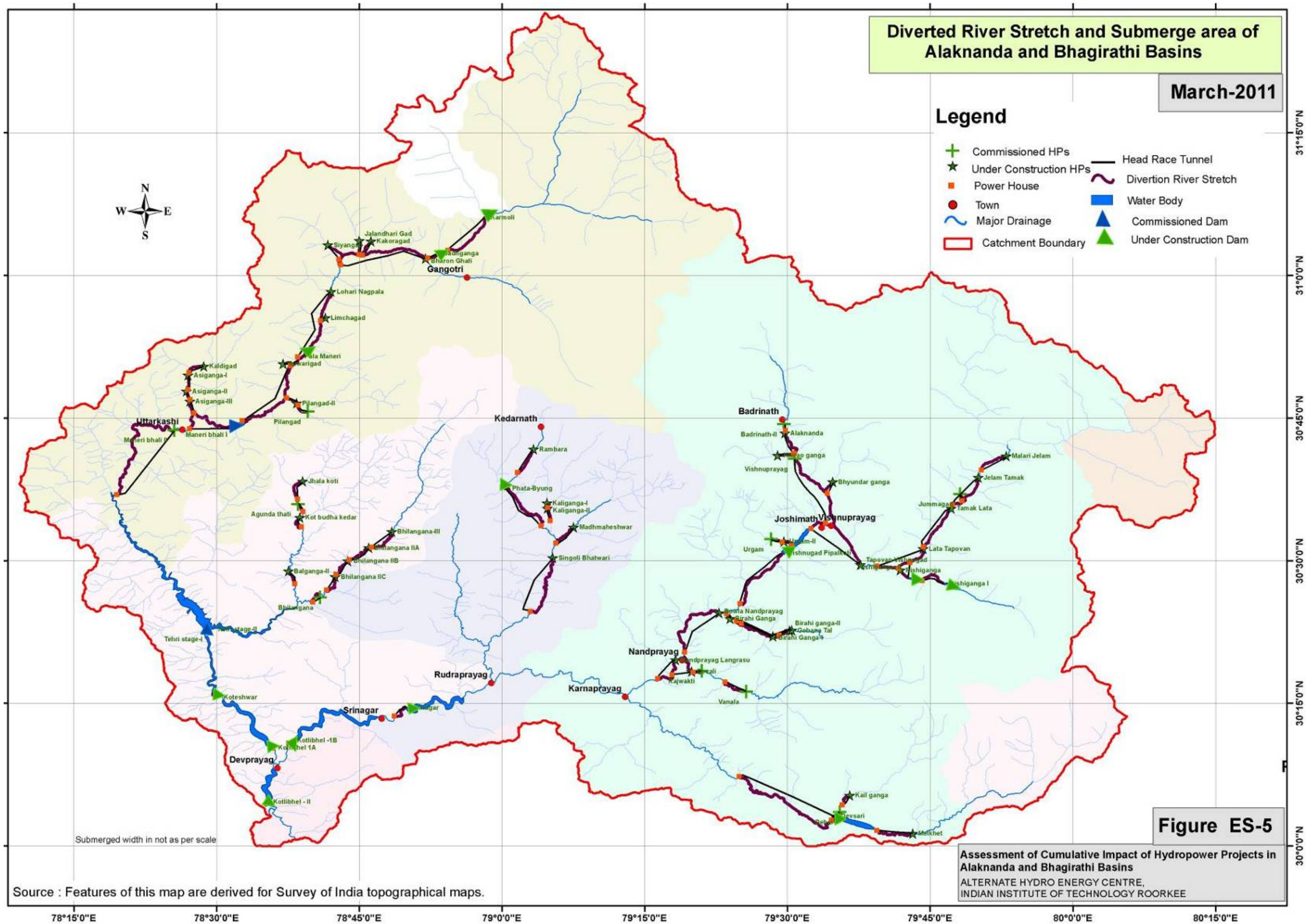


Fig. ES-5: All allotted projects with diversion and submergence of river Alaknanda and Bhagirathi Basins shows that storage based schemes have high electricity generation for each m head, viz. 23 MU for Srinagar and 15 MU Koteshwar, respectively. Small scale hydropower projects have low electricity generation for each unit of head available in the river gradient as they carry low discharge. Power plant utilization factor indicating a high value near to 1 for run of river project like Jumagad and as low as 0.45 and 0.4 for Kotlibhel 1B and Tehri storage projects, respectively,. Storage base project provide base load and are operated accordingly. Annual generation for each m length of river diverted and also ratio of diversion length (water conductor system for hydropower project with length of river stretch diverted) have been analyzed. It may also be seen that water conductor system for a large number of projects are in closed channel/tunnel/pipe. Closed system is useful, beneficial and safe for operation, maintenance, public, loss of land and landscape point of view. Its only disadvantage is that it involves tunneling which may interface with springs and ground water regime.

As per the detailed project reports of all hydropower projects, an investment of ₹406 Billion is planned on all 70 hydropower projects. The state is putting additional investments of about ₹10 Billion towards transmission lines. The break-up of investment in hydropower projects normally has the following cost components viz about 60 -70 % for civil works, about 20-30 % for E&M works, and about 10 % on engineering and implementation.

8.2 Hydropower Performance:

The performance for all projects has been analyzed and presented with high, medium and low performance indicator for five aspects i.e., Annual Generation per MW of Installed capacity; Annual Generation per unit meter Head, Annual Generation per unit discharge (cumec), Annual Generation /River stretch, Investment per unit discharge and Investment per unit Head. To create an overall performance index, weightage for each factor is needed and this requires extensive database and time resource which were limited in this study. This aspect is bit subjective and not attempted in this study. Annual generation for each cumec of discharge used has a very high value of 32 MU for Vishnuprayag project whereas for Koteshwar it is 1.8 MU. Storage based projects have high generation for each m of head available from the river due to large discharge. For Srinagar project, 336 unit of power is generated from each m of diverted river whereas it is 1000 unit for Pilangad small scale hydro project.

8.3 Economic Aspect of Hydropower Generation:

As per the state policy, the power generation from hydropower projects carries a premium on the investment and free power to the state as royalty. This royalty, at the rate of 12% is goes to the revenue of the state government for carrying out development and social welfare activities. The investments in the projects, especially by the private sector which are mainly from the outside of the state, further strengthen the economy of the state and its people by way of development. With a very estimate, @ about 10% of the investment through various activities on the project goes to the state and it brings a sum of ₹9,764 million for ongoing projects and ₹26,949 million for planned projects. Such aspects may be studied in details in due course for building up the database for the country which may be used for overall hydropower development in the country.

8.4 Reduction in Power Generation due to Environmental Flow:

Allocation of water for environmental flow, based on the comprehensive analysis considering hydrologic, hydraulic, morphological, biotic factors, will lead to certain reduced percentage of annual power generation compared to the approved detailed project report of each project. The reduction in annual generation is substantial for several schemes especially the small scale hydro. Exact values of EFR for every single project for implementation can only be established after carrying out the details measurements and consultation with the society.

9 IMPACT ON PLACES OF CULTURAL AND RELIGIOUS IMPORTANCE

Chapter 9 deals with the impact of hydro power projects in the Alaknanda and Bhagirathi valleys on places of religious and cultural importance.

In many cases in India, religion and culture are highly inter-twined and it is difficult to state whether a particular activity falls in the religious or cultural domain. The activities in which the river and/or its water plays a central role include taking a dip in the river (bathing) on auspicious days, shaving the head of an infant (*mundan*), cremation, *shraddha* ceremony etc. Flowing water, which is considered pure, is a pre-requisite for these rituals.

While there is a long history of religious pilgrimage in these basins, in the last decade or so these areas have also acquired a name for non-religious tourism based around water and other adventure sports, trekking, and eco-tourism as well. Fuelled by increasing prosperity, mobility improving infrastructure, and a taste for adventure, the new form of tourism has increased the pace of change in these river basins. Accordingly, though this study was concerned mainly with the historical cultural and religious practices in the area, it has also briefly considered the impact on other activities such as tourism.

The question of 'impact on places of religious and cultural importance' can be framed in a number of ways. In this study, the frame of analysis has focused on three areas:

(i) *Aviral Dhara* or 'uninterrupted flow' of the Ganga;
(ii) Diversion of river from its course and leaving large stretches with little water or dry; and
(iii) Effect of hydro power projects on the purificatory quality of the water.

The data for the study is qualitative, and not quantitative, in nature. This study captures the perceptions of people, using qualitative techniques of data collection based primarily on key informant interviews. Accordingly, key informant interviews were conducted with members of the religious community, business community, academic community, political groupings, staff of power companies and the residents of towns and villages in the basins. The main findings of these studies can be summarized as follows :

(a) The Bhagirathi and Alaknanda valley and its people have not remained unaffected by the major changes brought about by the recent spurt in economic growth in the country as a whole, and they have a legitimate desire to be part of the growth story, so to speak, and share in the gains. As far as the local people are concerned, the projects have positive economic impact in the form of employment opportunities, secondary economic benefits like opportunities for small contractors, transport, hotels and guest houses, spurt in trade and business especially market for local business, overall development of the area through roads, schools, and hospitals;

(b) For the people, economic considerations apparently seem to outweigh the social, cultural, and religious considerations, but if challenged and presented with feasible alternatives they may not be averse to accept a compromise that assures them a better economic status through assured livelihood opportunities along with preservation of the ecological health of the river;

(c) The Tehri Dam has affected the Bhagirathi basin much more than all other projects put together both in size and in the trend it has set. As a result, having accepted the Tehri dam with the displacement and disruption, the people feel cheated in being denied the benefits of project construction that promises them jobs and improved economic status without causing any significant displacement or disruption;

(d) The local people, especially those likely to face any adverse impact of project construction activities e.g., damage to houses and property, agricultural fields, water sources etc., must be taken into confidence prior to commencement of construction and should also be informed of the rehabilitation and compensation measures that are proposed. This should mitigate, to a large extent, some of the resentment that some projects generate. Though there is a provision for public hearings on environmental issues, more often than not, these turn out to be mere formalities without much advance publicity and with minimal public participation. Public hearings should be given greater importance.

(e) It should be ensured that the sites of religious and cultural importance at the local level, are clearly identified and efforts made to minimize the adverse effects on them on account of the projects.

(f) Though agriculture in the Bhagirathi and Alaknanda basins may not benefit directly from hydro power projects, the indirect benefits by way of better linkages and supply of inputs, access to markets, better prices as a result of increased prosperity and year round demand would definitely prove beneficial. Furthermore, there has been a marked improvement in condition of roads during the last decade. This is a result not only of large investment in road building under various government schemes, but is also due to the necessity for ferrying large machinery to the sites of hydro power projects. Improvements in roads will indirectly benefit the tourist industry.

(g) The local people in the Bhagirathi valley are, by and large, in favour of resuming work on the abandoned hydro power projects, especially the Loharinag Pala project on which substantial work has already been done. The justification was invariably given in terms of the economic benefits of the project viz., employment and other secondary activities, and the fact that since the damage had already been done, the people gained nothing from stopping the half-constructed projects.

On the basis of studies conducted to determine the impact of hydropower projects on places of religious, cultural and tourist importance. It is recommended that:

(a) To ensure that the opposition to such projects is minimized, the projects should ensure that a fair deal is offered to the affected areas and inhabitants and that the promises made, such as those relating to jobs, minimum water discharge, etc, are adhered to in 'letter and spirit'.

(b) The cess on power generation from the projects should be spent on the development of the affected areas.

10 HYDROPOWER AND STAKEHOLDERS

10.1 Views Expressed in the Press on HPs

Development of hydropower projects in an area plays an important role in transforming the lives of communities living in the vicinity of the projects. On the one hand they bring in economic benefits and infrastructural development in the area. On the other, they may cause dislocation and changes in life styles of communities in myriad ways affecting their social fabric and cultural values. It is also accompanied by influx of people from other regions.

The stakeholders in hydropower projects in the Alaknanda Bhagirathi Basin can be broadly divided into three main groups: (a) communities living in and around the project area, (b) people from other areas who migrate to the project and surrounding areas for varying durations and tourists who visit the area for short durations and (c) people living outside the area, who believe that the region is a repository of natural beauty and has a number holy places.

"Dainik Jagran" a Hindi Newspaper which is widely read and circulated in Uttarakhand and surrounding regions started a debate "*Urja Pradesh-Sach ya Sawal*" (Energy State – Truth or Question) in 2010 and invited people to express their news on the issue with reference to the state of Uttarakhand. The views expressed cover a wide range of questions and problems related to stoppage of construction and completion of hydropower projects. The people are generally in favour of the development of the hydropower projects and would not like the hydropower projects to be completely abandoned. The views expressed can be summarized as follows:

- Incomplete hydropower projects should be completed without further delay.
- Before start of the hydropower projects more rigorous environmental assessment should have been done.
- Hydropower Projects are the only energy alternative for the Uttarakhand.
- Some people are using hydropower projects as political tool and they are not concerned about environment, development or welfare of the people.
- Environment is more important than development; more emphasis should be on preserving the environment.

- Ganga River is not meant only for bathing and religious activity. Government should not have agreed to the movement run for closure of hydropower projects.
- Local people were not asked before ordering the closure of hydropower projects.
- Passing of Ganga water through tunnel cannot decrease the importance of Ganga River.
- People of Uttarakhand should have right to use its natural resources, like rivers, for development.
- Why people are concerned only about Ganga in Uttarakhand. They are doing nothing to stop pollution in Ganga River in the plains. Kanpur and Varanasi too should have been considered.
- Approach should be for sustainable development, maintaining a balance between nature and development.
- Hydropower Projects should be decided based on the opinion of the experts, and not by the political and religious leaders only.
- Himalayas are fragile and vulnerable. Efforts should be made to generate awareness, sense of participation and ownership, among the common man.
- Considerably smaller projects than Tehri, such as Loharinag Pala, cannot be harmful. Ganga should not be confined to spirituality and faith. It can be a source (mother) of development and the two should be harmoniously integrated – Loharinag Pala project should be revived.
- Works started should not be stopped as the damage could be much more. Local people are on the margin of consideration.
- Energy is necessary but Ganga should also receive attention.
- Cancellation of Loharinag Pala will not benefit environment. Nearly 40% of the work has been done. How can the loss be made up?
- Eco-sensitive zone has been declared over 135 km stretch of Bhagirathi from Gaumukh to Uttarkashi. It is causing immense losses to the people of the state.
- Ganga is not polluted due to passage through tunnels but is polluted by waste-water from sewers and effluent from industries such as leather.
- Hydropower is the cleanest form of energy. Other sources of energy have many negative point and HP option should be examined first.
- Since in the dry winter months, the flow is sharply reduced, the capacity of Loharinag Pala should be reduced to 150-200 MW.
- Those opposed to the HPs on Bhagirathi are hatching conspiracy against the interests of the state.
- Committees of experts should deliberate on the various aspects of hydropower development and make recommendations. The Government should take decisions based on the recommendations.

10.2 View of Environmentalists

Discussions with various experts and stakeholders can be summarized as that while developing hydropower projects it should be ensured that the quality of life of the people living in the area is enhanced and the positive effects of the hydropower projects outweigh the negative impacts. Furthermore, the development of hydropower projects should be based on scientific facts and not started or stopped due to pressures/lobbing by individuals/groups.

It is sometimes argued by some that Ganga delta is experiencing rapid changes in response to the anthropogenic activity in the Himalayas. One group argues that due to dam building activities the supply of sediment to the Ganga delta area is highly reduced causing erosion in Sagar Island. Another group argues that deforestation has caused increased soil erosion in the Himalaya causing siltation in the Ganga Plain. It is a natural phenomenon starting much before the anthropogenic activity. Thus, it cannot be related to the present-day anthropogenic activity in Alaknanda and Bhagirathi basins.

The investigators have had detailed discussions with various individuals and have received some written communication from various quarters. These have been considered while finalizing the report and making the recommendations.

10.3 Agreements Between HP Developers and the Local Communities

Local population in the vicinity of the HPs can be affected during the construction stages as well as after the projects have been completed as some effects of the HPs may be permanent. It is hence necessary to ensure that the project developers take the local population into confidence and proper public awareness and participation programmes are run to ensure cooperation of the local population. Consulting the various reports and write-ups on consultations between the project developers and the affected communities the many issues of concern of the local community come to light. These have been discussed in details in chapter 8.

It is hence necessary that some formal agreements preferably in the form of Memorandum of Understanding (MoU), be made between the project developers and the representative bodies of the local communities through *Gram Panchayats* in the region. This may also be viewed as a part of the Corporate Social Responsibility (CSR). In each hydropower project the local issues may be different and hence the MoUs should be project specific.

On the basis of studies conducted on the perceptions of the stakeholders the following recommendations are being made.

1. The local population has very little information about the projects before execution starts and hardly any consultation is done at the planning stages. If such consultations are carried out with the local population and they are taken into confidence, a lot of misconception and misunderstandings can be avoided.

2. In order that the local population is aware of the timings frequency and schedule of release of water from barrage it is essential that there are set procedures for the same and they are made know to the local population.

The impact of construction activities and details of submergence area and affected villages is discussed in chapter 10. The impacts of HPs during construction stage is generally local and can be mitigated by taking appropriate steps for muck disposal and proper monitoring of dumping sites.

11 CUMULATIVE IMPACT ASSESSMENT OF HPS ON COMPONENTS OF ECO SYSTEM

The cumulative impact analysis and assessment of HPs on components of ecosystems has been discussed in chapter 11. Tables ES 1A, ES 1B and ES 1C show the Cumulative Impact Analysis of some HPs on Components of Ecosystem. Similar tables have been made for other hydropower projects also and have been discussed in chapter 11.

12 RECOMMENDATIONS

The key recommendation of the study are placed below summarizes the major conclusion and recommendations.

12.1. Impact Assessment

1 In view of the fact that the field of cumulative impact assessment (CIA) is new and is being introduced for the first time in India, there are many gaps in the knowledge necessary to undertake CIA with the desired degree of precision, particularly in the Himalayan region where the database is weaker than that in the rest of the country. It is, therefore, necessary that a major programme of research and development should be drawn and implemented as early as possible.

2 In Cumulative Impact Assessment literature, Adaptive Management is a recommended method of ensuring environmental and social sustainability of developmental projects. For applying it, data on Valued Ecosystem Components needs to be collected on a regular basis, and studied for deciding what measures need to be taken in the interest of sustainability.

12.2. Geology and Seismology

3 At the planning and execution stages of hydropower projects, detailed geo-scientific studies should be carried out to identify problematic areas of earth mass failure, site-specific, cost effective measures such as plantation on slope, re-grading of slope, shotcreting, grouting, anchoring, retaining and supporting walls, etc. along with proper drainage (surface and subsurface) measures to avoid saturation of earth mass, should be taken up. The studies that should be carried out are mentioned in Chapter 4, ‘Geological Studies’.

4 Geotracts 2 and 5 are very fragile zones in the Garhwal Himalayas. In Geotract 2, there have been incidents of infiltration of substantial quantity of water during tunnelling. Projects falling in these Geotracts should be carefully investigated for slope stability, ground water and springs.

5 Geological investigations will also help in avoiding interference with springs and ground water flows and in identifying suitable sites for dumping construction muck and in selecting sites for retaining walls to prevent flow of dumped muck into the river.

6 Tunnelling as well as adit sites be chosen in such a manner that they don’t cut through the underground water flow paths and spring.

ES Table 1A: Cumulative Impact Analysis of Some HPs on Components of Ecosystem

ALAKNANDA BASIN														
			Alaknanda main stream							Dhauliganga				
S. No.		Project Name / Features	Alaknanda	Vishnuprayag	Vishnugad Pipalkoti	Bowla Nandprayag	Nandprayag Langasu	Srinagar	Kotli Bhel-I B	Malari Jelam	Jelam Tamak	Tamak Lata	Lata Tapovan	Tapowan Vishnugad
1		Installed capacity (MW	300	400	444	300	100	330	320	114	126	250	170	520
2		Project Type	RoR	RoR	Storage	RoR	RoR	Storage	Storage	RoR	RoR	RoR	RoR	RoR
3		Location in Geotract	1	1	5	3	3	4	4	1	1	1	1	2
4		Location in Seismological Zone	5	5	5	5	5	4	4	5	5	5	5	5
5		Seismicity	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
6	Geology	Landslides	L-Medium	L-High	L-High	L-High	L-High	L-High	L-Low	L-Medium	L-Medium	L-Medium	L-High	L-High
7	Geology	Sedimentation	C-Medium	C-Medium	C-High	C-Medium	C-Medium	C-High	C-Mediun	C-Low	C-Low	C-Low	C-Low	C-Low
8	Environmental Flow	Fish	No Fish Zone	No Fish Zone	C-High	C-High	C-High	C-High	C-High	No Fish Zone	No Fish Zone	No Fish Zone	No Fish Zone	No Fish Zone
9	Environmental Flow	Flow	L-Low	L-High	C-High	L-Low	L-Low	C-High	C-High	L-Low	L-Low	L-Low	L-Low	L-Low
10	Environmental Flow	Remedy	Remedy is Possible	Remedy is Possible	Remedy is Possible	Remedy is Possible	Remedy is Possible	No Remedy is Possible	Remedy is Possible	Remedy is Possible	Remedy is Possible	Remedy is Possible	Remedy is Possible	Remedy is Possible
11	Environmental Flow	Power Generation	Medium	Medium	Medium	Low	Low	Medium	Medium	Medium	Medium	Medium	Medium	Medium
12		Springs & Drinking Water	Negligible	Negligible	L-Low	Negligible	L-Low	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	L-Low
13		Irrigation	Negligible	Negligible	Negligible	L-Low	L-Low	L-Low	L-Low	Negligible	Negligible	Negligible	Negligible	L-Low
14		Cultural and Religious places	Negligible	Negligible	Negligible	Negligible	Negligible	Negative	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
15		Tourism	Positive	Positive	Positive	Positive	Positive	Positive	Positive	Negligible	Negligible	Negligible	Negligible	Negative
16		Socioeconomic Environment	Positive	Positive	Positive	Positive	Positive	Positive	Positive	Positive	Positive	Positive	Positive	Positive
17		Construction Activities	L-Medium	L-Medium	L-High	L-Medium	L-Medium	L-High	L-High	L-Medium	L-Medium	L-Medium	L-Medium	L-Medium
18		Submergence	L-Low	Low	L-Medium	L-Low	L-Low	L-High	L-High	L-Low	L-Low	L-Low	L-Low	L-Low
19		Water Quality	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
20		Protected/Forest area	L-Medium	L-Low	L-High	L-Low	L-Medium	L-High	L-High	L-Low	L-Low	L – Low	L-Low	L-Low
		L: Localized Impact					C: Cumulative Impact							

ES Table 1B: Cumulative Impact Analysis of HPs on Components Of Ecosystem

ALAKNANDA BASIN										
			Rishi Ganga			Bhyundar ganga	Mandakini			Pindar
S. No.	Features	Project Name	Rishi Ganga II	Rishi Ganga-I	Rishi Ganga	Bhyundar ganga	Ram Bara	Phata Byung	Singoli Bhatwari	Devsari
1	**Installed capacity (MW)**		35	70	13.2	24.3	24	76	99	252
2	**Project Type**		Storage	Storage	RoR	RoR	RoR	Storage	RoR	Storage
3	**Location in Geotract**		2	1	2	3	1	2	3	3
4	**Location in Seismological Zone**		5	5	5	5	5	5	5	5
5	**Seismicity**		Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
6	**Geology**	**Landslides**	L-High	L-High	L-High	L-High	L-High	L-High	L-High	L-Medium
7	**Geology**	**Sedimentation**	C-High	C-High	C-Low	C-Low	C-Medium	C-Low	C-Medium	C-Low
8	**Environmental Flow**	**Fish**	No Fish Zone	No Fish Zone	No Fish Zone	C-Low	C-High	C-Medium	C-High	C-Low
9	**Environmental Flow**	**Flow**	L-Low	L-Low	L-Low	L-Low	C-Low	L-Low	C-Medium	L-Low
10	**Environmental Flow**	**Remedy**	Remedy is Possible	Remedy is Possible	Remedy is Possible	Remedy is Possible	Remedy is Possible	Remedy is Possible	Remedy is Possible	Remedy is Possible
11	**Environmental Flow**	**Power Generation**	High	High	High	High	High	Medium	Medium	High
12	**Springs & Drinking Water**		Negligible	Negligible	Negligible	Negligible	Negligible	L-low	Negligible	L-medium
13	**Irrigation**		Negligible	Negligible	Negligible	Negligible	Negligible	L-Low	L-Low	Negligible
14	**Cultural and Religious places**		Negligible	Negligible	Negligible	Negative	Negligible	Negligible	Negligible	Negligible
15	**Tourism**		L-Positive	L-Positive	Negligible	Negative	Negligible	Negligible	Negligible	Positive
16	**Socioeconomic Environment**		Positive	Positive	Positive	Positive	Positive	Positive	Positive	Positive
17	**Construction Activities**		L-Low	L-Low	L-Low	L-Low	L-Low	L-Medium	L-High	L-High
18	**Submergence**		L-Low	L-Low	Negligible	Negligible	Negligible	L-Low	Negligible	L-Medium
19	**Water Quality**		Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
20	**Protected/Forest area**		L-High	L-High	L-Low	L-Medium	L-High	L-High	L-Medium	L-Low
	L: Localized Impact									

ES Table 1C: Cumulative Impact Analysis of HPs On Components Of Ecosystem

BHAGIRATHI BASIN												
			Bhagirathi Main Stream								Jadh Ganga	
S. No.	Project Name Features		Bharon Ghati	Lohari Nagpala	Pala Maneri	Maneri bhali I	Manaeri bhali-II	Tehri stage-I	Tehri stage-II	Koteshwar	Kotli Bhel-IA	Karmoli	Jadh Ganga
1	Installed capacity (MW)		381	600	480	90	304	1000	1000	400	195	140	50
2	Project Type		RoR	RoR	Storage	Storage	RoR	Storage	Storage	Storage	Storage	Storage	Storage
3	Location in Geotract		1	2	2	3	3	4	4	5	6	1	3
4	Location in Seismological Zone		4	4	4	4	4	4	4	4	4	4	4
5	Seismicity		Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
6	Geology	Landslides	L-Medium	L-High	L-High	L-Medium	L-Medium	L-Medium	L-Medium	L-Medium	L-Medium	L-Medium	L-High
7		Sedimentation	C-Medium	C-Medium	C-High	C-High	C-Medium	C-High	C-High	C-Low	C-Low	C-High	C-High
8	Environmental Flow	Fish	No Fish Zone	No Fish Zon	C-High	C-High	C-High	C-High	C-High	C-High	C-High	No Fish Zone	No Fish Zon
9		Flow	L-Medium	L-Low	L-Medium	L-Medium	L-Medium	C-High	C-High	C-High	C-High	C-Medium	C-Medium
10		Remedy	Remedy is Possible	Remedy is Possible	Remedy is Possible	Remedy is Possible	Remedy is Possible	No Remedy i Possible	No Remedy is Possible	Remedy is Possible	Remedy is Possible	Remedy is Possible	Remedy is Possible
11		Power Generation	Low	Low	Low	Medium	Medium	Medium	Nil	Medium	Medium	Low	Low
12	Springs & Drinking Water		L-Low	Negligible	L-Low	L-Low	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
13	Irrigation		L-Low	L-Low	L-Low	L-Positive	L-Low	L-Positive	L-Positive	L-Positive	L-Positive	Negligible	Negligible
14	Environmental Cultural and Religious		Negligible	Negligible	Negative	Negative	Negative	Negative	Negative	Negative	Negative	Negligible	Negligible
15	Tourism		Negative	Negative	Negative	Negative	Negative	Positive	Positive	Positive	Positive	Negligible	Negligible
16	Socio-economy Environment		Positive	Positive	Positive	Positive	Positive	Positive	Positive	Positive	Positive	Positive	Positive
17	Construction Activities		L-Medium	L-Medium	L-High	L-High	L-High	L-High	L-High	L-High	L-High	L-Medium	L-Medium
18	Submergence		L-Low	L-Low	L-Low	L-Low	L-Low	L-High	L-High	L-Medium	L-High	L-Low	L-Low
19	Water Quality		Negligible	Negligible	Negligible	Negligible	Negligible	Considerable	Considerable	Negligible	Negligible	Negligible	Negligible
20	Protected/Forest area		L-Low	L-Low	L-High	L-Low	L-Low	L-High	L-High	L-High	L-High	L-High	L-High
	L: Localized Impact			C: Cumulative Impact								

7 It is recommended that the reservoir based hydro projects of more than 20 m high, especially close to Main Central Thrust zone, may be avoided and if constructed, these should be monitored for geo tectonic activity.

12.3. Soil Erosion and Sedimentation

8 Since hill slopes around reservoir are likely to be affected by discrete, isolated shallow landslides in the initial stages of operation, a no-activity buffer zone above the Maximum Reservoir Level (MRL) along the rim of the reservoir may be created to avoid untoward incidences. The width of this zone may vary from a few meters to about 50m, depending on topography, lithology and structural attributes of the area. The zone be monitored for change in hill slope of the rim area.

9 Catchment Area Treatment Plans are prepared for all major projects. However, their effective implementation is crucial. Their implementation needs to be monitored and its effectiveness ensured.

10 For all projects, accumulation of sediment upstream of the project should be studied and measures for its stabilisation should be designed and implemented.

12.4. Hydrological Aspects

11 Optimum environmental flows should be released from every project keeping in view hydrological requirements of organisms, especially, during the winter dry season and residual flows should be set at a level that is compatible with maintaining integrity of the aquatic environment downstream. This will ensure that the diverted stretch of the river will maintain flows necessary to meet ecological requirements. All projects should have outlets at lower levels in the dam so that EFR can be released.

12 There is a need for a research programme on EFR so that the best methodology for estimation of EFR for Indian basins is evolved. On projects which have been completed, such studies should be carried out to see how the aquatic life is impacted when the flow is diverted for generation of power.

13 Hydrological variability is important for maintaining health of fluvial ecosystems. Natural variation occurs during flooding, fluctuations in water levels during the period of snow melting, which determines biological aspects of the ecosystem, such as habitat and species distribution, fish migration and spawning and various stages of life cycles of benthic aquatic macro-invertebrates. To mimic natural variations in flow regime, recommended variability in environmental flows should be maintained.

14 Modification or manipulation in morphology of stream channel in the form of increasing bed form, roughness, heterogeneity, and channel sinuosity is also recommended to improve habitat structure and induce hyporheic exchange flow in streams and rivers.

15 Regular flushing of the bed should be carried out so that the sediment deposited on the bed at the barrage is removed and benthic condition for fish eggs is improved. Benthic stability of the bed should be regularly monitored.

16 Gap between two consecutive projects along a stream should be sufficient for the river to recuperate itself.

17 In the diverted stretch of the river bed, at suitable intervals, about one meter high check dams may be constructed where water would collect to meet the needs of the local population.

12.5. Hydropower Related Aspects

18 No further allotment of HP sites may be made for rives where percentage of river length affected is high. A threshold, say 70%, may be fixed for this purpose.

19 Projects where energy generation per unit of diverted discharge is low may be discouraged and a suitable threshold may be fixed for this purpose.

20 Environmental flow requirement depends on development stage of the area and societal requirement and this shall reduce the hydropower generation during lean season as well as advantage of peaking. Exact values of EFR for every single project for implementation should be established after carrying out detailed measurements of discharge, river cross sections and assessment of impact on biotic life as a result of reduced discharge on commissioned hydropower projects and consultation with the local community. The installed capacity of a hydropower project should be planned to be in conformity with the water available after satisfying the needs of environmental flow.

12.6. Environment and Biodiversity

21 Typically, river restoration focuses on surface system and their longitudinal and lateral connections, whereas the vertical dimensions are largely ignored. Thus, a holistic view to protect surface and sub-surface systems (hyporheic zone) and their fauna is recommended.

22 Fish passes may be made an integral part of hydropower projects.

23 Reforestation or riparian planting in degraded sites of the regulated river should be undertaken for stabilizing banks to reduce peak temperatures and source of particulate organic matter which can be entrained into river bed sediments during bed load movements.

24 Biological Monitoring: Regular biological monitoring should be undertaken at the project level under the guidance of expert environmental biologist, for assessing the level of environmental degradation with the help of potential bioindicators. The potential indicators for assessing the health of ecosystem are recommended as members of macroinvertebrates (Ephemeroptera and Trichoptera), hyporheic organisms (meiofauna), fish (Mahseer and other migratory fish) and a few aquatic periphyton/phytoplankton and macrophytes. This biological monitoring is required for adaptive management. An adaptive management plan based on specific requirements of aquatic organisms and the regulated river and the necessary modification made after thorough management effectiveness evaluation is recommended for effective conservation and management of aquatic biodiversity and integrity of the fluvial ecosystems. Environmental monitoring should be coordinated by a central agency for minimizing the cumulative footprint of these hydropower projects in Alaknanda and Bhagirathi basins.

25 Ecosystems of small streams or tributaries of Alaknanda and Bhagirathi should not be overexploited for hydropower generation as these streams are the main contributors of biological production of the main rivers. These small streams act as hatcheries for biological production at the first and second trophic levels of freshwater ecosystems and are a rich source of aquatic biodiversity. These streams have been identified as Nayar, Birhi Ganga, Bhyunder Ganga, Balganga and Asiganga which should not be exploited further as these are the lifelines of the main ecosystem of Alaknanda and Bhagirathi rivers.

26 The study on "Self-Purification Capacity of River Bhagirathi: Impact of Tehri Dam" conducted by NEERI for THDC in 2004 concluded that the self-purificatory quality of Bhagirathi or Ganga is not likely to be adversely affected by any reservoir or tunnel through which the water of the river is made to pass.

12.7. Religious and Social Aspects

27 Though there is a provision for public hearings on environmental issues, more often than not, these turn out to be mere formalities without much advance publicity and with minimal public participation. Public hearings should be given greater importance and conducted in such a manner that the general public feel that they are partners.

28 To ensure that opposition to such projects is minimized, the projects should ensure that a fair deal is offered to the affected areas and inhabitants and that the promises made, such as those relating to jobs, minimum water discharge, etc, are adhered to in 'letter and spirit'.

29 A feeling among local people has been discerned that the projects benefit people from other regions at the cost of people around the project site. Compensation, however generous, can never be enough for a person who is dislodged from his place and profession or even if not dislodged, goes through a number of difficulties and tensions of temporary and permanent nature. Consequently, people in the area suffer mentally and physically from uncertainty, worry and hardships. Moreover, there are many persons whose property is not acquired and still they have suffered mental agony. The cess on power generation and part of income from free power available from developers of projects should be spent on development of affected areas and providing facilities such as health, education, transport and development of physical and social infrastructure.

30 It should be ensured that sites of religious and cultural importance at the local level are clearly identified and efforts are made to minimize adverse effects on them on account of the projects.

31 A view expressed by many stakeholders is that Tehri Dam has affected the Bhagirathi basin much more than all other projects put together, both in size and in the trend it has set. As a result, having accepted the Tehri dam with the displacement and disruption, they feel cheated in being denied the benefits of project construction that promises them jobs and improved economic status without causing any significant displacement or disruption.

32 An issue that has been relatively neglected but which deserves serious attention is that the local people, especially, those likely to face any adverse impact of project construction activities e.g., damage to houses and property, agricultural fields, water sources etc., must be taken into confidence prior to commencement of construction and also informed of rehabilitation and compensation measures that are proposed. This should mitigate, to a large extent, resentment that some projects have generated.

33 Bathing ponds (kunds) may be constructed adjacent to rivers at places of religious and social importance. These should be connected to the river so that there is continuous flow of fresh water and adequate depth of water is present.

34 Regarding water requirement at places of religious importance, their needs on different festivals should be ascertained and the needed quantity of water should be released to meet these needs.

35 It is necessary to plan human settlements that will arise as a result of HPs and the growth of service industry such as tourism, banking, business etc. Needless to say that safe disposal of solid and liquid waste should enjoy the highest priority. For temporary shelters needed during the construction phase, arrangements for safe disposal of solid and liquid waste should be made.

12.8. Construction Related Aspects

36 Suitable dumping sites for disposal of muck generated during construction should be identified well in advance. The dumped muck should be protected by a retaining wall at the toe up to HFL. This is equally necessary for small hydropower projects.

37 Construction gives rise to large quantities of dust. During construction water should be regularly sprinkled on roads so that it does not become airborne. Water should also be sprinkled on crushing and batching plants. The HP at Srinagar is a case in point where dust and noise is a big nuisance. Generators and other equipment used need to conform to prescribed standards of CPCB.

12.9. Monitoring

38 Project authorities of large projects are expected to monitor prescribed parameters of the project and send periodical reports to the MoEF. It appears desirable to monitor, among others, the following parameters:

- Aquatic biodiversity in the reservoir and in the river beyond the reservoir,
- Landslides near the rim of the reservoir,
- Water quality at different depths and at different parts of the reservoir,
- Impact on water table and springs in the catchment upstream of the project,
- Landslides downstream of the dam,
- Flow (discharge) downstream of the project in the diverted length of the river,
- Aquatic life in Ganga downstream of Devprayag, and
- Any springs that may have dried up.

39 In addition to monitoring of physico-chemical characteristics of water, regular bio-monitoring should be undertaken under the guidance of an expert environmental biologist for assessing the level of change with the help of potential bio-indicators. Details are given in the Chapter 6 on Water Quality, Biodiversity and River Ecology.

40 There should be a State Environmental Monitoring Mechanism to formulate a monitoring programme for all projects to generate data so that Adaptive Management can be practised. It is only appropriate that monitoring is done with the association of representatives of civil society.

41 There should be a depository where all the data generated in relation to the project should be deposited and it should be available to any interested person and, preferably, be on the internet.

42 It is necessary to regulate land use near the project site as well in the entire river stretch covering some distance beyond the floodplain of the river.

CHAPTER -1

INTRODUCTION

1.1. Assignment

The National River Conservation Directorate (NRCD), Ministry of Environment and Forests (MoEF), Government of India (GoI), vide letter no. J11022/1/2010-NRCD-II dated July 15, 2010 assigned a study to Alternate Hydro Energy Centre (AHEC), IIT Roorkee, for "Assessment of Cumulative Impact of Hydroelectric Projects in Alaknanda- Bhagirathi Basins". The Terms of Reference of the study are given as Annexure 1.1.

1.2. Geographical Area of Study

The study area, comprising of Alakananda and Bhagirathi Basins, is shown in the index map (Fig. 1.1). Ganga Basin is the largest river basin in India with an area of 8,61,404 sq.km and home to for nearly 43% of India's population (448.3 million as per 2001 census) (Fig. 1.2, Anon, 2009). The Alaknanda and Bhagirathi rivers are in the North Western part of the State of Uttarakhand, which is cradled in the Himalayas. These rivers have their confluence at Devprayag and lose their names to acquire a new one "Ganga".

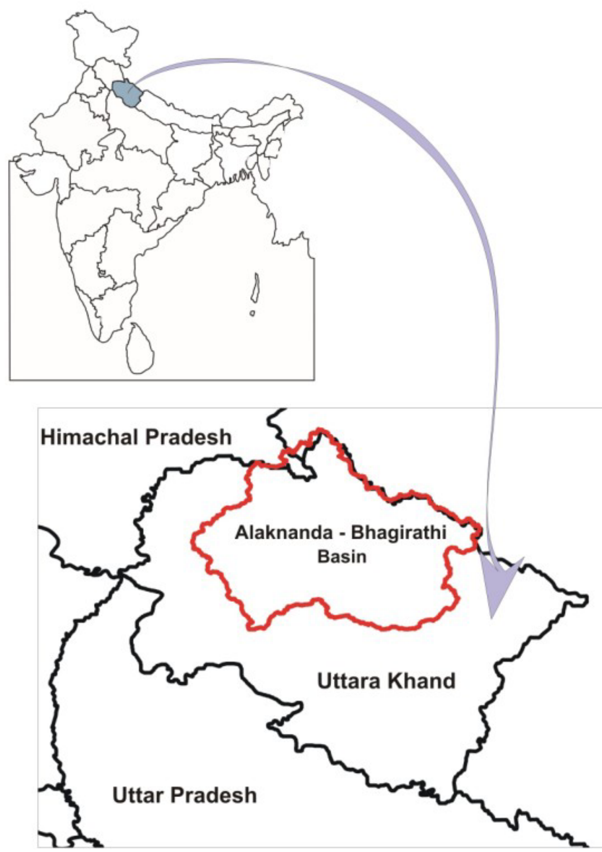


Fig. 1.1 Index Map of Alaknanda and Bhagirathi Basins

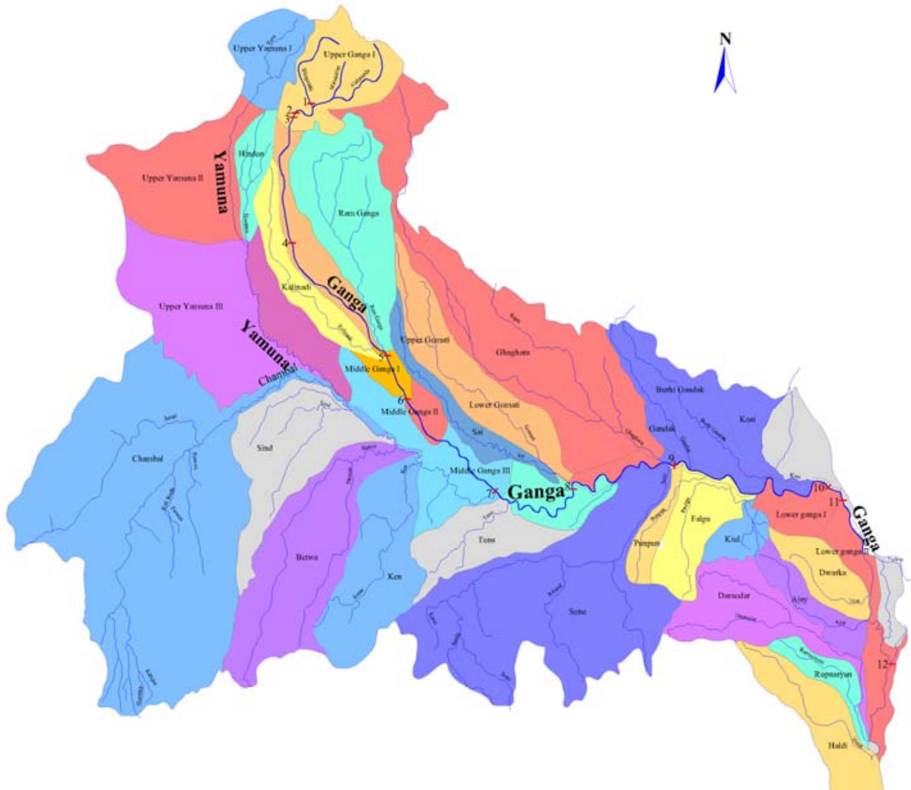


Fig. 1.2 Map of Ganga Basin (from National River Conservation Directorate, Ministry of Environment and Forests, "Status paper on River Ganga" 2009.)

As a result of a combination of various factors Alaknanda and Bhagirathi basins are rich in water resources. Additionally the topography provides a large number of sites for setting up hydropower projects to generate large quantity of electricity with relatively low investments. Some hydropower projects have already been commissioned and many more are either under construction or are planned. For this study hydropower projects with installed capacity exceeding 1 MW have been considered as the smaller ones will have much smaller impact.

The present generation capacity of the commissioned hydropower projects is 1,850.8 MW. Hydropower projects under construction and development will add another 7,712.5 MW of power to the existing capacity and if all the identified sites are made operational 9,563.3 MW of additional power will be added. (Annexure 1.2).

1.3. Components of the Ecosystem for Cumulative Impact Assessment

There is an apprehension that if hydropower potential of the study area is developed without a study of their impact on various components of the ecosystem (response components), then cumulative impact of these projects on various components of the ecosystem of the basin could be significantly adverse and would therefore be unacceptable. The components on which the impact of development of hydropower projects needs to be assessed, identified by NRCD, MoEF are as follows:

a) geological (tectonic) stability,
b) stability of glaciers resulting in more frequent avalanches,

c) stability of slopes resulting in landslides,
d) soil erosion reducing productivity of land and producing frequent floods,
e) requirement of environmental flow,
f) altered surface and ground water regime affecting drinking and irrigation water sources and their potential to provide water,
g) flows in streams, tributaries and rivers and, above all, environmental flows necessary for sustaining biotic life and observing religious practices,
h) impact on places of cultural and religious importance and
i) details of submergence area under protected area network,

1.4. Objectives of the Study

Objectives of this study are the following

a. To assess the cumulative impact of commissioned, under construction and proposed hydro power projects in Alaknanda and Bhagirathi basins. The assessment would consider, interalia, factors mentioned in paragraph 1.2 of ToR, and mentioned in Section 1.3 from a) to i) above.
b. To estimate the extent to which hydropower potential identified in the basins should be developed without risking stability of landforms and environment. At the same time ensuring that the quality, quantity, and timing of water flows required to maintain functions, assimilative capacity and aquatic ecosystems that provide goods and services to people are maintained.
c. Restrictions, if any, that need to be placed in the development of hydropower in the two basins.

1.5. Other Requirements of the Study

1.5.1. Collection of Maps

The following maps were collected

a) topographical maps of the two basins,
b) satellite imageries and geological maps of the basins.
c) satellite imageries of large completed projects to detect any discernible change between preconstruction period and post construction period.

1.5.2. Collection of Reports

The following reports were collected

a) Detailed Project Reports and Prefeasibility reports (DPRs/PFRs) of all commissioned / proposed Hydropower Projects and
b) EIA studies and Environmental Management Plans (EMPs) of all commissioned/ proposed HPs.
c) Clearances accorded to all HPs.
d) Monitored observations and activities under taken post clearances as per requirement
e) Meteorological data
f) Surface and ground water hydrology

i. discharge upstream of hydropower sites.
ii. discharge downstream of the hydropower sites.

g) Available ground water levels in affected areas.
h) Available socio-economic data of affected areas.
i) Water quality data at each potential site.

1.5.3. Collection of Data Relating to Completed Projects With Capacity Above 25 MW

This study includes an assessment of impact of large hydropower projects on environment and other factors mentioned in paragraph 1.2. In particular the following data was gathered:

a) landslides
b) loss of irrigation potential, if any
c) Health hazards
d) Socio-economic survey of the area to assess the socio-economic impact of completed projects.
e) Water quality and discharge studies in the immediate vicinity and d/s of the project
f) Study the impact on springs.

1.5.4. Deliverables

Based on this study the following reports are to be delivered

a) The impact of large completed hydropower projects in the basin of rivers Alaknanda and Bhagirathi, up to Devprayag.
b) Based on the above study, drawing empirical inferences in assessing impact of hydropower projects under implementation / proposed.
c) Cumulative impact of
   i. All projects on a stream on the tributary.
   ii. All projects located on a tributary at its confluence with river Alaknanda.
   iii. All projects located on a tributary at its confluence with river Bhagirathi.
   iv. All hydropower projects proposed / established on river Alaknanda and Bhagirathi upto Devprayag.
d) This report addresses the following issues
   i. Whether acceptable limits of geomorphologic stability or of environmental sustainability, particularly of environmental flows, are likely to exceed at any small or large hydropower project site(s).
   ii. Whether there will be a depletion of irrigation potential or availability of drinking water in habitations as a result of any project.
   iii. Impact on ground water and springs in the basin.
   iv. Impact of these projects on places of cultural, religious or of tourism importance.
   v. Whether any restrictions should be placed on development of hydropower in the basin.
   vi. The impacts should be expressed qualitatively and quantitatively.

The Terms of Reference (ToR) of the assignment are given at Annexure 1.2.

1.6. Background of the Problem

As is well known, the state of Uttarakhand and the country are acutely short of electricity, a prerequisite for development. In view of rapid economic growth the gap between demand and supply of electricity has been increasing. In this context all sources of power generation need to be harnessed. In the last 50 years, although the role of hydropower in meeting the power requirement of the country has increased in terms of output, its share in the mix of power has significantly reduced and is far below the desirable level.

Any form of power generation affects the environment. Hydrocarbons and coal release a large amount of green house gases and particulate matter which pollutes the atmosphere and may also contribute to global warming. Wind, tidal and geothermal related power plants can be located only in very specific and limited areas where suitable conditions exists, moreover, cost of power production by these plants is invariably high. Solar energy requires panels which are made from rare earth elements. The rare earth elements are expensive and available at the moment only in very limited regions of the world and hence have to be imported. Moreover, cost of production of solar panels by the present known technology is high and large scale use of solar energy in the next few decades seems unlikely. Material required to generate nuclear energy (nuclear fuel) is available only with large constraints and serious environmental hazards are associated with this form of electrical energy generation in case of an accident. The occurrence of such accidents, however few, are serious environmental hazards.

Considering the above, hydropower generation appears to be a viable alternative to meet the ever increasing power demand. Before a decision is taken to harness this considerable hydropower potential in the basin under study it is necessary to understand the cumulative impact of development of this hydropower potential on the response components of the ecosystem. In view of the above an attempt is made in this study to assess the cumulative impact of hydropower projects in Alaknanda and Bhagirathi Basins.

1.6.1 Cumulative Impact Assessment

1.6.1.1 Concept

The impact of human activity or a project on an environmental resource or eco-system may be considered insignificant when assessed in isolation, but may become significant when evaluated in the context of the combined effect of all the past, present, and reasonably foreseeable future activities that may have or have had an impact on the resources in question. The Council for Environmental Quality established under the US National Environmental Policy Act of 1969 (NEPA) came to the view that a conventional project and site-specific approach to environmental assessment has its limitations when it comes to assessing potential cumulative effects on environmental resources.

1.6.1.2 Definition of Cumulative Impact

Cumulative impact is defined by the US Council on Environmental Quality as "the impacts on the environment that result from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions (RFFA) regardless of what agency undertakes such other actions." Thus the practice of Cumulative Effects Assessment (CEA) of projects in a region began. Various aspects of CEA began to be studied.

There are several reasons why Cumulative Impact Assessments should be carried out i.e.,

i. Conceptual reasons – For a group of projects, the environmental effects of primary concern tend to be cumulative and it will not be advisable to consider simply the effects of individual projects
ii. Pragmatic reasons – CEA guidance and other EIA legislation of the 1990s requires that CEs be assessed
iii. Regulatory reasons – make “room” for future developments
iv. Idealistic reasons – minimize negative CEs, promote resource sustainability

In India, so far, there is no law requiring the conduct of Cumulative Environmental Impact Assessment before a development project is given Environmental Clearance.

During 1980s and 1990s, it became the practice in many countries to include Cumulative Effects in Environmental Impact Statements. CEA processes were also developed. Litigation in courts also clarified some of the concepts. With the dawn of the present millennium i.e., 2000s practice for project CEAs was improved; methods of analysis developed and existing methods expanded.

In view of the above the present study attempts to deal with the issue of cumulative impact assessment of hydropower projects in Alaknanda and Bhagirathi basins in light of the prevailing concepts of cumulative impact assessment of hydropower projects.

1.7. Description of Area

1.7.1. Uttarakhand State

Uttarakhand (formerly known as Uttaranchal) was carved out of Uttar Pradesh as the 27th state of India on 9th November 2000. The state lies between latitudes 28°43′N to 31°27′N and longitudes 77°34′E to 81°02′E, with a total geographical area 53,484 sq km (1.6% of total area of the country). Forest area of 34,651 sq km, is 63.99% of the total area of the state (Kumar, 2010).

This state is predominantly mountainous, with hilly area covering 46035 sq km (86.07%) and the plains having an area of 7448 sq km (13.93%). The state is divided into two divisions Kumaon and Garhwal, and has 13 districts, with 78 Tehsils, 95 Development Blocks, 670 Nyaya Panchayats, 7541 Gram Panchayats and 16826 villages, excluding forest settlements, of which 15761 are inhabited. Total population of the state, as per 2001 census, was 84,89,000. Bulk of the population, 46.24%, lives in the three plain districts of Hardwar, Dehradun and Udham Singh Nagar. Population density of the state is 159 persons/ sq km as against 324 at the national level. Urban component of population is 25.59 per cent, slightly lower than the national average of 27.78 per cent. The female population is 962 per thousand males, a little higher than the national average of 933 recorded by the last census. However, rural areas have a better sex ratio with 1007 females per thousand males.

In the overall ranking of different states in the country, the state ranks 20th in terms of population, 18th in terms of area, 25th in terms of population density and 14th in terms of literacy. District wise data for the state is given in Table 1.1.

Table 1.1 Statistical Data on Uttarakhand as per 2001 Census

District	Headquarter	Area (sq km)	Population	Male	Female	Population Density (persons /sq km)	Literacy rate (%)
Uttarkashi	Uttarkashi	8016	295013	152016	142997	37	65.71
Tehri Garhwal	New Tehri	3796	604747	295168	309579	166	66.73
Pauri Garhwal	Pauri	5230	697078	331061	366017	124	77.49
Rudraprayag	Rudraprayag	2439	227439	107535	119904	115	73.65
Chamoli	Gopeshwar	7520	370359	183746	186614	43	75.43
Pithoragarh	Pithoragarh	7169	462289	227615	234674	65	75.95
Bageshwar	Bageshwar	2246	249462	118510	130952	111	70.42
Champawat	Champawat	1766	224542	111084	113458	126	71.29
Udham Singh Nagar	Rudrapur	3055	1235614	649484	586130	486	64.96
Nainital	Nainital	4251	762909	400254	362655	179	78.36
Almora	Almora	3689	630567	293848	336719	201	73.64
Hardwar	Hardwar	2360	1447187	776021	671168	613	63.75
Dehra Dun	Dehra Dun	3088	1282143	679583	602560	415	78.99
Total	**Uttarakhand**	**53,484**	**8489349**	**4325925**	**4163427**	**159**	**71.6**

The state is also known as Dev Bhumi ("Abode of Gods) and tourism plays an important role in the economy of the state. It has the famous pilgrim centers: four dhams (Badrinath, Kedarnath, Gangotri and Yamnotri), five prayags (Vishnuprayag, Nandprayag, Karnprayag, Rudraprayag and Devprayag), besides Hardwar and Rishikesh which are prominent religious centres for Hindus. The famous "Kumbh Mela" is held every twelve years at Hardwar. Hemkund Sahib, a prominent pilgrim centre for Sikhs is also situated in Uttarakhand. Besides centres of religious importance, many hill stations are very popular tourist destinations like Nainital, Mussorie, Kausani, Ranikhet, Almora and Lansdown. These places are famous for their natural beauty. The state also has several sites for winter, river and adventure sports at Auli, Dayara Bugyal, Tehri Dam, Kodiyala etc.

The Alaknanda basin lies mainly in Chamoli, Rudraprayag, Tehri Garhwal and Pauri Garhwal districts with small areas of Pithoragarh and Bageshwar districts also included in it. The Bhagirathi basin is confined within Uttarkashi, Tehri Garhwal and Pauri Garhwal districts. After the confluence of Alaknanda and Bhagirathi Rivers, at Devprayag, the river is called Ganga. Fig. 1.3, shows districts and towns of the state,

Fig. 1.4 shows villages in Alaknanda and Bhagirathi basins and Fig. 1.5 shows the location of commissioned and under development power projects along with protected areas.

Uttarakhand has consistently recorded a high rate of economic growth even though more than 61 per cent of the area is covered by forests which contributes very little directly to the State Domestic Product, and only a little over 13 per cent of the area is available for any meaningful agriculture. Per capita income has been slightly higher than the national average. Level of literacy recorded in the last census was 71.6 percent, with 83.3 percent for males and 59.6 per cent for females, much higher than the national average.

Since the formation of the State its GDP has generally been higher than the national GDP, except for a few years.

A decade has passed since the formation of this State. In this period contribution of primary sector to the State GDP, which was 31%, has declined to 18% and that secondary sector increased from 18% to 35%. Thus, roles of the two sectors have been reversed. The share of tertiary sector has marginally declined. The secondary sector comprises of manufacturing, organized and unorganized; construction; and electricity, gas and water supply. Trade, hotels and restaurants, as a sub-sector, had the largest share in the tertiary sector followed by public administration and transport in most districts.

Contribution of Alaknanda and Bhagirathi Basins to the state GDP is low, being only ₹ 400 million against the state GDP of ₹ 207 million, as is to be expected because of the rugged terrain. The districts constituting the basin under had in 2008-09 per capita NDDP about half of that of Hardwar the district with the highest per capita NDDP.

1.7.2. Climatic Conditions

The state has two distinct climate regions (a) the predominant hilly terrain and (b) the plain region. Alaknanda and Bhagirathi Basins fall under the first category. The mountain regions do not have a uniform type of climate and variations are due to location, altitude, aspect and morphology. Places situated on southern slopes of the Himalaya receive more sunshine and a larger amount of rainfall. But due to a high rate of evaporation and transpiration, these slopes remain generally dry. The duration of sunshine is shorter on northern slopes, with the result that the moisture retaining capacity of the soil is higher, even though these slopes receive less rainfall. Uttarakhand has been divided into seven broad climatic zones based primarily on altitude as given in Table 1.2.

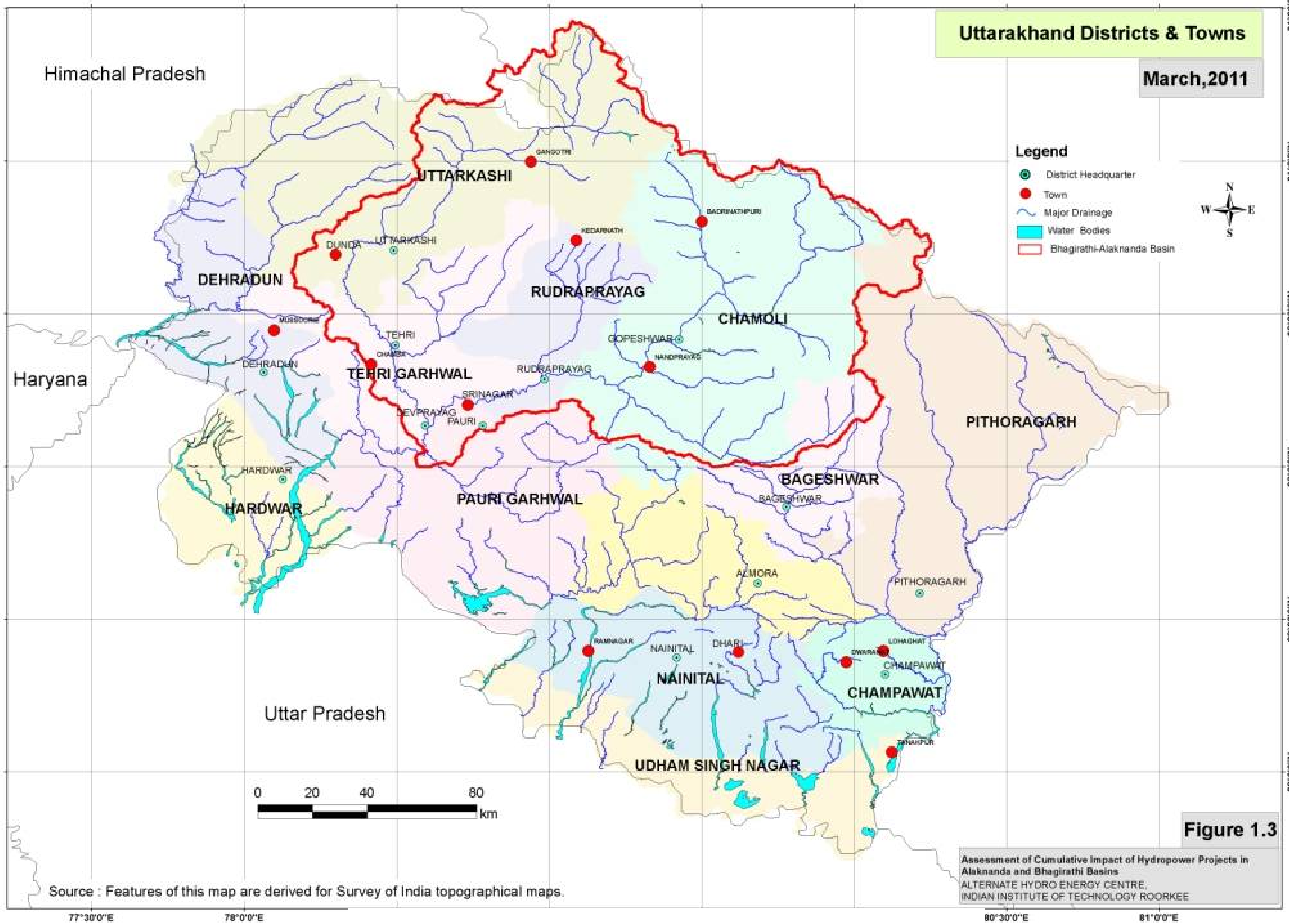


Fig. 1.3 Uttarakhand Districts and Towns

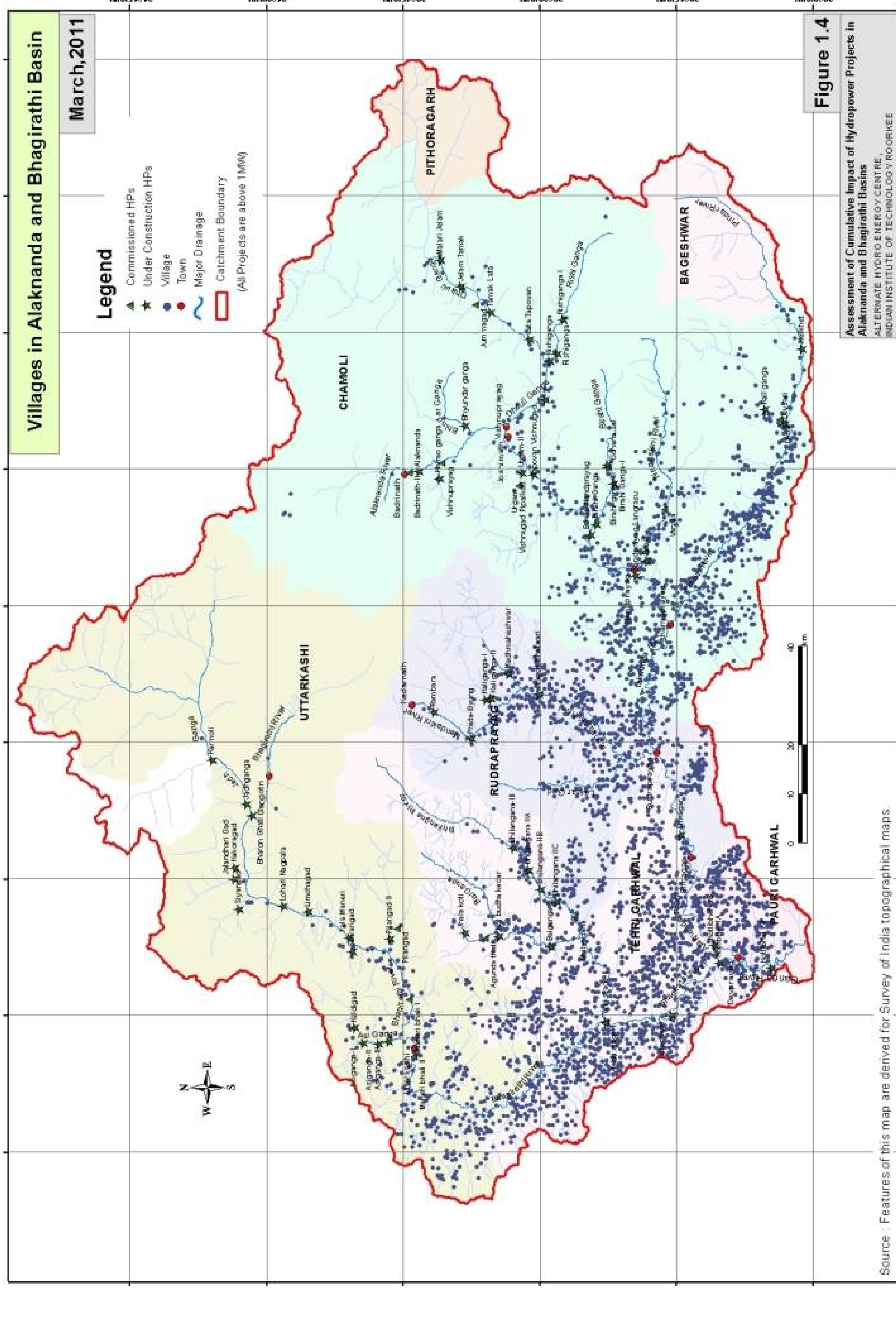


Fig. 1.4 Villages in Alaknanda and Bhagirathi Basins

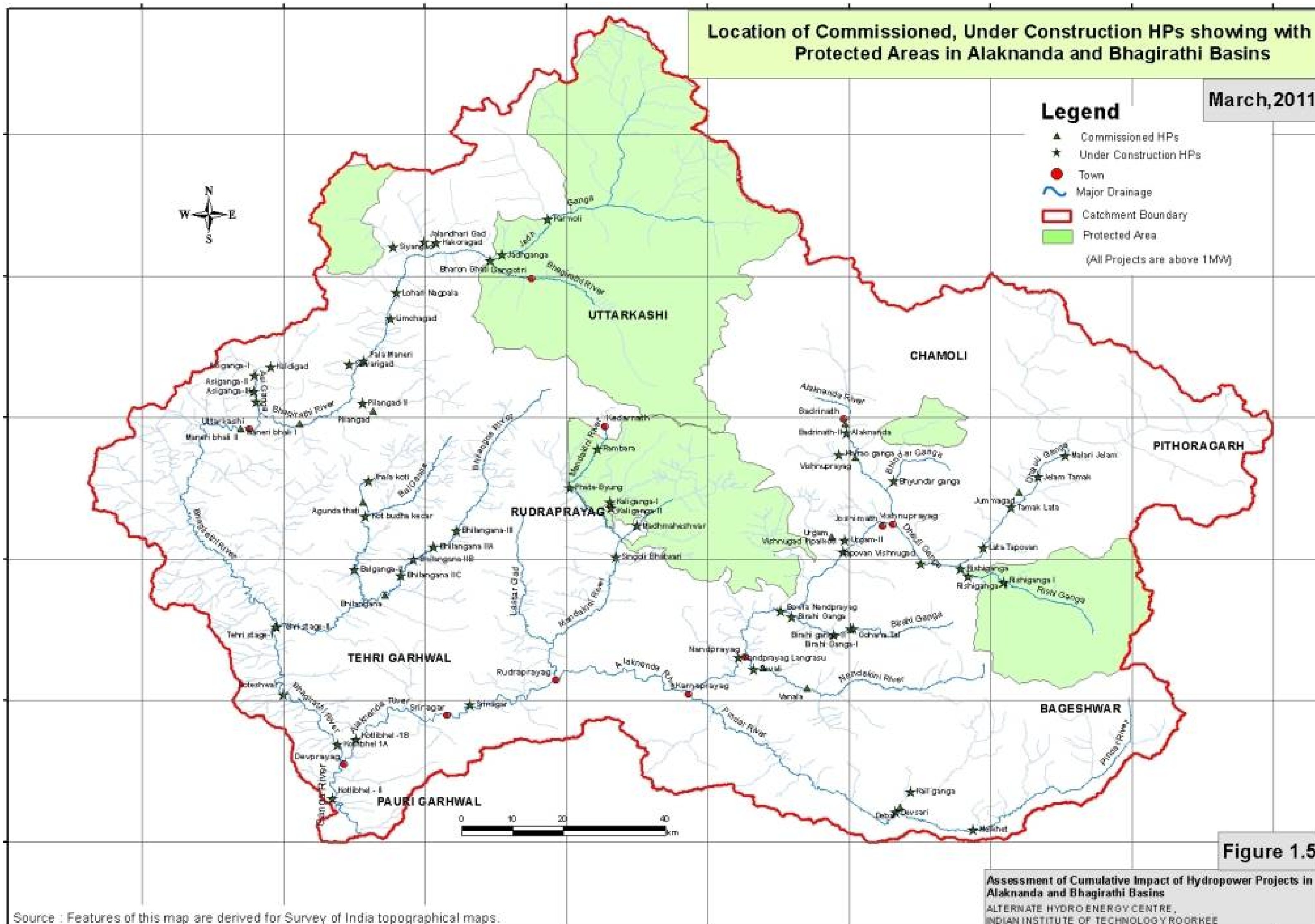


Fig. 1.5 Location of commissioned, under construction HPs shown with protected areas in Alaknanda and Bhagirathi Basins

Table 1.2 Climatic Zones in Uttarakhand

Climatic Zone	Altitude (m)	Average Temperature Range (°C)		
		Annual	June	January
• Tropical Zone	300–900	18.9–21.1	27.2 – 29.4	11.1–13.3
• Warm Temperature (Sub-Tropical)	900–1800	13.9–18.9	21.1–27.2	6.1–11.1
• Cool Temperature	1800–2400	10.3–13.9	17.2–21.1	2.8–6.1
• Cold Zone	2400–3000	4.5–10.3	13.3–17.2	1.7–2.8
• Alpine Zone	3000–4000	3.0–4.5	5.6–13.3	Below Zero
• Glacial Zone	4000–4800	For ten months, below zero, and in July and August between 2.2°C and 3.9°C		
• Perpetually Frozen Zone (Cold desert, No vegetation)	Above 4800			

1.7.3. General Geological Setup

Uttarakhand is located in the central part of the Himalayan mountain chain, in the northern part of the Indian subcontinent. The Himalaya in the Uttarakhand is subdivided into east-west trending linear belts with their specific physiographic features. These belts are, from north to south, Tethys Himalaya, Great Himalaya (Higher Himalaya), Lesser Himalaya and Sub-Himalaya (Himalayan Foot hills i.e., Siwalik hills). In the south of the Himalayan belt, the Ganga alluvial plain is located.

These physiographic belts of the Himalaya also show specific geological and rock characteristics. The Tethys Himalaya is made of sedimentary rocks (Tethys zone), the Great Himalaya is made up of metamorphic rocks (central crystalline zone), the Lesser Himalaya is made up of Precambrian sedimentary rocks and some metamorphic rocks (Krol belt, Inner Sedimentary belt) and the Sub-Himalaya is made up of young friable sedimentary rocks (Siwalik zone). These belts are also separated by regional tectonic lineaments, namely Basement Thrust Front (BTF) between Tethys and Central Crystalline zone, Main Central Thrust between Central Crystalline zone and Inner Sedimentary belt, Main Boundary Thrust between Krol belt and Siwalik belt and Himalayan Frontal Thrust between Siwalik belt and Ganga Alluvial Plain. These thrusts and faults are the main deep-seated weak zones. Additionally, there are a large number of small faults crisscrossing the entire area.

The study area is a part of the seismically active regions of the world. According to seismic zoning map of India it falls in seismic zones IV and V. The area has witnessed many earthquakes of medium to large size in the recent past. These earthquakes are related to two major tectonic features, namely Main Central Thrust (MCT) and Main Boundary Thrust (MBT). The study area is part of local seismicity zone extending from Barkot to Chamoli towns. The study area has the Main Central Thrust (MCT) in the central part of the Bhagirathi and Alaknanda river basins. Geology in detail is discussed in Chapter 4 and seismicity is discussed in Chapter 5.

1.7.4. Alaknanda – Bhagirathi Basins

Both Bhagirathi and Alaknanda rivers originate from glaciers, namely Gangotri glacier and Satopanth and Bhagirathi Kharak, respectively. Several tributaries also originate from glaciers and snow fields. However, contribution of snow melt in the river system is rather limited. Rivers of the region show strong fluctuation in discharge depending upon the season of the year. Total catchment of Alaknanda and Bhagirathi basins up to Devprayag is 19,600 sq. km. Alaknanda and Bhagirathi rivers meet at Devprayag and downstream, the river acquires the name Ganga.

The area occupied by river drainage is rather rugged with deep, steep river valleys separated by linear narrow ridges in between. In general the pattern of drainage is dendritic. In several segments the tributaries show preferred parallelism and other preferred orientation indicating a tectonic or lithological control on the drainage development.

An important feature of rivers of the area is that these are deeply incised and possess steep valley slopes. Many minor tributaries meet the trunk river with steep slopes and often bring large quantities of debris. The Himalaya is undergoing fast erosion and large quantities of sediment are generated due to intense physical weathering. This sediment is quickly moved along steep slopes and downstream by rivers.

In some segments of river valleys, particularly in the upper reaches, valley slopes are very steep and unstable. These segments regularly witness landslides and sediment movement as debris flow. Landslides are very intense and cause destruction of forest cover on hill slopes. Due to this phenomena large parts of valley slopes are barren, without any vegetation cover.

A regular feature of the river system of the area is that it receives intermittently huge amount of sediment from valley slopes; but most commonly from steep gradient minor tributaries. Often this sediment transfer takes place as a quick single event of few hours. The amount of sediment is so large that it blocks flow in the channel by making a temporary dam, and converting the river upstream into a temporary lake. This natural damming may exist for a few hours, days, weeks or in exceptional cases several decades. The breaking of these natural dams releases large amount of water and sediment debris. It may cause local flooding in downstream areas and also huge amount of sediment can be deposited on fertile agricultural land. Some important such lakes are Barital in Rishiganga, Chinatal in Patalganga, and Gauna lake in Alaknanda.

In higher reaches, particularly during winter, snow avalanches take place which may temporarily block flow in the river. Breaking and melting of snow avalanches causes flash flood in downstream areas locally.

In monsoon season the main source of water discharge is surface runoff of rainwater, along with some contribution from snow melt water and groundwater. In the post-monsoon season discharge is essentially from groundwater. In summer season discharge is from melt water and groundwater.

These rivers, along with their catchment, are depicted in Fig 3.6. Other hydrological details of the basin may be seen in Chapter 7 on Hydrological Studies.

In the study area several high altitude protected areas (national parks) are present, namely Govinda National Park, Gangotri National Park, Kedarnath Wild Life

Sanctuary, Valley of Flowers National Park, and Nanda Devi National Park. These areas are partly located above the snowline and partly incorporate drainage basins of tributaries of Bhagirathi and Alakhnanda rivers in their upper reaches. The study shows a rich biodiversity. The flora shows a wide range from low altitude to high altitude alpine flora. This region is well-known for growth of a wide variety of medicinal and aromatic plants.

In the last few decades changes in Himalayan landforms and ecosystem have been observed. One important factor for changes has been population growth and haphazard developmental activities, namely, unplanned construction of residential and commercial buildings. Road construction and mining activity has not been properly planned. In some areas unplanned construction activity has caused land subsidence and increased landslides. Improper building design and construction has been responsible for large-scale damage of humans and buildings in case of recent Uttarkashi and Chamoli earthquakes.

This study does not include socio-economic survey of the area, the effect of Hydropower Projects on landscape, livelihood of people living in the area around hydropower projects, development of transportation and other infra structural facilities due to coming up of hydropower projects in the region, effect of hydropower projects on fauna in the region and health of people living in the region. This is because these aspects were not covered in the terms of reference of the study and because of time constraints. It may, however, be added that it is felt that major conclusions and recommendations of the study would not change even if these were included.

References:

Anon ((2009): Status Paper on Ganga, National River Conservation Directorate, Ministry of Environment and Forest 31p.

Sanjay Kumar (2010): Know Your State Uttarakhand, Arihant Publications (i) Pvt. Ltd., Meerut 208p.

ANNEXURE 1.1

Terms of Reference to undertake study for the Assessment of Cumulative Impact of Hydropower Projects in Alaknanda and Bhagirathi Basins as per The National River Conservation Directorate (NRCD), Ministry of Environment and Forests (MoEF), Government of India (GoI), letter no. J11022/1/2010-NRCD-II dated July 15, 2010.

Terms of Reference

1. Background

1.1. Alaknanda and Bhagirathi Basins

The rivers Alaknanda and Bhagirathi, which have their confluence at Devprayag, give birth to the holy river Ganga. Their basins comprise glaciers in the higher reaches of the mighty Himalayas, which feed the rivers. The entire region has enormous social and cultural significance.

Both these rivers, along with their tributaries, are rich in water resources. Because of the hilly terrain huge falls are available and the identified potential for hydropower in the area is large. There are a number of identified sites for large and small hydropower projects.

Hydroelectric projects in the area may have major implications for the environment, for flow in stream/rivers, ground water etc. The risks in many cases may not be obvious but could be latent. Among the environmental conditions the quantity and quality of water during different parts of the year (environmental flow) is very important.

1.2. Probable Impact of Hydropower Projects

Before taking up any hydropower project of more than 25 MW capacity an EIA is mandatory and the project can be implemented only if the environmental clearance is accorded and the environmental safeguards prescribed are complied with. However, environmental impact assessment of isolated projects, on a case to case basis, may not present the true picture of the cumulative impact of all the projects that are proposed/ under implementation in due course. Against a large number of sites with potential to develop large/medium/small hydro power projects in the basin, only few projects have so far been set up or are under execution. With the projects proposed / being developed, it is important to ensure that their cumulative impact does not exceed the limits in terms of the following parameters:-

a) geological (tectonic) stability,
b) stability of glaciers resulting in more frequent avalanches,
c) stability of slopes resulting in landslides,
d) soil erosion reducing productivity of land and producing frequent floods,
e) requirement of environmental flow,
f) altered surface and ground water regime affecting drinking and irrigation water sources and their potential to provide water,
g) flows in the streams, tributaries and rivers and, above all, environmental flows necessary for observing religious practices and sustaining biotic life,

h) impact on the places of cultural and religious importance,
i) details of submergence area under protected area network,

2. Objective of the Study

2.1. To assess the cumulative impact of existing/ proposed/ under construction hydro power projects in the Alaknanda and Bhagirathi basins. The assessment should consider, inter alia, the factors mentioned in paragraph 1.2.

2.2. To assess the extent to which the hydropower potential identified in the basins should be developed without risking stability and environment and at the same time ensuring that the quality, quantity, and timing of water flows required to maintain the functions and assimilative capacity that provide goods and services to people are maintained.

2.3. Restrictions, if any, that needs to be placed in the development of hydropower in the two basins.

3. Approach

There are three kinds of hydropower project sites. One where hydropower projects are operational. The second which are under implementation and the third those sites where work is yet to commence.

Study of the impact of projects that have already been implemented will give empirical evidence of the consequences of activities whose impact otherwise is difficult to precisely predict. This will help in drawing suitable inferences of the impact of activities w.r.t. the projects which are under implementation or where implementation has not begun.

The impact of the hydropower projects may be studied stream, tributary and river wise in series moving from upstream to downstream. The project most u/s on the uppermost stream may be taken first and its impact should be taken in to account while assessing the impact on the next d/s project. Tributaries and streams should also be studied in the same sequence. This approach will ensure that at any particular site the impact of all the u/s sites is reflected.

There are already a few projects which have been set up and are operational. The projected impact of u/s identified projects that may come up in the future needs to be superimposed on the impact of the existing Hydropower Project. The cumulative impact of the project should then be superimposed on the assessed impact of the identified d/s projects that have not been set up so far upto Devprayag.

The available EIA reports of all existing/proposed projects in the two river basins may be used. Prudence will require that impacts of these projects when implemented do not exceed the limits of safety or sustainability.

4. Methodology

4.1. Identification of Stakeholders

The stake holders shall be identified and they be taken in to confidence in the process of impact assessment at various stages.

4.2. Assessment of the requirement of data

The impact assessments that need to be made will have their own requirements of data. This requirement shall be identified. Whatever data is available shall be collected. This will enable identification of the gaps in the data which will be filled up through primary collection of data.

4.3. The hydropower projects may have implications on geologic stability, stability of slopes, landslides and erosion of soil in the catchment. Geological information will, therefore, need to be gathered.

4.4. Maps, Reports & Data

The following data shall be collected:

a) Topographical maps, satellite imageries and geological maps of the basins. For completed projects, three satellite imageries, one pertaining to pre-project period, second pertaining to the period immediately after completion and the third pertaining to the latest period. These can be used to:

   i. Mark the streams, tributaries and the completed projects, projects under implementation, Sites with potential for the development of hydropower, both large and small.
   ii. Identify the area upstream and downstream likely to be affected by the hydro-power potential sites and mark the villages.
   iii. Natural features – glaciers, tributaries, streams, other drainage lines.
   iv. Geological Features in the affected areas.
   v. Present land use
   vi. Subsidence Erosion Intensity Maps, Relief and Aspect Maps should be prepared.
   vii. Changes that have taken place over the time – since the establishment of hydropower projects in the basin
   viii. Sites from where building material was either extracted or material is proposed to be extracted.

b) Reports

j) DPRs *I* PFRs of all commissioned *I* proposed Hydropower Projects and
k) EIA studies and Environmental Management Plans (EMPs) of all commissioned/ proposed HEPs.
l) Clearances accorded to all HEPs.
m) Monitored observations and activities under taken post clearances as per requirement
n) Meteorological
o) Surface and ground water hydrology
    discharge upstream of the hydropower sites.
    discharge downstream of the hydropower sites.
p) Ground water levels in the affected areas.
q) Socio-economic data of the affected areas.

r) Water quality data at each potential site.

4.5. Completed Projects -Data Collection for Impact Assessment

The projects with capacity 25 MW and above which have been completed and are operational would have made an Impact. The study should include an assessment of their impact on environment and other factors mentioned in paragraph 1.2 in particular the following data should be gathered:

a) landslides
b) loss of irrigation potential, if any
c) Health hazards
d) Socio-economic Survey of the area to assess the socio-economic impact of the completed projects.
e) Water quality and discharge studies in the immediate vicinity and d/s of the project
f) Study the impact on springs

4.6. This data should be compared with the base line data as available in the EIA report of the project.

4.7. Use of the above data to generate further outputs such as

i. Develop Digital Elevation Models (DEM), wherever needed.
ii. Mark existing and new transmission lines that will need to be erected.
iii. Mark villages which get their drinking water and or irrigation water from streams likely to be affected by hydropower plants
iv. Mark areas which are prone to land slides
v. Mark areas which are prone to soil erosion.

4.8. Analysis of Data and Recommendations:

The data will be analysed to assess the impact of each activity necessary to implement the hydropower projects. The safe limits of parameters for geological and slope stability, environmental flows, availability of water for various traditional uses and other natural resources and environmental sustainability should be determined based on the standard methodologies. It should be examined if any of these limits will exceed at any site or sites and if so what measures need to be taken to take care of safety and sustainability norms.

5. Deliverables

a) Study the impact of large completed hydro-electric projects in the basin of the rivers Alaknanda and Bhagirathi up to Devprayag. It will include all factors mentioned in paragraph 1.2.
b) Based on the above study, drawing empirical inferences in assessing impact of hydroelectric projects under implementation / proposed.
c) A report, on the cumulative impact of
    i. all projects on a stream on the tributary.
    ii. all projects located on a tributary at its confluence with the river Alaknanda.
    iii. all projects located on a tributary at its confluence with the river

Bhagirathi.

iv. all hydroelectric projects proposed / established on river Alaknanda and Bhagirathi up to Devprayag.

(i). The report should, inter-alia, address whether the acceptable limits of geomorphologic stability or of environment al sustainability, particularly of environmental flows, are likely to exceed at any small or large hydropower project site(s).

(ii). Whether there will be a depletion of irrigation potential or availability of drinking water in habitations as a result of any project.

(iii). Impact on ground water and springs in the basin.

(iv). Impact of these projects on places of cultural, religious or tourism importance.

(v). Whether any restrictions should be placed on the development of hydropower in the basin.

d) The impacts should be expressed qualitatively and quantitatively.

6. Time to Cary out the Assignment

Six months

ANNEXURE 1.2

Table Showing Operational, Under Construction and Under Development Hydropower Projects in Alaknanda and Bhagirathi Basins

S. No.	Project Name	Basin	Name of River/ Tributary	Installed Capacity (MW)
In Operation				
1	Agunda thati	Bhagirathi	Dharamganga	3
2	Badrinath II	Alaknanda	Rishi ganga	1.25
3	Bhilangana	Bhagirathi	Bhilangana	22.5
4	Debal	Alaknanda	Kailganga	5
5	Jummagad	Alaknanda	Jummagad	1.2
6	Maneri bhali I	Bhagirathi	Bhagirathi	90
7	Manaeri bhali-II	Bhagirathi	Bhagirathi	304
8	Pilangad	Bhagirathi	Pilangad	2.25
9	Rajwakti	Alaknanda	Nandakini	3.6
10	Tehri stage-I	Bhagirathi	Bhagirathi	1000
11	Urgam	Alaknanda	Kalpganga	3
12	Vanala	Alaknanda	Nandakini	15
13	Vishnuprayag	Alaknanda	Alaknanda	400
			Total Capacity	**1850.8**
Under Development – At Construction Stage				
1	Bhilangana-III	Bhagirathi	Bhilangana	24
2	Birahi Ganga	Alaknanda	Birahi Ganga	7.2
3	Kail ganga	Alaknanda	Kailganga	5
4	Kaliganga-I	Alaknanda	Kaliganga	4
5	Kaliganga-II	Alaknanda	Kaliganga	6
6	Koteshwar	Bhagirathi	Bhagirathi	400
7	Lohari Nagpala	Bhagirathi	Bhagirathi	600
8	Madhmaheshwar	Alaknanda	Mandakini	10
9	Phata Byung	Alaknanda	Mandakini	76
10	Rishi Ganga	Alaknanda	Rishi ganga	13.2
11	Singoli Bhatwari	Alaknanda	Mandakini	99
12	Srinagar	Alaknanda	Alaknanda	330
13	Tapowan Vishnugad	Alaknanda	Dhauliganga	520
14	Vishnugad Pipalkoti	Alaknanda	Alaknanda	444
			Total Capacity	**2538.4**
Under Development – At Other Stages				
1	Alaknanda	Alaknanda	Alaknanda	300
2	Asiganga-I	Bhagirathi	Asiganga	4.5
3	Asiganga-II	Bhagirathi	Asiganga	4.5
4	Asiganga-III	Bhagirathi	Asiganga	9
5	Balganga-II	Bhagirathi	Balganga	7
6	Bharon Ghati	Bhagirathi	Bhagirthi	381
7	Bhilangna-II A	Bhagirathi	Bhilangana	24
8	Bhilangna-II B	Bhagirathi	Bhilangana	24
9	Bhilangna-II C	Bhagirathi	Bhilangana	21

S. No.	Project Name	Basin	Name of River/ Tributary	Installed Capacity (MW)
10	Bhyundar ganga	Alaknanda	Bhyundar ganga	24.3
11	Birahi Ganga-I	Alaknanda	Birahi ganga	24
12	Birahi Ganga-II	Alaknanda	Birahi ganga	24
13	Bowla Nandprayag	Alaknanda	Alaknanda	300
14	Devsari	Alaknanda	Pinder	252
15	Dewali	Alaknanda	Nandakini	13
16	Gohana Tal	Alaknanda	Birahi ganga	50
17	Jadh Ganga	Bhagirathi	Jadhganga	50
18	Jalandharigad	Bhagirathi	Jalandhari	24
19	Jelam Tamak	Alaknanda	Dhauliganga	126
20	Jhala koti	Bhagirathi	Balganga	12.5
21	Kakoragad	Bhagirathi	Kakoragad	12.5
22	Kaldigad	Bhagirathi	Kaldigad	9
23	Karmoli	Bhagirathi	Jadhganga	140
24	Khirao ganga	Bhagirathi	Khaiaoganga	4
25	Kot Budha Kedar	Bhagirathi	Balganga	6
26	Kotli Bhel-I A	Bhagirathi	Bhagirathi	195
27	Kotli Bhel-I B	Alaknanda	Alaknanda	320
28	Kotli Bhel-II	Ganga	Ganga	530
29	Lata Tapovan	Alaknanda	Dhauliganga	170
30	Limcha Gad	Bhagirathi	Limcha Gad	3.5
31	Malari Jelam	Alaknanda	Dhauliganga	114
32	Melkhet	Alaknanda	Pinder	15
33	Nandprayag Langrasu	Alaknanda	Alaknanda	100
34	Pala Maneri	Bhagirathi	Bhagirthi	480
35	Pilangad- II	Bhagirathi	Pilangad	4
36	Ram Bara	Alaknanda	Mandakini	24
37	Rishi Ganga-I	Alaknanda	Rishi ganga	70
38	Rishiganga II	Alaknanda	Rishi ganga	35
39	Siyangad	Bhagirathi	Siyangad	11.5
40	Suwari Gad	Bhagirathi	Suwari Gad	2
41	Tamak Lata	Alaknanda	Dauliganga	250
42	Tehri Stage-II	Bhagirathi	Bhagirathi	1000
43	Urgam-II	Alaknanda	Kalpganga	3.8
			Total Capacity	**5174.1**

CHAPTER -2

METHODOLOGY

2.1 INTRODUCTION

Every development project has impact on a number of parameters of environment. Some impacts may be cumulative in nature and some may have only localized impact. This study addresses the issue of Cumulative Impact Assessment on identified components of environment in the basins of Alaknanda and Bhagirathi of hydropower projects only and not of other development projects. Impacts, both pertaining to a single project and cumulative of projects in cascade, are covered.

According to Guidelines of the MoEF on EIA issued under the Environment Protection Act, hydropower projects with an installed capacity exceeding 25 MW are required to seek environmental clearance on the basis of EIA report and Environmental Management Plan. So far there is no provision for cumulative impact assessment (CIA) in India.

Globally EIA has been in practice for more than half a century. However, cumulative environmental impact assessment is a relatively recent development. The concept and the manner in which it should be made are still evolving.

The methodology adopted for carrying out studies in different areas are summarized below.

2.2 SELECTION AND CATEGORIZATION OF HYDROPOWER PROJECTS FOR THE STUDY

Hydropower Projects (HPs) with installed generating capacity exceeding 1 MW (70 in number) have been considered for this study and details of these projects are discussed in Chapter 8 on hydropower development. Smaller HPs, i.e., with installed capacity of 1 MW or below have not been considered for the following reasons:

(i). Projects with such small capacity are seldom located on main rivers but are on small tributaries.
(ii). Their impact is low and localized and their cumulative impact is negligible.
(iii). The Ministry of Environment and Forests (MoEF) had never required EIA of projects unless their cost was ₹ 500 million or more or if the installed capacity was at least 25 MW or the area under submergence was greater than 10000 Ha. This is evident from the following notifications of the MoEF.

Reference	Applicability
Notification no. S.O. 60(E) dated Jan 27, 1994	Projects of cost above ₹ 500 Million
Revised notification no. S.O. 632(E) dated June 13, 2002	Projects of cost above ₹ 1000 million or submergence area > 10,000 Hectare
Notification no. 1533(E) dated Sept 14, 2006 and published as S.O. 195(E) dated Jan 19, 2009	Projects with installed capacity of 25 MW or more. Cultivable command area>10,000 Hectare

On the assumption that the cost of such projects in 1994 was ₹ 50 million/MW) the projects required environmental clearance only if their installed capacity exceeded 10 MW corresponding to a minimum cost of Rs. 500 million.

Thus, for projects approved prior to 1994 no environment impact assessment was carried out and for projects sanctioned after 2002 or 2006, there are no EIA reports if the installed capacity was 25 MW and below.

Out of the 70 HPs selected for this study in the basin, only four large Hydropower Projects (with installed capacity exceeding 25 MW) have been commissioned. These HPs have been selected for detailed hydrological study. For assessment of their cumulative impact all projects on main rivers i.e., Alaknanda and Bhagirathi, their tributaries and streams have been considered. Data and details of these sites have been collected mainly from project developers. Data availability of commissioned projects has been low, especially on monitoring of impacts on environment. Projects which are under construction also are monitored to a limited extent. Thus, limited availability of baseline data and lack of proper monitoring is a major handicap in this study.

As described in detail in the chapter on Hydropower development, hydropower projects have been divided into two categories including (i) Commissioned Hydropower Projects (HPs) and (ii) HPs under development. The HPs under development are further divided into two categories namely (a) Where construction has started and (b) Where construction has not started although the sites have been allotted. This categorization is useful because it enables the assessment of hydropower projects in various stages of their development. Impacts both during the stage of construction and after completion have been considered.

2.3 DIVISION OF THE WORK INTO STUDY FIELDS/ SPECIALIZATION

After the assignment was awarded, the team members deliberated on the approach to solve the problem. Data requirement was worked out and the process of gathering requisite data was initiated. The inception report was prepared and submitted to MoEF vide letter no. AHEC/5-67 dated August 08, 2010.

The study involved many disciplines and therefore, the work was divided into the following study areas:

(i). Remote Sensing and Geographical Information Systems Studies
(ii). Geological Studies
(iii). Seismological Studies
(iv). Water Quality
(v). Aquatic Biodiversity
(vi). Hydrological Studies
(vii). Hydropower Development
(viii). Study Related to Places of Cultural, Religious and Tourism Importance
(ix). Studies Related to Stakeholders in Hydropower
(x). Cumulative Impact Assessment of Hydropower Projects
(xi). Integration of the Work Carried out in Different Study Areas.

The work of each of the above areas is briefly described below. The methodology in detail is given in the respective chapters.

2.3.1 Remote Sensing (RS) and Geographical Information Systems (GIS)

The objective of RS and GIS studies was to compliment other study areas and provide the maps needed by them in GIS format. Satellite data and Survey of India (SoI) topographical maps were used to prepare thematic maps which were also used by other study areas. SoI topographical maps on 1:50,000 scale were used for precise location of towns, rivers and their tributaries. The task force made maps by rectification and georeferencing of satellite data for the years 2000 and 2009 which helped in observing changes in landform and land use over a period of a decade.

Data of LISS-III sensor from IRS satellite (spatial resolution of 23.5m) and IRS P-6 LISS-IV (spatial resolution of 5.8 m) for selected areas, especially where hydropower projects are present, were used for preparation of various thematic maps and analysis.

After making necessary corrections, using various standard techniques, GIS data base was created for different layers exhibiting streams, water bodies, hydropower project sites, important towns, etc. Land use and soil erosion maps were also prepared. Digital Elevation Model (DEM) helped in visualization of topographic variations of the basin areas of Alaknanda and Bhagirathi and their tributaries. Details of the methodology and description of maps are given in Chapter 3.

Emphasis has been given first to evaluate the impact of commissioned hydropower projects for which some data base is available. Attempt has also been made to incorporate the impact of under construction hydropower projects and proposed hydropower projects when they would become operational. The stress has been to integrate the information and impact of individual hydropower projects to understand and estimate the cumulative impact of all hydropower projects on Alaknanda and Bhagirathi basins.

The following types of maps for the study area have been prepared:

(i). Maps showing Alaknanda and Bhagirathi Rivers, their tributaries, streams and hydropower projects in the basin.

(ii). Maps showing areas upstream and downstream of HPs likely to be affected by them.

(iii). Maps showing Geological Features (Geotracts, landslides, springs, seismotectonics, earthquake epicenters, glaciers etc. in Alaknanda and Bhagirathi Basins.

(iv). Land use maps for the years 2000 and 2009.

(v). Soil Erosion, Relief and Aspect Maps.

(vi). Map showing transmission line networks

(vii). Districts, District Headquarters, Towns, places of religious and cultural importance, protected areas and Villages.

(viii). Map showing areas under submergence and diverted river stretches

2.3.2 Geological Studies

In the process of development of hydropower potential constructional activities are undertaken that interfere with natural geological features and through this interference there could be an impact on geotectonic stability, landslides and seismicity. Analysis of the geological set up of the study area was carried out to study the distribution of various rock units and tectonic lineaments on the regional scale. Essentially published geological maps on the regional scale, geological studies given in different EIA and EMP reports of the projects, detailed field studies of few important project sites were used. Presence of tectonic zones, namely the major thrusts faults and fractures were evaluated. Further, the task force studied the slope stability and landslides using the Survey of India topographical sheets, information in project reports and field work at hydropower project sites. With the help of these studies the area was classified into six Geotracts which are relatively homogeneous among themselves but hetrogenous between themselves. Based on lithological, geomorphological, structural features zones susceptible to natural landslides were ranked and depicted on the map showing the location of various HPs. Impact of hydropower projects on slope stability and geotectonicity of the region was evaluated. Details of this aspect are discussed in the chapter 4.

2.3.3 Seismological Studies

With a view to evaluating the impact of hydropower projects especially the larger reservoirs based project namely Tehri HP, information available pertaining to seismic investigations was analysed and attempted probabilistic estimation of induced seismicity due to the reservoirs. An assessment of seismotectonic features of the study area has been made for the purpose of identification of seismic potential of tectonic features. Seismotectonic model and maps were prepared considering the spatial distribution of earthquakes, magnitude and depth between latitude 27° N to 33° N and longitude 75° E to 85° E for the period July 1720 to January 2009 along with source mechanism of earthquakes. Seismicity data pertaining to this study was procured from India Meteorological Department (IMD), New Delhi. Local seismicity data recorded through local network between the period from 1994 to 2009 was analysed for examining the nature of microearthquake activity associated with reservoir impounding. These aspects are elaborated in Chapter 5.

2.3.4 Environmental Studies

2.3.4.1 Water Quality and Aquatic Biodiversity Studies–

This study area addresses the following issues:

(i). Determining the status of water quality at different locations in undisturbed stretches of rivers, at hydropower project sites and assessing the impact of hydropower projects on water quality in the basin.

(ii). Status of aquatic life

(iii). Requirement of environmental flows for sustaining aquatic life.

2.3.4.2 Sampling Locations

For determination of water quality, samples were collected and analysed for water quality at different locations which may be classified as below:

(i). Rivers and tributaries in high altitude where the rivers are undisturbed by human activity.

(ii). River segments where hydropower plants are in operation. In such segments, samples were collected at the point of intake of the project and downstream after tail race. The comparison of water quality analysis of these two points provided data on impact (if any) of hydropower plant on the water quality.

(iii). Samples were collected after several hydropower plants in cascade on a river to see the cumulative effects of several plants on the water quality.

2.3.4.3 Water Quality and Aquatic Biodiversity

Parameters that are important for sustainability of aquatic life were selected. These included temperature, pH, dissolved oxygen, conductivity, total dissolved solids, turbidity, BOD, faecal coliform, phosphates and nitrates. Details of water analysis are given in Chapter 6.

Aquatic biodiversity was determined using following biotic components, phytoplankton, periphyton- microphytes, zooplankton, macrobenthos, fish, other aquatic vertebrates. This information helped in determining the ecological status of the river. Benthic macroinvertebrates, fish and otter were used to determine the Valued Ecosystem Components (VEC) of the study area. Determination of hydrological requirements, namely water depth and water velocity for macroinvertebrates, fishes was done to determine the environmental flows. These biological parameters were used to determine the impact of hydropower projects on the aquatic life of rivers.

For aquatic biodiversity and requirements for its sustainability the study focuses on on-going and proposed hydropower developments on the Alaknanda and its tributaries (Dhauliganga, Rishiganga, Birahiganga, Pinder, Nandakini, Mandakini) and Bhagirathi and its tributaries (Asiganga, Bhilangana, Balganga) up to Devprayag.

The entire study area was divided into different stretches/zones on the basis of the habitat characteristics (geological/morphological/hydrological and biological). The primary data on collection of biotic valued ecosystem components (macroinvertebrates, fish and fish otter) were made after visiting all major river zones of study area. The secondary data related with biotic components were also collected from the published literature. Benthic macorinvertebrate data were derived from samples taken following standard protocols.

The data on fishes and fish otter were collected through primary and secondary sources. Data on important basin ecological indicators were also collected for assessing the environmental management class of rivers.

Hydrological requirements (water depth and water velocity) of macro invertebrates, fish and fish otter were determined on the analysis of characteristics of their natural habitat and their life activities in the Alaknanda –Bhagirathi basin. Published literature was also consulted extensively for assessing hydrological requirements of these organisms. There are various approaches for classifying rivers on the basis of biotic communities or various basin ecological indicators. These are based on elevation of the terrain, the rhithronic status and environmental management class. These have been used in classifying different stretches of rivers in the Alaknanda-Bhagirathi basin. The depth of water and velocity required have been suggested for different stretches of rivers.

2.3.4.4 Impact of Hydropower Projects during its Construction Stage

During construction of the hydro power projects a number of temporary and permanent impacts are usually noted. Impacts of hydropower projects during construction in respect of the following projects have been assessed:

Commissioned Projects	: Badrinath II, Vishnuprayag, Urgam, Rajvakti, and Vanala
Under Construction Projects	: Tapovan Vishnugad, Visnugad Pipalkoti, Phata Byong, Singoli Bhatwari, and Srinagar

Both positive and negative impacts are observed during the construction period. Every project site was visited, project authorities and local people were met and photographs taken.

2.3.5 Hydrological Studies:

This study area addresses the following topics:

(i) Brief description of physiography of the area
(ii) Estimating flows in rivers at hydropower project sites
(iii) Concept of Environmental Flows
(iv) Description of various techniques for assessment of environmental flows.
(v) Assessment of Environmental Flows for sustenance of river eco-system and at places of religious and cultural importance.
(vi) Impact of operation of selected hydropower projects on variability of downstream river flows.

The appraisal of surface water resources generally includes estimation of (i) annual run-off and its monthly / ten daily / daily distributions, and (ii) aerial distribution of water resources within the basin. For a reliable appraisal of water resources, stream flow records for around 25 years are desirable. In case of short records, temporal extrapolation is required using suitable techniques. Gauge-discharge observation taken once a day is sufficient for most yield studies.

Processing of surface water data in the present study was completed in the following steps:

(i) The study area was sub-divided into sub-basins (sub catchments/ watersheds) keeping in view the existing and proposed storage / diversion schemes, size of watersheds and demand areas (towns, agriculture land etc.).
(ii) Suitable gap-filling techniques are employed where the discharge data records were incomplete.
(iii) Estimation of water-year runoff (daily/10-daily/ monthly/annual) in sub-basins was made as follows:
    a) Estimate water-year rainfalls in sub-basins,
    b) Estimate total flow at a river gauge site / sub-basin, and
    c) Estimate water-year dependable yields in each un-gauged gauge site / sub basin: Compute the total flow at an un-gauged site based on proportionate catchment area and weighted rainfall. For hydropower and environmental purposes surface water of 75% and 90% water-year project dependability criteria is required. In addition, flows with 50%, 60%, and 90% were also computed.

Each of the sub-basins (Alaknanda and Bhagirathi) has only 2 to 3 rain gauges and also data is available for a few years only. Moreover, discharge data from CWC are for the years 1989 to 2008. Therefore, discharges at un-gauged sites were estimated from discharge data of CWC only on the basis of catchment area ratios. The stream flow data obtained from the Central Water Commission (CWC) at 9 gauging sites was processed and used to estimate flows at different project sites and places of religious importance. Hydrographs and Flow Duration Curves at five dependabilities were prepared.

Environmental flows at selected hydropower project locations were determined using different methodologies and suitable recommendations have been made.

2.3.5.1 Methodology for Environmental Flows Assessment (EFA)

Since the mid-1970s, there has been a rapid proliferation of methods for estimating environmental flow for a given river. Although it is recognized that a myriad of factors influence the ecology of aquatic ecosystems (e.g. temperature, water quality and turbidity), the common supposition of these approaches is that the flow regime is the primary driving force (Richter et al., 1997). The various approaches developed to estimate environmental flow requirements can be divided into four broad categories.

The area under study is of immense importance due to its fragile ecosystem and the presence of many shrines including Char Dhams (four religious sites: Badrinath, Kedarnath, Gangotri and Yamunotri). In addition, seven Prayags (confluence of two rivers) are located in this area. Most Hindu festivals are associated with bathing in holy ponds and rivers. A large number of pilgrims assemble on the banks of rivers and ponds to take holy dip. For this purpose, river flows and water quality, particularly during lean season, have to be maintained.

Moreover, keeping in view the location of major hydropower projects (Commissioned and under construction), 31 sites have been identified for assessment of environmental flows i.e.:

Hydro Projects in Operation: 9 in number,
Hydro Projects under Development: 14 in number,
Places of religious and cultural importance: 8 in number.

Using different approaches environmental flow requirements have been assessed.

2.3.5.2 Ground Water and Springs

Groundwater in the higher Himalayan region is available only in shallow aquifers. Rocks in these areas have low primary porosity. Groundwater in this region is generally present in fractured and weathered zones which may be localized. Extensive aquifers in Himalayan region are not present due to rugged topography and steep slopes. Moreover, residence time in these shallow aquifers is small (not more than a few years). Thus, measurement of groundwater levels and fluctuations in mountain areas through observation wells and piezometers are not practical. It is learnt that the CGWB does not have a network of piezometers to record ground water levels in the basin. In recent years, Departments of the Government of Uttarakhand State like Jal Nigam / Jan Sansthan / Swajal have installed a number of hand pumps, to meet water requirements of villages of Uttarakhand. Attempts have been made to collect groundwater level and fluctuation data (based on water table in hand pumps).

In hilly areas, springs or streams emanating due to seepage of water fulfill drinking water needs of the local population. The impact of construction of HPs on springs in the vicinity of hydropower projects has been examined.

Due to construction of a dam, groundwater recharge is likely to increase. In addition to that, in the vicinity of the project, it is expected that there would be a positive impact of project for groundwater recharge and availability. As impact of the project would be localized, the cumulative impact may not be applicable for groundwater resources.

The impact of any individual project can be assessed if long term data of groundwater levels and other data are available. However, in the absence of relevant groundwater data in the pre-project scenario, it may be difficult (or improper) to conclude with confidence the impact of construction of hydro projects on the availability of groundwater and drinking water sources to the population in the project area. However, some general inferences may be drawn from the data of hand pumps / springs.

2.3.5.3 Soil Erosion Studies

Assessment of soil loss has been done to identify soil erosion prone areas within the Alaknanda and Bhagirathi Basins. Sediment flows to the HP sites along with water and gets deposited at the dam / barrage. In the present study, RUSLE, which is the most extensively used empirical soil erosion model, has been used. Basically RUSLE, which lumps inter-rill and rill erosion together, is a regression equation. The Revised Universal Soil loss Equation (RUSLE) like its predecessor the Universal Soil loss Equation (USLE) is an erosion prediction model designed to predict the long-term average annual soil loss from specific field slopes in specified land use and management systems (i.e. crops, rangeland, recreational areas). This study helps to identify priority areas and suggest soil conservation measures.

2.3.6 Hydropower Development

As the subject of the study has been the impact of hydropower projects in the basin the methodology adopted for the project has been to obtain the data from the project developers (both private and government) as well as the Government agencies like Central Water commission, Central water board and Survey of India. State government and EIA division of MOEF was also approached for the data. Technical, financial, hydrological, morphological details of all hydropower projects were put in the matrix and were analyzed on various considerations. Their impacts on power generation, state revenue and investment related development have been also analyzed. All the data were plotted on the basin map as well as gradient section. The diverted as well as submerged stretches of the river were analyzed from power generation consideration.

Literature survey (national and international) on the environment concerns of hydropower was carried out. Concerns for hydropower development like Energy Payback ratio and Life Cycle Assessment and Green House Gas (GHG) emission from Hydropower were studied and presented. The chapter has also included the power scenario of the state, hydropower policies of the state, basics of hydropower, operational water use for hydropower generation in terms of water withdrawal and water consumption. Hydropower facilities as barriers for fish migration have been studied and possible mitigation structure have been suggested.

2.3.7 Studies related to impact on places of Cultural, Religious and Tourism Importance

The study area is rich in places of religious and cultural importance. The impact of hydropower projects on such places has been assessed. Primary data collection was done using qualitative techniques based on Key Informant Interviews and Focus Group Discussions. The aim was to obtain opinion across a broad range of stake holders. To generate summary and inferential statistics interviews were conducted with members of religious, business and academic communities, political groupings, staff of power companies and residents of towns and villages. Their opinion was obtained on topics like soil erosion, landslide, changes in spring water, effect on houses, water quality, health hazards, agriculture activity, tourism, economy. Data obtained at individual locations has been integrated to assess the cumulative impact. In each basin, at least three commissioned projects and one under construction project and hydropower projects were examined. Details of findings are discussed in details in Chapter 9.

2.3.8 Hydropower and Stake Holders

In order to take into account opinions of stake holders on effects of HPs in the area, consultations were held with eminent environmentalists like Shri Chandi Prasad Bhatt, recipient of Padma Bhushan and others and correspondence was received from some individuals. Members of the study group also held discussions with representatives of the Ganga Maha Sabha at Hardwar. “Dainik Jagran” a widely read Hindi news paper in Uttarakhand ran a column entitled. “Urja Prakash – Sach Ya Sawal” to elicit people’s view of Hydropower Projects in the state. These have been studied and summarized. Agreement made between the HP developers and local communities and available details of various meetings held with local communities with the HP developers were studied. Views expressed by stakeholders in publications including news papers and books were also seen. Synthesis of these has been elaborated in Chapter 10.

The stakeholders can be broadly divided into three main groups: (a) communities living in and around the project area, (b) people from other areas who migrate to the project and surrounding areas for varying durations and tourists who visit the area for short durations and (c) people living outside the area, who believe that the region is a repository of a number of holy places which represent the most sublime in religious and cultural ancient values and who are of the view that the region should be left largely undistributed.

2.3.8.1 Impact on Socio-economic Environment

This part of the study aims to assess impact of Hydropower Projects (HPs) on socio-economic environment, as a hydropower project will inevitably bring economic and social changes to the project area. It may stimulate economic growth, building of roads, schools, hospitals, cultural, and recreational facilities, and it may also have negative impacts on the lifestyle of some people. If the local population are indigenous people, social and cultural aspects of the project have to be managed with particular sensitivity in order to avoid negative effects on their lifestyle and culture.

The assessment was based on discussion with project authorities, examination of the material and information supplied by them, visit to the project site and the villages and talking to villagers for verification of the information.

2.3.9 Cumulative Impact Analysis - Assessment of HPs on Components of Ecosystem

Assessment of the impact of each of the hydropower projects in light of the prevailing concepts of cumulative impact assessment on the identified ecosystem components in the Bhagirathi and Alaknanda basins and the cumulative impact of HPs has been carried out in this chapter. The HPs affect a large number of components of the ecosystem and socio-economic environment. In accordance with the Terms of Reference of this study, the following components are covered (a) Seismicity (b) Geological (i) Landslides (ii) Sedimentation (c) Fish (indicative of aquatic life) (d) Environmental Flow (i) Flow regime of the stream (ii) Whether the impact is remediable (iii) Impact of ensuring environmental flow on power generation (d) Springs and Drinking Water (e) Irrigation (f) Places of Cultural and Religious Importance (g) tourism (h) Socio-economic Environment (i) Submergence and (j) Water Quality. The impacts have been categories in to two types. Localized Impact and Cumulative Impact Tables have been prepared for qualitative assessment of the impacts on the components of the ecosystem for the select hydropower projects. The project wise details of impacts are discussed in detail in the chapter. The qualitative assignment was not feasible in the present set of data and resources.

2.3.10 Conclusions and Recommendations

Integration studies involved organizing meetings and discussion amongst the experts involved in the study to discuss specific and general aspects of various study areas. The meetings helped individuals to discuss a methodology and exchange of data and ideas to develop a coherent assessment and exchange of ideas at different stages to achieve a common goal to assess the cumulative impact of hydropower plants. This helped individuals in obtaining information from various agencies of State and Central Governments and the Project owners. The conclusions arrived by the investigators working on different areas of study have been summarized and the recommendations made are given in Chapter 12.

CHAPTER – 3

REMOTE SENSING & GIS STUDIES

3.1 INTRODUCTION

Remote Sensing (RS) data can be considered an essential data source for the appraisal of natural environments as it provides valuable information for interpreting the landscape. This technology has already demonstrated its capabilities to provide information on natural resources such as crop patterns, land use, soils, forest etc on periodic basis. Multispectral characteristics of RS data provide an opportunity to explore intricate details of the area which are not available by normal surveys. Repeated coverage of RS data provides the capability to study both spatial and temporal changes in a region. Similarly, Geographic Information System (GIS) is the latest tool available to store, retrieve and analyze different types of data for management of natural resources. It facilitates systematic handling of data to generate information in a devised format. Thus, it plays an important role in evolving alternate scenarios for natural resources management. Combination of RS and GIS provide multi-dimensional information for mapping of an area.

The scope of work in the present study includes rectification and georeferencing of satellite images pertaining to years 2000 and 2009-10, preparation of maps for the area including maps of land use/ land cover, major streams and tributaries etc. using satellite imageries and topographic maps, marking the location of hydropower projects, their area of influence and other features in the Alaknanda and Bhagirathi basins.

RS and GIS based analysis has been carried out to provide vital inputs for detailed assessment of cumulative impact of Hydropower Projects in Alaknanda and Bhagirathi basins.

3.2 PROCUREMENT OF SURVEY OF INDIA TOPOSHEETS

Survey of India toposheets at the scale of 1:50,000 and 1:250,000 were also used in the study. Toposheet nos. 53I, 53J, 53M, 53N, 62B (5 nos.) at 1:250,000 scale and toposheet nos. 53I/12, 15, 16, 53J/1, 2, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 53M/ 3, 4, 8, 12, 53N/1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 62B/1, 2, 3, 4 (41 nos.) at 1:50,000 scale were used to collect spatial and topographical characteristics of the area. Toposheets at 1:50,000 scale provided better details and information about the area included in the catchment of Alaknanda and Bhagirathi. Although these toposheets provided good planimetric controls and height information, but the available toposheets were surveyed in different years quite some time back. Therefore, latest information about roads and river courses were obtained using satellite images of latest available dates to get the updated spatial data about the project areas.

3.3 PROCUREMENT OF SATELLITE DATA

Indian Remote Sensing Satellite's (IRS) Linear Imaging and Self Scanning Sensors (LISS-III and LISS-IV) images have been used for the study.

LISS-III sensor images at 23.5 m spatial resolution have been used for study of the entire area of Alaknanda and Bhagirathi basins. LISS-III data has four multispectral bands pertaining to green, red, near infrared (NIR) and short wave infrared (SWIR) wavelengths, which are useful for preparation of land use land cover maps. LISS-III satellite data from IRS P6 and IRS 1D satellites have been procured from National Remote Sensing Centre (NRSC), Hyderabad after browsing the NRSC website for availability of satellite data for required sensor/ date/ area and verifying for minimum cloud cover. Satellite images of two time periods of year 2000 and 2009 have been procured for evaluating the impact of hydropower projects with respect to time. LISS-III data procured and used in the present study is listed in Table 3.1. The spatial extent (layout) of individual LISS-III images pertaining to years 2000 and 2009 are shown in Figs 3.1 and 3.2, respectively.

Table 3.1 LISS-III data used for the present study.

S. No.	Satellite	Sensor	Path-Row	Date
1.	1 D	L-3	096-049	28-Oct-2000
2.	1 D	L-3	097-049	03-May-2000
3.	1 D	L-3	097-050	30-Sep-2000
4.	1 D	L-3	098-049	27-Sep-2000
5.	1 D	L-3	098-050	27-Sep-2000
6.	P 6	L-3	097-049	23-Oct-2009
7.	P 6	L-3	097-050	23-Oct-2009
8.	P 6	L-3	098-049	28-Oct-2009
9.	P 6	L-3	098-050	28-Oct-2009

IRS P-6 LISS-IV data has also been procured for the year 2008-10 to study in detail important hydropower projects. LISS-IV data has three multispectral bands pertaining to green, red and near infrared (NIR) wavelengths, at a better spatial resolution of 5.8 m. It is used for preparation of land use land cover maps for the areas surrounding the HPs. It has relatively lesser swath of 23.5 km, therefore availability of LISS-IV data is some what uncertain for a particular time period. Hence, in case good quality cloud free LISS-IV data pertaining to year 2010 for a particular area was not available, data for year 2009 or 2008 was procured. Area above 4000 m elevation, is covered with snow and glaciers, hence it has not been considered for detailed study. LISS-IV data procured for the present study is listed in Table 3.2. The year 2000 was chosen as base line data as no big hydropower projects had been constructed in the area by then and 2009 data was used for comparison purpose. These two data sets were considered sufficient as the intervening period of 10 years is the period in which construction has taken place on most hydropower projects in the area.

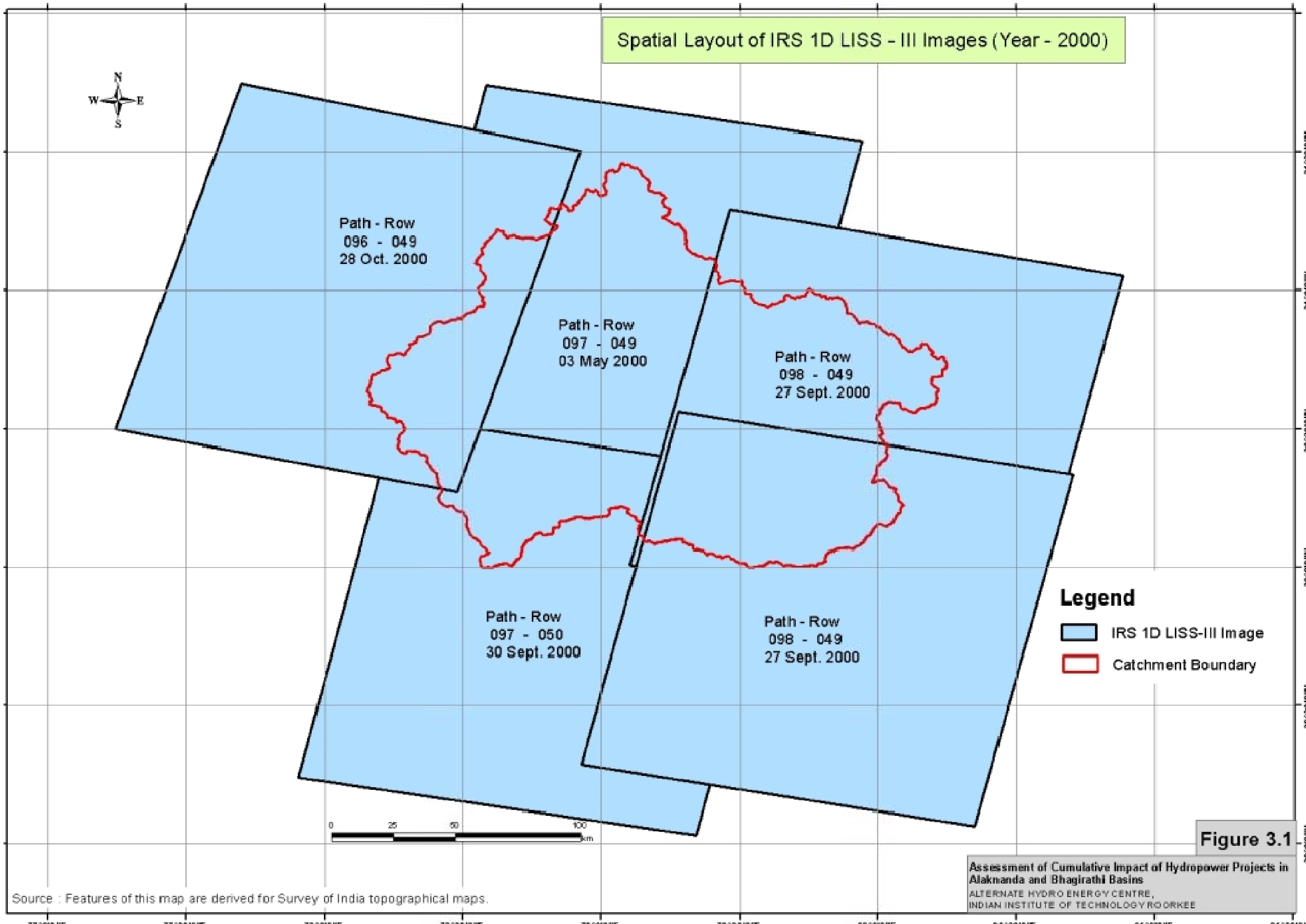


Figure 3.1 Spatial Layout of IRS 1D LISS-III Images (Year – 2000).

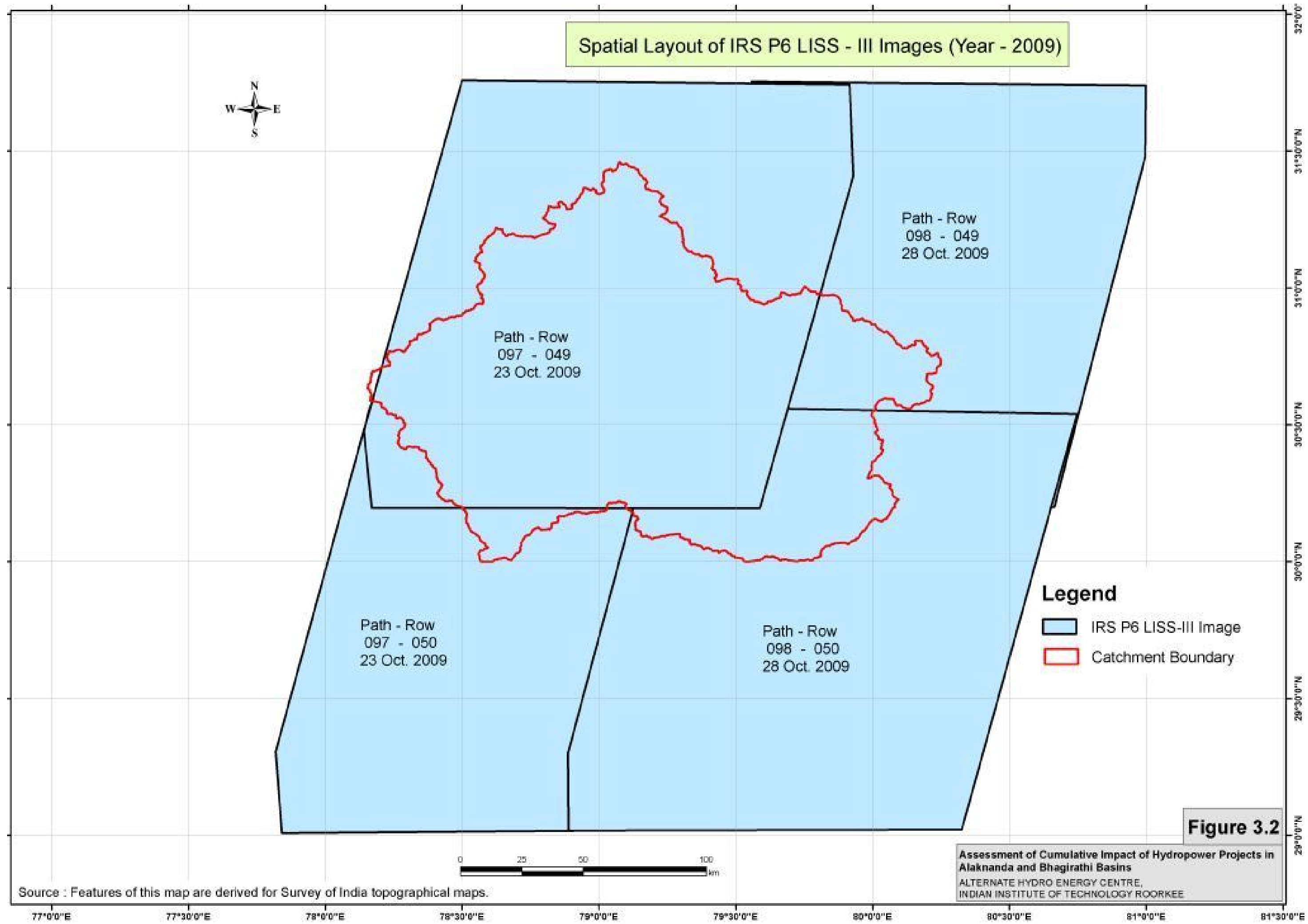


Figure 3.2 Spatial Layout of IRS 1D LISS-III Images (Year – 2009).

Table 3.2 LISS-IV data used for the present study.

S. No.	Satellite	Sensor	Path-Row	Date
1.	P 6	L-4	102-020	16-Nov-2008
2.	P 6	L-4	202-027	15-Dec-2008
3.	P 6	L-4	102-017	08-Jan-2009
4.	P 6	L-4	101-005	19-Apr-2009
5.	P 6	L-4	101-006	19-Apr-2009
6.	P 6	L-4	102-003	16-Nov-2009
7.	P 6	L-4	202-021	23-Apr-2010
8.	P 6	L-4	102-016	28-Apr-2010

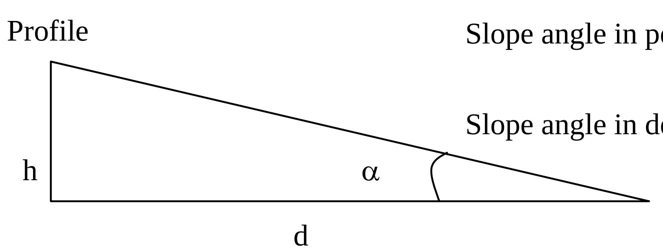
3.4 GEOREFERENCING AND MOSAICING OF SATELLITE DATA

Satellite data has been checked for radiometric errors and basic corrections for radiometry for line dropout and striping have been applied. Individual scenes of the satellite data are georeferenced with respect to the Survey of India topographic maps and limited control points from GPS (Global Positioning System). 2^{nd} order polynomial transformation was used to achieve higher accuracy in georeferencing. This polynomial requires 6 or more ground control points (GCPs) for geometric rectification of satellite data. To ensure better geometric fidelity of the images minimum twenty GCPs, well distributed spatially, have been used for each satellite image. Lambert Conforma1 Conic (LCC) projection system and Modified Everest datum have been used for georeferencing satellite images. LCC is a conical projection, which has good compatibility with polyconic projection of topographic maps, therefore seamless images are obtained after georeferencing and mosaicing. The georeferenced satellite images have been mosaiced using the histogram matching technique for radiometric balancing among the various satellite images. Also, feathering option has been used while mosaicing to get the seamless boundaries between different satellite images.

3.5 PREPARATION OF DEM, SLOPE AND ASPECT MAPS

The area under study being an intricate hilly area, DEM (Digital Elevation Model) from ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) at 30 m planimetric resolution has been used. This DEM has good resolution for overlaying and viewing the geographical features over 3-D to have a better visualisation for the terrain for analysts and decision makers.

DEM helps in delineating the different slope values with respect to individual cell/pixel of the DEM image. A slope angle or slope percentage has been calculated for each pixel in the raster DEM map, as shown in the figure below:



Slope angle in percentage = $100 \times \left(\frac{h}{d}\right)$

Slope angle in degree (α) = $\tan^{-1}\left(\frac{h}{d}\right)$

where, h is the height difference between two points and d is the distance between them on the map. The slope map has been prepared using ArcMap software. A 3 x 3 pixel window (each pixel being 30 m square) is used to calculate the slope at each pixel. For a pixel, at location (x,y) the elevations around it are used to calculate the slope. The slopes are calculated for x and y directions, then average slope is calculated for that pixel.

Aspect (slope direction) map is an image file that is coded according to the prevailing direction of the slope at each pixel. Aspect is expressed in degrees from North direction, clockwise, from 0° to 360°. A value of -1^{o} or 361° is used to identify flat surfaces such as water bodies. Calculation of aspect value has been performed by using a 3 x 3 window around each pixel of the slope map to calculate the prevailing direction it faces. Aspect values are recoded as continuous values from 0° to 360°, where 0° aspect denotes the North direction, 90° aspect denotes the East direction, 180° aspect denotes the South direction, and 270° aspect denotes the West direction. The other aspect angles are the values in between these prominent directions. For understanding, the aspect values of 338°–360° and 1°–22° can be assigned as North direction. Similarly aspect values of 23°–67°, 68°–112°, 113°–157°, 158°–202°, 203°–247°, 248°–292°, 293°–337° can be assigned as North-East, East, South-East, South, South-West, West, North-West directions, respectively. The relief, slope and aspect maps of the study area are given as Figs. 3.3, 3.4 and 3.5, respectively.

3.6 PREPARATION OF DATA LAYERS

Different spatial layers (thematic maps) for topographic and man-made features were prepared in the GIS environment using satellite images and ancillary data. The non-spatial database is also created for these layers by inserting the related attribute information. The following major thematic maps are prepared. Some of these maps are given in the relevant chapters.

3.6.1 Preparation of Soil map

Soil maps at the scale of 1:500,000 prepared by National Bureau of Soil Survey and Land Use Planning (NBSSLUP), Nagpur have been used. The maps have been georeferenced with respect to LISS-III satellite image and the relevant soil classes pertaining to the catchment area have been digitized.

3.6.2 Preparation of Drainage map

Drainage map has been prepared using the LISS-III satellite data of year 2009. At some places, where the drainage is not clearly identified due to shadow and relief effect on the satellite image, the drainages were modified by using the information available in topographic maps. The drainages are also available in topographic maps, but these maps were prepared in years 1965 to 1975, therefore in order to get the updated river network, the drainages are marked over satellite image of 2009 (Fig. 3.6).

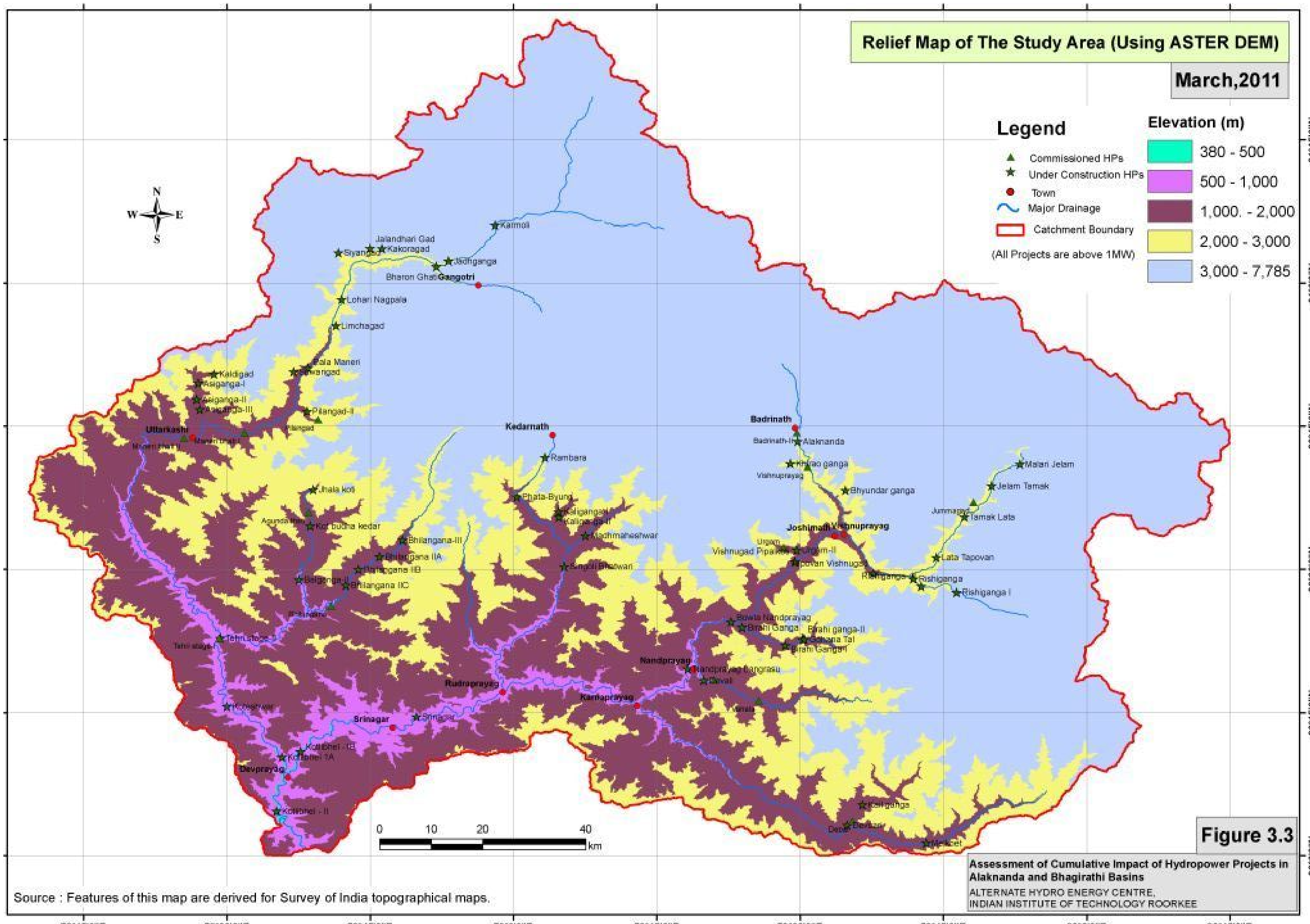


Figure 3.3 Relief Map of the Study Area (Using ASTER DAM)

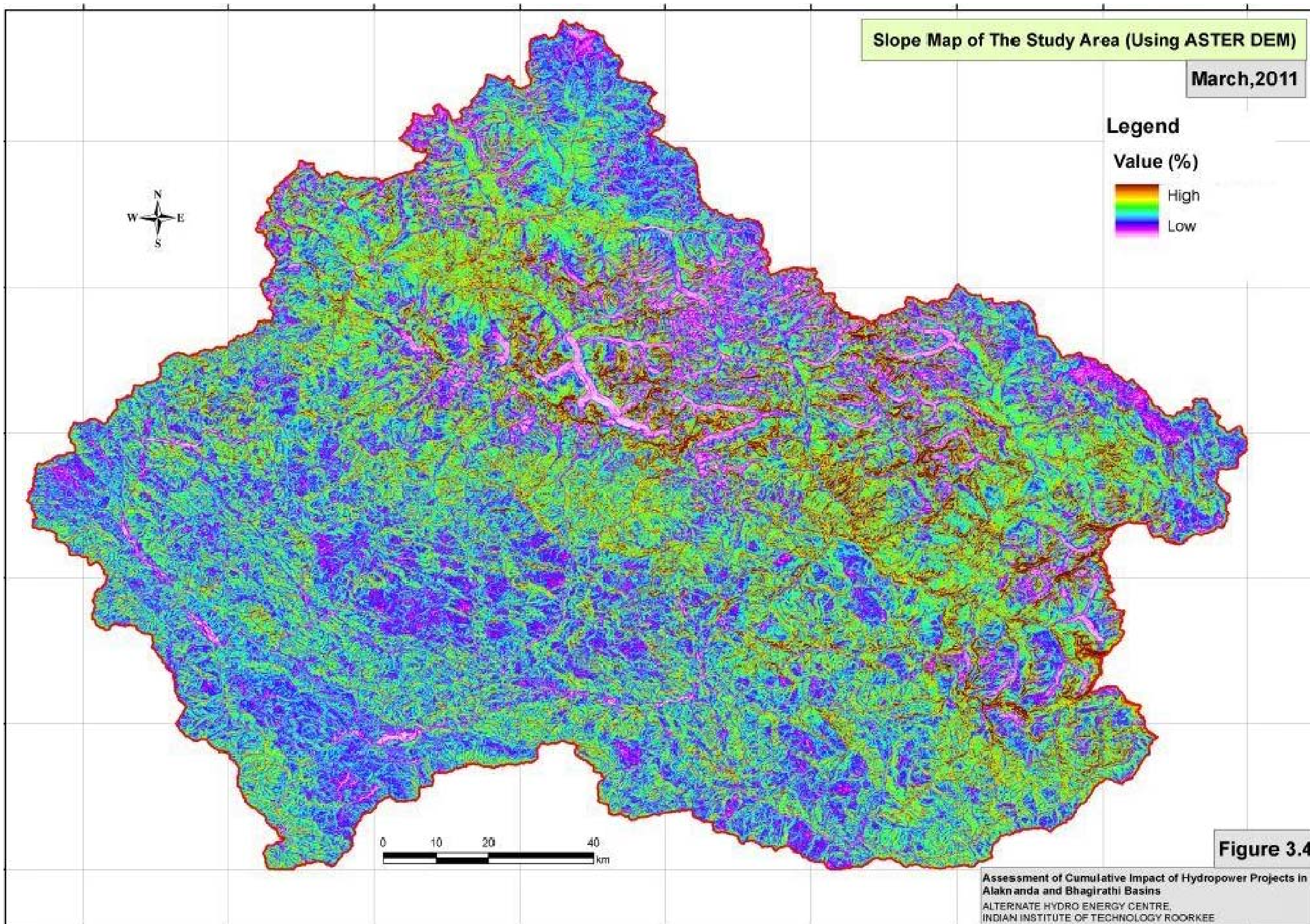


Figure 3.4 Slope Map of the Study Area (Using ASTER DEM)

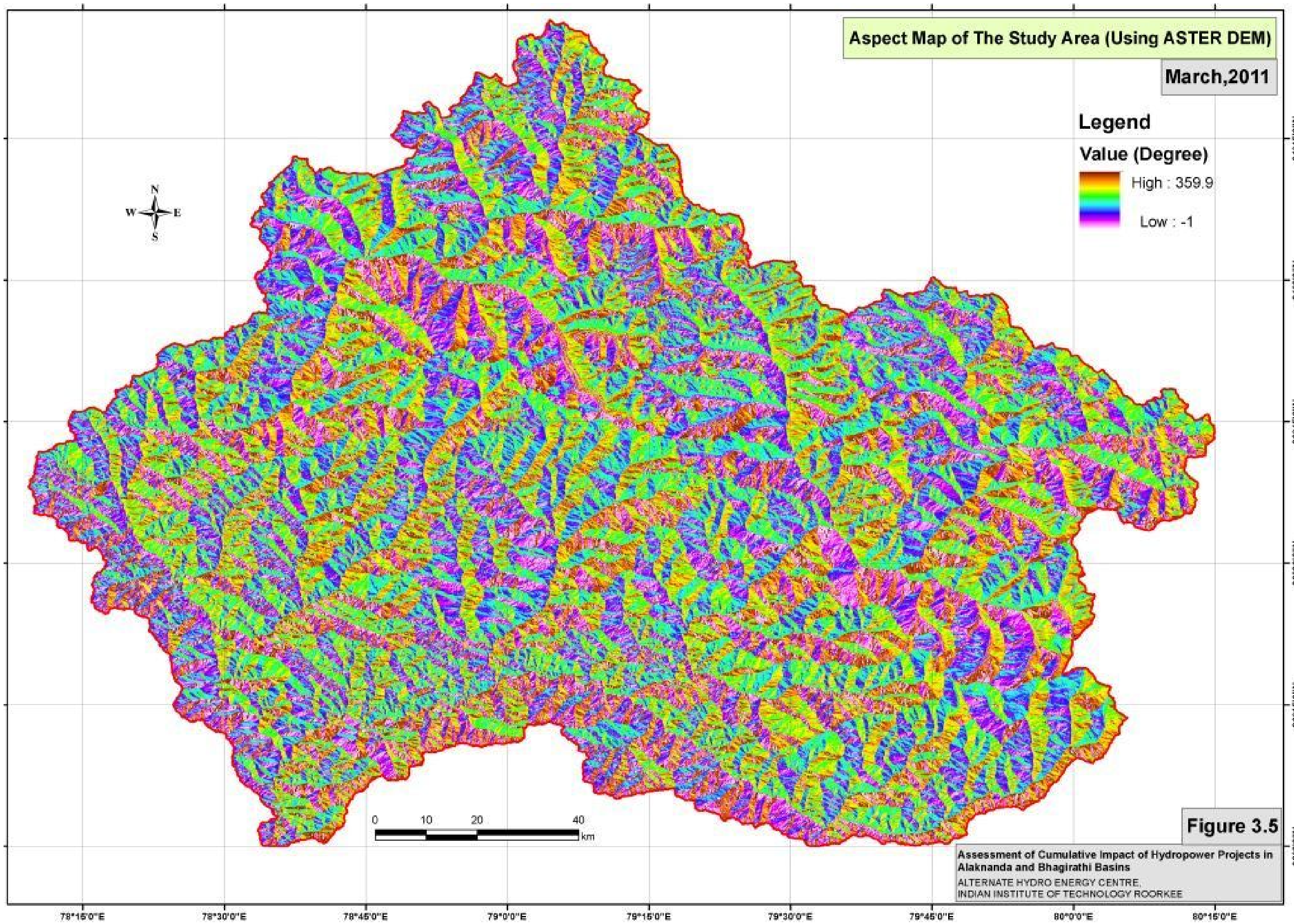


Figure 3.5 Aspect Map of the Study Area (Using ASTER DEM)

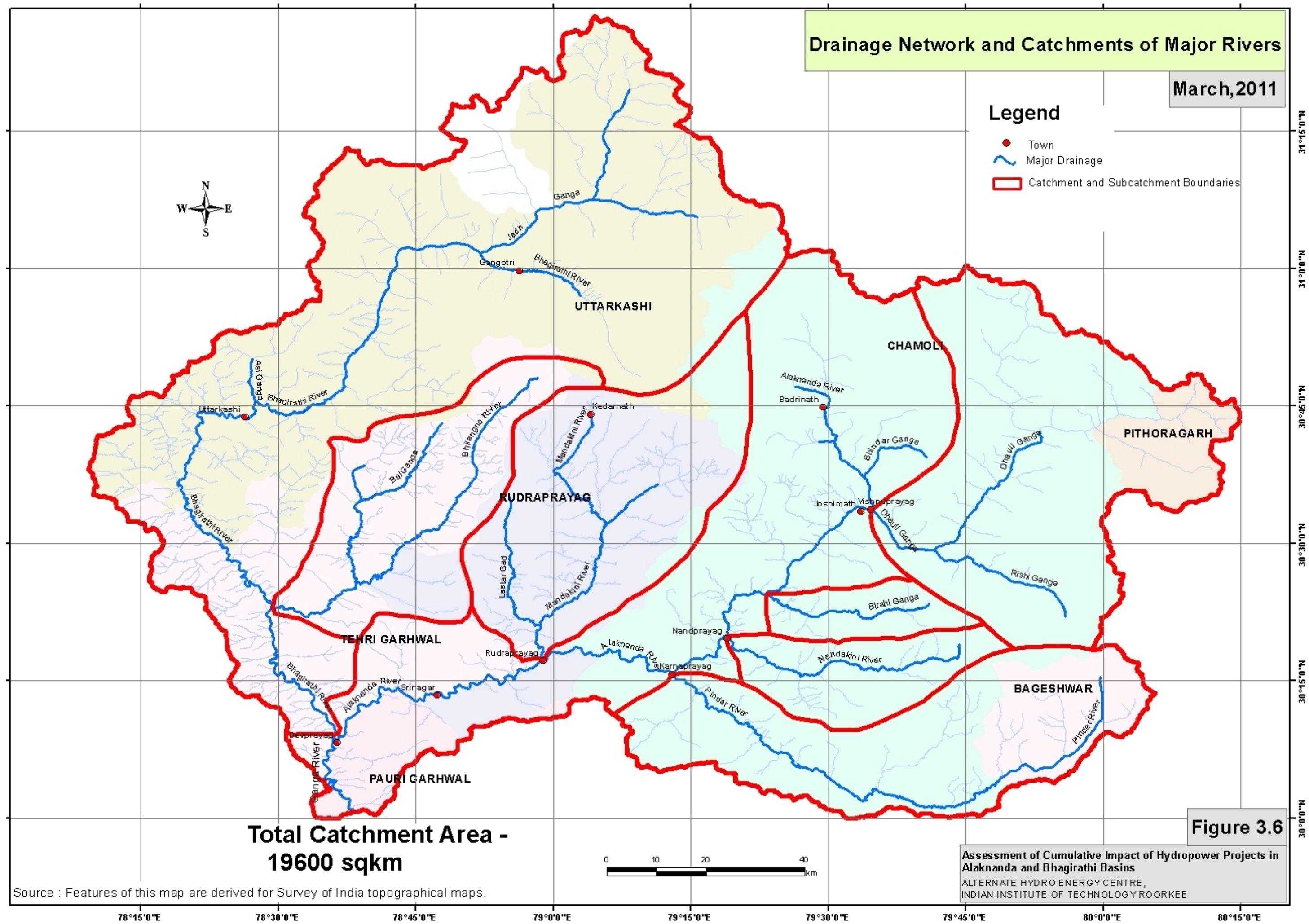


Figure 3.6 Drainage Network and Catchment of Major Rivers

3.6.3 Delineation of catchment and sub-catchments of Alaknanda and Bhagirathi Basins

Alaknanda and Bhagirathi are the two major tributaries of Ganga river. Their catchment has been delineated using the ASTER DEM and the drainage map by Arc GIS software. Initially, the sink or depression areas in the DEM raster have been filled to remove small imperfections in the data. Then on the basis of relative slopes between the cells/pixels, flow direction is determined. Flow accumulation grid and feature pour point raster have been prepared using these data. Now the location of catchment outlet has been decided for the Alaknanda and Bhagirathi rivers, which is Devprayag in the current study. Using the above data, output map watershed is delineated in raster format, which is converted into vector to make the catchment boundary. The catchment boundary of Alaknanda and Bhagirathi basin has been overlaid on all the major thematic maps.

Similarly, sub-catchments have also been delineated for other tributaries of Alaknanda and Bhagirathi rivers eg. Bhilangna, Mandakini, Dhauliganga, Birahi Ganga, Nandakini and Pinder (Fig. 3.6).

3.6.4 Preparation of other spatial maps

Other features like road network (Fig. 3.7), hydropower project sites, district headquarters and towns, transmission line network are plotted over the satellite images and topographic maps. A GIS database has been created for all these layers.

3.6.5 Preparation of base map

A base map has been prepared using topographic maps and satellite images, by including the information about major roads, major rivers, location of major towns and hydropower projects etc. This map has necessary information for the use of other team members, which have analysed various aspects of impact of hydropower projects in this region. This map has also been useful for various teams who have carried field visits for collecting ground data related to the study.

3.6.6 Preparation of land use land cover map

The satellite images have been processed for the preparation of land use land cover map. Supervised classification has been performed on LISS-III data of year 2000 and 2009, using the training samples collected from limited ground truth data. Major classes delineated are dense forest, open forest, water bodies (including rivers, lakes etc.), sand, other vegetation/ agriculture, snow, settlement etc. The digital classified map has been verified for the accuracy assessment for major land use classes present in the area and land use land cover map has been finalized. A land use land cover map has also been prepared by supervised classification of LISS-IV data of year 2008-10 for the above mentioned classes. This map has more details to facilitate the in-depth analysis of the chosen large hydropower project sites. The land use land cover maps for year 2000 and 2009 are shown in Fig. 3.8 and 3.9, respectively.

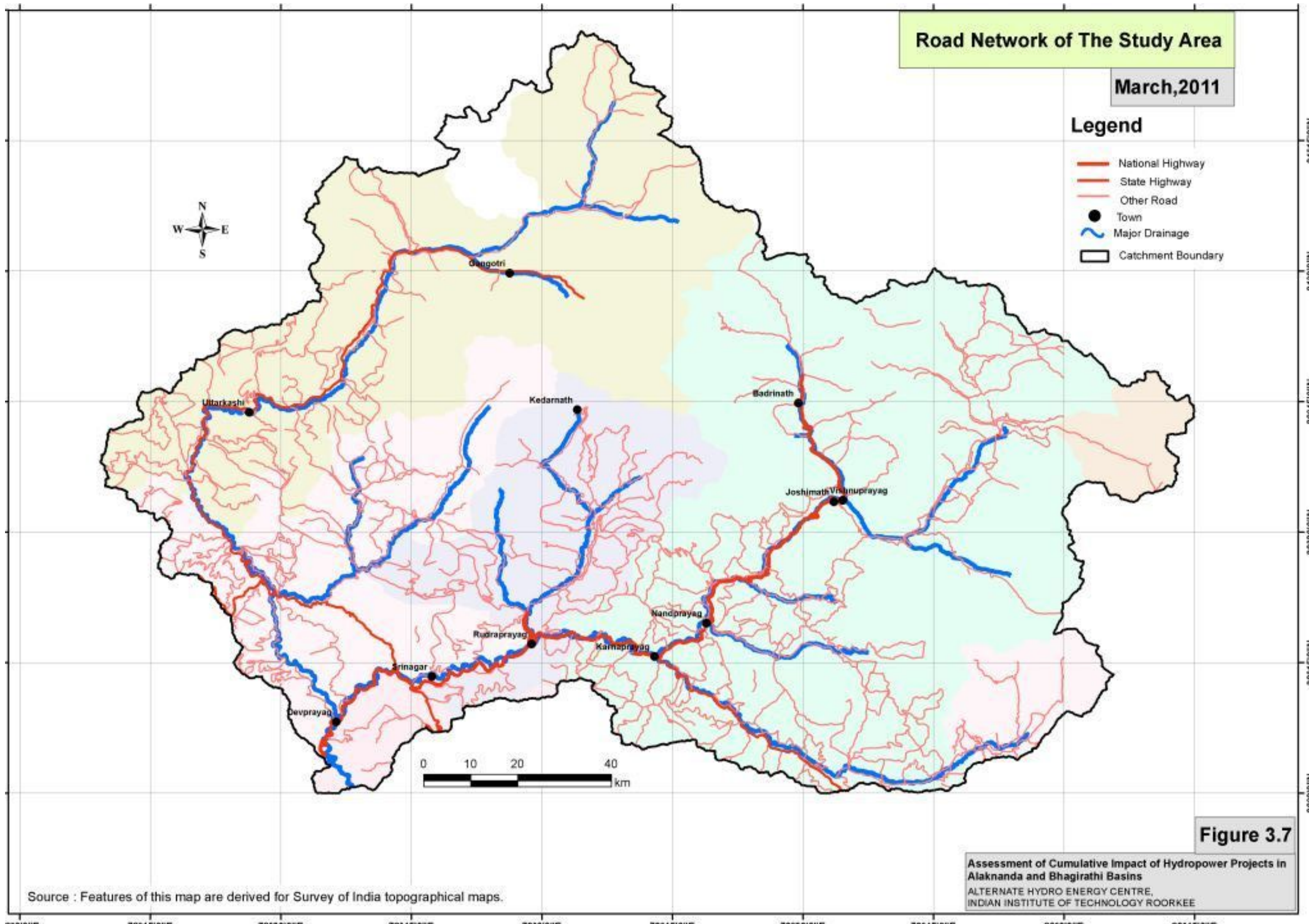


Figure 3.7 Road Network of the Study Area

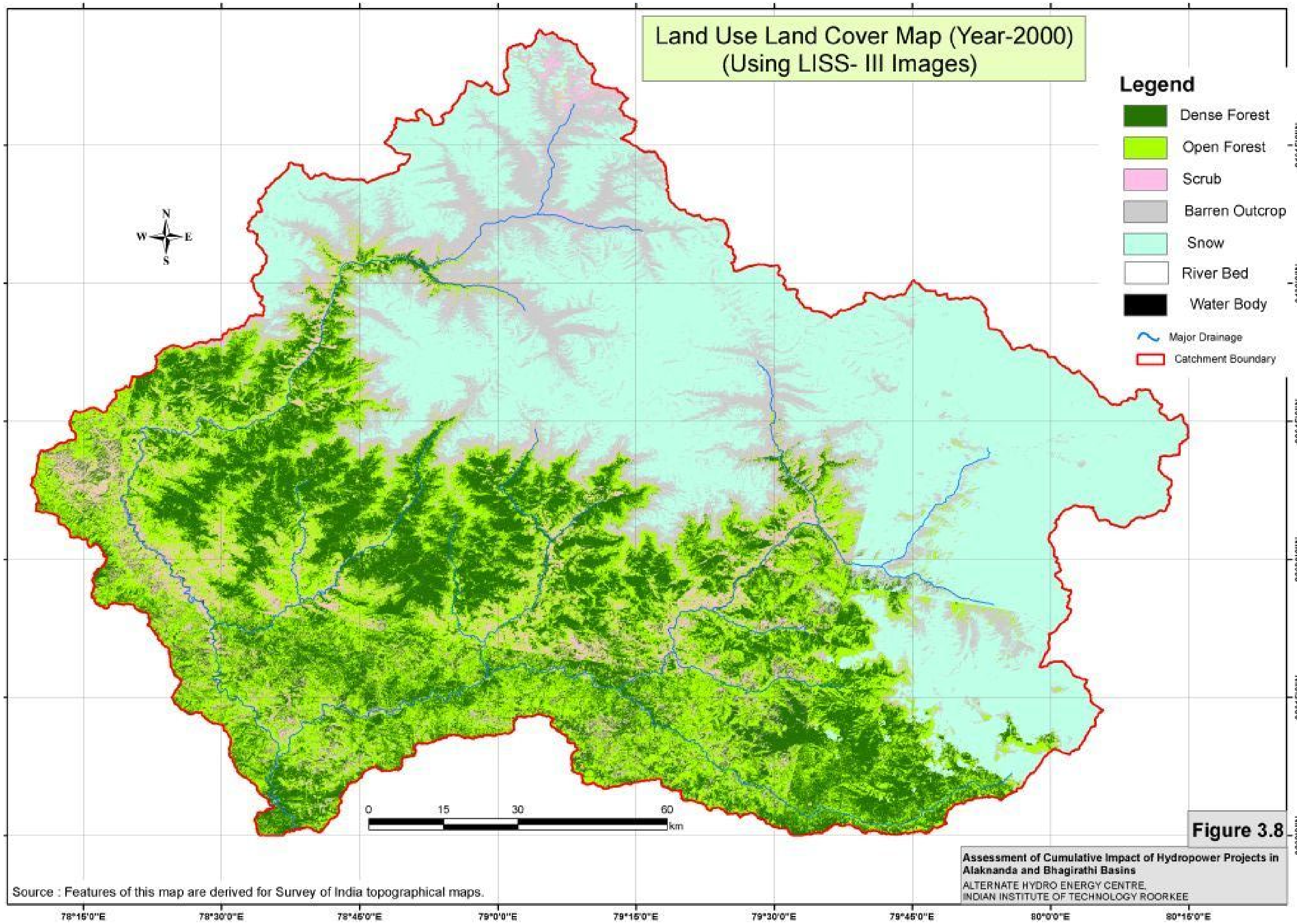


Figure 3.8 Land Use Land Cover Map (Year – 2000)
(Using LISS-III Images)

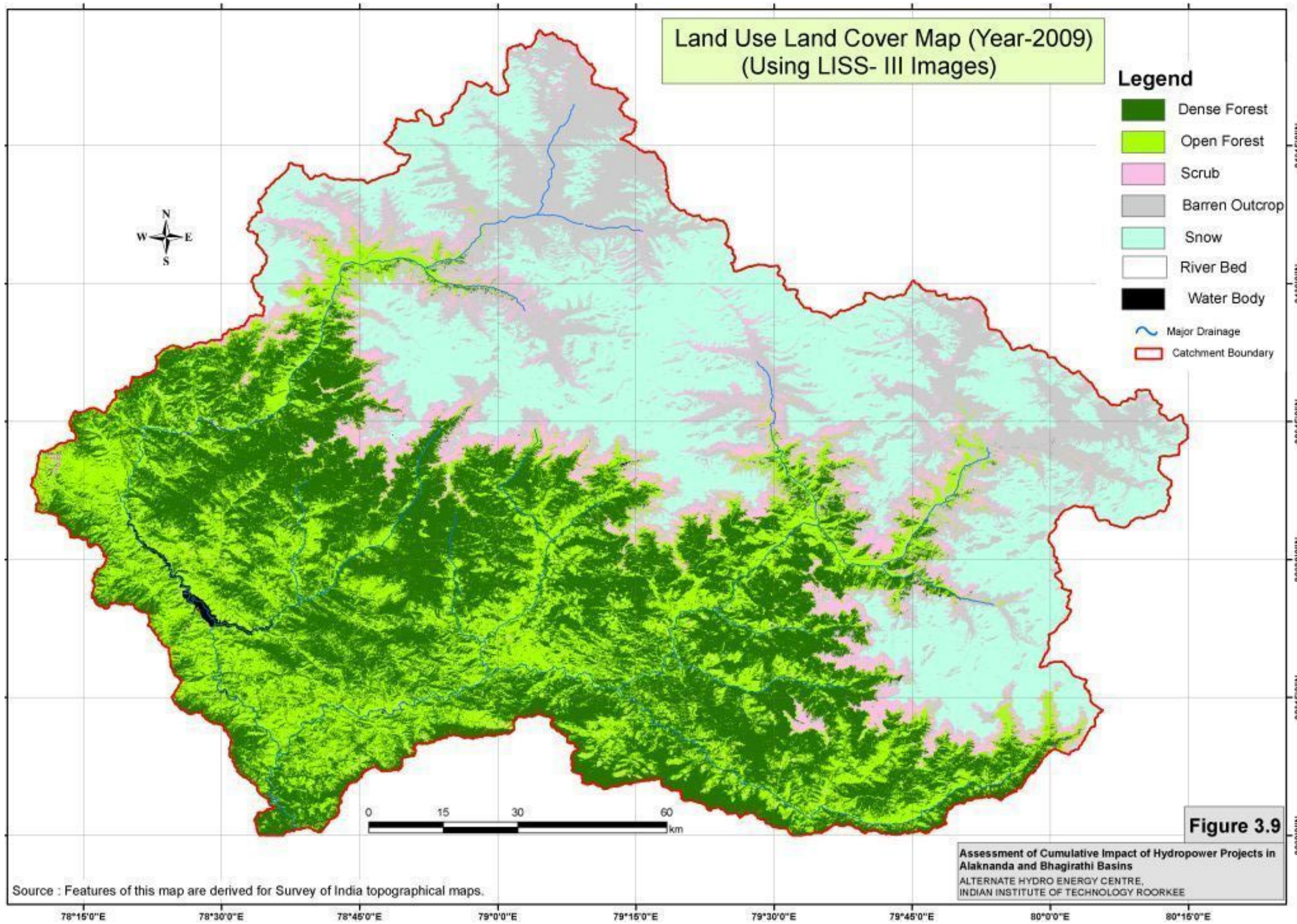


Figure 3.9 Land Use Land Cover Map (Year – 2009)
(Using LISS-III Images)

3.6.7 Change Detection for year 2000 and 2009

The new state of Uttarakhand came into existence on 9th November 2001, as the 27th state of the union of India. Creation of the new state resulted in tremendous growth in infrastructure and economy. New districts have been created with increase of administrative setup. Road network has been enhanced causing larger inflow of tourists and migrant labour. Therefore, change in land use is a cumulative effect of all these developments as well as coming up of hydropower projects. During the period of 2000 to 2009, three major hydropower projects have been completed and work on about ten projects have been taken up.

Satellite images of year 2000 and 2009 have provided extensive information on land use land cover changes in the span of ten years. Prominent change in this decadal period is the formation of huge reservoir of Tehri dam. A few other hydropower projects have been commissioned before 2009. The forest areas have encountered only marginal changes. However, statistical comparison of land use in 2000 and 2009 could not be made due to constraints of satellite data. Since the satellite data procured was of different seasons (May to October for year 2000 and October for year 2009), hence results of comparison should be viewed with this limitation in mind.

The 23.5 m spatial resolution of LISS-III sensor data is optimum for this work, as ground details at this level will be clear for delineating and mapping ground features. However, the swath (width of one scene of the satellite data) of LISS-III data is 141 km, while the catchment area is quite large in comparison to the size (141 km x 141 km) of a single scene of LISS-III. Therefore, a mosaic of different scenes of LISS-III data needs to be generated. Himalayan region is normally full of clouds for major part of the year and since optical (visible and near infrared) wavelengths can't penetrate clouds; it becomes difficult to get good quality cloud free satellite scenes for the entire area of interest with minimum time gap. Thus the LISS-III scenes procured for the study have considerable time gap, which has induced the change in dynamic land cover e.g. snow etc. It has created a statistical imbalance in the extent of the features delineated and the change detection could not be carried out effectively. Also, scientifically it is not appropriate to compare scenes of different season for different years, since there is a seasonal variation in land use land cover of the same year.

3.7 URBAN SPRAWL ANALYSIS OF MAJOR CITIES LYING IN THE BASIN AREA

It has been observed that major cities of Uttarakhand lying in the basin area of Alaknanda-Bhagirathi have expanded considerably during the past decade, especially after the formation of Uttarakhand state. A brief account of growth of a few cities on the basis of analysis of satellite images of year 2000 and 2009-10 given below.

3.7.1 Srinagar

Considerable change in the urban area has been observed in Srinagar town. It has become an education hub. Chouras campus of HNB University has also come up in the last decade. Urban areas have expanded for almost the entire city, with increase in density of built-up area for all parts of the city. There has been a decrease in vegetated areas in the vicinity of the city. Agricultural areas have also been reduced. A few minor landslides have been witnessed in the surroundings of the city, which may be triggered by natural factors.

3.7.2 Tehri

Tehri area has witnessed maximum change in the last decade of the twentieth century. With the commissioning of the Tehri Hydropower project in year 2006, the formation of reservoir on Bhagirathi river was started which has become a large lake with an area of 42 sq.km. by year 2010. Only marginal change has been observed in the New Tehri town (from the year 2000 onwards since major construction activity had already been completed by that time) in terms of enhancement in the built-up area. Density of vegetation has appeared to be slightly on the lower side. No major landslide has been witnessed in the surroundings of the city.

3.7.3 Uttarkashi

Appreciable changes have been observed in Uttarkashi town, with considerable increase in settlements along the Uttarkashi - Chinyalisaur road and Uttarkashi - Gangotri road. Density of built-up area has also increased. The Maneri-Bhali Phase-II project has been completed and there is a remarkable increase in settlements and other activities in that area. There has been a reduction in agricultural areas, while a marginal decrease in vegetated area has also been observed. A major landslide is visible on the Varunavart hill.

3.7.4 Gopeshwar

Gopeshwar is the district headquarters of Chamoli. It has gone through marginal changes. It is observed that most of the urban sprawl has taken place towards the southern side or towards the Gopeshwar - Chamoli road, although density of the built-up area has increased for almost the entire town. There is an appreciable change in areas covered with vegetation, while areas under agriculture appeared to have marginally increased. No major landslide is visible in the vicinity of the town due to natural or developmental activities.

3.7.5 Joshimath

Joshimath is an important town, as it is considered as the first halt for pilgrims of ‘Char Dham Yatra’ who are heading towards the Badrinath shrine. It is also the gateway of Hemkunt Sahib, one of the most important religious places for Sikhs. Joshimath has also seen only a marginal change in terms of development of the town. Density of the built-up area has not increased much. The town has witnessed some expansion towards the northern side, in the direction of Joshimath - Vishnuprayag road (one reason may be due to commissioning of the Vishnuprayag Hydropower project) and towards the eastern side in the direction of Joshimath - Tapovan road. There isn't any appreciable change in the vegetated area in and around the town. A few minor landslides are visible towards the eastern side of the town towards Tapovan, which may be trigged due to widening of the Joshimath-Tapovan road.

3.8 ASSESSMENT OF LAND USE LAND COVER CHANGES IN THE VICINITY OF SELECTED HYDROPOWER PROJECTS

Area of influence of hydropower projects has been delineated along the river on the basis of subjective assessment of the possible impact of HP on the surroundings. A rectangular region covering an area approximately 5 km upstream (U/S) and 5 km downstream (D/S) of the river in the buffer of about 1 to 2 km on either side of the river, has been considered for the study of impact of HPs. However, for a few large HPs, e.g. Tehri HP, Srinagar HP etc., a larger region has been covered as the area of influence for that particular project. At the same time, if appreciable impact is not visible on the U/S and D/S side, a smaller area has been considered. An index map of areas of LISS IV images is given in Fig. 3.10.

3.8.1 Bhilangna Hydropower Project

Assessment of land use land cover changes has been carried out for the area surrounding the Bhilangna Hydropower Project using the IRS 1D LISS-III image of September 2000 and IRS P6 LISS-IV image of April 2010. 12.32 sq.km. area surrounding the hydropower project, 3.5 km U/S and 5 km D/S, has been taken as the approximate influence area of the HP. Both images have been georeferenced. Their geometric fidelity with respect to each other is also checked. Since the spatial resolution of LISS-III image is 23.5 m, this image has been resampled to 5 m pixel size in order to get pixel by pixel comparison of LISS-III of year 2000 and LISS-IV image of 2010 and to obtain a difference image for the land use land cover changes. A brief account of the land use land cover classes surrounding the Bhilangna Hydropower Project in year 2000 and 2010 has been given in Table 3.3.

Table 3.3 Comparison of area under various land use land cover classes surrounding the Bhilangna Hydropower Project for year 2000 and 2010

Class	Area (%)	
	Sep. 2000	Apr. 2010
Dense Forest	5.36	3.33
Open Forest	65.01	68.09
Scrub	25.97	20.85
Water Body	2.46	2.36
River Bed	1.22	5.36
Total	**100.00**	**100.00**

Land use land cover map of the area surrounding the Bhilangna Hydropower Project prepared by using LISS-IV image of year 2010, is shown in Fig. 3.10(a).

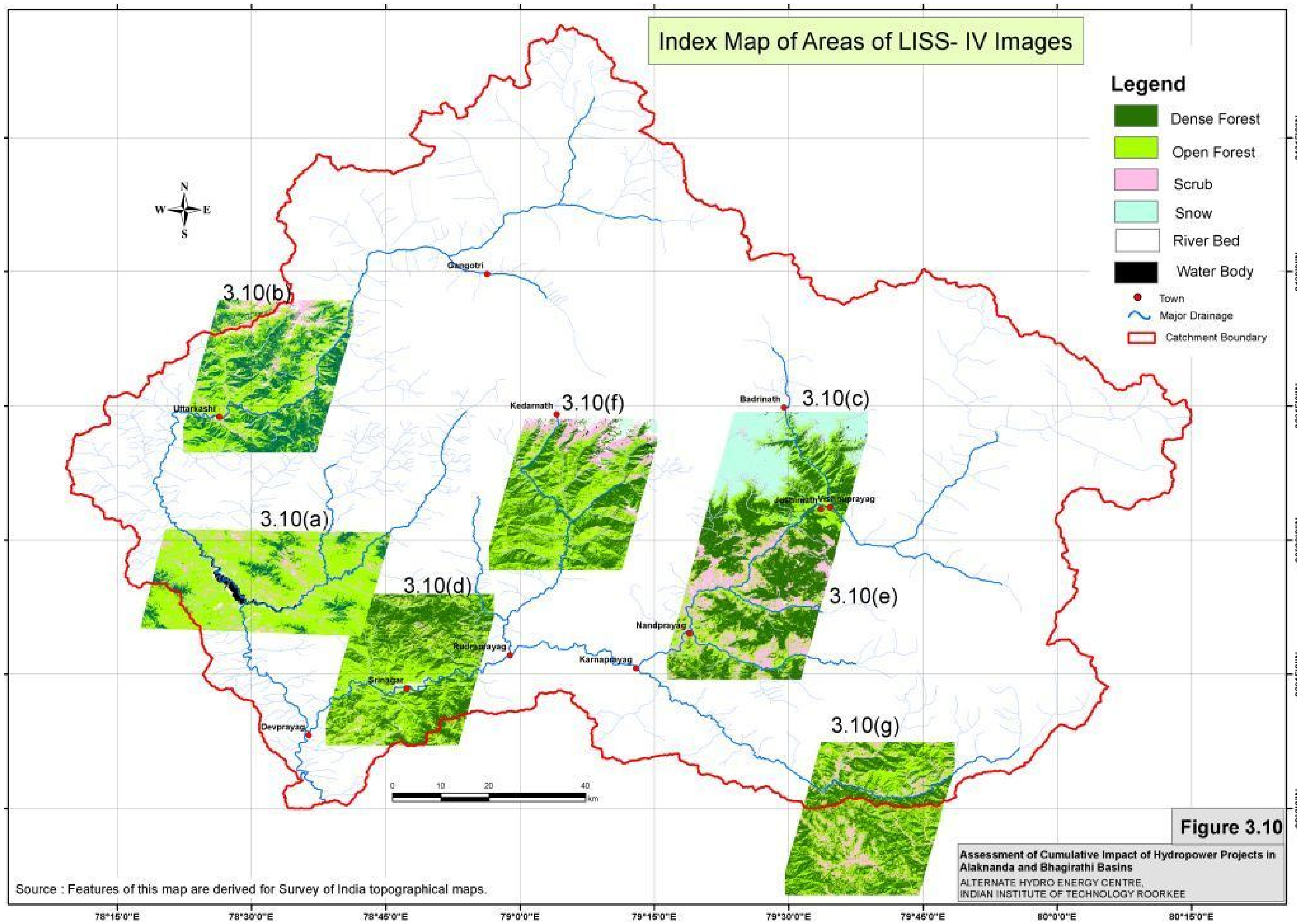


Figure 3.10 Index Map of Areas of LISS-IV Images

3.8.2 Maneri Bhali - I and Maneri Bhali - II Hydropower Projects

Land use land cover change assessment for the area surrounding the Maneri Bhali - I and Maneri Bhali - II hydropower projects using the LISS-III image of October 2000 and LISS-IV image of November 2008 has been carried out. 9.49 sq km area surrounding the Maneri - I hydropower project and 11.05 sq.km. area surrounding the Maneri - II hydropower project have been taken as the approximate influence areas of the HPs. Satellite images for both projects have been georeferenced. Their geometric fidelity with respect to each other is also checked. Since spatial resolution of LISS-III image is 23.5 m, this image has been resampled at 5 m pixel size in order to get pixel by pixel comparison of LISS-III of year 2000 and LISS-IV image of 2008 and to obtain a difference image for the land use land cover changes. A brief account of land use land cover classes surrounding the Maneri Bhali - I and Maneri Bhali - II Hydropower Projects in year 2000 and 2008 has been given in Tables 3.4a and 3.4b.

Table 3.4a Comparison of area under various land use land cover classes surrounding the Maneri Bhali - I Hydropower Project for year 2000 and 2008.

Class	Area (%)	
	Oct. 2000	Nov. 2008
Dense Forest	7.68	10.67
Open Forest	63.89	53.09
Scrub	20.64	22.44
Water Body	0.78	2.99
River Bed	7.06	10.82
Total	**100.00**	**100.00**

Table 3.4b. Comparison of area under various land use land cover classes surrounding the Maneri Bhali - II Hydropower Project for year 2000 and 2008.

Class	Area (%)	
	Oct. 2000	Nov. 2008
Dense Forest	19.19	27.32
Open Forest	64.80	44.69
Scrub	12.40	19.27
Water Body	2.00	2.57
River Bed	1.60	6.15
Total	**100.00**	**100.00**

Land use land cover map of the area, surrounding the Maneri Bhali – I and Maneri Bhali - II Hydropower Projects prepared using LISS-IV image of year 2008, has been shown in Fig. 3.10(b).

3.8.3 Alaknanda Hydropower Project

Assessment of land use land cover changes has been carried out for the area surrounding the Alaknanda Hydropower Project from the LISS-III image of September 2000 and LISS-IV image of April 2009. An area of 8.12 sq km surrounding the hydropower project has been taken as the approximate influence area of the HP. Both images have been georeferenced. Their geometric fidelity with respect to each other is also checked. Since the spatial resolution of LISS-III image is 23.5 m, this image has been resampled to 5 m pixel size in order to get pixel by pixel comparison of LISS-III of year 2000 and LISS-IV image of 2009 and to obtain a difference image for the land use land cover changes. A brief account of land use land cover classes surrounding the Alaknanda Hydropower Project in year 2000 and 2009 has been given in Table 3.5.

Table 3.5 Comparison of area under various land use land cover classes surrounding the Alaknanda Hydropower Project for year 2000 and 2009.

Class	Area (%)	
	Sep. 2000	**Apr. 2009**
Dense Forest	13.79	12.46
Open Forest	20.92	22.93
Scrub	48.75	49.93
Water Body	2.75	3.93
River Bed	0.08	0.12
Snow	13.80	10.63
Total	**100.00**	**100.00**

Land use land cover map of the area, prepared using LISS-IV image of year 2009, surrounding the Alaknanda Hydropower Project has been shown in Fig. 3.10(c).

3.8.4 Tehri Stage - I and Tehri Stage - II Hydropower Projects

Land use land cover change assessment has been carried out for the area surrounding the Tehri Stage - I and Tehri Stage - II Hydropower Projects from the LISS-III image of September 2000 and LISS-IV image of April 2010. Tehri Hydropower project has a large reservoir, therefore its influence area is covered in two LISS-IV images dated 23 April 2010 and 28 April 2010. Thus a mosaic of two images of year 2010 has been taken in the analysis. 217.50 sq.km. area surrounding the hydropower project, (16 km U/S for river Bhagirathi and 19 km U/S for river Bhilangna; 4 km D/S after the confluence of Bhagirathi and Bhilangna rivers) has been taken as the approximate influence area of the HP. Both images have been georeferenced. Their geometric fidelity with respect to each other is also checked. Since the spatial resolution of LISS-III image is 23.5 m, this image has been resampled to 5 m pixel size in order to get pixel by pixel comparison of LISS-III of year 2000 and LISS-IV image of 2010 and to obtain a difference image for land use land cover changes. A brief account of land use land cover classes surrounding the Tehri Stage - I and Tehri Stage - II Hydropower Projects in year 2000 and 2010 has been given in Table 3.6.

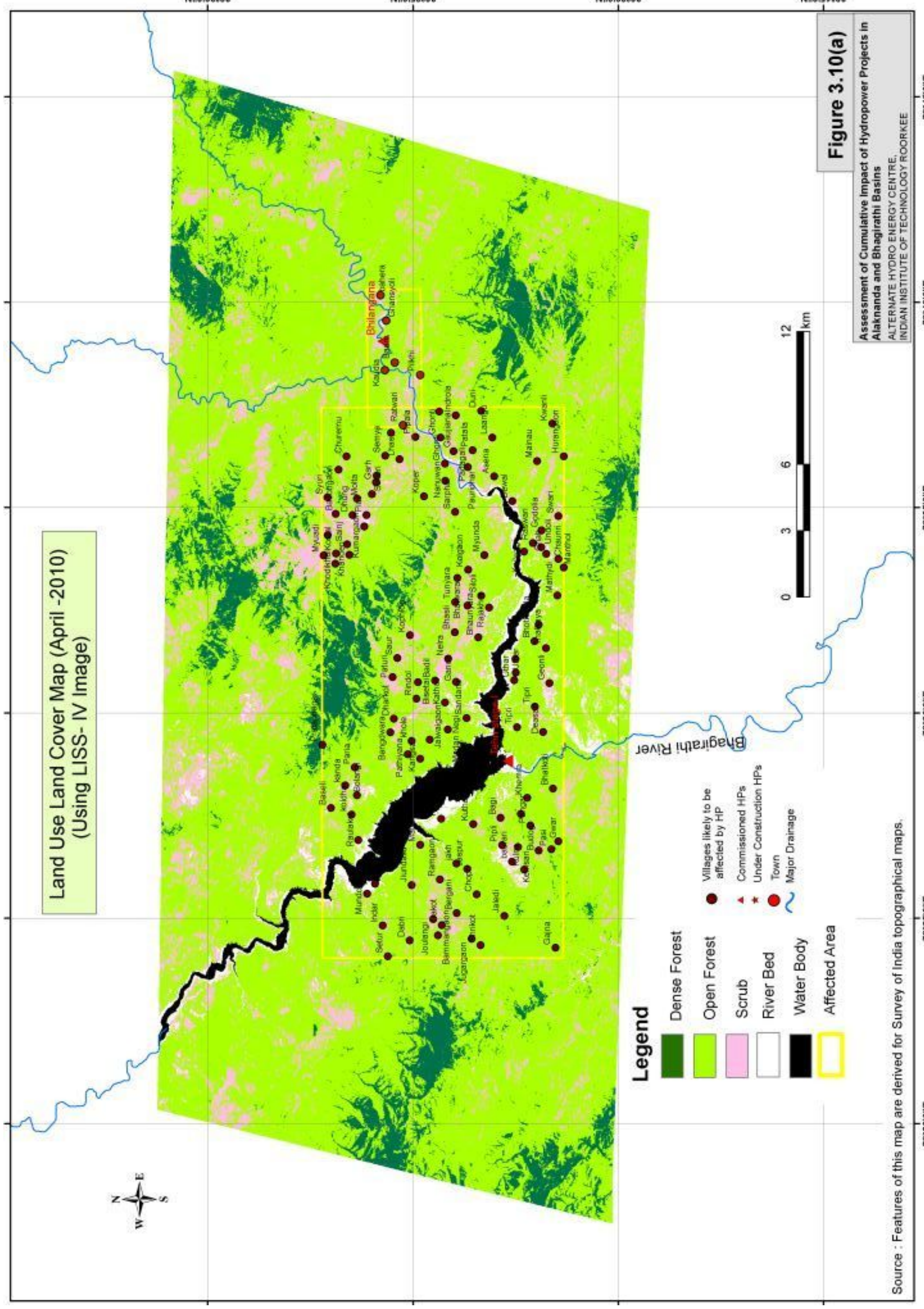


Figure 3.10(a) Land Use Land Cover Map of the area surrounding Bhilangana and Tehri I & Tehri II Hydropower projects, prepared by using IRS P6 LISS-IV Satellite Image of April-2010

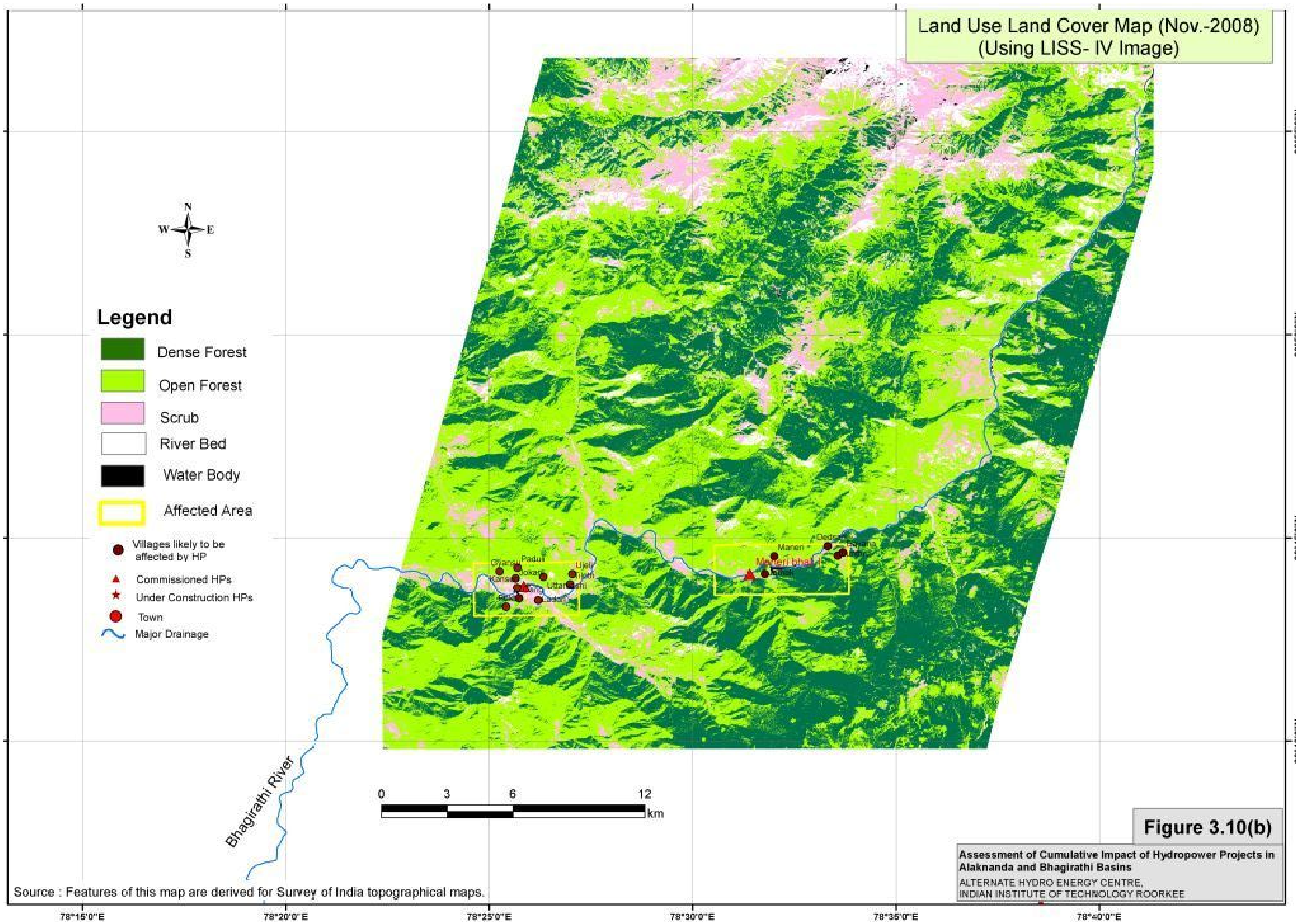


Figure 3.10(b) Land Use Land Cover Map of the area surrounding Maner Bhali I & Maneri Bhali II Hydropower projects, prepared by using IRS P6 LISS-IV Satellite Image of Nov-2009

Table 3.6 Comparison of area under various land use land cover classes surrounding the Tehri Stage-I and Tehri Stage - II Hydropower Projects for year 2000 and 2010.

Class	Area (%)	
	Sep. 2000	Apr. 2010
Dense Forest	17.75	5.35
Open Forest	59.65	71.55
Scrub	21.30	13.78
Water Body	1.21	8.19
River Bed	0.09	1.14
Total	**100.00**	**100.00**

It has been observed that there is a manifold increase in the area under water body. It is due to the formation of reservoir of Tehri dam, which did not exist in year 2000. Land use land cover map of the area, prepared using LISS-IV image of year 2010, surrounding the Tehri - I and Tehri - II Hydropower Projects has been shown in Fig. 3.10(a).

3.8.5 Srinagar Hydropower Project

Assessment of land use land cover changes has been carried out for the area surrounding the Srinagar Hydropower Project from the LISS-III image of September 2000 and LISS-IV image of January 2009. An area of 50.10 sq.km. surrounding the hydropower project, 2.5 km U/S and 13.5 km D/S has been taken as the approximate influence area of the HP. Both images have been georeferenced. Their geometric fidelity with respect to each other is also checked. Since spatial resolution of LISS-III image is 23.5 m, this image has been resampled to 5 m pixel size in order to get pixel by pixel comparison of LISS-III of year 2000 and LISS-IV image of 2009 and to obtain a difference image for land use land cover changes. A brief account of land use land cover classes surrounding the Srinagar Hydropower Project in year 2000 and 2009 has been given in Table 3.7. Land use land cover map of the area, prepared using LISS-IV image of year 2009, surrounding the Srinagar Hydropower Project has been shown in Fig. 3.10(d).

Table 3.7. Comparison of area under various land use land cover classes surrounding the Srinagar Hydropower Project for year 2000 and 2009.

Class	Area (%)	
	Sep. 2000	Jan. 2009
Dense Forest	28.52	25.20
Open Forest	62.02	55.83
Scrub	8.64	11.74
Water Body	0.32	0.51
River Bed	0.50	6.74
Total	**100.00**	**100.00**

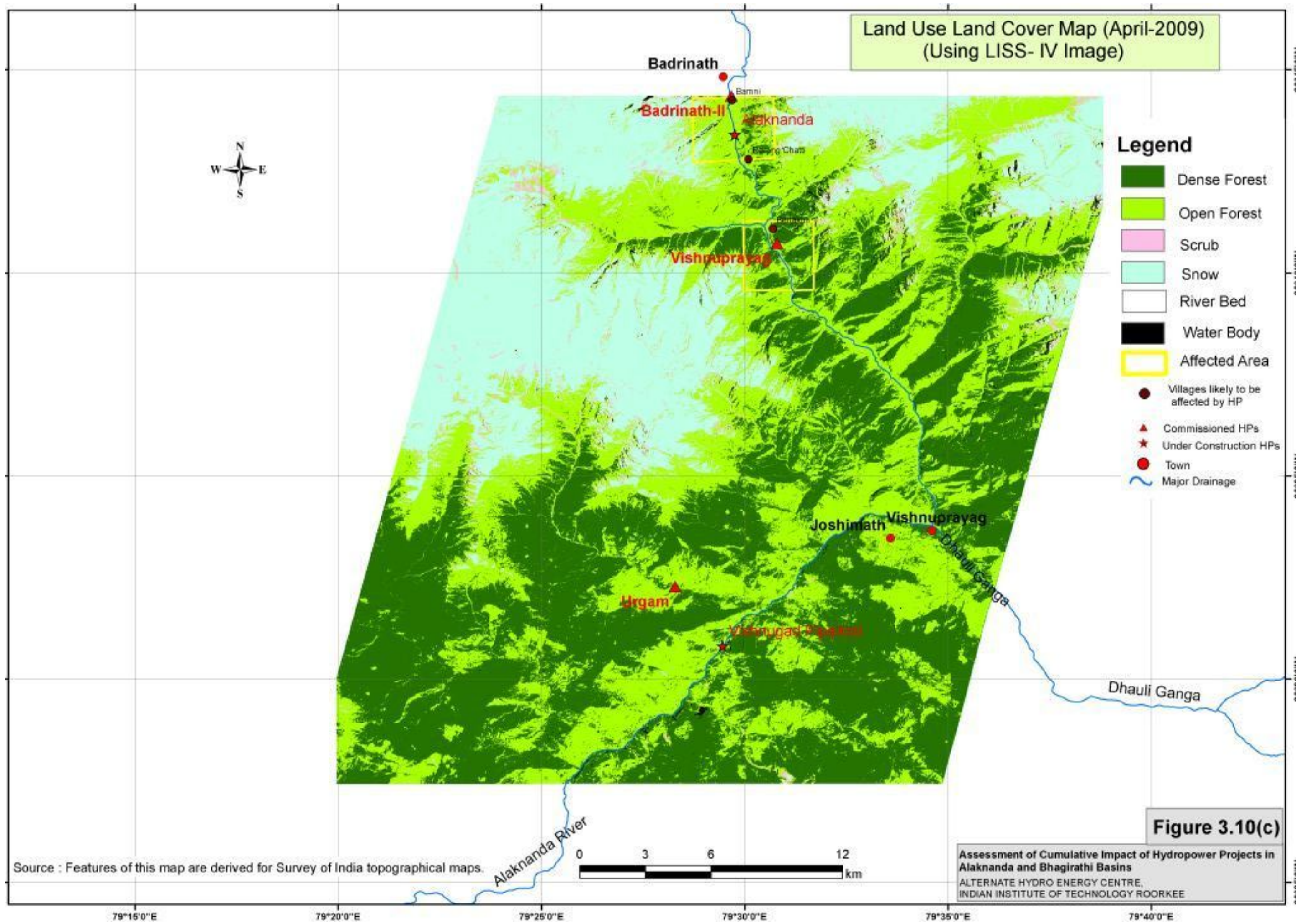


Figure 3.10(c) Land Use Land Cover Map of the area surrounding Alaknanda Hydropower projects, of (April 2009) prepared by using LISS-IV Satellite Image of April 2009

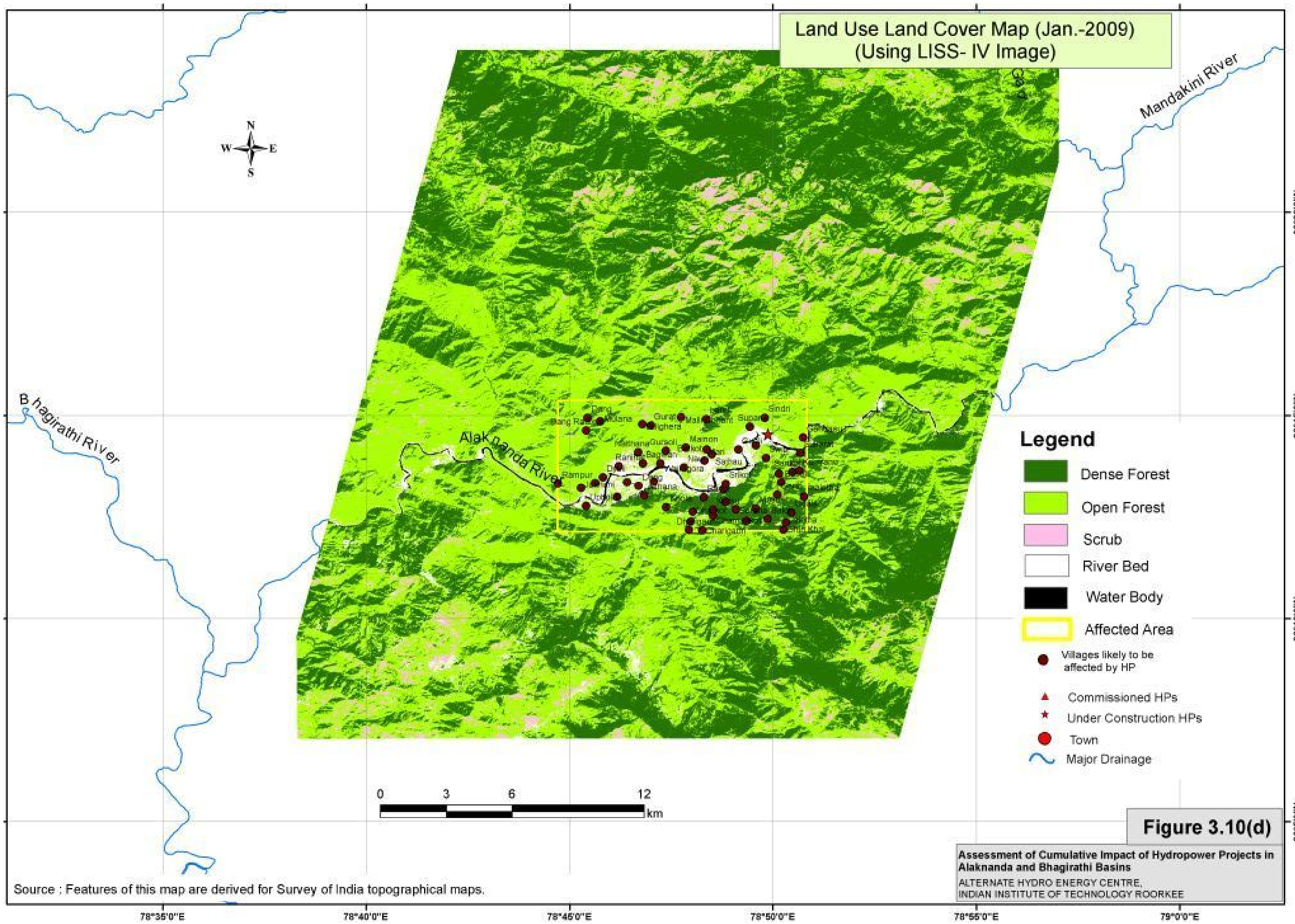


Figure 3.10(d) Land Use Land Cover Map of the area surrounding Srinagar Hydropower projects, prepared by using IRS P6 LISS-IV Satellite Image of January 2009

3.8.6 Rajwakti Hydropower Project

Land use land cover change assessment for the area surrounding the Rajwakti Hydropower Project from the LISS-III image of September 2000 and LISS-IV image of April 2009 has been carried out. 47.89 sq.km. area surrounding the hydropower project has been taken as the approximate influence area of the HP. Both images have been georeferenced. Their geometric fidelity with respect to each other is also checked. Since spatial resolution of LISS-III image is 23.5 m, this image has been resampled to 5 m pixel size in order to get pixel by pixel comparison of LISS-III of year 2000 and LISS-IV image of 2009 and to obtain a difference image for the land use land cover changes. A brief account of land use land cover classes surrounding the Rajwakti Hydropower Project in year 2000 and 2009 has been given in Table 3.8.

Table 3.8. Comparison of area under various land use land cover classes surrounding the Rajwakti Hydropower Project for year 2000 and 2009.

Class	Area (%)	
	Sep. 2000	Apr. 2009
Dense Forest	40.37	46.76
Open Forest	38.00	36.95
Scrub	18.21	13.43
Water Body	0.78	0.91
River Bed	2.63	1.96
Total	**100.00**	**100.00**

Land use land cover map of the area, prepared using LISS-IV image of year 2009, surrounding the Rajwakti Hydropower Project has been shown in Fig. 3.10(e).

3.8.7 Phata-Bhyang Hydropower Project

Assessment of land use land cover changes for the area surrounding the Phata-Bhyang Hydropower Project from the LISS-III image of May 2000 and LISS-IV image of December 2008 has been carried out. 40.50 sq.km. area surrounding the hydropower project, 6.5 km U/S and 6.5 km D/S has been taken as the approximate influence area of the HP. Both images have been georeferenced. Their geometric fidelity with respect to each other is also checked. Since spatial resolution of LISS-III image is 23.5 m, this image has been resampled to 5 m pixel size in order to get pixel by pixel comparison of LISS-III of year 2000 and LISS-IV image of 2008 and to obtain a difference image for land use land cover changes. A brief account of land use land cover classes surrounding the Rajwakti Hydropower Project in year 2000 and 2008 has been given in Table 3.9.

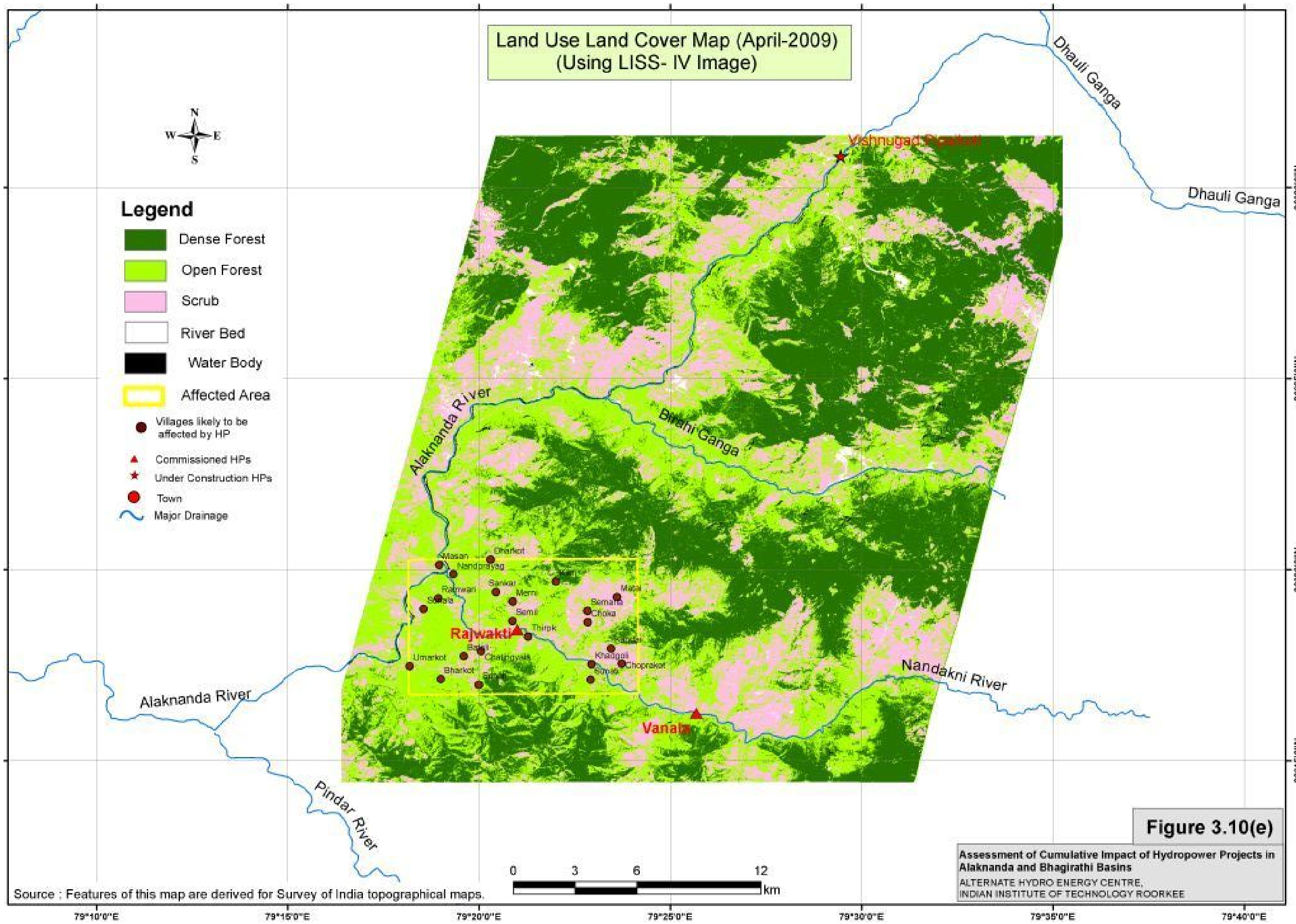


Figure 3.10(e) Land Use Land Cover Map of the area surrounding Rajwakti Hydropower projects, prepared by using IRS P 6 LISS-IV Satellite Image of April 2009

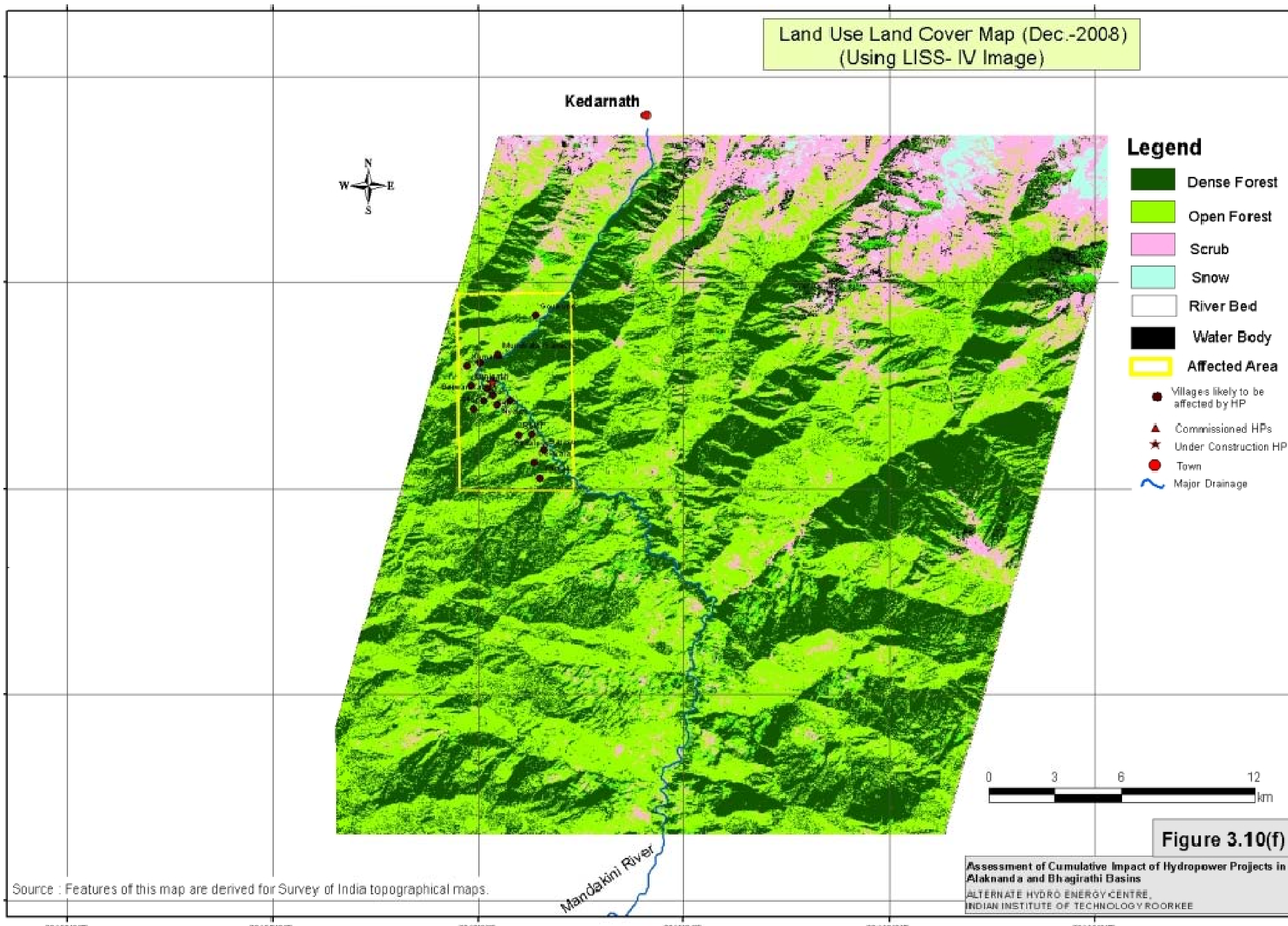


Figure 3.10(f) Land Use Land Cover Map of the area surrounding Phata Bhyang Hydropower projects, prepared by using IRS P6 LISS-IV Satellite Image of December 2008

Table 3.9 Comparison of area under various land use land cover classes surrounding the Phata-Bhyang Hydropower Project for year 2000 and 2008.

Class	Area (%)	
	May 2000	**Dec. 2008**
Dense Forest	59.93	45.17
Open Forest	36.92	46.95
Scrub	2.73	5.23
Water Body	0.37	2.57
River Bed	0.05	0.08
Total	**100.00**	**100.00**

Land use land cover map of the area, prepared using LISS-IV image of year 2008, surrounding the Phata-Bhyang Hydropower Project has been shown in Fig. 3.10(f).

3.8.8 Deval Hydropower Project

Land use land cover change assessment has been carried out for the area surrounding the Deval Hydropower Project from the LISS-III image of September 2000 and LISS-IV image of November 2009. An area of 21.21 sq km surrounding the hydropower project, 3.5 km U/S and 5 km D/S has been taken as the approximate influence area of the HP. Both images have been georeferenced. Their geometric fidelity with respect to each other is also checked. Since spatial resolution of LISS-III image is 23.5 m, this image has been resampled to 5 m pixel size in order to get pixel by pixel comparison of LISS-III of year 2000 and LISS-IV image of 2010 and to obtain a difference image for the land use land cover changes. A brief account of the land use land cover classes surrounding the Deval Hydropower Project in year 2000 and 2009 has been given in Table 3.10.

Table 3.10 Comparison of area under various land use land cover classes surrounding the Deval Hydropower Project for year 2000 and 2009.

Class	Area (%)	
	Sep. 2000	**Nov. 2009**
Dense Forest	53.87	45.41
Open Forest	42.04	38.10
Scrub	1.22	13.88
Water Body	1.44	1.57
River Bed	1.41	1.04
Total	**100.00**	**100.00**

[Land use land cover map of the area, prepared using LISS-IV image of year 2009, surrounding the Deval Hydropower Project has been shown in Fig. 3.10(g)].

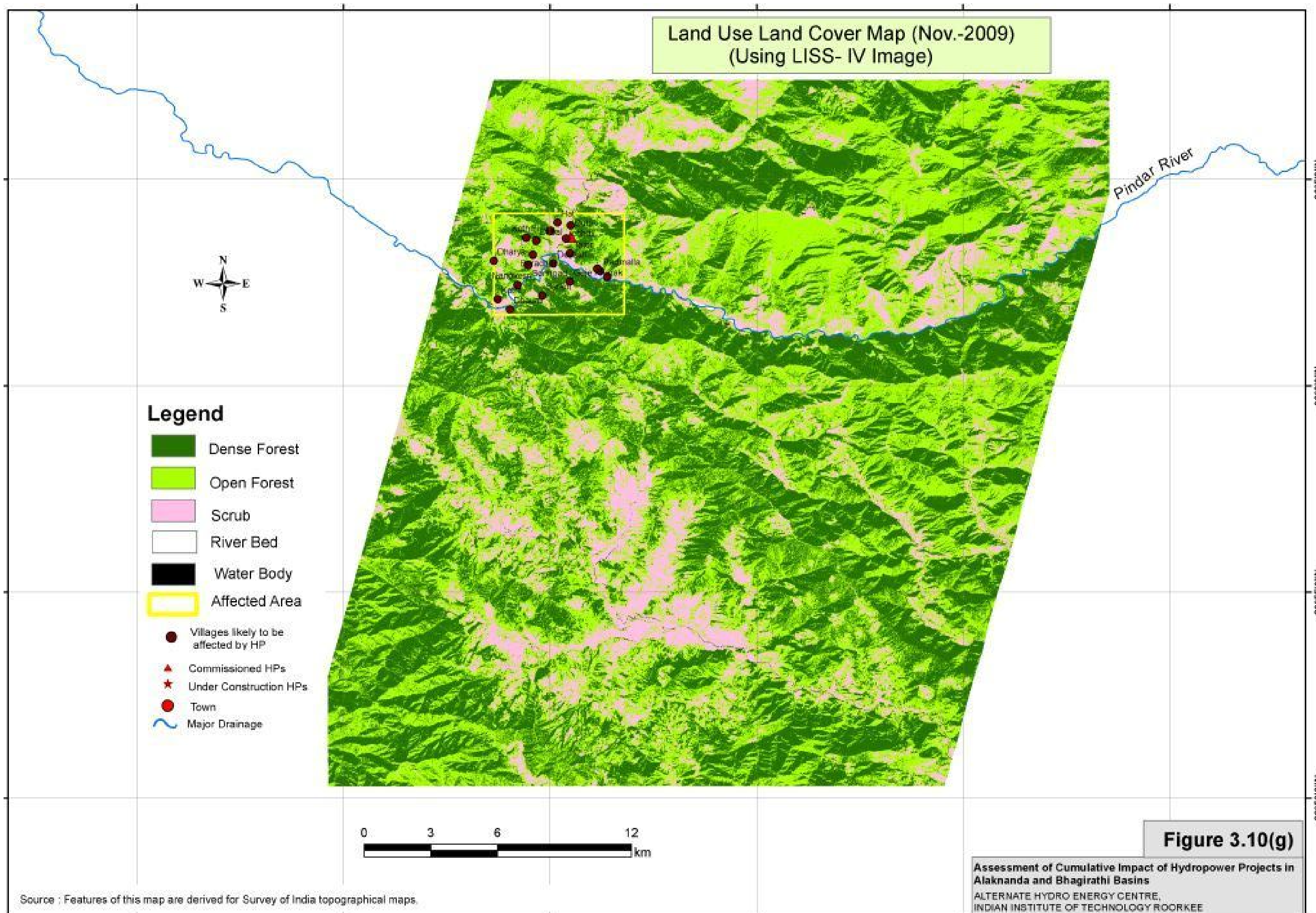


Figure 3.10(g) Land Use Land Cover Map of the area surrounding Deval Hydropower projects, prepared by using IRS P6 LISS-IV Satellite Image of Nov 2009

CHAPTER – 4

GEOLOGICAL STUDIES

4.1. BACKGROUND

4.1.1. Geomorphic and Climate Changes during Holocene

The earth has been witnessing changes in climate and geomorphology. Record of these changes is often preserved as different proxies on the earth. Many changes we are observing on the earth's surface, at present, are due to natural processes. To assess the changes in the vegetation, landform, climate due to anthropogenic activity, it is very important to understand the changes which are taking place due to natural processes.

The earth is a dynamic system, and it has witnessed continuous changes since its formation about 4.5 Ga. The changes have been of different magnitude and on different time scale. Initially, earth was made up of small continental masses which joined together to make larger continental masses. These continents moved due to seafloor spreading leading to formation of oceanic crust, and collided with each other destroying the larger oceans and oceanic crust.

As a result of this process continental masses break up, move to new longitudinal – latitudinal positions collide to make new continental assembly and mountain chains. As continents move to different positions, they also witness changed climatic conditions, development of new landforms and changes in flora and fauna. This process operates on a scale of several millions of years. There were periods in the earth's history when there were no ice sheets in polar regions and climate showed less latitudal variability. On the contrary, there were times when polar ice sheets were very prominent, and earth exhibited strong latitudinal climate variability.

India was part of a large continental mass, the Gondwanaland located in the southern hemisphere. It was situated very close to the South Pole during Permian time and witnessed very cold glacial climate. India broke up from Gondwanaland and moved northwards crossing the equator around 60 Ma ago, then collided with the Asian continent around 55 Ma ago and since then it is more or less in the present position, moving northwards at a very slow rate. This collision of India with Asia produced Himalayan mountain chain. The Himalayan mountain chain became very prominent around 20 Ma ago and it is also the time the monsoon circulation system was established.

The Himalayan mountain chain since its inception is undergoing intense erosion, removing large amount of sediments to be deposited in the Ganga Plain, Ganga-Brahmaputra delta and Deep sea fan (Bengal fan) in the Bay of Bengal. At present also, the Himalayan terrain is witnessing intense erosion and changes in the landform, transporting large amount of sediment to Ganga Plain, Ganga-Brahmaputra Delta and Deep Sea Fan (Bengal Fan). There are evidences globally that in the last two million years (the Quaternary) the earth witnessed climate change on millennium, century and decade scale. These climate change lead to change in the vegetation, landform and water budget.

4.1.1.1. The Quaternary Period

The Quaternary time is the youngest time span in the earth's history representing about 1.8 Ma of the earth's history. It is subdivided into two periods, namely Pleistocene (1.8 Ma to ca. 10,000 yrs) and Holocene (Last ca. 10,000 years). The term Late Quaternary is used to describe the time span of Late Pleistocene (120 ka to 10 ka) and Holocene (10 ka – present).

The Quaternary time is characterized by prominent climatic changes which caused glacial and interglacial events which also affected the sea-level, flora, fauna and rate of erosion. The major climate events of the Quaternary are ascribed to the orbital changes in the earth, mostly described as Milankovitch cycles. They are caused due to changes in percession of equinoxes (19 and 23 ka cycle), changes in eccentricity of the earth's orbit (main periodicities of 400 and 101 ka), and changes in obliquity (41 ka cycle) (Berger, 1977; Laskar, 1990; Imbrie et al. 1992). Fig.s 4.1 and 4.2 show four major glacial cycles and small cycles in the last 400,000 years, with data of different proxies and inferred sea level changes.

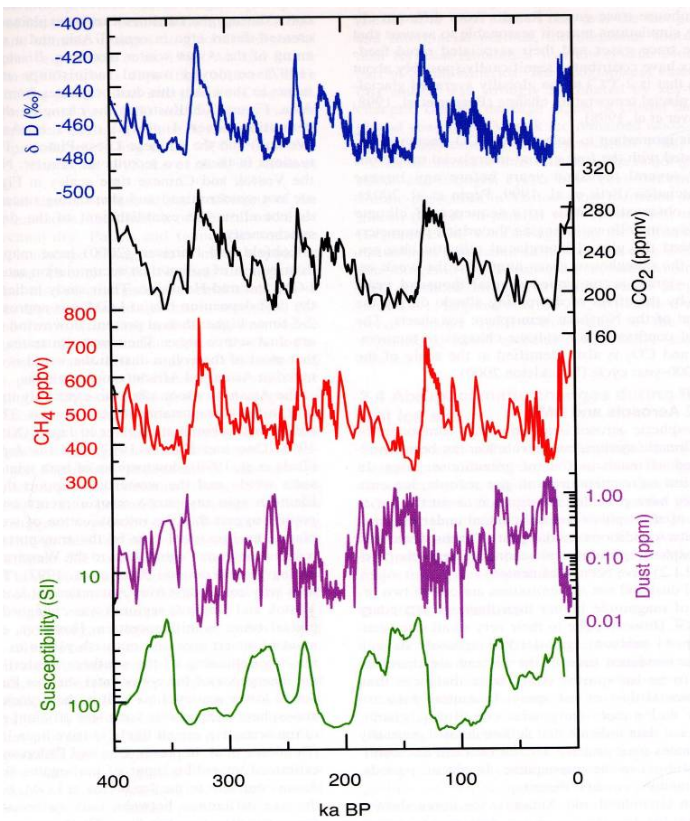


Fig. 4.1 Four major climatic cycle in last 400,000 years, based on different proxies (From Raynaud et al. 2002).

Late Quaternary time (Late Pleistocene – Holocene) has been particularly studied in detail and climatic cycles on millennium, century and decadel scale have been identified. Last major interglacial event is identified around 120 ka which was similar to the present – day situation. There are a number of small cold – warm cycles (known as interstade and stade) during the time space 120 – 18 ka. The last important glacial event is known as Last Glacial Maxima (LGM) and it is dated around 18 ka, when the sea – level was lowered by about 130 m. The climate was cold and rainfall pattern was disrupted. The LGM event at 18 ka was very important event, which caused lowering of sea-level and weak monsoon system. In the low latitudinal area climate became relatively dry and arid causing expansion of deserts. This period also witnessed down cutting of the river valleys and large-scale removal of sediments to the oceans. Vegetation also showed remarkable changes.

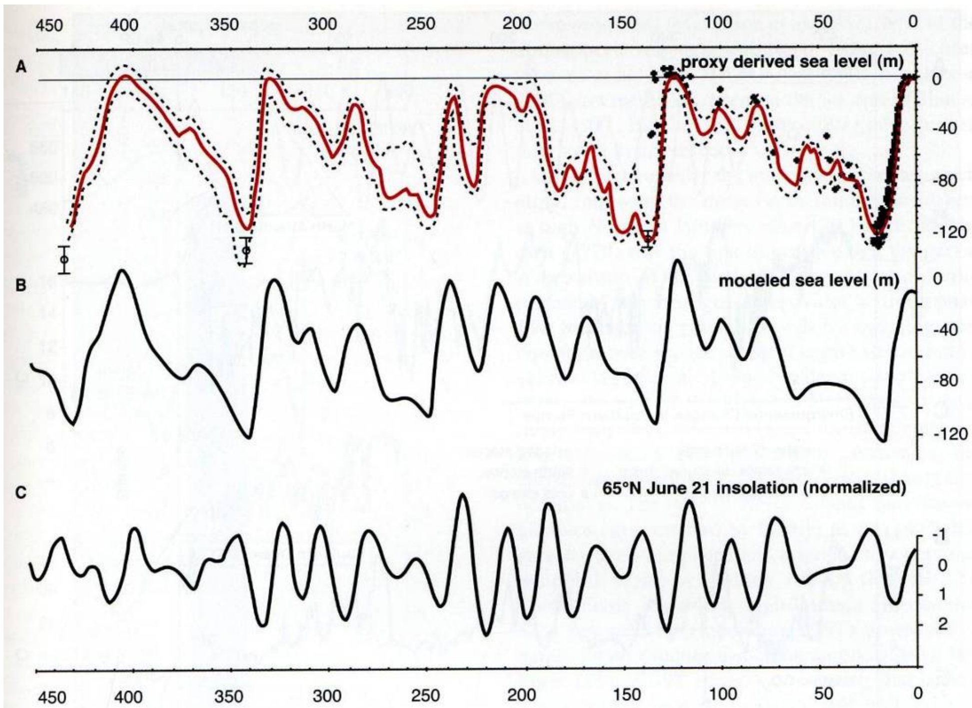


Fig. 4.2 Sea level change over four glacial cycles (From Labeyrie et al., 2002).

After 18 ka, there was a sudden and fast change in the climate, melting large volumes of ice in the polar regions leading to very fast rise in sea-level. During time span of 13-6 ka years, sea-level rose at a very high rate due to melting of ice in polar areas and glaciers. it reached a level of only few metres below the present day sea level. Monsoon system was intensified and it was a time of high rainfall. During last 6000 years, the sea-level is rising at a very slow rate and it is relatively stabilized. The rainfall is lower than the earlier period but shows strong fluctuations. The time period of last about 10000 years is known as Holocene. This period had similar climate to those existing today. However, it shows important fluctuations in the rainfall pattern, i.e. Early – Middle Holocene with high rainfall, Middle Holocene with low rainfall, and Late Holocene with moderate rainfall. Fig. 4.3 shows climate changes during last 25,000 years.

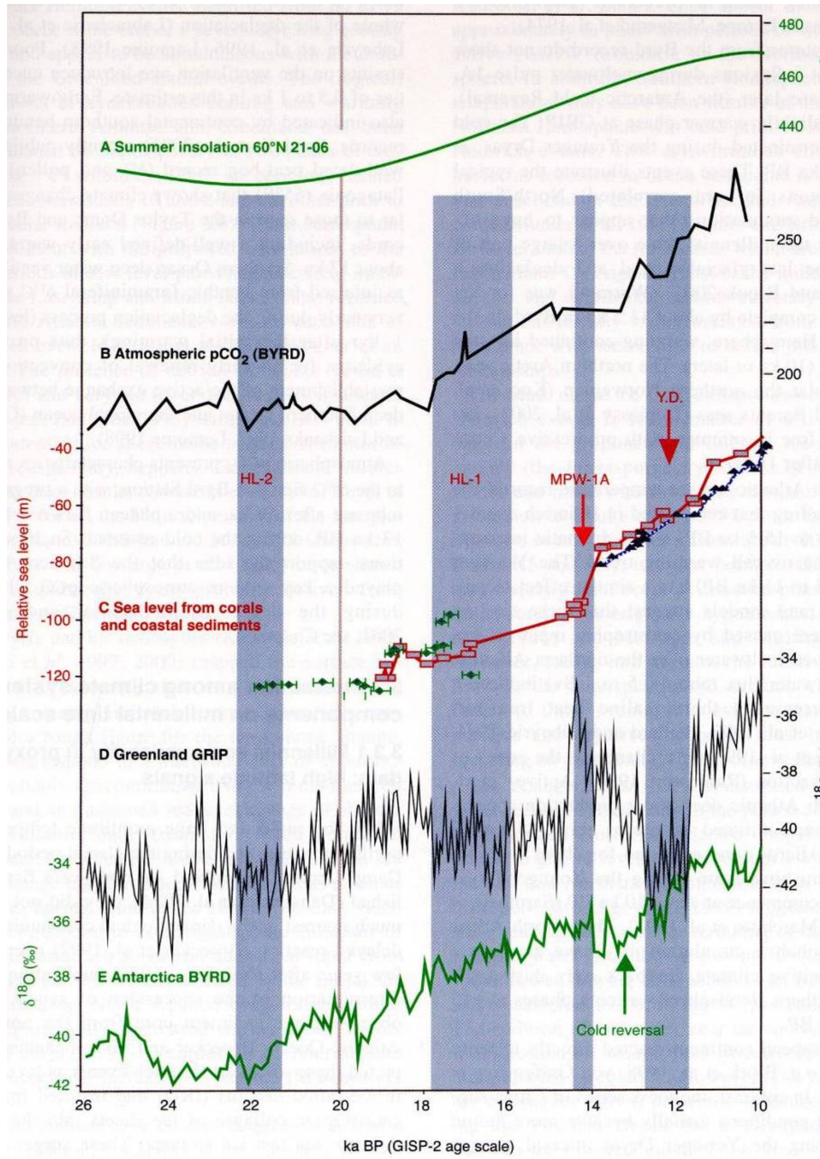


Fig. 4.3 Latest Pleistocene – Holocene (Last Glacial Maxima) and deglaciation changes recorded in various proxies (Labeyrie et al., 2002).

4.1.1.2. The Monsoon System

The climate of South Asia, including India is largely dominated by monsoon winds showing seasonal reversing wet and dry monsoon winds. During summer (June-September), the southwesterly winds (summer monsoon) travelling over the ocean brings rainfall over the land area. During winter (December-February), the northeasterly winds (winter monsoon) are dry and variable. Some rainfall, particularly in northwestern India and snowfall in the Himalaya during winter months is caused by northwesterly winds. The rainfall brought by southwest monsoon strongly affects the water budget of India as it accounts for 70-80% of the total annual rainfall. This influences the agriculture-based economy of India.

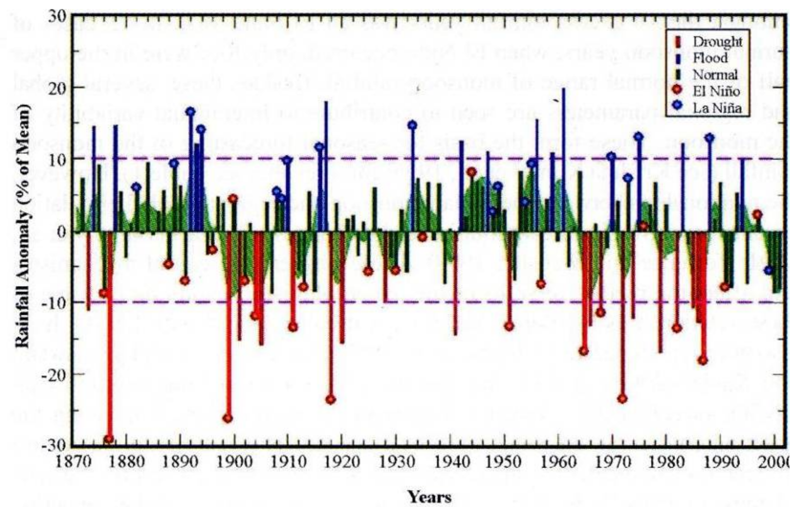


Fig. 4.4 Variation in all – India summer monsoon rainfall during 1871-2004. Data of IMD (From Singhvi et al., 2006).

The rainfall pattern in the historical past shows high variability. There are evidences that droughts were prominent during 18^{th} and 19^{th} century (Abhyankar, 1987). Analysis of monsoon rainfall pattern for the last about 100 years does not show any significant trend. Interannual scale fluctuations are strong (Fig. 4.4). The monsoon shows teleconnection to South Oscillation Index and E1 Nino events. Hingane et al. (1985) reported that there is an increase in mean annual temperature between 1901 – 1982 at a rate of 0.4°C/100 years. However, pattern of temperature increase is highly variable (Fig. 4.5).

4.1.1.3. Late Quaternary Climate in India, with Reference to Garhwal Himalaya

It has been already mentioned that the climate, particularly the rainfall pattern in India is essentially controlled by the monsoon system. During Late Quaternary time the monsoon system shows strong changes in its intensity in response to the changes in the ocean circulation system, wind circulation patterns, and temperature gradients. The southwest (summer) monsoon shows strong variability on a time scale of 10^3 – 10^4 years. This monsoon variability strongly controls the annual rainfall, as 90% of the precipitation takes place only in about 4 months.

The monsoon system was moderate during last interstade (35-18 ka) with some several millennium scale fluctuations. During Last Glacial Maxima (LGM) (18 ka) summer monsoon was weakened and precipitation over India was reduced. Later, ameliorating climate intensified the monsoon system. The precipitation by monsoon system increased over India during 13-6 ka, when rainfall was about 35% more than today. There is an important event of cold climate with low rainfall at about 12 ka, known as Younger Dyraas. Within the intense monsoon period of Early Holocene, there are weakening periods during 12-10 ka and 8.5-8ka. The monsoon system weakened in the time span of about 5000 – 4000 yrs BP, when rainfall was low and aridity in some areas increased. After 4000 years BP, the moderate monsoon system was established which is continuing today. During this period of moderate monsoon there are many century and decade scale fluctuations of low precipitation.

Interestingly, these smaller events of climate change are observed in most parts of the world, which suggests global teleconnectivity of the events.

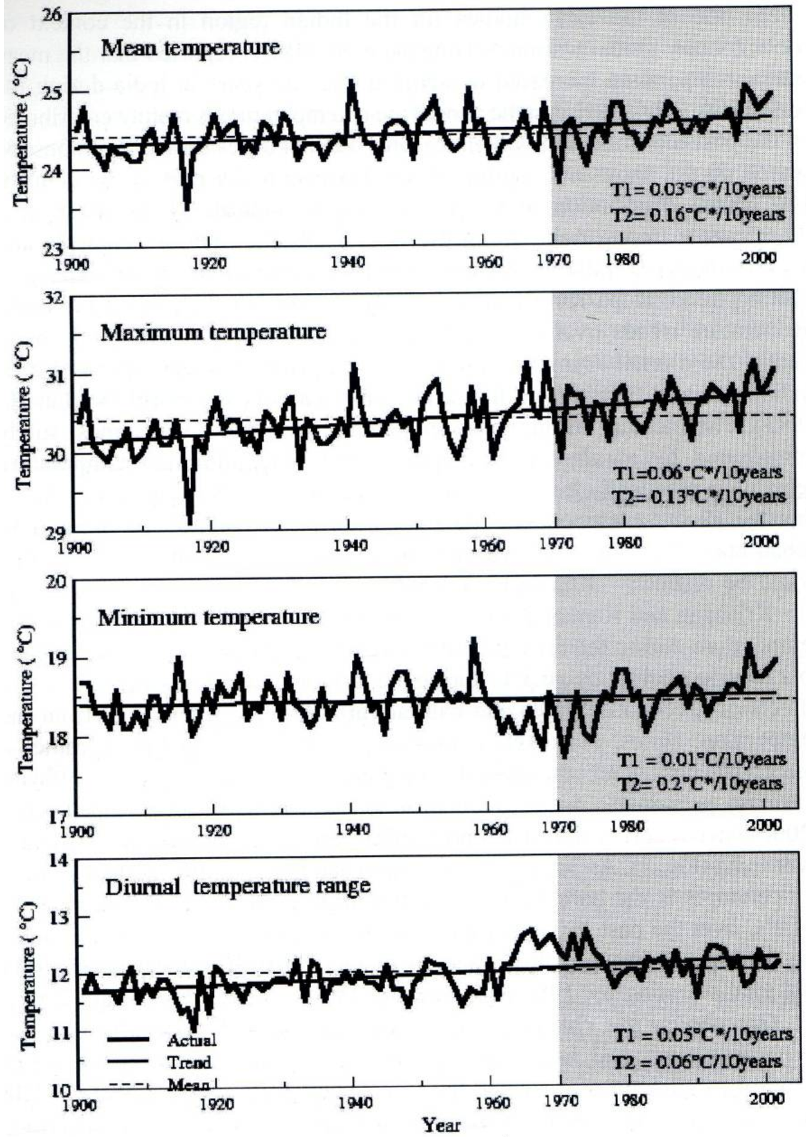


Fig. 4.5 Variation of all-India mean, maximum and minimum temperatures during 1901-2003. Data of IMD (Fram Singhvi et al., 2005).

Reconstruction of past climate, particularly the rainfall changes can be done using a number of proxies, namely, dendrochronology (tree ring analysis), pollen analysis in lake sediments, ice cores, cores of marine sediments, cave deposits, sediment analysis. In all these studies it is prerequisite to have a record of last few centuries to several thousand years and dating of the succession using different methods, i.e. radio-carbon dating, luminescence dating, etc.

The Garhwal Himalaya, especially in the Alaknanda – Bhagirathi basins shows highly diversified landforms, namely glaciers, lakes, forests and river valleys. These landforms are highly sensitive to climate change, particularly the rainfall. The climate change with rainfall change during Late Quaternary strongly affected this area. The record of these changes are preserved in several forms in different geomorphic domains. In the following we describe the past climate changes in the Alaknanda – Bhagirathi basins, inferred by the study of different proxies.

4.1.1.4. Changes in Palaeovegetation

Changes in the climate directly affect the nature of vegetation. As pointed out, during last 10,000 yrs there has been distinct changes in the monsoon rainfall pattern. Lakes in any area receive sediments and pollens from the adjoining areas of the lake. Sediments in a lake are continuously deposited. If a sediment core from lake is retrieved and analysed for pollen spectrum and the sediments are dated by different techniques, the changes in the pollen spectrum through time can be interpreted in terms of changes in the vegetation and related to the changes in climate (rainfall and temperature).

A number of sediment profiles from the different lakes located in the Uttarakhand have been studied. Some of the lakes studies are located in the Alaknanda and Bhagirathi basins.

Deoria Tal is situated near Okhimath town in Chamoli district. At present this area receives about 2000 mm rainfall annually. It is concluded that around 6000 yrs BP oak dominated forests were present in the area. The climate was warm temperate and humid. Around 3600 yrs BP dramatic change in the vegetation is observed in the form of reduction in density of forests and increase in ground vegetation like grasses. It indicates cooler, slightly drier climate. Around 1700 yrs BP, the oak forests started becoming prominent again due to humid warm temperate climate. Cerelia Pollens indicating increased anthropogenic activity became prominent around 3000 yrs, though they are present earlier also in low numbers. (Sharma and Gupta, 1997; Sharma et.al., 2000).

In another study of sediment profile of Sat Tal located near Harsil in Uttarkashi district, it is demonstrated that between 2800 – 1900 yrs BP luxuriant mixed forest existed indicating moist temperate climate. Between 1900 – 1200 yrs BP, the vegetation shows a decline in forest density indicating a cool climate and less humidity and reduction in lake. In the last 1200 years mixed temperate forests became prominent. The climate shows deterioration. In the later period there is evidence of anthropogenic activity in the pollen record. (Chauhan et al., 1997).

Study of Nachiketa Tal in Uttarkashi also shows changes in vegetation in response to the climate change during last 1500 years (Gupta and Sharma, 1993).

Pollen record from a peat deposit of shallow lake near Dokriani glacier shows that between 7800 – 5000 years BP, the vegetation was of oak forest with grasses indicating cold and wet climate. There were two small events of relative dryness at 7200 and 6600 yrs BP The time between 6000-4500 years BP represents high rainfall intensity. Between 4000 – 3500 years BP conifers decrease indicating cooling and decrease in rainfall. It was followed by warm and wet period with two short-lived dry events at 3000 and 2000 years BP, becoming humid at 1000 years BP, similar to present climate (Fig. 4.6). However, there is a dry event at about 800 years BP (Phadtare, 2000).

The above examples, clearly show that in the Alaknanda and Bhagirathi basins, there has been millennium to century scale changes in the climate in the last about 8000 years which have affected the corresponding changes in the vegetation.

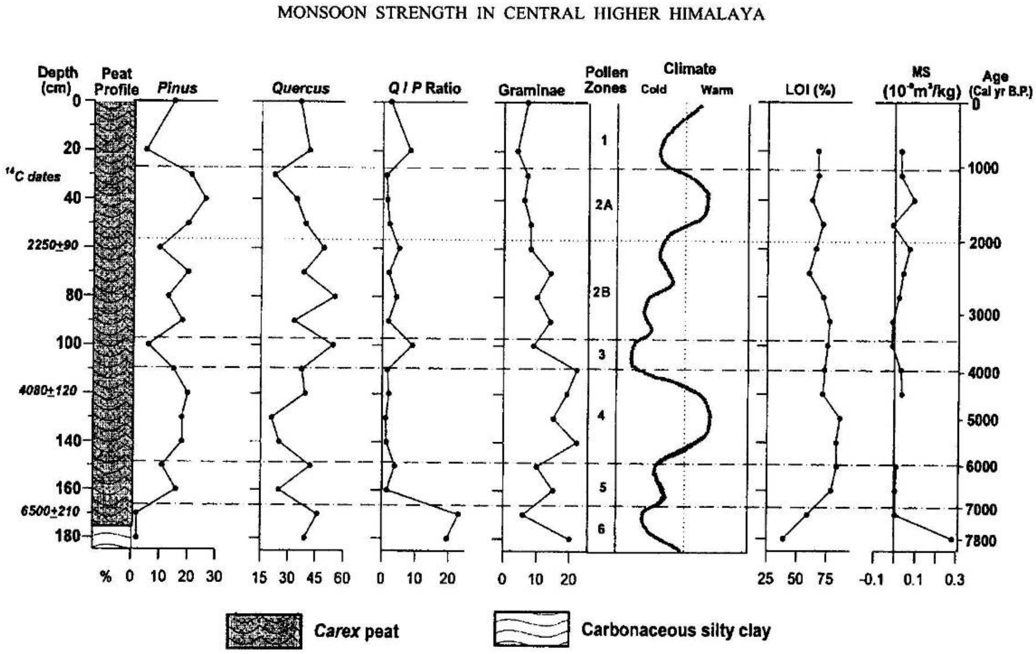


Fig. 4.6 Summary of pollen content and inferred climate based on peat near Dokriani glacier (From Phadtare, 2000).

4.1.1.5. Changes in Sediment Yield and Supply

The southwest monsoon was much stronger than today in the time span of about 13000 – 7000 yrs BP. Studies in the Ganga-Brahmaputra delta (G-B delta) show that the formation of present G-B delta started around 11,000 yrs BP. It has been estimated that the supply of sediment in the time span of 11000 to 7000 yrs BP was about 2.3×10^9 t/yr. Present sediment load of G-B rivers is about 1×10^9 t/yr (Goodbred and Kuehl, 2000). Thus, during Early Holocene due to high rainfall on Indian subcontinent, the rate of erosion and supply of sediment from catchment area of Ganga-Brahmaputra river system was very high. It suggests that in the Uttarakhand Himalaya in the Alaknanda and Bhagirathi basins of Ganga River System, the rate of erosion and sediment transport must have been much higher during Early Holocene time than at present.

4.1.1.6. Climate Change Record from Tree-Ring Analysis

Growth of a tree is strongly influenced by the humidity (rainfall) and temperature. Many trees show prominent tree rings which indicate annual growth. The tree rings are prominent, if the seasonality is strong. The width of the tree ring broadly relates to the humidity and temperature. Several variety of trees growing in high altitude region of Garhwal Himalaya have been studied for reconstruction of palaeoclimate. More than two thousand years old trees have been studied by dendrochronology (tree ring analysis). These tree species are *Cedrus deodara*, *Pinus gerardiana*, *Juniperus Polycarpos*,

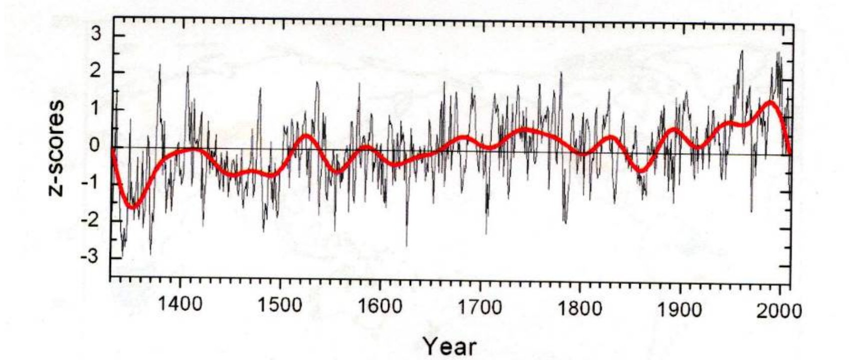


Fig. 4.7 July – August precipitation reconstruction for 1330-2008 based on tree ring analysis (From Yadav, 2011).

The climate reconstructions are essentially for mean temperature of pre-monsoon season and precipitation of pre-monsoon season. The pre-monsoon precipitation in western Himalaya is brought by westerly disturbances. Reconstruction for the western Himalaya in general shows considerable interannual to decadel scale variability (Fig. 4.7). A 50–year running mean indicated dry periods during 1471-1520, 1584-1633 and 1773-1882. The humid periods are 1359-1408, 1723-1772, 1817-1866 and 1949-1998 (Fig. 4.8). It suggests dry conditions in the late eighteenth century and wet conditions in the twentieth century. It corresponds to the dry and wet conditions of the Little Ice Age (LIA). Temperature reconstruction for western Himalaya shows interdecadel variability superimposed over strong interannual variability. The cool periods recorded are 1573-1622, 1731-1780, 1817—1846 representing interdecadel variability during LIA cooling. There is a trend of decreasing temperature in the late 20th century, which may be related to the anthropogenic activity. There appears to be a subdued late 20th century warming also. (Yadav, 2009; 2011) (Fig. 4.9).

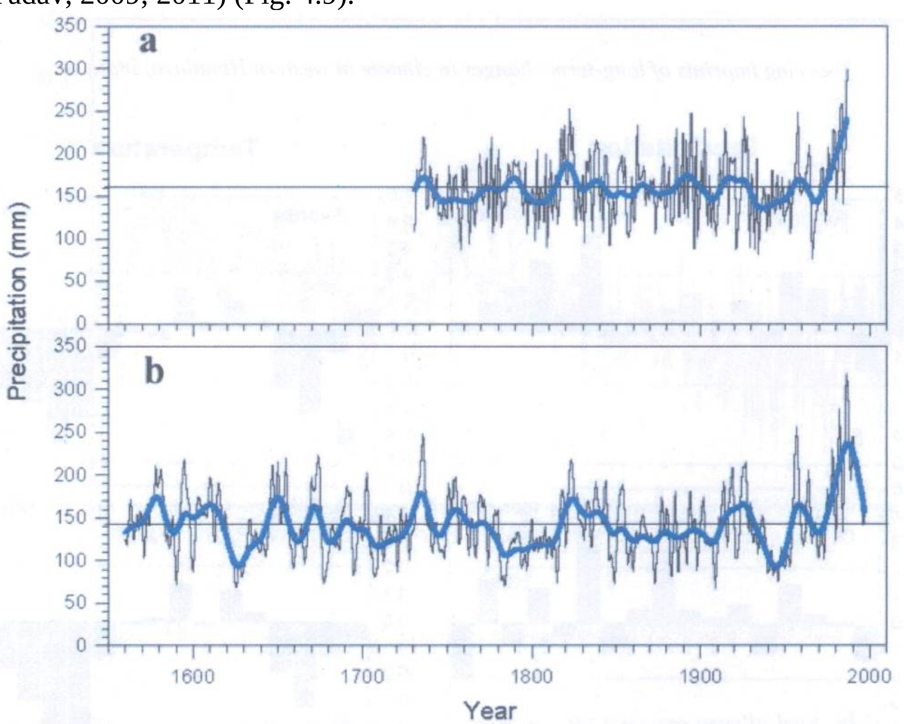


Fig. 4.8 Premonsoon (March-May) precipitation reconstruction using tree ring analysis of Bhagirathi and Tons basins (Yadav, 2009).

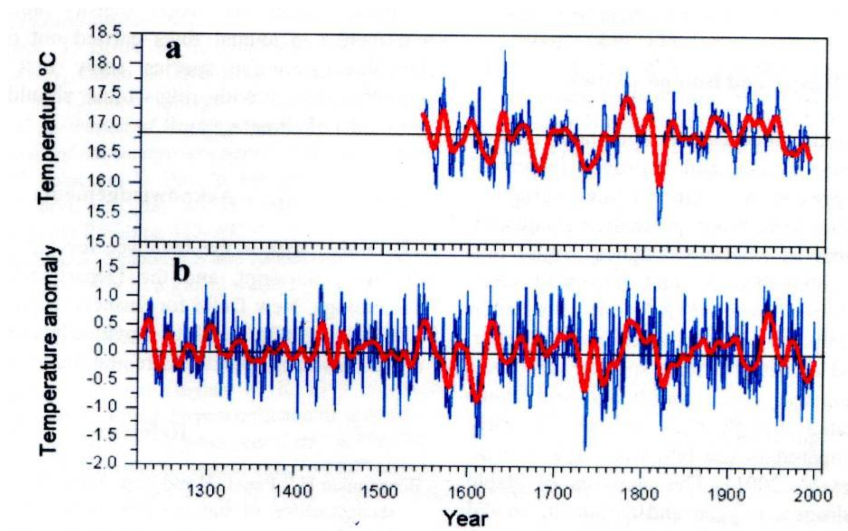


Fig. 4.9 Mean temperature reconstruction using tree ring analysis of Bhagirathi and Tons basins (Yadav, 2009).

4.1.1.7. Gomorphic Changes in River Valleys of Alaknanda and Bhagirathi Basins

It is argued that during last interstade (35-18 ka), the extent of glaciers in Himalaya was much more than at present (Owen et al., 2002). During this period in the river valleys, the supply of sediment was high, but water discharge was relatively low. Fig. 4.10 shows extent of glaciers during 63 ka and the present extent of glaciers in Alaknanda and Bhagirathi basins. The sediment filled most of the river valleys and also carried large amount of sediment on the Ganga Alluvial Plain. During LGM (ca.18ka) glaciers slightly retreated, releasing much sediment. Due to decreased rainfall during LGM, the river valleys retained large amount of sediment. It is postulated that during this period the river valleys of Alaknanda and Bhagirathi basins were filled with tens of meter thick sediment, and bed rocks in river bottom and lower parts of the valley slopes were not exposed. Intensification of monsoon during 13-7 ka, increased the discharge of rivers. This led to erosion and transportation of valley fill sediments downstream to Ganga Alluvial Plain and beyond. At present, at many places, bed rocks are exposed on the river channel floor, while only a thin apron of sediment is present in some segments. At present, we see remnants of these valley filling sediment at various heights on the valley slopes, such deposits are prone to landslides during excessive rainfall events.

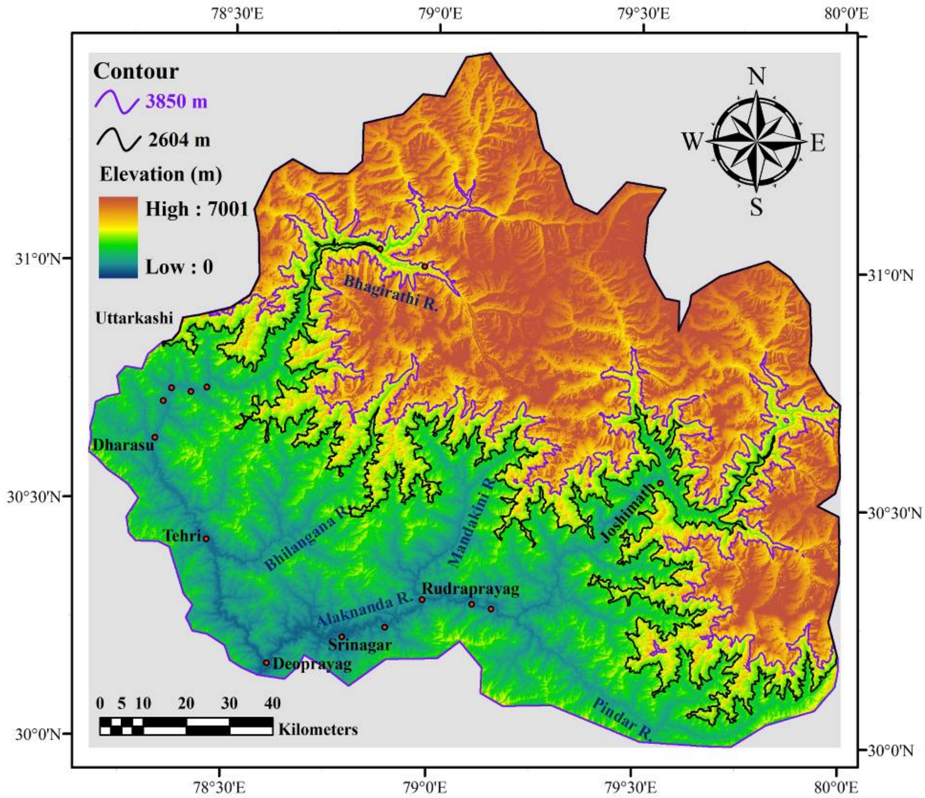


Fig. 4.10. Area occupied by glaciers during 63-18 ka, and the present glacier - snowfield boundary in Alaknanda – Bhagirathi basins. 2604 m is contour for 63 ka and 3850 m is contour for present day glaciers (courtesy P. Srivastava, WIHG, Dehradun).

Ray and Srivastava (2010) investigated the Alaknanda valley from the point of view of its evolution in response to climate changes during Late Quaternary. Luminescence dating has indicated that the valley was filled by sediments during 49-25 ka and 18-11 ka due to large supply of sediment in the catchment with low water discharge. Incision of the valley fill started around 11 ka due to increased discharge. The Alaknanda valley shows well-developed terraces, mostly of cut-and-fill type. In several areas terraces with deep bed rock steps are present. The bedrock incision may have initiated during last 5000 years (Srivastava et al., 2008).

Terraces are present in between Bhatwari upstream of Main Central Thrust (MCT) and Dharasu near North Almora Thrust (NAT). Terrace sequences in the upstream area are having bedrock at their base and can be termed as the strath terraces. On the other hand, terrace sequence downstream of the MCT are fill terraces and having broadly four levels of terraces. In the Bhagirathi valley two phases of aggradation occurred: first from ~55ka to 18 ka and from 10 ka to 2 ka. The major phase of aggradation is around 35-20 ka.

At Devprayag, in the Alaknanda valley, there are evidences of two palaeofloods of high magnitude dated 1200 years BP and 200-300 years BP, probably in response to high rainfall in the region (Srivastava, et al. 2008).

4.1.1.8. Paleo-landslides in Alaknanda Valley

Alaknanda and Bhagirathi rivers traverse through all major lithotectonic domains of Himalaya that are neotectonically active. The combined effect of rainfall and tectonic instability cause excessive landsliding in the region. In Srinagar, there are evidences of landslides and formation of lakes related to the neotectonic activity along North Almora Thrust – lakes were formed on the slopes during 18-5 ka. Large-scale instability in area causing landslide terminated the lakes around 5000 years BP (Sundriyal et al., 2007). The records of palaeo-landslides in the Alaknanda – Dhauliganga valley are studied that suggested that in the zone lying north of Main Central Thrust (MCT) a phase between 18-9 ka is characterized by intense mass wasting and landslides and similarly the areas in the vicinity of Alaknanda fault (AF) and North Alaknanda Thrust (NAT) were experiencing active landslides between 30-20 ka and 12-6 ka respectively (Fig. 4.11). The data suggests that tectonic instability along the major structural discontinuities, viz. MCT, AF and NAT is an overriding factor that induces landslides, and that the activity along these faults has changed through time on a scale of 10^3-10^4 years (unpblished data, P. Srivastava).

The above discussion demonstrates that in the Alaknanda and Bhagirathi basins dramatic changes took place in the landform and river valley development in response to the climate change in the last about 20,000 years. These changes were exclusively due to natural processes, in response to the changing climate, particularly the variability in the monsoon rainfall. There are also evidences of changes in tectonic activity causing landslides in specific areas. These changes are on millennium, century or decadel scale. We still have only preliminary information on the impact of these changes in the Alaknanda and Bhagirathi basins.

The available information in the form of pollen studies and archaeological data indicates that humans were living in the area at least since last 3000 years. With time human population increased and the authropogenic activity of different types, namely habitation, agriculture, water requirement started having some impact on the nature. The present-day changes taking place in Alaknanda and Bhagirathi basins are partly natural changes and partly anthropogenic. It is not always easy to assess what fraction of changes can be assigned to human activity. In order to assess the impact of hydropower projects in the Alaknanda and Bhagirathi basins, it is important to assess the changes caused by natural processes and changes due to other anthropogenic activity in the area.

4.1.2. Glaciers of the Alaknanda and Bhagirathi Basins

The upper reaches of Alaknanda and Bhagirathi basins are located above the snow line and covered by a large snowfield. This snowfield consists of a large number of glaciers of varying dimensions. Bhagirathi River originates from the Gangotri glacier; while Alaknanda River originates from Satopanth and Bhagirath Kharak glaciers. Several other small tributaries of Bhagirathi – Alaknanda river system also originate from small glaciers of this area.

The glaciers of the Alaknanda and Bhagirathi basins are of high – activity type and show evidences of fast retreat during last two centuries. This resulted in formation of large paraglacial areas with extensive deposits of outwash fans, morainic ridges

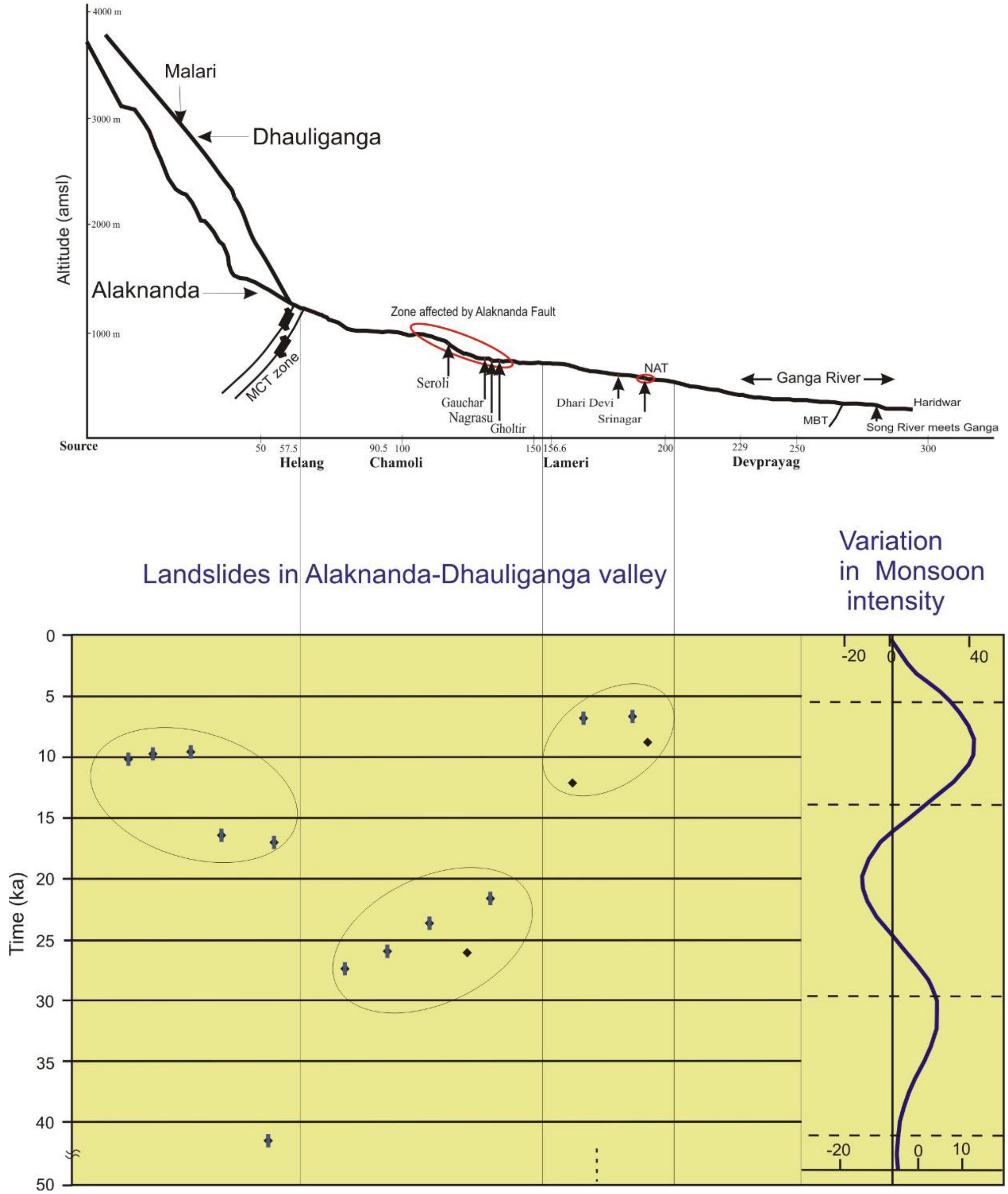


Fig. 4.11 Diagram showing position of palao-landslides in Dhauliganga valley. The palaeo-landslides fall in three age clusters, indicating neotectonic activity in different segments (Courtsey, P. Srivastava, WIHG, Dehradun).

and debris flow cones. These glaciers have source areas in high altitudes. The Equilibrium Line Altitude of the area ranges from 4510 to 5390 m asl. Most of the glaciers are debris mantled due to high sediment production in the upper reaches of the glaciers.

The maximum extent of the these glaciers took place during time span of 63 ka and 5 ka B.P. and since then they have retreated to their present position. The retreat of the these glaciers varies between about 40 to 10 km in different parts of this system. It is often argued that advance and retreat of the Himalayan glaciers are related to monsoon activity. At present some of the Himalayan glaciers show advance because these areas are receiving high precipitation.

Study of Gangotri glacier (Sharma and Owen, 1996) demonstrates that the Gangotri glacier extended into Bhagirathi river valley, about 40.5 km from the snout of the glacier during the time span of 63 – 5 ka BP. This stage is designated as Bhagirathi Glacial Stage. During Middle Holocene (<5 ka BP) there is evidence of extension of Gangotri glacier about 2 km from its snout. It is named as Shivling Glacial Advance. Another, glacial advance is during 200-300 years BP, known as Bhujbas Glacial Advance, when glacier extended by about 1-2 km from the present – day snout. This corresponds to the cooler period of Little Ice Age (LIA). During last 200 years, there has been a progressive retreat of glacier snout, which has accelerated during last few decades. The sediments left behind during glacial retreat in the Bhagirathi river valley are being reworked by paraglacial processes (Barnard et al., 2004). Kumar et al. (2008) record the retreating rates of Gangotri glacier and show that rates of retreat has been fluctuating on annual and decadel scale.

Dokriani glacier is a compound valley type glacier in the Dim Gad Catchment, a tributary of Bhagirathi River. It has been studied to document the changes in the glacial morphology and changes at snout. The study shows that during 1962-1995, the glacier retreated by 550 m with an average rate of 16.6 m / year, during 1991-1995, the rate of recession was 17.4 m / year. During 1991-2007 the retreat of snout is at an average rate of 15.6 m/year. There is a decrease in rate of retreat from 17-18 m/year (1991-2000) to 16.6 m / years (2001-2007) (Dobhal et al., 2004; Dobhal and Mehta, 2010).

The Satopanth and Bhagirath Kharak glaciers are the source of Alaknanda River. The source of these glaciers are in the eastern slopes of the Chaukhamba group of peaks. The Satopanth and Bhagirath Kharak glaciers follow a curvy-linear course due to presence of a number of spurs within its course. The glaciers are covered by a thick pile of supraglacial moraine. The Equilibrium Line Altitude (ELA) for Satopanth and Bhagirath Kharak glaciers is located at 4677 m and 4942 m respectively. These glaciers show retreat of their snout. The total area vacated in time space of 1962-2006 is 0.314 sq.km for Satopanth glacier and 0.13 sq.km for Bhagirath Kharak glacier. The average annual retreat (1962-2006) of the snout of Satopanth and Bhagirath Kharak glaciers is 22.88 m /year and 7.42 m / year respectively. During 2005-2006, the retreat of snout was 6.5 m / year and 1.5 m / year for Satopanth and Bhagirath Kharak glaciers respectively. This suggests strong temporal changes in the rate of recession on decadal and annual scale.

The study of glaciers in the Alaknanda and Bhagirathi basins strongly indicates that most of the glaciers in the area are showing a retreat of snout, which is highly variable from one glacier to the other. In the geological past (63-5 ka) the glaciers of the basins were much larger and snowline was probably down to 2500 m asl; in contrast to the present snowline of about 4500 m asl. In the last two centuries the glaciers of the area show a strong and fast retreat. In the last few decades also the glaciers are showing a retreat of snout. However, the rate of the retreat of snout shows decadel and inter-annual fluctuation. The retreat of snout of the glaciers is indicative of snow melting and snow melt discharge in the rivers. The decadel and annual scale fluctuations in the retreat of snout of glaciers will be reflected in the changes in the discharge of rivers of the area during summer months.

The glaciers are located in the much higher altitudes and long distances upstream from the locations of hydropower projects, both in the Alaknanda and Bhagirathi river basins. The construction and operational activities at hydropower projects will have little or no impact on the behaviour of glaciers, whether it is melting (receding) or aggrading (advancing). Moreover, the natural fluctuations in the glaciers, particularly at the snout of the glacier are significant as mentioned in the preceding paragraphs.

In the winter months, much snowfall takes place at altitudes much below the snowline and location of glaciers. The snowfall takes place down to an altitude of about 2000 m asl. During heavy snowfall much snow may accumulate on the slopes of a river valley. Occasionally, this snow avalanches downwards and may block the river flow for a short duration. These snow avalanches are related to the unstable steep slopes, amount of snowfall, and a change of temperature at the end of the winter season. The hydropower projects can not have any impact on the frequency and intensity of snow avalanches. However, if a steep, unstable slope is created due to various constructional activities, including road building, hydropower construction, a local area for snow avalanches may be created. It is surmised that constructional activities of any type must not disturb the hill slopes.

4.2. GEOLOGICAL STUDIES

4.2.1. Introduction

Bhagirathi and Alaknanda river systems of Uttarakhand have vast potential of hydroelectric power. Construction of Hydropower projects involves huge excavation and dumping of earth mass for building of dams with reservoir, construction of roads and other infrastructures etc. These activities may lead to change in geo-environment in and around the project site mostly in the form of enhanced slope instability. It is important to assess the impact of HPs on the geoenvironment of the area. Stand alone and the cumulative impact of HPs on geotectonics and landslides form the subject matter of this study.

4.2.2. Methodology

The hydropower projects are planned, designed and constructed taking into consideration the existing geology and topography of the region. The lithological aspects and structural discontinuities are studied to assess the impacts on slope stability and geotectonics due to the hydropower projects. The thrusts faults, fractures, joints and other tectonic elements are investigated. Based on geological features the area has been divided into six geotract each one of which is relatively homogenous within and heterogenous among themselves. Further, based on the geotracts a landslide susceptibility map was prepared. Hydropower with more than 75 MW capacity were investigated for their impact on geotectonics and landslides in totality.

The slope instability conditions of large reservoirs during these hydropower operation as compared to the earlier conditions before their filling started, are studied. Main emphasis is given to understand if they are stabilized with time.

4.2.3. Regional Geological Frame Work

Uttarakhand is a hill state, most of which occupies a part of Himalaya stretching about 320 km between Himachal Pradesh in the west and Kali River in the east, forming the Indo-Nepal border.

The Himalaya is a young and dynamic orogenic belt with rising mountain ranges. It trends roughly east-west for about 2400 km with width span varying between 325-425 km. The Himalayan terrain owes its origin to the collision of north to north-eastward moving Indian lithospheric plate, with the Asian plate in the north at about 56 Ma (Patriat and Achache, 1984, Molnar, 1986) and thus forms a continent-continent collision type orogenic belt (Valdiya, 1984).

The Himalaya from north to south is divided into five distinct geological units based on tectonic and lithologic discontinuities and separated by major Himalayan thrust faults dipping northwards (Wadia, 1957; Gansser, 1964; Valdiya, 1980; Powers *et al.*, 1998) (Fig. 4.12 & 4.13). Each unit has its own geotectonic and seismotectonic characters. The major geological units and thrust faults control the present morphology of the Himalayan ranges.

4.2.3.1. The Trans-Himalaya:

The Trans-Himalaya consists of volcanic, plutonic, and metamorphosed Precambrian-Mesozoic rocks. The southern limit of this is marked by the Indus Tsangpo Suture Zone (ITSZ), which defines the zone of collision between the Indian and Asian plates. The ITSZ comprises of ophiolites and ophiolitic melange, fore-arc sediments and a magmatic arc consisting of plutonic-volcanic rocks of Cretaceous to Early Tertiary age (Corfield *et al.*, 1999). The ophiolite complexes are located along the entire belt of ITSZ from Ladakh to southern Tibet. The ophiolitic melanges are composed of an intercalation of flysch sediments and ophiolites of the Neotethys oceanic crust.

4.2.3.2. The Tethys Himalaya:

The Tethys Himalaya is confined between the Tethyan Detatchment Fault (TDF) in the south and the Indus Tsangpo Suture Zone (ITSZ) in the north. It comprises the Late Precambrian to Eocene marine sediments deposited in the Tethyan Sea. These sediments are largely unmetamorphosed and dominantly fossiliferous occurring in synclinorium-type basins (Bagati, 1991).

4.2.3.3. The Greater Himalaya:

The Greater or Higher Himalaya is limited by the Main Central Thrust (MCT) to its south and the Tethyan Detatchment Fault (TDF) to its north. It comprises high grade Precambrian crystallines, Cambro-Ordovician (500±50 Ma) granites/orthogneisses and the Tertiary leucogranites. The Great Himalayan sequence shows progressive regional metamorphism ranging from green schist to upper amphibolite facies

(Thakur, 1992). The granites frequently intrude the medium- to high-grade metamorphic sequences of metasedimentary rocks. The MCT, marking the southern boundary of the Greater Himalaya, is one of the most important tectonic elements associated with the Himalayan orogenesis and it separates the high-grade metamorphic rocks of the Higher Himalaya (hanging wall) in the north from the weakly metamorphosed rocks of the Lesser Himalaya (footwall) (Gansser, 1974; Valdiya, 1980).

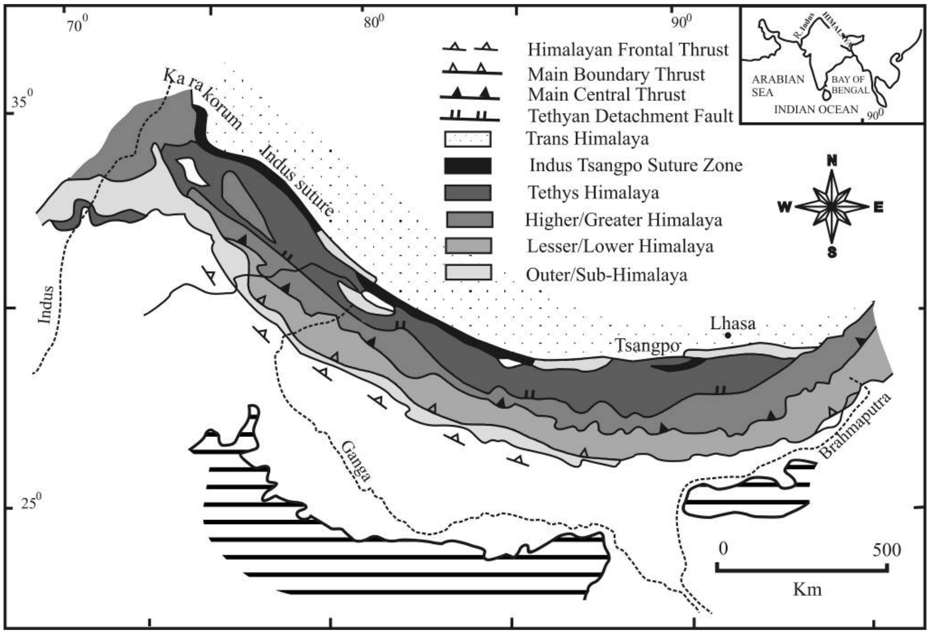


Fig. 4.12 Lithotectonic Map of Himalaya (From Valdiya, 1980)

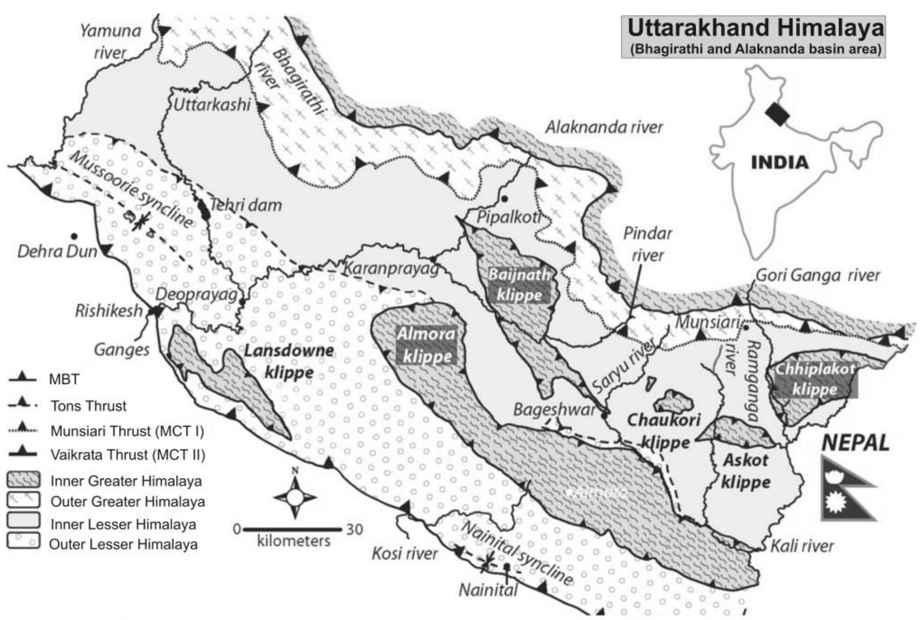


Fig. 4.13 General Lithotectonic Setup of Alaknanda and Bhagirathi Basins of Uttarakhand (From Celerier et al., 2009).

4.2.3.4. The Lesser Himalaya:

The Lesser or Lower Himalaya is limited by the Main Boundary Thrust (MBT), also designated as Main Boundary Fault (MBF) to its south and the MCT to its north and consists of the Late Proterozoic to Early Cambrian sediments intruded by some granites and acid volcanics (Valdiya, 1980; Srikantia and Bhargava, 1982). It mainly comprises the marine sequences of Late Proterozoic to Early Cambrian age and some sedimentary record of transgressing shallow sea during Permian and Late Cretaceous to Early Eocene periods. The predominant rock types are quartzites, siltstone, shale and carbonates. There are zone of phyllite, schists, with subordinate impure marbles, metamorphosed mafic rocks, and augen orthogneisses (Valdiya, 1980). The MBT separates the northern Lesser Himalayan sediments (hanging wall) from the sediments of the Sub-Himalaya (footwall) to the south.

4.2.3.5. The Sub-Himalaya:

The Sub-Himalaya or Outer Himalaya forms low altitude foothills between the Himalayan Frontal Fault (HFF) to its south and the Main Boundary Thrust (MBT) to its north. It preserves the record of the post-collision sediments produced by weathering and erosion of the debris of the rising Himalayan front. These sediments were carried and deposited in the foreland basin, the Himalayan Foreland Basin (HFB). It consists of the Lower Tertiary sediments (Paleocene to early Miocene) comprising Subathu, Dagshai, and Kasauli formations which are marine to brackish water sediments and the Upper Tertiary sediments (Middle Miocene to Middle Pleistocene) consisting of the Siwalik Group fluvial deposits, along with the late orogenic intermontane deposits and alluvium. The HFF separates the Siwalik sediments in the north from the Indo- Gangetic sediments towards south.

4.2.4. Geological Set up of Uttarakhand Himalaya

The Uttarakhand Himalaya includes a 320km stretch of the mountains between the Kali River forming the Indo-Nepal border in the east and the Tons-Pabar valleys forming the eastern border of Himachal Pradesh in the west. The geological framework of the area is rather complex. In this area, a large variety of rocks and rock complexes are developed in the central crystalline complex of Great Himalaya and the Lesser as well as Sub-Himalaya. The area has witnessed granitic intrusions at different times, the oldest being 2500 Ma, followed successively by intrusions at 2200 – 2100 Ma, 1900 – 1600 Ma and 1100 Ma. The rocks show much lateral facies changes. Some of the rock complexes seen in one valley, are absent in the other valley. The terrain is very sensitive to mass wasting processes. It is therefore, important to understand the lithostratigraphy and structure of the Uttarakhand Himalaya in the context of harnessing of water resources of the region for various hydropower projects on the Alaknanda and Bhagirathi basins.

Lithostratigraphy

The geology of the area is very complex. Various workers have often given different names to the same rock succession in different areas. The following, general stratigraphic succession as proposed by Kumar (2005), is given below.

Table 4.1: Stratigraphy of rock succession in Uttarakhand giving various geological units and their lithological characteristics (modified after Kumar, 2005)

Granite (1100 Ma)	--	
(iii) Vaikrita Group (part)/Jaunsar Group	Undifferentiated Vaikrita/Mandhali-Chandpur-Nagthat formations	Purple, grey quartzite, grits and conglomerate, thin bedded limestone-phyllite/slate, laminated greenish grey phyllite/slate with lenticular greywacke, purple green quartzite, grit, conglomerate
(ii) Garhwal Group	---	
	Granite (1900 Ma & 1600 Ma)	
	Berinag Formation	Quartzite with penecontemporaneous mafic volcanics
	-------------------Disconformity ---------------------	
	Deoban Formation	Limestone-dolomite, shale
	Rautgara Formation	Quartzite with penecontemporaneous mafic volcanics
	Granite (2200-2100 Ma)	
	Uttarkashi Formation	Quartzite with penecontemporaneous mafic volcanic, dolomite-limestone, shale
(i) Central Crystalline Group	Granite (2500 Ma)	
	Badrinath Formation	Garnet, sillimanite, muscovite, kyanite - bearing gneiss, mica schist, migmatite, calcsilicate
	Pandukeshwar Formation	Banded quartzite gneiss, para-amphibolites
	Joshimath Formation	Garnet-mica-schist, sillimanite-kyanite schist
	Bhimgora Quartzite	White quartzite
	Ragsi Formation	Kyanite-mica schist, gneiss, para-amphibolite

(i) Central Crystalline Group

It is exposed in the Greater Himalaya and occurs in a linear zone continuously in the Alaknanda Basin. They possibly form the oldest crystalline rocks of the Himalaya. The gneisses, migmatites, crystalline schist, thick quartzite with a conspicuous horizons of calc-silicates with psammite gneisses in the upper part form bulk of the metasediments. It is best exposed in the Alaknanda valley between Helang (south of Joshimath) and Badrinath and its southern contact with the Garhwal Group is a tectonic plane known as the Main Central Thrust (MCT).

Ragsi Formation: It is named after a prominent peak SW of Tungnath (between Alaknanda and the Mandakini valleys) and described as the Ragsi schist and gneiss Member of the Tungnath Formation. In Nagol Gad, it is in contact with the Garhwal Group along Main Central Thrust (MCT), and is overlain by the Bhimgora Quartzite. In the Alaknanda valley, along Helong it is associated with para-amphibolite/marble and gneisses. It continues westwards to the Mandakini valley and is represented by quartzo-feldspathic schist and gneiss, kyanite-staurolite schist and cummingtonitehornblende schist. In the Pindar River, the Ragsi Formation along with overlying Bhimgora Quartzite is cut-off by the MCT.

Bhimgora Quartzite: White coloured, fine grained recrystallized quartzites with abundant sericite flakes make the Bhimgora Quartzite. It is named after Bhimgora Chatti along the Chamoli-Okhimath road. It is traceable from Bhimgora in the Nagol Gad to north of Helang in the Alaknanda valley and outcrops again near Tapoban in the Dhauliganga section, upstream of Joshimath. In the Alaknanda valley, associated with it is chlorite phyllite which is possibly derived from amphibolites. In the Mandakini valley, it is exposed as a thin band north of Kalimath and continues westwards to south of Sonprayag and beyond.

Joshimath Formation: Joshimath Formation comprises regionally metamorphosed banded psammitic and pelitic sediments represented by interbedded sequence of garnet mica schist, staurolite kyanite schist, sericite quartzite, quartz porphyry, amphiobolite and associated coarse-grained biotite augen-gneiss.. These rocks continue westwards and have been mapped as the Chandersila Schist of the Tungnath Formation. Okhimath Formation outcropping between Okhimath and Lanka in the Mandakini valley. Valdiya (1980a), however, considered the latter contact to be a tectonic plane referred to as the Vaikrita Thrust.

Pandukeshwar Formation: The psammatic series of the Alaknanda at Pandukeshwar, consists of regularly bedded quartzites/banded quartzitic gneisses in which sedimentary structures such as cross bedding are preserved. Interbedded with quartzitic gneisses is garnet-biotite schist.

Badrinath Formation: It is well exposed between Hanuman Chatti and Badrinath in the Alaknanda valley. It consists of garnet, sillimanite, muscovite and kyanite-bearing gneiss, mica schist, migmatites, calc-silicates, and garnet amphibolites intruded by leucogranite and pegmatite. In Dhauliganga, the Badrinath Formation is well exposed around Kosa. Calc-silicates are seen north of Pongti Gad and to about 1.6 km east of Kosa where they are associated with quartzitic gneisses.

(ii) Garhwal Group

It consists of thick succession of low grade metasediments made up of quartzite with penecontemporaneous metabasics and carbonate rocks lying between the Main Central Thrust in the north and and the Main Boundary Fault (MBF-2) in the south. The Garhwal Group is intruded by granites dating ca. 2100, 1900-1800, 1600, 1200-1100 Ma and younger biotite and tourmaline granites.

The Garhwal group is subdivided into five formations (Table 4.2). Acid and basic igneous rocks intrude the rocks of Garhwal Group. Different formations of the Garhwal Group can be subdivided into several members which may occur locally.

Uttarkashi Formation: It is the oldest group of rocks exposed in anticlinal cores in the Bhagirathi valley around Uttarkashi. The Uttarkashi Formation is divisible into three members, viz. the Netala quartzite, Dhanari slate and the Khattukhal members, in ascending order. This formation is not encountered in Alaknanda basin.

Table 4.2: Lithostratigraphy of Garhwal Group (After Kumar 2005).

Formation	Member	Lithology
Berinag Formation	Hudoli member Nawagaon member	Thick bedded massive quartzite, quartzite-phyllite. White, massive, fine-grained to gritty, current bedded quartzite with lenticular informational conglomerate, with phyllitic partings and mafic metavolcanics.
Deoban Formation	Patet slate	Black carbonaceous slate/phyllite and bluish grey limestone, with bands of magnesite and talc-schist.
	Balgad dolomite	Massive dolomite with limestone and talc-chlorite-sericite schist.
	Naulara phyllite	Black carbonaceous phyllite and green slate, chlorite phyllite, quartzite, feldspathic grit.
	Tejam dolomite	Massive dolomite with dolomite limestone and talc sericite schist.
	Simgad member	Purple quartz-piedmontite siltstone and purple phyllite, banded greenish quartzite and calcareous phyllite and dolomite.
Rautgara Formation	Bhekuna metavolcanics	Mafic amygdaloidal lavas (spilitic) altered to hornblende-actinolite-chlorite phyllite, with veins of epidote and tourmaline.
	Nagnath quartzite	Interbedded fine grained quartzite and phyllite, with marble and calc-silicate in upper part.
	Karnaprayag metavolcanics	Mafic spilitic lava and keratophyre, amygdaloidal occasionally porphyritic, chlorite phyllite, actinolite-biotite-albite phyllite with veins of epidote. Intertrappean purple phyllite.
	Haryali quartzite	Massive, gritty, coarse to fine grained with occasional pebble bed, current bedded and graded bedded, ripple marked with thin partings of chocolate phyllite, lenticular dolomite/limestone.
	Dhari metavolcanics	Mafic amygdaloidal lava flows, altered to drab green chlorite phyllite, with phyllite and bands of quartzite.
Uttarkashi Formation	Khattukhal	Grayish black to grayish blue limestone and dolomite with thinly bedded grey slate.
	Dhaneri slate	Banded, grey green and purple slates interbedded with quartzite
	Netala member	White to buff, fine-grained, current bedded quartzite and interbedded slate with minor lenses of limestone.

Rautgara Formation: Rautgara Formation consist of massive, cream coloured, purplish and brownish fine grained quartzite interbedded with purple green mottled slate and calcareous phyllite. In the Alaknanda valley, it is made up of alternating bands of quartzite and metavolcanic. It is subdivided into five members, namely, Dhari metavolcanics, Haryali quartzite, Karnprayag metavolcanics, Nagnath quartzite and Bhikuna metavolcanics.

Deoban Formation: It is essentially made up of carbonates, conformably overlying the Rautgara Formation and is overlain by the Berinag Formation. In the Alaknanda basin it is exposed in the form of an anticline and is known as Calc Zone Of Chamoli. It is subdivided into five members, i.e. Simgad member, Tejam dolomite, Naulara phyllite, Balgad dolomite and Patet slate.

(iii) Vaikrita Group/Jaunsar Group

These groups consist of undifferentiated Vakrita/Mandhali – Chandpur – Nagthat formations. These are characterised by purple, grey quartzites, grits and conglomerates, thin bedded limestones phyllite/states; laminated greenish grey phyllite/state with lenticular greywacke, purple green quartzite, grit and conglomerate.

Berinag Formation: Lithologically it is similar to the Rautgara Formation and comprises of a thick succession of quartzite with penecontemporaneous mafic metavolcanics. It distinguishes from Rautgara Formation in having lower number of interbedded volcanic flows. The Berinag Formation is better developed in the western Uttaranchal and has the status of a Group where it is divisible into the Nawagoan member at the base and the Hudoli member at the top.

Structural Setup

The Outer Himalaya in the south is constituted of homoclinal autochthonous Siwalik Group of sediments of Neogene age. The Siwalik Group has three main divisions, namely Lower Siwalik Formation, Middle Siwalik Formation and Upper Siwalik Formation. The Siwalik rocks are separated from Lesser Himalaya by Main Boundary Thrust (MBT), which runs in a roughly NW – SE direction.

The Lesser Himalaya is characterized by a succession of thrust sheets piled one over the other. In general, the Uttarakhand Himalaya is divisible into four major lithotectonic units, each characterized by distinct lithological composition, stratigraphic succession, structural pattern and magmatic history (Valdiya, 1980). These units are:

i) The autochthonous unit of the Damtha and Tejam groups of Precambrian sedimentaries exposed in the vast widows in the inner (northern) belt.

ii) The thrust sheet, Krol Nappe of the Outer (southern) Lesser Himalaya constituted of the Jaunsar and Mussorie groups of sediments of Late Proterozoic to Early Cambrian age. In the Inner Lesser Himalaya, the Krol Nappe is considerably attenuated. Here it is represented by the Berinag Nappe, which is made up of the varying lithostratigraphic units.

iii) The Ramgarh Nappe and its extension as thrust sheet that cover parts of the Berinag and Krol nappes constituted of lithology that resembles the upper part of the Damtha Group.

iv) The Lesser Himalayan rocks are separated from Higher Himalayan rocks by Main Central Trust (MCT), which is exposed near Bhatwari. The Higher Himalayan rocks collectively called Central Crystallines, consists of gneisses, schists, amphibolites and migmatites. On the basis of metamorphic grades, the rocks of Central Crystallines are divided into three parts namely Lower, Middle and Upper (Purohit *et al.*, 1990). The Lower Crystallines are constituted of low grade metamorphic rocks such as chlorite schist, schistose quartzite, biotite schist and mylonitic migmatites, which are in close contact with MCT. The Middle Crystallines, sandwiched between Lower and Upper Crystallines, consist of varying types of migmatites such as gneissic and banded migmatites and biotite gneisses. The Upper Crystallines rocks are represented by medium to high grade of metamorphic rocks such as kyanite schist, garnetiferous-mica schist and biotitegneisses (Agarwal *et al.*, 1973).

The Uttarakhand is characterized by three structural Units namely the Main Himalayan Belt, Folded Frontal Belt and Indo-Gangetic Plain. The details are given in Fig. 4.14.

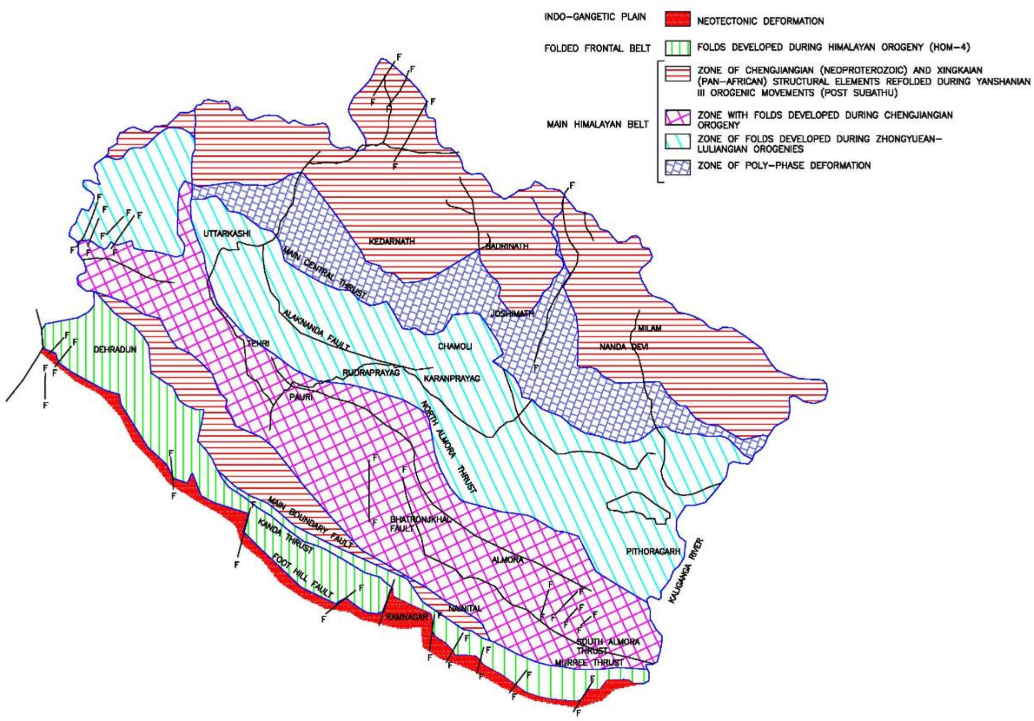


Fig. 4.14 Structural Map of Uttarakhand

Tons Thrust/North Almora Thrust (NAT): The south eastern extension of Tons Thrust is known as North Almora Thrust. It is a high angle 45-70° WNW-ESE to NW-SE trending tectonic plane which separates the Garhwal Group in the Inner Lesser Himalaya in the north from the Jaunsar and Dudatoli groups of the Outer Lesser Himalaya in the south. In general, it dips towards south in the eastern part but at places it is vertical to sub-vertical dipping on either side. It is locally referred to as the Srinagar Thrust in the Alaknanda valley or as the Dharasu Thrust in the Bhagirathi valley.

Alaknanda Fault: It is a major fault mapped in the Alaknanda valley extending from south of Nandprayag in the east to beyond Chirpatiyakhal in the west. It continues northwestwards, and running almost parallel to the North Almora Thrust, appears to offset the MCT in the Bhagirathi valley.

Cross-faults: There are a number of cross faults mapped within MBF which off-set major structural elements. These faults in general trend north-south or NNE-SSW. Of these, the Martoli Fault is north-south trending major cross-fault near Niti Pass and continues beyond into Tibet, in the north. Continuing southwards, it has been mapped in the Girthi valley, near Barmatiya. Further in the south, it is traceable to the Rishiganga valley and beyond within the Central Crystalline Group.

Folds: A number of folds like the Garhwal syncline and Mussoorie syncline are developed in the Lesser Himalaya. There is not sufficient structural data from the Central Crystallines, which appears to be poly-phased, deformed and metamorphosed. In other sequences, some folds are common to all the sequences while some are restricted and confined to a particular sequence. Folds F_1, F_2 and F_3 are restricted to the Central Crystallines, Garhwal and Jaunsar/Vaikrita groups, and are not recorded from the overlying younger successions.

Some of the other important structural features in the study area are:

Regional Tectonic Succession

Tectonic activity in the area has affected the normal stratigraphic succession of various rock units in the area. Valdiya (1980) has worked out such tectonic succession of Uttarakhand Lesser Himalaya in the Table 4.3.

Table 4.3: Regional Tectonic Succession of Uttarakhand Lesser Himalaya (Valdiya, 1980)

OUTER LESSER HIMALAYA		INNER LESSER HIMALAYA	
Almora Group	Gumalikhet Formation Champawat Granodiorite Saryu Formation	---------------	Vaikrita Group Precambrian Main Central (Vaikrita) Thrust-------------
-----------	Almora Thrust -------	--------------	Munsiary Formation Munsiari Thrust -----------
Ramgarh Group	Debguru Porphyroid Nathuakhan Formation		Barkot and Bhatwari Units
-------------	Ramgarh Thrust -----	-------------	Barkot-Bhatwari Thrusts-----
Sirmur Group	Subathu Formation (Lr. Eocene) Singtali Formation (Palaeocene)		
Mussoorie Group	Tal Formation Krol Formation Blaini Formation		
Jaunsar Group	Nagthat Formation Chandpur Formation Mandhali Formation		Berinag Formation
-------------	Krol Thrust ----------	Tejam Group	Mandhali Formation (Up.

OUTER LESSER HIMALAYA		INNER LESSER HIMALAYA	
	Subathu (Lr.Eocene)		Riphean-Vendian) Deoban Formation (Upper Mid. Riphean)
————	Uncomformity	————	
Damtha Group	Rautgara Formation Chakrata Formation	Damtha Group	Rautgara Formation (Lower Mid. Riphen) Chakrata Formation (Lr. Riphean)

The major thrusts MCT-1 & MCT-II occur closest to each other in the Alaknanda River sections which cuts across the complex geological set up.

4.2.5. Tectonic Activity

The Indian plate broke off from the Gondwana land in the Early Cretaceous (~130-125 Ma) and drifted northward (Patriot and Achache, 1984; Molnar, 1986). It subducted beneath the Asian plate, and subsequently collided with it around 56 Ma, giving rise to the well known Himalayan mountain range. The northerly movement of Indian plate is presently going on with velocity varying from about 2 to 4 cm/year. Due to such a geodynamic activity, the Himalayan terrain has been and is under lateral compression from south and southwest, resulting in continuous deformation of rocks in the form of folding, faulting, fracturing, shearing, metamorphism and igneous activity on regional scale. A number of planes of major discontinuities namely HFT, MBT, MCT, TDF and ITSZ (Fig.1a) which run along the Himalaya are the conspicuous manifestations this activity. Along these northerly dipping thrust such as HFT, MBT and MCT in this orogenic belt, the Indian plate has been sliced through southerly overthrusting. Beside thrust fault zones, the terrain is also affected by normal as well as strike slip faults. Evidences of neotectonism along these surfaces of dislocation as well as along new faults, have been recorded by many workers (Sati and Rautela, 1998; Kumar *et al.*, 2001, Thakur and Pandey, 2004; Virdi *et al* 2006; Bali *et al.*, 2011).

The continual ongoing tectonic movements cause build up of stress in the rocks and whenever the stress is released, earthquakes take place. The Himalaya terrain is therefore earthquake prone. Distribution of earthquakes and their magnitude is strongly controlled by the geological units and the associated thrusts.

Narula and Shome (1989) have classified the NW Himalaya in three Himalayan Seismic Blocks which correspond to basic geological units of the Himalaya. Each of these blocks have specific earthquake occurrence and fault plane mechanism.

(i) **Greater Himalaya Seismic Block:** The block of lithotectonic unit north of MCT, is characterized by earthquakes, mostly of magnitude 5; but many of magnitude < 5.6 and some of magnitude > 6.5. They are associated with the N-S trending deformation with normal fault mechanism.

(ii) **Lesser Himalayan Seismic Block:** This crustal block laying between the MBT in the south and MCT in the north has highest seismicity level with source faults as thrusts trending parallel to Himalayan trend. The epicentral location in this block is concentrated close to MCT.

(iii) **Frontal Hill Seismic Block:** This crustal block to the south of MBF upto HFT and beyond, includes also a number of thrusts and transverse tear faults in the foothill belt. These longitudinal and transverse fault surfaces are neotectonically active.

4.2.6. Geomorphic Aspects

The Uttarakhand Himalaya exhibits a variety of geomorphic features, which give distinctive characteristics to each geological units, namely Higher Himalaya, Lesser Himalaya and Outer Himalaya. The Bhagirathi River, originating from Gangotri Glacier in Gaumukh, and the Alaknanda River from Satopanth Bhagirath kharak group of glaciers of Himalaya, form broad U-shaped valley in their upper reaches. Downstream they cut deep V-shaped gorges while flowing through Greater and Lesser Himalayan terrain. The main rivers are fed with numerous small first and higher order streams from both sides. They cut through a variety of lithologies with variable structural features, and deposit glacial, glacio-fluvial and fluvial sediments.

The landforms in the area are structural, glacial, fluvial, and denudational in origin. Inversion of relief in highly metamorphosed rocks, in the north, reflects the impact of high rate of erosion process on long term scale of millions of years in the area. Rapid tectonic uplift, intense fluvial and glacial incision produce long steep slopes (Shroder and Bishop, 1998). Common geomorphic features are the cliffs, rocky slopes, waterfalls, major and minor ridges and Quaternary deposits along the hill slope and the river valleys. The major geomorphic features observed in and around the river valley are: highly dissected denudational hills, moderately and low dissected denudational hills, river terraces, and various fluvial geomorphic features like point bar, meandering scars, natural levees, terraces (Chakraborty, 2007).

The effect of high relief and structural control is reflected by deep gorges and wide valleys carved by numerous channels. The river bed gradients are in general steeper (20m/km) in the Greater Himalaya and in parts of Lesser Himalaya. It becomes gentler (15m/km and less) southwards, in general. The loose Quaternary deposits / other sediments and old rock falls, landslides, glacial, periglacial and hill slope scree process generally cover the middle valley slopes. The thickness of these deposits vary from 2m to more than 15m depending upon the slope angle, aspect and bedding plane of the parent rock.

4.2.7. Landslides

The slope instability in the study area is mainly controlled by valley slopes and their orientational relationalship with the attitude of discontinuity surfaces, amount and nature of loose deposits on these slopes, rainfall pattern, nature of rocks exposed, and structural and tectonic features present, besides human interaction in the terrain. Thus, it is important to understand the geomorphic setting of the HP project along with other geological parameters.

The Himalayan terrain is characterized by predominance of high relative relief. The tectonic movements have adversely affected these rocks in the form of intense shearing, faulting, fracturing. In addition, surfacial and near surfacial processes, have also affected the rocks causing jointing, cracking and fracturing. Monsoon rains further aggrevate the problem of landslides. These factors make the Himalayan slopes landslide prone. Also, the poorly consolidated Quaternary deposits, scree material of the slope and the old stabilised landslides (e.g Joshimath area) are also susceptible to failures. Hill slopes, therefore, are vulnerable and frequent landslides are witnessed in this area, especially during the monsoon season, when the percolating water, not only decreases the cohesiveness of rock/earth material but exerts pore water pressure against the planes/ surfaces of discontinuity. The critically stable slopes, therefore, become unstable, specially where the discontinuity surfaces like bedding planes, joint planes, fault planes etc dip at an angle equal to or less than the hill slope angle and the dip/ and slope directions are same or nearly same. At places, undercutting of slope by fluvial processes causes slope failures.

There are cases of landslide during non-monsoon time, e.g., the Uttarkashi landslide of 23rd September, 2003 (post monsoon) and the Ramolsari landslide of 30th March 2005 (pre-monsoon) in the catchment area of the Bhagirathi River (Rautela and Pandey, 2006). In addition to these natural causes, indiscriminate development activities also result in destabilising the slope. At times, developmental activities in this fragile tectonogenic regime of Himalayan mountain range, have also triggered landslides of critically stable slopes.

Some of the devastating landslides as listed in Table 3, indicate the high susceptibility of the terrain for landslides of the hill slope in this region. In view of fragile geologic, geomorphic, lithologic and tectonic features, and prevailing climatic conditions, this earthquake prone terrain of the Himalaya is very sensitive to mass wasting and slope failures. Fig. 4.15 shows the hill slope areas prone to slide, along the Alaknanda River and its tributaries.

All construction activities related to all HP’s (under construction and under planning), were stopped in the year 2010. However, there have been unprecedented landslide activities throughout the area in September – October, 2010 due to heavy rains. These landslides were certainly related to excessive rains which triggered this exceptional mass movement of sediments and rock masses.

Table 4.4: List of major landslides in Uttarakhand (updated after Rautela and Pandey, 2006)

1816	Pauri landslide
1842	Joshimath landslide
1857	Massive landslide blocked the flow of the Mandakini River
1868	Landslide at Chamoli Garhwal blocked Alaknanda River, swept two villages and killed 70 pilgrims
1880	Landslide in Nainital Town: massive destruction and killed more than 150 persons
1893 1894	Landslide blocked Birahi Ganga and formed lake near Gohna village in Garhwal Himalaya Breach of Gohna lake causing "Birahi disaster" in Alaknanda valley
1906	Helang landslide
1945	Patalganga landslide
1963	Nainital landslide
1963	Kaliasaur landslide
1965	Karnaprayag landslide
1970	Landslides formed lake in the upper catchment of Alaknanda River affected 101 villages, 25 buses of pilgrims swept away, 55 persons and 142 animals died. District headquarter of Chamoli district devastated and subsequently shifted to Gopeshwar
1979	Okhimath landslide, 39 persons died
1981	Uttarkashi-Kedarghati landslide
1986	Landslides at Jakholi in Tehri Garhwal and at Devaldhar in Chamoli, 32 lives lost
1991	Gopeshwar landslide, 36 persons in 6 villages died
1996	Bhimtala landslide
1998	Massive landslides in Okhimath area formed an lake blocking the course of Madhyamaheshwar River (tributary of Mandakini River), 109 people died, 1,908 families from 29 villages affected and 820 houses damaged
1998	Malpa landslide into Kali River, wiped out Malpa village near Dharchula in Pithoragarh, more than 300 people died
2001	Phata and Byung Gad landslides, around 20 persons killed and several houses damaged
2002	Landslides at Budhakedar and Khetgaon
2003	Uttarkashi landslide
2004	Amparav landslide
2005	Ramolsari landslide
2009	Pithoragarh landslide
2010	Landslides at Khakhra (near Varhi Devi Mandir), Srinagar, Joshimath, Badrinath, Bageshwar, Chamoli, Rishikesh Gangotri road, and Almora due to cloud burst.

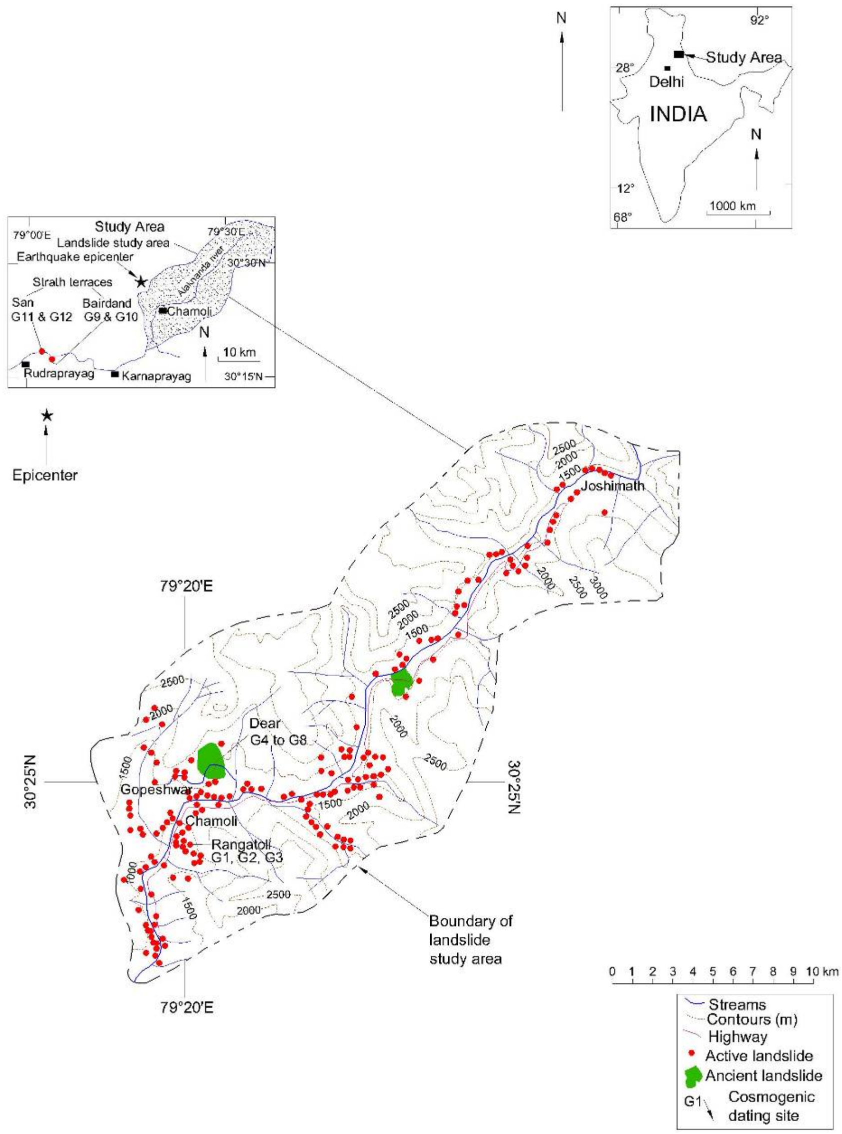


Fig. 4.15 Map Showing the Active and Ancients Landslides (After Patrick et al., 2001)

Common Types of Landslides in the area

A review of landslides in the area indicates that there are number of factors which have caused instability in the area leading to landslides. These landslides are genetically of the following types.

a. Seismically induced landslides

A stable slope may become unstable due to seismic activity. Uttarkashi earthquake (29.10.1991; magnitude 6.6) and Chamoli earthquake (29.3.1999; magnitude 6.8) activity caused hundreds of new landslide and reactivation of many old slides.

b. Monsoon induced Landslides

These are the most common landslides in the area caused by monsoonal rains, heavy rains due to cloud burst. Every year during monsoon seasons hundred of landslides, small and large take place.

c. Non monsoonal landslides

The post monsoonal Uttarkashi landslide (September, 2003) and the pre monsoonal Ramolsari landslide (March, 2005) have been attributed to the slow and long time weathering process (Rautela and Pandey 2006). Such events, though few can be regionally very important as they occur in areas with critically stable slopes.

d. Developmental Activity Induced Landslides

As mentioned earlier, the area is very sensitive to slope failure. Patrick et al. (2001) have reported a number of human induced landslides also in Garhwal Himalaya. Therefore, the human interaction with it for developmental activities namely, construction of roads, construction of dam and reservoir, deforestation, terracing, and agricultural activities can increase the possibility of slope failure.

4.2.8. Landslide Susceptiblity Zonation

Based on the geomorphic, lithologic, structures, tectonics of the Alaknanda and Bhagirathi river Basins under the prevailing climatic conditions, a Landslide Susceptibility Zonation Map has been prepared (Fig. 4.16). The maps show the areas of High, Medium and Low Susceptibility Zones in this landslide prone terrain. This Landslide Susceptibility Zone (LSZ) can be used as a first step to locate a prospective site for HPs. The site selection for HPs in the area can be done on the basis of locating a local geological scene that is best in the area which is otherwise instability prone in nature. On the basis of the landslide susceptibility Map, all the 70 HPs have been classified into High, Medium and Low Landslide Susceptibility Classes (Table 5).

The whole study area has zones which are very sensitive to landslides which are often triggered by natural causes. Any developmental activity in the area, pertaining the construction activity can increase the frequency of landslides locally. It is important that any human activity which affects the stability of slopes must involve proper geoscientific investigations, good planning, continuous monitoring and necessary preventive measures.

4.2.9. Geotracts and HP Project Sites

A review of geomorphological, lithological, structural and tectonic aspects of the Alaknanda and Bhagirathi basins shows that the terrain indicates a general pattern of changes in the following geological attributes.

- Average height of mountain range decreases southward.
- Glacial effect decreases southward.

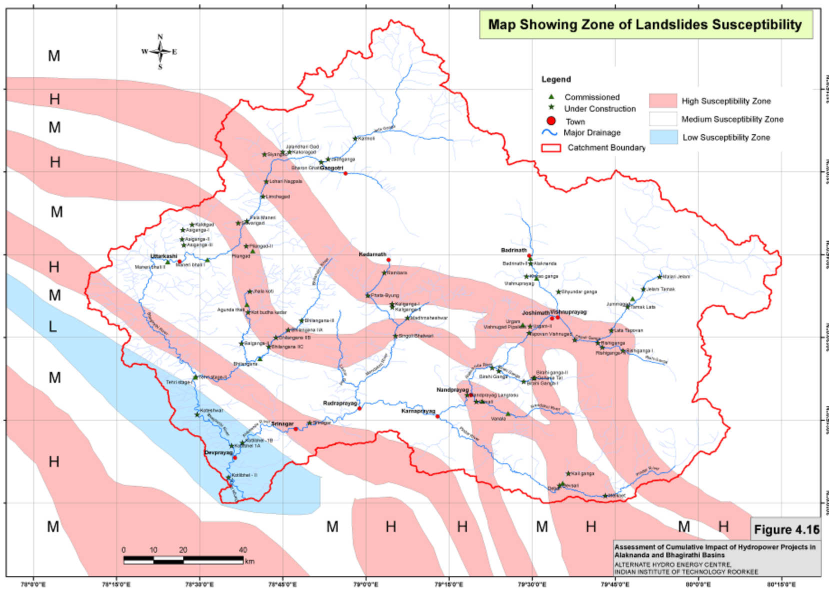


Fig. 4.16 Map Showing Landslides Susceptibility Zones (LSZ)

- The valley shape changes southward from U shaped in the north to V shaped /gorge to broad open in the south.
- The river bed gradient decreases southward. The coarseness of sediments in the valley decreases downstream.
- The compactness of rocks decreases southward.
- The metamorphic and igneous rocks decrease southward.
- The older crystalline rocks occur in the north and the younger sediments in the south, in general.
- The terrain is tectonically active and falls in the Seismic Zones IV in the west (Bhagirathi basin and part of Alaknanda basin to the west of Nandprayag) and Zone V (only the catchment area of the Alaknanda basin, east of Nandprayag). The fault induced tectonic activity in the form of seismicity is more in the southeast (seismic Zone V).
- The MCT zone is tectonically more active as compared to other tectonic zones of the area.
- Compact and dense crystalline rocks such as gneiss, quartzite and granite in the north are less prone to landslides; except in the areas close to discontinuity surfaces, especially when these are daylighted adversely on the valley wall slopes. Similarly, loose and unconsolidated deposits and sheared zones are also prone to slide.

On the basis of above, the Alaknanda and Bhagirathi river basin can be classified into the following six geological units named as Geotracts (Fig.4.17) (Table 5) which are generally homogeneous within themselves and heterogeneous among themselves and are separated from each other by regional discontinuity surfaces in the form of longitudinal thrusts.

Table 4.5: Geotract, Landslide Susceptibility Zones and Basinwise Distribution of HPs							
S. No.	**Project Name**	**Basin (A/B)**	**Name of River/Tributary**	**Type of HP**	**Geotract**	**Landslide Susceptibility Zone**	**Remarks**
Commissioned							
1	Badrinath II	A	Rishi ganga	ROR	1	M	
2	Jummagad	A	Jummagad	ROR	1	M	
3	Vishnuprayag	A	Alaknanda	ROR	1	H	
4	Urgam	A	Kalpganga	ROR	2	H	
5	Vanala	A	Nandakini	ROR	5	H	
6	Rajwakti	A	Nandakini	ROR	5	H	
7	Debal	A	Kailganga	ROR	3	H	
8	Pilangad	B	Pilangad	ROR	2	H	Close to 3
9	Maneri bhali I	B	Bhagirathi	ROR	3	M	
10	Agunda thati	B	Dharamganga	ROR	3	H	
11	Bhilangana	B	Bhilangana	ROR	3	M	
12	Manaeri Bhali-II	B	Bhagirathi	ROR	3	M	
13	Tehri Stage-I	B	Bhagirathi	Reservior	4	M	
Under Construction							
1	Birahi Ganga	A	Birahi Ganga	ROR	3	M	
2	Kail Ganga	A	Kailganga	ROR	3	H	
3	Phata Byung	A	Mandakini	Reservior	2	H	Close to 1
4	Madhmaheshwar	A	Mandakini	ROR	2	H	Close to 3
5	Singoli Bhatwari	A	Bhagirathi	ROR	3	H	
6	Rishi Ganga	A	Rishi ganga	ROR	2	H	
7	Vishnugad Pipalkoti	A	Alaknanda	Reservior	3	H	
8	Srinagar	A	Alaknanda	Reservior	3	H	
9	Tapowan Vishnugad	B	Dhauliganga	ROR	2	H	
10	Bhilangana-III	B	Bhilangana	ROR	2	M	
11	Kaliganga-I	B	Kaliganga	ROR	2	M	
12	Kaliganga-II	B	Kaliganga	ROR	2	M	
13	Lohari Nagpala	B	Bhagirathi	ROR	2	H	Close to 1
14	Koteshwar	B	Bhagirathi	Reservior	4	L	
Under Different Stages of Development							
1	Khirao ganga	A	khaiaoganga	ROR	1	M	
2	Alaknanda	A	Alaknanda	ROR	1	M	
3	Bhyundar ganga	A	Bhyundar ganga	ROR	3	M	
4	Malari Jelam	A	Dhauliganga	ROR	1	M	
5	Jelam Tamak	A	Dhauliganga	ROR	1	M	
6	Tamak Lata	A	Dauliganga	ROR	1	M	
7	Lata Tapovan	A	Dhauliganga	ROR	1	H	
8	Rishi Ganga-I	A	Rishi ganga	Reservior	1	H	
9	Rishiganga II	A	Rishi ganga	Reservior	2	H	

Table 4.5: Geotract, Landslide Susceptibility Zones and Basinwise Distribution of HPs							
S. No.	**Project Name**	**Basin (A/B)**	**Name of River/Tributary**	**Type of HP**	**Geotract**	**Landslide Susceptibility Zone**	**Remarks**
10	Asiganga-I	A	Asiganga	ROR	3	M	
11	Asiganga-II	A	Asiganga	ROR	3	M	
12	Asiganga-III	A	Asiganga	ROR	3	M	
13	Birahi Ganga-I	A	Birahi ganga	ROR	2	H	
14	Birahi Ganga-II	A	Birahi ganga	ROR	1	H	
15	Bowla Nandprayag	A	Alaknanda	ROR	3	H	
16	Devsari	A	Pinder	Reservior	3	H	
17	Gohan Tal	A	Birahi ganga	ROR	3	H	
18	Nandprayag Langasu	A	Alaknanda	ROR	3	H	
19	Melkhet	A	Pinder	ROR	3	H	Close to 2
20	Kotli Bhel-I B	A	Alaknanda	Reservior	4	L	
21	Ram Bara	A	Mandakini	ROR	1	H	
22	Urgam-II	A	Kalpganga	ROR	2	H	
23	Balganga-II	B	Balganga	ROR	3	M	
24	Karmoli	B	Jahnvi	Reservior	1	M	
25	Jadh Ganga	B	jahnavi	Reservior	1	M	
26	Bharon Ghati	B	Bhagirthi	ROR	1	M	
27	Jalandharigad	B	Jalandhari	ROR	1	M	
28	Bhilangna-II A	B	Bhilangana	ROR	2	H	
29	Bhilangna-II B	B	Bhilangana	ROR	3	H	
30	Bhilangna-II C	B	Bhilangana	ROR	3	M	
31	Tehri stage-II	B	Bhagirathi	Reservior	4	M	
32	Dewali	B	Nandakini	ROR	5	H	
33	Kakoragad	B	Kakoragad	ROR	1	M	
34	Jhala koti	B	Bhilangana	ROR	3	H	Close to 2
35	Siyangad	B	Siyangad	ROR	1	H	
36	Limcha Gad	B	Limcha Gad	ROR	2	M	
37	Pala Maneri	B	Bhagirthi	Reservior	2	H	
38	Suwari Gad	B	Suwari Gad	ROR	2	H	Close to 3
39	Pilangad- II	B	Pilangad	ROR	3	H	
40	Kot budha kedar	B	Balganga	ROR	3	H	
41	Kaldigad	B	Kaldigad	ROR	3	M	
42	Kotli Bhel-I A	B	Bhagirathi	Reservoir	4	M	
43	Kotli Bhel-II	Ganga	Ganga	Reservoir	4	L	

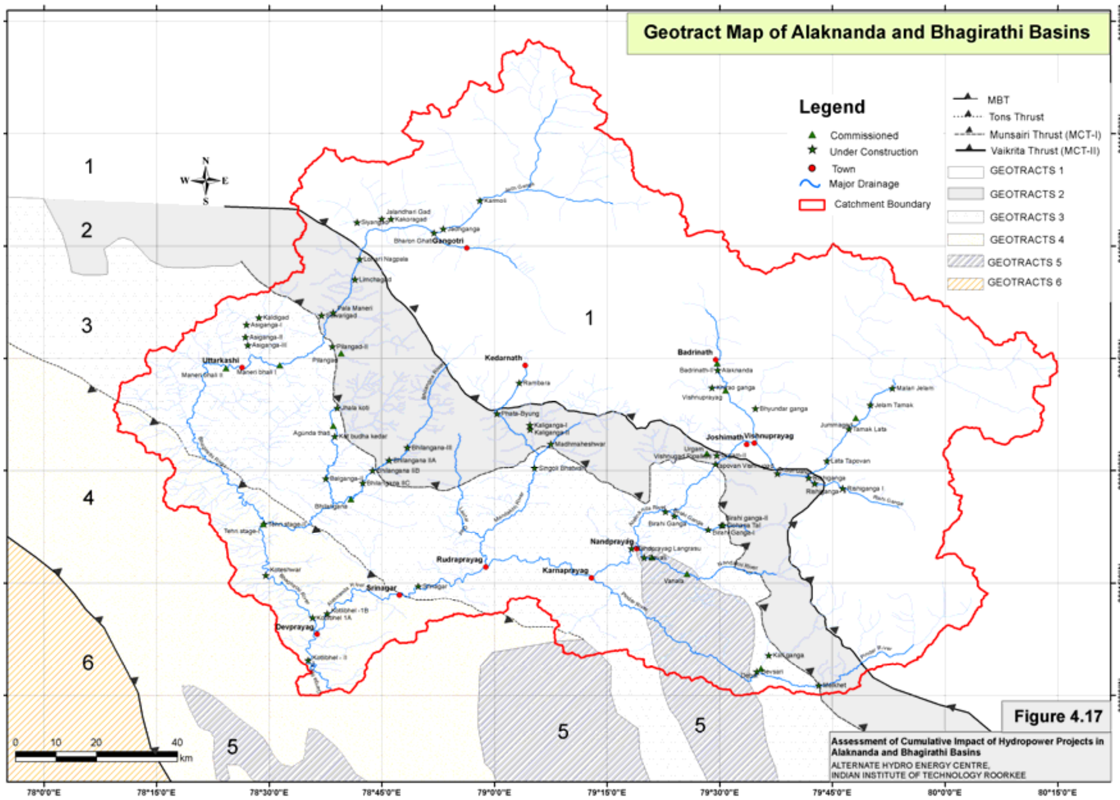


Fig. 4.17 Map of Alaknanda and Bhagirathi Basins showing different geotracts.

GEOTRACT – 1

It lies to the north of the Main Central Thrust (MCT-II) and forms a part of Higher Himalaya. Its northern part is characterized by discrete occurrence of glaciers which provide water to the Alaknanda and Bhagirathi rivers, and their tributaries. The area is characterized by high grade metamorphic rocks namely the gneisses and schist, migmatite, quartzite, calc-silicate, amphibolites; beside granite and pegmatite intrusions at places. With U shaped valleys in the upper reaches, this high relief terrain is characterized by V shaped steep sided long valleys in southern part. The river bed gradients are steep (>20 m/km). Tectonically, the area is active and falls in the Seismic Zone IV (Bhagirathi and western part of Alaknanda river downstream of Nandprayag). To the east of Nandprayag, the Alaknanda basin area is in the Seismic Zone V. The rocks are generally hard and compact. The loose and unconsolidated fluvio-glacial and fluvial sediments are prone to landslides. The landslides are localized and are mainly due to monsoonal activity. The landslide susceptibility is high (Close to MCT-II) to medium. In this Geotract, the following 18 HPs, i.e. 13 in Alaknanda basin and 5 in Bhagirathi basin are located.

HPs – Geotract-1	Alaknanda Basin	Bhagirathi Basin
Commissioned	1. Badrinath-II 2. Vishnuprayag	
Under Construction	3. Alaknanda 4. Bhyundar Ganga 5. Jalandharigarh 6. Jelam Talak 7. Jumunagad 8. Khiraoganga 9. Lata Tapovan 10. Maleri Jhelam 11. Rambara 12. Rishiganga-1 (RB) 13. Tamak Lata	1. Bhaironghati 2. Jodh Ganga (RB) 3. Kakoragad 4. Karmoli (RB) 5. Siyangad

RB – Reservoir Based HPs; All others are run-of- river (RoR)

GEOTRACT – 2

Occurring just south of Geotract – 1, this tract is confined between two major thrusts – the Main Central Thrust-II (MCT-II) in the north and the MCT-I in the south. It is characterized by sheared, fractured, jointed and weathered rocks. The main rocks are schists (chlorite and biotite), mylonite, migmatite, quartzite and gneisses, with basic intrusions. The valleys are V-shaped. The river bed gradient is also high (>20 m/km). The tract is tectonically active and falls in the Seismic Zones IV in the west and V to the east (Alaknanda valley). The tectonic activity is mainly due to the thrust bound MCT zone. The width of this tract is narrowest (≃ 4 km) at the Alaknanda valley, widest (≃ 35 km) at Bhilangana valley and about 20 km in Bhagirathi valley. The Bhagirathi river water passing through the wider part of this geotract is expected to carry more sediment load and total dissolved solids than the Alaknanda river water. This inference is corroborated by the water quality analysis done for these two rivers (Chapter – 6). A number of hot water springs through deeper fractures, are observed. Due to shearing, fracturing, faulting, the terrain is more prone to instability, specially along the Alaknanda River. The instability of loose, unconsolidated deposits/scree material on the slope is also observed. The land susceptibility in this tract is high (Close to MCT-I and MCT-II) in the Alaknanda river section and high to medium in the Bhagirathi-Bhilangna river.

The following 16 HPs (5 in Alaknanda basin and 11 in Bhagirathi basin) are located in this Geotract.

HPs – Geotract-2	Alaknanda Basin	Bhagirathi Basin
Commissioned	1. Urgam	1. Pilangad
Under Construction	2. Madhumaheshwar 3. Phata Byung (RB) 4. Rishiganga 5. Rishiganga (RB)	2. Bhilangana – II 3. Bhilangana – III 4. Kaliganga – I 5. Kaliganga – II 6. Limchaged 7. Loharinagpala 8. Pala – Maneri (RB) 9. Suwarigad 10. Tapovan Vishnugad 11. Urgam – II

RB – Reservoir Based HPs; All others are Run off the river (RoR)

GEOTRACT – 3

It occurs south of Geotract – 2 and is bounded by MCT-I in the north and the Tons thrust/ North Almora Thrust (NAT) in the south. It falls in the Inner Lesser Himalaya. It forms footwall block of both the bounding thrusts. The river bed gradients are decreased but still high (15 to 20 m/km) and more in relatively broader river valleys. The major rock types are medium to low grade metamorphic rocks. There is facies change in the rocks. The rocks are mainly the quartzite intercalated with chloritic schist, phyllite and metabasic rocks, besides dolomite. The area falls in the Seismic Zone IV in the west and Seismic Zone V in the east. The rocks are dissected by a number of shears and joints. The area witnesses slides along the adversely daylighted surfaces of discontinuities at places, and also, due to mass wasting of loose, unconsolidated material. Earthquakes induced landslides have also been witnessed by this tract near Uttarkashi and Chamoli in the recent years. The landslide susceptibility is high (Close to MCT-1 and Tons thrust / NAT and is medium in the Central part lying between these two thrusts. The following 27 HPs (15 in Alaknanda basin and 12 in Bhagirathi basin) are located in this Geotract.

HPs – Geotract-3	Alaknanda Basin	Bhagirathi Basin
Commissioned	1. Debal	1. Agunda Thati 2. Bhilangana 3. Maneri Bhali– I (RB) 4. Maneri Bhali – II
Under Construction	2. Asiganga – I 3. Asiganga – II 4. Asiganga – III 5. Birahiganga 6. Birahiganga – I 7. Birahiganga – II 8. Bowla Nandprayag 9. Devsari 10. Gohantal 11. Kailganga 12. Melkhet 13. Nandprayag Langasu 14. Srinagar (RB) 15. Vishnugad Pipalkoti (RB)	5. Balganga – II 6. Bhilangna – II B 7. Bhilangna – II C 8. Jhalakoti 9. Kaldigad 10. Kotbudha Kedar 11. Filangad – II 12. Singoli Bhatwari

RB – Reservoir Based HPs; All others are run of river (ROR)

GEOTRACT – 4

It occurs south of Tons Thrust /North Almora Thrust, and is bounded by the Main Boundary Thrust in the south. It falls in the Outer Lesser Himalaya. The river bed gradient is less than 15m/km. The valleys are broader as compared to their upstream part in the north. The rocks are of low metamorphic grade, mainly the phyllite slates, quartzite and shale/slates. They are weathered, jointed and sheared at places. This Geotract falls in the Seismic Zone IV in the downstream reaches of Bhagirathi and Alaknanda rivers and the upstream part of the Ganga River. The argillites are, in general, soft and of low competence. These rocks and the loose, unconsolidated mass on the slope, at places are prone to landslides. The landslide susceptibility is high close to thrusts, it is medium to low in the Central part (between the thrusts). This Geotract has all the 4 important 'reservoir based HP's located in the Bhagirathi basin and one in the Alaknanda basin.

HPs–Geotract-4	Alaknanda Basin	Bhagirathi Basin	Ganga River
Commissioned	-	1. Tehri stage – I (RB)	
Under Construction	1. Kotlibhel-1B RB	2. Koteshwar (RB) 3. Kotlibhel – 1A (RB) 4. Tehri Stage – II (RB)	1. Kotlibhel-II (RB)

RB – Reservoir Based HPs

GEOTRACT – 5

This Geotract comprises discrete, separate, klippes, namely the Baijnath Klippe, in the east, followed westward by Almora Klippe and the Lansdowne Klippe in the west (Fig. ??). They cut across the Geotracts 3 and 4. Only the eastern Baijnath Klippe occurs within the catchment area of the tributaries of Alaknanda River namely, the Pindar and the Nandakini rivers. The landslide susceptibility is high to medium. The following three, low capacity (15 MW and less) run of river HPs are located in this Geotract on the Nandakini River – a tributary of the Alaknanda River. There are only three run of river project.

HPs– Geotract-5	Alaknanda Basin	Bhagirathi Basin
Commissioned	1. Rajwakti 2. Vanala	
Under Construction	3. Dewali	

GEOTRACT – 6

Lying south of Geotract 4, this tract is bounded by the Main Boundary Thrust (MBT) in the north and Main Frontal Thrust (MFT) in the south. This low, hilly region, has the youngest Tertiary and Quaternary sediments. The landslide susceptibility is high in the areas close to MBT-HFT. It decreases away from these thrusts. It is located in the south beyond the catchment area of the Alaknanda and Bhagirathi river systems and is not under the scope of present study.

4.2.10. Geo-environmental Impact of Hydroelectric Projects

4.2.10.1. Slope Stability Aspects

A total of 19 HPs (15 HPs of capacity more than 75 MW and 4 HPs of smaller than 75 MW - mostly 25 MW) on Alaknanda river system and Bhagirathi river system were studied for their local and cumulative impacts on geoenvironment in terms of slope stability, geotectonics and sedimentation aspects. The details of this study are given in the Annexure – 2.

A study of various reservoirs, small and big, indicates that the dam construction across the rivers, may lead to an effective change in the existing hydrological environment and also the stability of hill slopes. Under the present geological scenario, river initially has a fluvial or running water environment and once the dam/barrage is constructed and water impounded/restricted behind it, the regime gets changed to lacustrine (standing water) environment locally. The reservoir based HPs are larger and have larger capacity, in general, as compared to run of river type HPs. They have, therefore higher probability for adverse impact on geoenvironment than the smaller and low capacity run of river based projects. Nevertheless both types of HPs have affected to varying extent, the local geoenvironment in an around them in terms of land and water distribution, stability of hill slopes, sedimentation patterns, and ecosystem.

The reservoir operation is associated with fluctuations of water level between maximum reservoir level (MRL) and dead storage level (DSL). When the water is at MRL, the valley slopes close to the rim would have two characteristic zones – a dry zone above the water level and a water submerged zone. In the water submerged zone, though the weight of slope material is reduced due to uplift pressures of the water, the lateral thrust of the standing water prevents the sliding tendency of the slope. If the water level falls down significantly, then there will be three zones - dry zone, water charged zone and water submerged zone. In the water charged zone, the weight of the slope material is increased considerably, while the shear strength gets reduced causing conditions which lead to instability of the critically stable slopes of reservoir rim area. This is a major reason for a series of shallow failures induced during the initial stages of operation of the reservoir.

In case of failures of the slopes of the rim zone of the reservoir, the resultant debris get accumulated at the toe of the hill slope, unlike a fluvial environment where the materials are swept away by the flood waters. With increased accumulation of the debris, the general slope gradient also would get flattened (Fig-4.18). The horizontal thrust of the standing water will lead to better compaction of the loose debris accumulated at the toe. Any further sliding in the area will gradually cause further flattening of slope and accumulation and compaction at the toe gradually leading to increased stability environment of the rim slopes. This phenomena was observed very distinctly in Bhakra dam reservoir, which is one of the largest reservoirs in Himalaya (Anbalagan, 1993) and the Maneri Bhali-1.

Under the prevailing geological conditions, the stability or instability of slopes existing in one reservoir does not cause any cumulative impact on any other reservoirs planned in the further downstream or upstream reaches of the river.

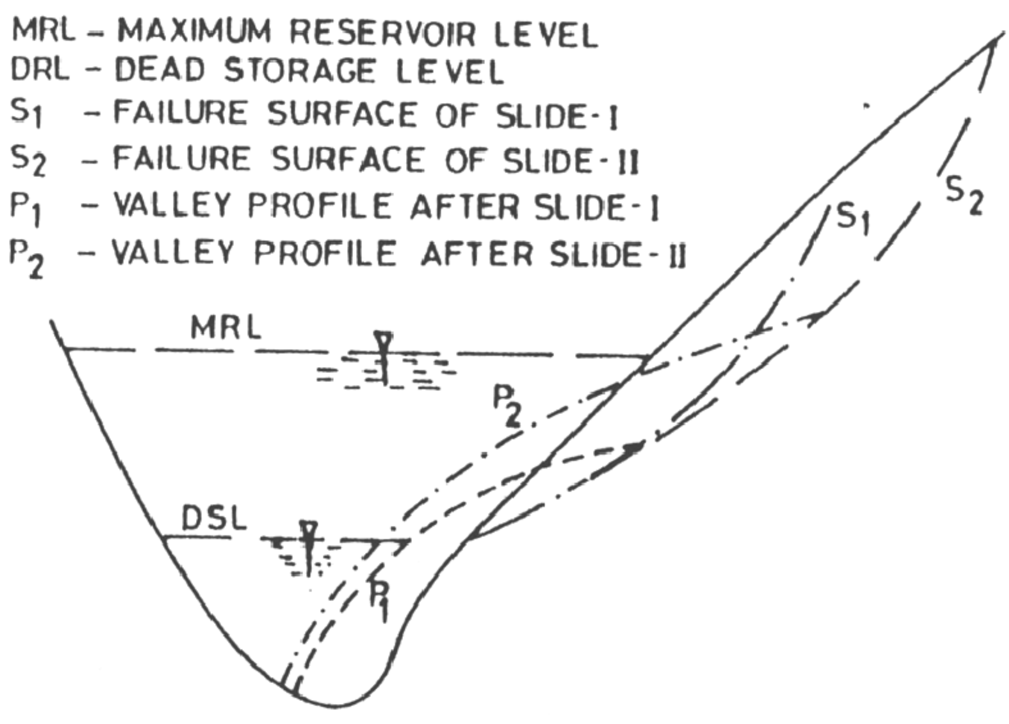


Fig. 4.18 Influence of reservoir on stabilization of surficial landslides

4.2.10.2. Geotectonic Aspects

The area is geodynamically active and falls in seismic Zone V and IV. Most of the projects are located in the tectonically active Higher Himalaya or in the Lesser Himalaya. The area has been experiencing tremors due to tectonic earthquakes and has in the near past been jolted by many earthquakes causing instability in parts of this fragile terrain. This may trigger many landslides. Tehri Dam is one of the biggest dams in whole of Himalaya. This has not affected the tectonic regime of the area, as there has not been any change in the tectonic activity of the area, i.e. this biggest reservoir has not induced seismicity in this region. Other smaller project located separately in rivers of both the Alaknanda and Bhagirathi basins have also not collectively changed the tectonic scenario, under prevailing geological conditions. Detailed analysis of seismic instability of this region are discussed in the chapter Seismologic Studies.

4.2.10.3. Sedimentation Aspects

The river bed gradients of Himalayan rivers are generally steep. They are relatively steeper in the initial reaches of the rivers, in Higher Himalayan segment and the Inner Lesser Himalayan segments with a general gradient of more than 20 m per km. Many of these rivers originating from the glaciers and glaciated terrain carry huge amount of sediment load. This region supplies bulk of the sediment load to these rivers. The sediment load is high both in terms of bed load and suspended load. The bed load consists of larger boulders, pebbles and sand. In upper reaches of these rivers several RoR projects have been planned. The RoR projects have diversion dams and barrages of small heights. Large amount of sediment, particularly the bed load is retained by these structures. In case of series of such projects, the sediment load in the downstream part shall decrease. Reduction is in both bed load and suspension load, but it would be more significant in the former. At the dam sites of RoR, rapid aggradational takes place.

In case of reservoir dams, like Tehri, large-scale retension of sediment in the reservoir takes place, and there is a strong reduction of sediment downstream of the reservoir – based HP project.

Such large scale retension of sediments of HP projects shall reduce the sediment load of the river in the downstream section. It can have impact in the downstream section and therefore can have important consequences on nature of river, particularly its erosive power and have affect on geomorphic features of the river channel and its aquatic life.

It may be pointed out, that in case of Alaknanda – Bhagirathi basins large and amount of sediment is contributed by steeply sloping rocks through their tributaries. It may help partly to regain some of its lost sediment load due to HP projects. However, so far no quantitive analysis on the sediment load of the rivers, particularly the influence of HP projects is available. This aspect of sediment load has also been discussed in the chapter on Hydrology.

4.2.11. Geological Inferences

Geologically, the terrain is under compression due to subduction of Indian Plate below the Tibetan plate and thus is geotectonically sensitive. This sensitivity is expressed in the form of earthquake activities of varying magnitudes – and in the recent past the maximum magnitude of earthquake experienced in the area was of 6.8. Earthquake of 6.8 and higher magnitude require huge stresses generated by large scale natural process. Under such a tectonic scenario, creation of an artificial reservoir as big as Tehri Dam reservoir is often an issue of concern to trigger reservoir induced seismicity. The fact that there has not been any indication of change of tectonicity in and around the reservoir before and after its formation, suggests that the impact of HPs on the geotectonics of this area is insignificant and not experienced. The seismological studies carried out in this area are discussed in details in Chapter 5.

The terrain is prone to surfacial instability due to landslide, specially during rains. The study indicates that during the construction and after the commissioning of project, some slopes made up of rocky or loose unconsolidated masses in the project area, become unstable. This instability is local and not of regional extent. This phenomena is found in and around the project areas. One HP does not have any effect on the slope stability of adjoining HP. It is interesting to note that in the initial filling of reservoir, landslide take place on rim area slopes. Such a phenomenon is seen on the rim of the Tehri Dam reservoir at villages Raulakot, Kangsali, Nakot, Motna Chaundhar, Bhainga, Jange, etc. Similar landslide phenomenon was also witnessed initially by Maneri Bhali and Bhakhra Dam reservoir and many other similar reservoirs. However, it is significant to note that after 5 to 10 yrs, the slopes around the rim of their reservoirs got stabilized. The impact of HP on hill slope instability is of only localized nature. Mostly, the HPs are located and spaced outside the region of their impact on local geological scenes of one another and therefore have no recognizable cumulative impact on the stability of hill slope on one hand and geotectonics of the area on the other.

Between Devprayag and Badrinath/Gangotri numerous landslides are observed in the road sections of Alaknanda and Bhagirathi rivers. Although no well documented data are available on this aspect, it is surmised that in view of the fact that very small number of HPs have been constructed, the land slides are more due to the road constructions.

The glaciers Satopanth and Bhagirath Kharak are the source of the Alaknanda River. Similarly, the Gangotri glacier at Gaumukh is source of the Bhagirathi River. These glaciers are located at much higher altitudes and at long distances from the hydropower projects. The construction and operational activities at hydropower site are localised to the project areas only and therefore will have no impact on the behaviour of the glaciers located for away at higher elevations, whether they are melting (receding) or aggrading (advancing).

4.2.12. Recommendations

The Alaknanda and Bhagirathi basins have complex geological set up and are landslide prone. Landslides are very common during rainy season. There were unprecedented landslides due to heavy rains in the months of September - October 2010. The saturation of pores of earth mass with water, decreases the cohesion in the earth mass and increase pore fluid pressure on the pore walls. This rain caused phenomenon led to the failure of critically stable slopes of this region. It may be noted that the construction activities of HPs were stopped in the year 2010 prior to these rains. The hydropower projects, therefore, had little or no role in most of these failures.

In view of above, it is proposed that before, and during construction and before impounding of the reservoir with water, the following detailed geo-scientific studies be carried out to identify problematic areas of earth mass failure, and, site-specific, cost effective measures such as plantation on slope, re-grading of slope, shotcreting, grouting, anchoring, retaining and supporting walls, etc. along with proper drainage (surface and subsurface) measures to avoid saturation of earth mass, be taken up.

1. The following cost-effective geo-scientific studies, as a policy, be carried out for identifying potential slope stability problems that may arise during the operation of the reservoir based dam projects and these investigations may be done during DPR stage and may continue even during construction stage, but should be completed before start of reservoir filling.

    i) Initially a slope facet map should be prepared from the topographical map of the reservoir area. The facet map may cover the entire reservoir area and its rim extending up to the ridge top of the valley on both the banks. In case of RoR Projects (<20m height), the reservoir size is small and generally extends over a distance of few kilometers. The above studies in such projects be carried out up to the height of about 50m above the Maximum Reservoir Level (MRL) or the top of the ridge. The map should be prepared on 1:10,000 to 15,000.
    ii) Using the slope facet map as the base, geological mapping may be done covering the reservoir and its rim.
    iii) Geological cross sections, at least one per facet, may be prepared showing the reservoir water level at the toe.
    iv) Stability analysis of each of these sections should be carried out with reservoir water at the toe, to identify the critical and vulnerable slopes for failure during the operation of the reservoir. A separate map may be prepared showing the distribution of the nature of instability of the slopes within the reservoir area.
    v) In addition, a landslide hazard zonation map of the area under project and its vicinity be also prepared.
    vi) Based on these studies, detailed slope management plans to stabilize the critical slopes be formulated and implemented in different phases depending upon the requirements of the site.
    vii) All the above activities be carried out under the guidance of Technical Monitoring Committees, which may be formed separately for both Alaknanda and Bhagirathi basins.

2. In case of tunneling operations and other construction activities it is commonly observed at many sites that the excavated muck is dumped in huge quantities over the river bank slopes (e.g., Srinagar Hydel Project, Tapovan - Vishnugad Hydel Project, Vishnuprayag Hydel Project, etc.) Since the toe of the muck is left unsupported in many instances, the muck gets washed out continuously, particularly during high floods.

It is proposed that the technical committee as suggested above identify suitable dumping sites for the disposal of the muck from tunnels. The dumped muck should be protected suitably by a concrete retaining wall at the toe up to HFL.

3. The Geotract boundaries are tectonic boundaries characterized by major regional thrusts. The rocks in these Geotract boundary zone are, in general, fractured, faulted, sheared, mylotinized, incompetent, and therefore can be cause of perpetual geoengineering problems. In view of this, it is proposed to avoid siting a large, the reservoir based hydropower projects of more than 20 m height close to the thrusts, specially the MCT zones which are geotectonically fragile. Such projects be monitored for geotectonic activities.

4. Since the hill slopes around the reservoir are likely to be affected by discrete, isolated shallow landslides in the initial stages of operation, a no-activity buffer zone above the Maximum reservoir level (MRL) along the rim of the reservoir may be created to avoid untoward incidences. The width of this zone may vary from a few meters to about 50m depending on the topography, lithology and structural attributes of the area. The zone be monitored for the change in the hill slope of the rim area.

5. The tunnels invariably face the problem of leakage of water from sheared, fractured and jointed rocks zones they cut through. Besides geoenngineering problems, the inflow of water in the tunnel is directed to the river downstream. Due to this the sources of water through rocks down the slopes in the area get dried up or the flow is reduced. It is suggested that tunneling as well as adit sites be choosen in such a manner that they don't cut through such zones specially the underground water flow regime. Should the need arise the possibility of recharging the suitable areas locally, be done.

6. This sediment load carrying water erodes the loose, unconsolidated earthmass on the slope of valley. This phenomena not only destabilize the slope but also increases this sediment load downstream. Therefore, the sediment load in both upstream and downstream of the dam/barrage be monitored and appropriate retaining support be provided to the debris / muck.

7. Presently, only limited number of hydropower projects in the area have been completed and where actual construction activity is in an advanced stage the construction works have been done only during last decade. The information gathered during the present study does not show any effect of one HP on the other HP located downstream in the geological parameters. It can be vizualized that if several HP projects are developed in a single river valley, each HPs has it own area of influence both on the upstream and the downstream. Therefore, the project must be spaced so that their areas of influence do not interfare with each other, on the contrary, there should be a sufficient gap between them for the river to recuperate.

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ANNEXURE-1

DETAILED GEOLOGICAL DESCRIPTION OF ALAKNANDA AND BHAGIRATHI VALLEY

Alaknanda River Sysetem

A brief account of various geological features at different locations in the Alaknanda valley are described below (Gaur, 1970 & 1983) and a geological map of the area is given in Fig. 4.19, 4.20 & 4.21.

Fig. 4.19 Geological map of the Garhwal Group, Alaknanda Valley (After Gaur, 1983)

At Srinagar the greyish green slates are exposed which extend up to 6 km upwards along the road, where these have a thrusted contact with the quartzites. The schists are also associated with thinly bedded highly jointed slates. The dip varies between 70° and 80° towards S 35° E to S 45° E. The quartzites generally dip between 40° and 70° towards SW to SSW. The quartzites are of greyish white, pink and of greenish grey colour. They are inter layered with basic rocks. Near Kaliasar this unit is highly disturbed by the cross faults, close folds and is highly jointed. The main plunge directions are S50°E, S55° E and S35° E and the main fault trends are — N30°W- S30° E, NW-SE, N25°E-S25°W and N30°W-S30°E. Southeast of Kaliasar near Chatikhal the limestone is underlain by the quartzite and basic rocks having a faulted contact. At the contact limestone is highly crushed.

Near Rudraprayag a very thick basic rocks is encountered within the quartzites which are overlain by thin shales. Further northeast, thick basic rock is overlain by the

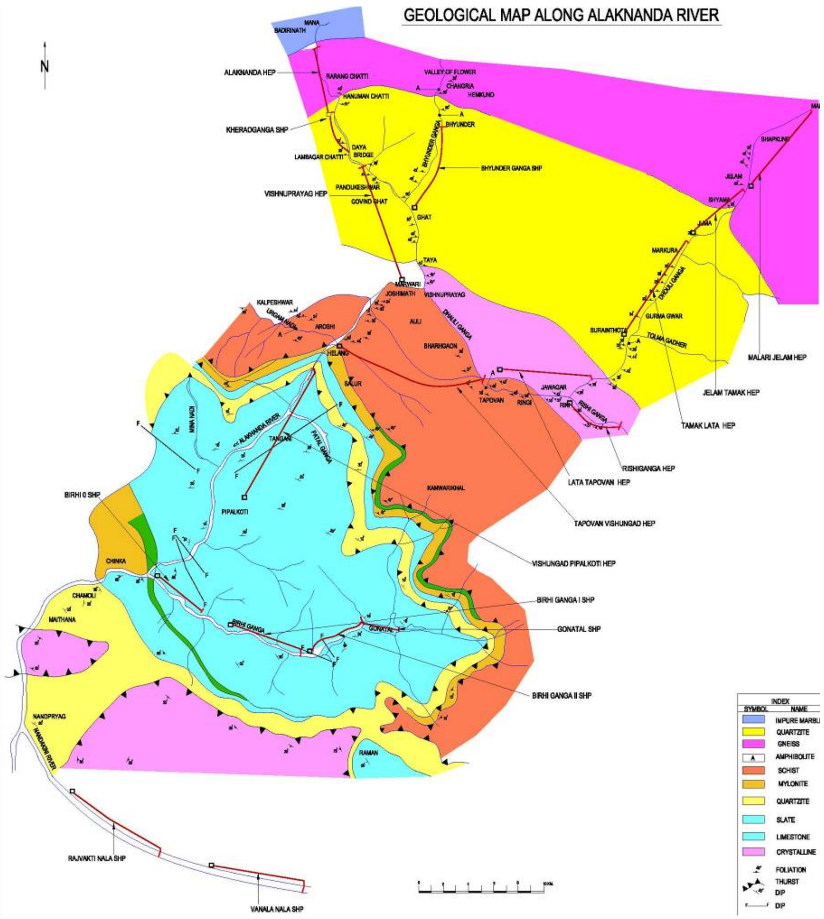


Fig. 4.20 Geological map along Alaknanda River (After Gaur, 1983)

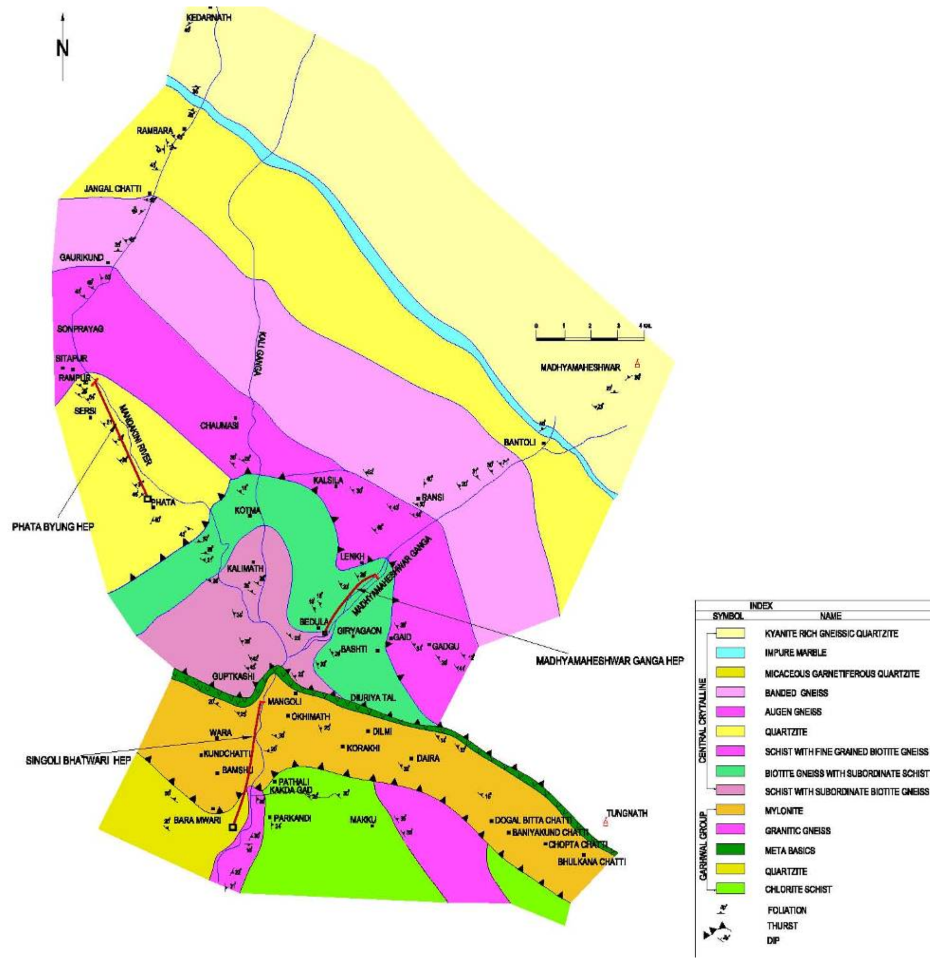


Fig. 4.21 Geological map along Mandakini River (After Gaur, 1983)

quarzites. The limestone is present between the 166.3 to 169 km having the tectonic contact with the underlying and overlying quartzites. After the quartzites of Ralna, Saur and Bela the gritty quartzite of Nagrasu occurs between the thick basic rocks. This quartzite south of Nagrasu dips 50° due SW whereas near Sail dips toward NNE. This sequence is again followed by the quartzites with basic rocks and the quartzite is underlain by the grey schistose slates. At Gauchar thick basic rock is exposed followed by the grey talcose slates with basic rocks, of Chutwapipal. It is followed by the huge pile of quartzites near Karnaprayag. At Karnaprayag the quartzites are striking N12°W-S12°E vertically. Further upwards a series of thick green chlorite-sericiteschist grades into chlorite-quartz schist having thin intercalations of amphibolites and quartzite. In this succession the dip and foliation vary between 50°and 60° due N70°E.

At Simli, black slate is exposed which is separated by a small anticlinal folded band of quartzite from the next zone of slates of Jaikan. The dip is towards east. These slates of Jaikan are followed by thick quartzites dipping 60^0 due E. This quartzite grades into chloritic slates. At Langasu massive marble and amphibolite are exposed, which are followed by two more bands of marble, separated by slates. At Langasu the dip is NE and further upstream it suddenly becomes westerly. From Sunla upto Nandprayag sericite chlorite schist is exposed which is having the intercalations of thin quartzite layers. Here again foliation is towards NE. The River Nandakini is flowing along a fault as the dip along the left bank is 50° due NW, and along the right bank is 40° due NE.

Upstream of Nandprayag the valley sides are covered by slide materials and only a few scanty exposures of sericite quartzite and mica schists are found, which dip due NE. At places, the gneissic bands are also encountered. The thick body of quartzite is occurring up to south of Maithana where biotite gneiss of about half km thickness is exposed having a thrusted contact with the underlying quartzites. Below the gneisses, the amphibolite (200 m thick) is followed by quartzite (about 100 m thick), which has a thin amphibolite layer and is further followed by a thin amphibolite layer. This whole unit abut against the Chomoli quartzites about *2 k*m south west of Chamoli, having a thrusted contact. This rock assemblage occurring between Nandprayag and south of Chomoli forms a syncline and belongs to an older metamorphic (crystalline) group which also occurs at Helong.

The quartzite of Chamoli has large thickness and extension. At Chanioli town the thickly bedded, massive and fine grained quartzite having buff colour dips 20°to 26° due SE. These quartzites become greyish green near Chinka. Around 100m north of Charnoli and at village Math the shear zones are found, where the quartzites are schistose. At Chinka above the quartzites a thinly foliated phyllite band is observed which is followed by a thin band of amphibolite containing small but conspicuous amount of magnetite grains. This band is succeeded by thin biotite-schist which further eastwards grades into chlorite sericite quartz schist having foliation 40^0 due SE. This schist extends up to Birhi River. The rocks between Chinka and Birhi make a syncline and at Birhi an anticline which plungs SE.

The Chamoli quartzite extends to a fairly long distance upstream in the Birhi valley. Here the quartzites are partially crushed and are weathering into white sand.

This quartzite is underlain by a narrow zone of gneisses and schistose amphibolite. It is followed by the calcareous zone consisting of thin intercalations of black shales and dark limestones which dip 40^0 to 60^0 due SWW. These shales and limestones are highly folded and faulted throughout up to the Gaona village resulting into highly crushed zones. The main plunge directions are SW, SWW, SSW, SE and NNE and the main fault dips are 50° due NNW, 20° due N60°E, 20° due S40°F and 70° due N30°E. This calcareous zone having intercalation of shales and limestone is also associated with the dark coloured splintary shales, greenish and pinkish purple coloured splintary shales, massive grey white dolomite, massive dark limestone and the greyish thinly bedded dolomites. Upward of the Gaona Tal this calcareous zone is flanked by the quartzites and later followed by the older metamorphics. Thus this calcareous zone forms a tectonic window, called by Auden (1039) as Chamoli Window.

To the north of the bridge at Birhi, schists are followed by the quartzite and a thin zone of gneisses and schistose amphibolite on the top. After this thin band, again extension of the calcareous zone of Chamoli Window exposed along the Birhi valley is encountered. Near the Jesal village the greyish white medium grained marble grades upward into light coloured flaggy limestone. This carbonte unit is associated with the thin shaly layers, which in marble zones are micaceous / talcose.

From Jesal to Pipalkoti the alternations of the slates and slaty limestone are encountered. The slates vary in colour from steel grey to dirty green. The steel grey slates are thinly laminated and show colour bandings. The dirty green slates are chloritic, whereas the other slates are sometimes calcareous.

North of Pipalkoti the rocks are dipping towards north to northwest. Here the minor folds are frequent and the most common plunge is 20^0 due SW. The rocks are light grey to dirty green coloured chloritic slates interbedded with thinly laminated grey white to greyish limestone. This zone extends nearly up to the confluence of Mena Nadi with the Alaknanda River. Here, closed northerly dipping folds are abundant. From Mena Nadi to north of Garur Ganga steel grey slates similar to slates of Jesal are exposed. The limestone is subordinate. The dip of rocks is 25° due NEE, where a few meters north of Garur Ganga the dip changes suddenly to southwest. Here a plane of movement is also distinct.

North of Garur Ganga a dolomitic limestone approximately 150 meters thick is exposed south of Tarosi and extends towards Pukhni. Between Garur Ganga and Belakuchi the rocks are locally folded and to the south of Belakuchi crushed dolomitic limestone having talc bands comes in contact with the steel grey slates which are intensely traversed by quartz veins. The contact between the two seems to be highly disturbed. The dip of the beds is reversed and becomes northerly forming an anticline. The limestone is highly shattered and very thin talc layers are developed partially in them. The overlying dark grey slate zone extends right from Belakuchi to the Langsi, a few meters ahead to the old bridge site. Here the dip becomes northerly.

A steep NE dipping fault zone strikes NE-SW from near Pakhi on the right bank of Garur Ganga to the Panaigad and Sialgad just below the old track and further northwards it runs above the old track near to Tangni. The rocks are here highly folded, jointed and crushed. North of Tangani the phyllites have a faulted contact with the overlying limestone. The contact surface dips 10^0 due N10°E. Low angle dipping faults are also present within this zone.

Upstream of Patal Ganga the slates extend up to the southeast of Patal Ganga bridge where the limestone group of south of Belakuchi is found. This carbonate zone extends beyond the village Ganai where thin quartz schist zone separates the quartzites. Upstream of the Patal Ganga bridge the right bank is mainly made up of loose material which is composed of boulders and a large mass of soil. This extends up to villages Ganai and Darmi. In the Patal Ganga valley the dip is low, i. e. 20° to 25^o due NNE to NE. The limestone is highly folded and faulted on minor scale and the main plunge directions are NW and SE. The quartzite beyond the Ganai vi1lage extends eastwards. Near the Kanwari Khal the mica schist, paragneisses and garnetiferous schists are exposed.

North of the Langsi the dolomitic limestone comes in contact with the grey slates of Belakuchi. In the upper part this limestone becomes extremely fine grained. The dip is 20^0 to 30^0 due N10°E to N25°E. This zone of limestone is overlain by quartzite just north of Gulabkoti and extends to 1.5 km northeast of it. The quartzites are micaceous, white to greenish white in colour. The rock shows a consistent dip of 25° due N15^0E.

Further north this quartzitic zone is overlain by the dolomitic limestone followed by fine grained siliceous marble. This zone is overlain by highly sheared quartzites similar to that of Gulabkoti. These quartzites are highly jointed and fractured. The quartz veins and pockets containing micas, kyanite and black and blue tourmaline are abundant in this zone and in the Gulabkoti quartzite.

This thin quartzite zone is overlain by highly metamorphosed sericite-biotite schist and the rocks similar to paragneiss. The foliation is 40^o due N5°W. The contact with the quartzites and the metamorphosed unit seems to be a major dislocation plane which dips 50° to 60° due N15°E. The same evidences are also observed on the foot track.

This thin zone of metamorphosed sediments is again overlain by a very thin band of limestone and by thick quartzites having thin schistose bands. At Helong the highly metamorphosed sediments, *i.e.* schists and gneisses overlie the quartzitic group. The nature of contact is not clearly observable at the road sections, as also described by the earlier workers (Auden 1935; Gansser 1935; Singh 1967), and according to them, the indirect evidences of the Main Central Thrust is along with this contact. At the same time a major dislocation plane was also observed north of Gulabkoti separating the sedimentaries from the metamorphics. Thus, here it seems that the thrust is made up of two thrust sheets, one at Helong and the other occurring between Helong and Gulabkoti. The same conclusion was also arrived by Singh (1967).

Upwards from Helong, the metapelites, i.e., augen gneisses, chlorite schist, biotite schist and subordinate quartzite bands are encountered. Near the Paini the schists are in contact with the quartzites having a faulted contact. The contact dips 30° due N10°E, whereas the foliation of schists is 35° due N10°E and of quartzite is 30^0 due N10°E.

Further, near Sharkula village the quartzite dips 35° due N25°E and is in contact with the gneisses. This sequence continues up to south of Joshimath where thick augen gneisses are exposed and the foliation is generally 30°due N10° E.

At Vishnuprayag the biotite gneisses are exposed. Above it, the metamorphic rocks are observed which are thick mica schists with garnet, gneisses, garnetiferous-mica schists followed by thick piles of quartzites having thin mica-schist zones. The foliation in schists is 40° due Nl0° E whereas the quartzites dips 40° to 70° due Nl0° E to N2O°E. Near the Kalainkoti the rocks are metasedimentaries and augen-gneisses characterized by silicates. The general dip is 60° due N15°W. This is followed by a series of quartzites and calc-silicates interbedded with gneisses and amphibolitic layers. Between Bamni and Badrinath, the biotite gneiss, mica schists, banded calc-silicates, gneisses and gneissic quartzites are occurring, which are followed by high grade metasediments with gneisses and calc-silicates at Badrinath. This sequence extends up to the meeting point of Satopanth and Bhagat Kharak glaciers.

From Joshimath towards malari the augen gneisses are exposed for fairly long distance after that the biotite and chlorite schists are encountered. From Baragaon upto Tapoban the quartz-muscovite-hematite schist is encountered in which the foliation varies between 40° to 45° due NE. These rocks have been puckered and folded, the plunge directions vary between N to N10°E. These rocks are also faulted near the Tapoban. The hematite grains in the schist have given the lineation. The unit is followed by the quartz-mica gneiss which extends upto south of Reni. At Reni the strike continuation of the augen gneisses of Joshimath is encountered in which the foliation varies between 30° to 40° due NE. Between Suraithota and Juma the garnetiferous -biotite schist interbedded with the quartzite bands is exposed. Garnets are arranged the linear pattern. The quartz lenses are also abundant in this unit. This unit is followed by the felspathic quartzite, which in general is light coloured. It is associated with the biotite-schist bands. At places the biotite flakes have given rise to the gneissose character. The quartz lenses are abundant which contains the tourmaline crystals and at some places the fibrous kyanite. These rock units at places have thin bands of amphibolite.

GEOMORPHOLOGY OF IMPORTANT RIVERS IN ALAKNANDA BASIN

The geomorphology of the area is the most vivid expression of the powerful river erosion on the one hand and the action of ice and glaciers on the other hand. The deep gorges, the V-shaped valleys of Alaknanda River, Dhauli Ganga, Birhi Ganga, and the presence of numerous moraines and river terraces have faithfully preserved the signature of various events of erosion and deposition in the past and present. The avalanche and large and small landslides have further modified the morphological features. In general, the geomorphology of the area is immature and is in youth stage where the erosion is rapid and the slopes are mostly steep and unstable. The drainage of the area is dendritic but beyond the Joshimath the drainage pattern becomes rectangular. The main rivers of the area are Alaknanda River, Dhauli Ganga, Rishi Ganga, Birhi Ganga, Nandakini River, Mandakini River and Pindar River.

Alaknanda River

Alaknanda River originates from the confluence of Satopanth and Bhagirath Kharak glaciers. It forms longitudinal valley before it meets Saraswati river near Mana. Alaknanda River has cut a V-shaped gorge across the moraines in the Vasudhara valley and on the north side of it moraines and scree material are existing. The two glaciers have their actual end near each other and almost on the same level.

After meeting with the Saraswati River at Mana the Alaknanda River comes down to the wide valley of Badrinath, which is of a bowl shape. According to Bose (1965), it is a gigantic old amphitheatre where old glaciers met in the past. The mixed lake deposits with the moraines indicate the formation of valley due to the blocking of the river in the geological recent past. On the left side of the valley, fan shaped moraine deposits exist which seems to have been left due to recession of the glacier.

From Badrinath upto Radang Chatti and Bamni several small glaciers are seen on the right hand side of the Alaknanda River. On the road side of the river the Kanchan Ganga River is present.

Between Bamni and Radang Chatti the river gradient becomes very steep whereas, at Badrinath the gradient is very gentle. While flowing in transverse valley, suddenly at Hanumanchatti the direction changes to east-west for a distance of 250 m and then again follows through the transverse valley in a direction roughly S30° E. At Hanumanchatti the glacial debris is covering a large area, and nala just south of the Chatti brings the huge glacial debris which must have blocked the river in the past. Near the bridge on Alaknanda River, north of Lambagarh, a nala on the left bank has brought huge muck due to which the river has been forced to flow on the right side. At this place the damming of river in the past is also apparent. At Lambagarh, the fluvio-glacial material is lying along the right bank whereas the glacial debris is lying along the left bank. Here also the damming of river in the past is possible. Just below the Lambagarh, a huge stretch of paleo- glacial deposit extends up to the river channel. Along the road this deposit has been cut by a vertical plane along which continuous slides are taking place. At VinayakChatti also the fan shaped fluvio-glacial/debris is found along the confluence of nala with the Alaknanda River. At Pandukeshwar the river enters into a wide valley where the gradient also becomes gentle for a shorter distance. It is due to the damming of river in the past by several slides on both the sides the valley. Around Pandukeshwar several dip slope failures are observed.

From Pandukeshwar up to Vishnuprayag where Dhauli Ganga meets the Alaknanda River, the river flows in a transverse V-shaped valley with convex slopes. Both the sides correspond to each other and indicate strongly the formation of this transverse valley exclusively by river erosion.

From Vishnuprayag below Joshimath the Alaknanda River forms a longitudinal valley. The right side of the valley is steep, whereas the left side is made up of a huge land slide mass. Near Paini, a huge slide block is existing on which the road is taking many bends. Between Joshimath and Pipalkoti several small rivers meet the Alaknanda River, namely Urgam nadi, Patal Ganga, Garur Ganga and Mena nadi which have steep gradients and great errosive power. At Helong, the Karamnasa nadi flows down the homogeneous debris from the fresh slided zones and at the confluence with the Alaknanda River the temporary damming of the river was clearly seen from the alluvial fan deposited during the flood of July 1970. The same evidences of damming were also observed, along the confluences with the Patal Ganga. Downward of confluence of Patal Ganga and Alaknanda River up to Belakuchi, the Alaknanda River is flowing through a deep valley having nearly vertical walls. Before the flood of July 1970 the river at Belakuchi was flowing along the right side of the valley, which might have been due to the old slide of Belakuchi which had forced the river to the right side. It seems that during the flood the channel first eroded the toe of the old slide which later resulted in fresh slide and thus washed down Belakuchi market. Along both the sides of river fresh, terrace deposits have been formed after the flood .The fresh terrace deposits and the fresh slides along valley sides can be traced up to Pipalkoti. Around Pipalkoti the river has cut an imposing gorge in the limestones, where both the sides of the river show typical convex shape steepening downward. River terraces have been formed by the river at this place.

Chamoli shows a long intersected terrace which seems to be parallel to the actual course of river. North of Nandaprayag the whole eastern mountain slope, made of mica schist has slipped down. At Nandprayag, Nandakini River meets the Alaknanda River and is situated on a terrace. Near Langasu the whole left side of the valley is made up of river terraces and here the river has started the erosion of the terrace. Near Karnaprayag the river passes through a deep gorge and at Karnaprayag it meets with the Pindar River. Here also the river terraces are found. Near Rudraprayag also the river passes through a gorge. Between Karnaprayag and Rudraprayag, at various places, the toe erosion is still prominent in the softer and consolidated zones along the river channel. At Rudraprayag, Mandakini River meets the Alaknanda River and the town is located on a terrace. Downward of Rudraprayag the river flows more or less in the wide valley and the river terraces are more prominent. The terraces of Nagrasu and Gauchar are of very large extensions. At Kaliasor, the river is very active in toe erosion. Near Srinagar the river enters in a very wide valley totally made up of the terrace deposits. At a place (stone Srinagar 6 kilometer) along the nala a well-developed terrace exists along a dry nala. From this point up to the south of Srinagar the prominent terraces exist on both the sides of the valley.

Dhauliganga River

Dhauliganga River which meets Alaknanda River at Vishnuprayag has formed a deep valley and first making a transverse section and then cutting a longitudinal section down to its confluence with the Alaknanda River. They meet at an obtuse angle.

In general, it is observed that the Dhauliganga in its northwestern course has been forced to the right, giving rise to the steep walls along the right side of the valley. It has been explained, as a result of the general dip of the gneisses and schists toward NE and due to the slipping of the left valley side along the micaceous bedding planes.

At Tapoban, Dhauliganga River has cut an epigenetic gorge. According to Heim and Gansser (1939) in cutting across the great barrier wall, the river did not strike its old way again, but has cut an epigenetic gorge into mica schists and quartzite, above the bridge of Tapoban. The filling of the valley is indicated by features on the east side of the frontal wall of the slide. All along the road upto the Reni village the river valley is moderately wide.

Near the Reni village, the Rishi Ganga is meeting with the Dhauliganga. Here the terraces are seen on a higher level which indicate the blocking of the river in the past. The Dhauliganga River suddenly widens west of village Lata, where a clear river blocking is seen. The damming is due to mountain slide from the right side of the valley. This widened valley extends up to Suraithota. Right from Lata up to Suraithota, the river terrace deposits as well as gravel deposits are seen.

At Suraithota, a nala, Tomla Gad is meeting in wide valley with the Dhauliganga. The Suraithota village is itself situated on the terrace deposits. On the mouth of Tomla Gad on both the sides about 10 m high old terrace deposits are seen.

The fluvioglacial deposits are seen all along the road side of the valley right from Tomak upto Malari. Near Tomak the striated boulders are found along with the big sand deposit. Near the Juma village the prehistoric damming can be again visualized where clay deposit and boulders are existing. After the village of Juma, the river valley widens and about 5 km upwards from Juma it seems to have cut an epigenetic gorge, as lake deposits are still existing along the walls of the valley. From Juma upto the Malari for a major part the right side of the valley is made up of loose debris. At Bhupkund again the river flows through a very narrow valley. Here the avalanche debris of large boulders can be seen. Between Bhupkund and Malari the left side of the valley is made up of loose debris which is mainly due to the receding of the glaciers.

Birhiganga River

Birhiganga meets the Alaknanda River at about 6 km upstream of Chamoli township. Originating from the Nanda Glacier, it runs nearly in east-west direction crossing the various lithological units like older metamorphics, quartzites and Calc Zone of Chamoli. The river throughout, from the confluence point up to the end of Gona lake flows in a very wide valley, which at present has gained a U shape. This shape is due to the excess of river borne material like gravels and boulders accumulating in the river bed . The terrace deposits exist all along the walls of the valley showing the recent erosion.

Heim and Gansser (1939) have given a good account of the slide making of Gona lake. This lake was totally destroyed on the 20th July, 1970 in the similar catastrophic way as it was formed causing a great loss of property and life in the valley. A detailed account of this catastrophe has been given by Gaur (1970). Due to the heavy run-off and additional debris, the lake was damaged and the lake deposits were partially eroded away and driven off to the roaring Alaknanda River. The whole material could not, however, be removed and the alluvial fan debris was deposited at the mouth of the Birhiganga. The bed level was increased considerably due to this addition of material. After the confluence of Pui Gadhera with the lake, the river flows through a very narrow gorge. The typical lake deposits are found in the abandoned lake.

Based on geology, geomorphology and structural set up, five zones are identified:

1. **Zone 1-** Zone lying above the MCT consisting of hard, massive and compact rocks. Landslides in this zone are characterized by failures along foliation planes or sliding of land mass from palaeoglacial deposits. This zone has following hydropower projects:

   Badrinath, Alaknanda, Khiraoganga, Vishnuprayag, Bhyunderganga, Malari Jelam, Jelam Tamak, Tamak Lata, Lata Tapovan, Rishiganga, Rishiganga I, Rishiganga II, Phata Byung, Madhyamaheshwar and Urgam II,

2. **Zone 2-** Zone lying close to MCT consisting of sheared, fractured and jointed rocks. Intense shearing along MCT has developed long weak planes. This zone has following hydropower projects:

   Tapoban Vishnugad, Singoli Bhatwari, Rajwakti, Vanala, Urgam

3. **Zone 3-** Zone lying below MCT and within the fragile Calc Zone of Chamoli. Development of mylonites along thrust plane and lithological and structural characters of Calc Zone have resulted in the formation of one of the most susceptible and fragile area. This zone has following hydropower projects:

   Vishnugad Pipalkoti, Birhi 0, Birhi 1, Birhi 2, Gohna Tal

4. **Zone 4-** Zone consisting of slightly massive but sheared quartzites and weathered metabasics. This zone has following hydropower projects:

   Bowla Nandprayag, Nandprayag Langasu

5. **Zone 5-** Zone consisting of schistose slates, and soft rocks. This zone has following hydropower projects:
   Srinagar HP

(B) Bhagirathi River System

The geological features of the Bhagirathi River System are in general conformity to the geological set up of the region. The litho tectonic successions in a few important sections of the Bhagirathi River and its tributaries are presented in Table 6 and Fig. 4.22 & 4.23.

Table 4.6: Lithotectonic Sequence in Bhagirathi Valley.

Bhagirathi section	Dodi-tal section
Tourmaline Granite Coarse to medium grained, grayish to greenish white, hard and compact granites. The rock on the lower parts are very coarse grained, some what friable in nature, and consists of abundant occasional garnet and kyanite blades. On the upper side biotite flakes are replaced by muscovite, traversed by numerous pegmatic veins, composed of quartz, feldspar, garnet (transparent variety also) beryl (aquamarine), muscovite etc.	____________
Quartzites Fine to medium grained, grey to purple coloured hard compact quartzites. Often large recrystallized quartz grains, give the appearance of gneissic character. Numerous veins of aplitic granite and pegmatite traverse these quartzites, fine thin bands of chloritic-schist and few coarse crystalline bands of banded gneisses are also encountered. Garnets are apparent at various places.	____________
Banded Gneisses Fine to medium grained, hard and compact banded gneisses, quartz and feldspar occur as big porphyroblast and often look as augens. The rock is traversed by aplitic granite consisting of tourmaline crystals and numerous veins of quartz and feldspar. Thin to thick bands of fine to medium grained, grey to purple coloured quartzites are also found interla yered.	____________
Schists Fine grained, grayish green, quartz-chlorite schist, talc-mica schist, garnetiferous-mica schist. At places they are highly puckered. Garnet occurs as big porphyroblasts. Often thin bands of fine grained gneiss are also encountered. Towards the top of it fine grained quartzites are present, which are grayish in colour, schistose in nature and consists of recrystallized quartz grains.	____________
Augen Gneisses Medium to coarse grained, hard and compact gneisses, having thin _____ or mica and comparatively thick layers of light coloured minerals mainly augen-shaped quartz and feldspar,	____________

Bhagirathi section	Dodi-tal section
within these gneisses thick bands of metabasics are encountered. Which are compact, greenish black, dark brown to black in colours.	
Magmatites Fine to medium grained, melanocratic to leucocratic, foliated banded and compact rocks. Foliation are marked by the preferred arrangement of micaceous minerals. The grain size of minerals increases from foliated to massive variety having augen structures. Tiny of quartz and feldspar form leucocratic bands and run almost parallel to main foliation, dark coloured minerals mark the melanocratic portion. Migmatites are interbanded with blackish green metabasics.	____________
Biotite-Gneiss Medium to fine grained, grayish black coloured rock, with well developed gneissosity. Streaks of fine porphyroblastic quartz and feldspar give it a micro-augen structure. These gneissic bodies are encountered near the Thrust Zone with metabasics at the base, metabasics are medium to fine grained, greenish black in colour, hard and compact.	**Biotite-Gneiss** Medium to coarse grained, grayish coloured rock, with well developed gneissosity. Porphyroblast of quartz give it a augen structure. In between the rock is interlayered with metabasics and chlorite schist. Metabasics are dark green, texturally fine grained, well developed foliation, grains of amphibole oriented along foliation planes.
Intra Thrust Zone This zone is comprised of schistose mylonitized quartzites and augen-mylonites. Mylonitic quartzites are schistose in nature, medium grained, greenish to grayish coloured, having elongated translucent porphyroblasts of quartz grains along the foliation planes. Augen mylonites are coarse grained, greenish to grayish green coloured, having elongated white coloured quartz porphyroblast along foliation planes, are characterized by intense schistosity with minor kinks and strain slip cleavage.	**Mylonitic Quartzites:** Medium grained, greenish to white coloured, hard and compact mylonitic quartzites, with thin bands of chlorite schist.
Quartzites Fine to medium grained, whitish grey to purple coloured, hard and compact quartzites, highly jointed and fractured with well developed current bedding. The quartzites are intercalated with chloritic schist and occasional limestone and slates.	**Schistose Quartzites** White to purple coloured, medium to fine grained, well developed schistosity, due to alignment of flaky minerals, hard and compact quartzites.

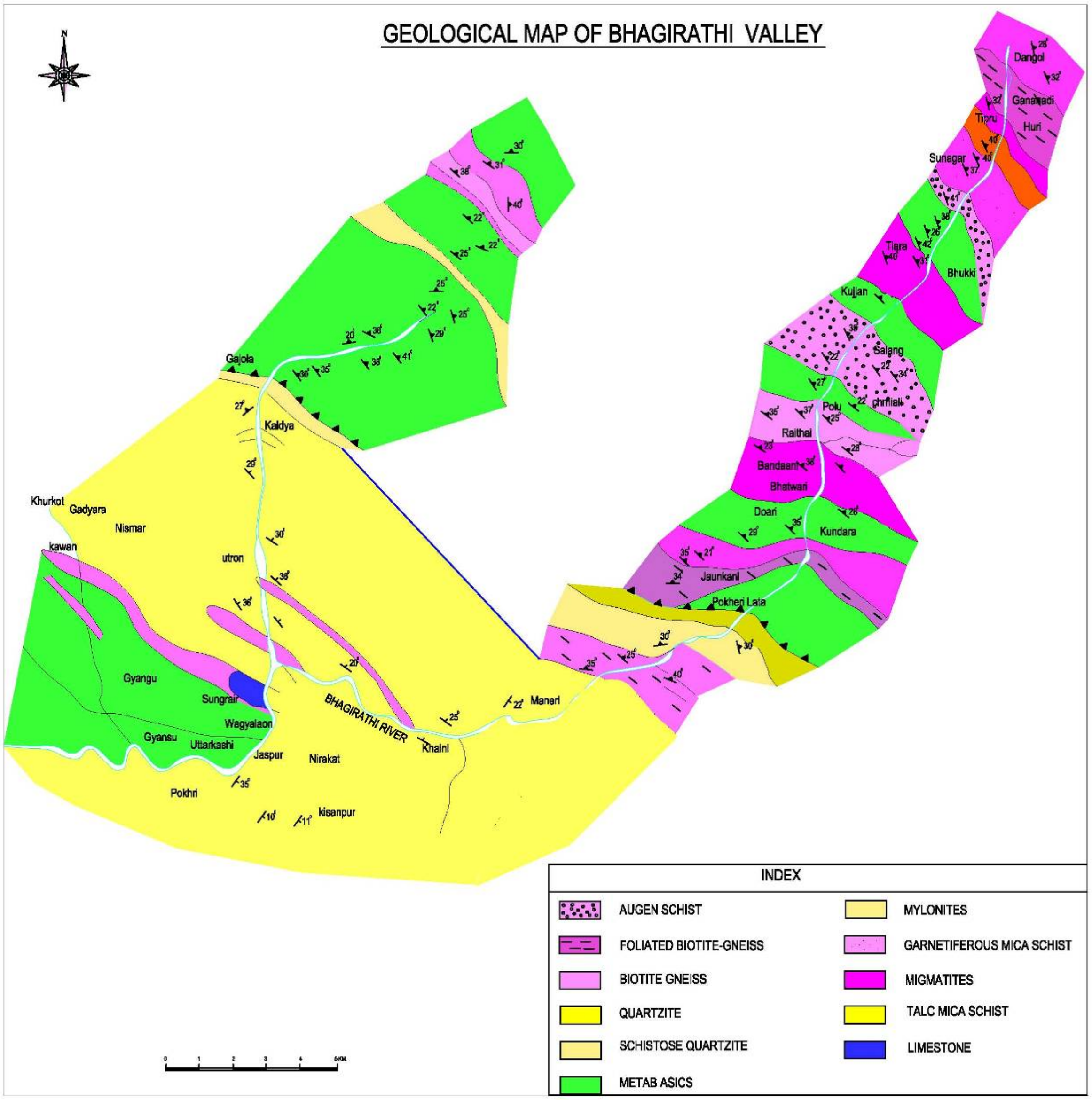


Fig. 4.22 Geological map of Bhagirathi sector

Table 4.7: Lithotectonic Sequences along various sections in Bhilangna Valley Sector.

Bhilangna Sector (Kharsoli to Ghonti)	Balganga Sector (Pinswar to Ghumetidhar))	Panwali Sector (Panwali to Ghuttu)
Biotite Gneiss Medium to coarse grained, schistose biotite gneiss. Quartz and feldspar porphyroblasts are alongated and stretched along the foliation planes, mineral lineation of micas is very prominent.	**Biotite Gneiss** Medium to coarse grained, schistose biotite gneiss. Quartz and feldspar porphyroblasts are elongated and stretched along the foliation planes, mineral lineation of micas is very prominent.	**Biotite Gneiss** Medium to coarse grained, schistose biotite gneiss. Quartz and feldspar porphyroblasts elongated and stretched along the foliation planes, mineral lineation of micas is very prominent.
Garnetiferous Gneiss Fine to medium grained, grayish coloured well foliated gneisses. Porphyroblasts of quartz, feldspars along with garnet occur along the foliation planes. Often complete lack of biotite. Thick recrystallized quartz veins are abundant.		
	Granite Gneiss Very coarse grained well foliated, grey coloured granite gneiss having well developed porphyroblasts of quartz, feldspar and specks and needles of tourmaline. Occassionally, tourmaline appears in radiating form.	**Granite Gneiss** Very coarse grained well foliated, grey coloured granite gneiss having well developed porphyroblasts of quartz, feldspar and specks and needles of tourmaline. Occassionally, tourmaline appears in radiating form.
Metabasics A persistant band of medium to fine grained, hard and compact, greenish black coloured, poorly foliated metabasics follows Panwali Thrust. Thin impersistant bands of chlorite schist are common.	**Metabasics** A persistant band of medium to fine grained, hard and compact, greenish black coloured, poorly foliated metabasics follows Panwali Thrust. Thin impersistant bands of chlorite schist are common.	**Metabasics** A persistant band of medium to fine grained, hard and compact, greenish black coloured, poorly foliated metabasics follows Panwali Thrust. Thin impersistant bands of chlorite schist are common.
Augen Mylonites Medium to coarse grained mylonite having sub-rounded to rounded and rectangular augen shaped porphyroblasts of white coloured feldspar white quartz. (giving spotted	**Augen Mylonites** Medium to coarse grained mylonite having sub-rounded to rounded and rectangular augen shaped porphyroblasts of white coloured feldspar and grayish white quartz. (giving spotted appearance).	**Augen Mylonites** Medium to coarse grained mylonite having sub-rounded and rectangular augen shaped porphyroblasts of white coloured feldspar and grayish white quartz (giving spotted appearance). Dark greyish to

Bhilangna Sector (Kharsoli to Ghonti)	Balganga Sector (Pinswar to Ghumetidhar))	Panwali Sector (Panwali to Ghuttu)
appearance). Dark greyish to greyish green fluxion bands and foliated matrix alternates with porphyroblasts layers, showing strong mineral lineation.	Dark greyish to greyish green fluxion bands and foliated matrix alternates with porphyroblasts layers, showing strong mineral lineation.	greyish green fluxion bands and foliated matrix alternates with porphyroblasts layers, showing strong mineral lineation.
Tourmaline Granite Gneiss Uniformly coarse grained, grayish black to grayish white coloured well foliated granite gneiss having large stretched and augen shaped porphyroblasts of feldspars and specks, needles and radiating crystals of tourmaline. A thick band of schistose talc-mica schist with recrystallized porphyroblasts of quartz also occur. These schists contain balls, aggregates of tourmaline needles.	**Tourmaline Granite Gneiss** Uniformly coarse grained, grayish black to grayish white coloured well foliated granite gneiss having large stretched and augen shaped porphyroblasts of feldspars and specks, needles and radiating crystals of tourmaline. A thick band by schistose talc-mica schist with recrystallized porphyroblasts of quartz also occur. These schists contain balls, aggregates of tourmaline needles.	**Tourmaline Granite Gneiss** Uniformly coarse grained, grayish black to grayish white coloured well foliated granite gneiss having large stretched and augen shaped porphyroblasts of feldspars and specks, needles and radiating crystals of tourmaline. A thick band by schistose talc-mica schist with recrystallized porphyroblasts of quartz also occur. These schists contain balls, aggregates of tourmaline needles.
Quartzites Massive, fine grained highly fractured, jointed quartzite having transluscent grains of quartz, sericite often shows mineral lineation. One persistant band of metabasics rings the circular outcrop of the quartzites. Impersistant bands of slate and phyllite also occur following the trend of quartzite. At the top of quartzite, foliated biotite gneiss occurs as a cap.	————	————
Biotite Gneiss Medium to coarse grained, schistose biotite gneiss. Quartz and feldspar porphyroblasts are elongated and stretched along the foliation planes, mineral lineation of micas is very prominent.	**Biotite Gneiss** Medium to coarse grained, schistose biotite gneiss. Quartz and feldspar porphyroblasts are elongated and stretched along the foliation planes, mineral lineation of micas is very prominent.	**Biotite Gneiss** Medium to coarse grained, schistose biotite gneiss. Quartz and feldspar porphyroblasts are elongated and stretched along the foliation planes, mineral lineation of micas is very prominent.

Bhilangna Sector (Kharsoli to Ghonti)	Balganga Sector (Pinswar to Ghumetidhar))	Panwali Sector (Panwali to Ghuttu)
Ganite Gneiss Very coarse grained well foliated, grey coloured granite gneiss having well developed porphyroblasts of quartz, feldspar and specks and needles of tourmaline. Occassionally, Tourmaline appears in radiating form.	**Ganite Gneiss** Very coarse grained well foliated, grey coloured granite gneiss having well developed porphyroblasts of quartz, feldspar and specks and needles of tourmaline. Occassionally, tourmaline appears in radiating form.	**Ganite Gneiss** ______________
Blasto-mylonite Medium to fine grained, micaceous greenish coloured, poorly foliated recrystallized mylonitic rocks. The degree of recrystallization is so high that original cataclasts are not visible	**Blasto-mylonite** Medium to fine grained, micaceous greenish coloured, poorly foliated recrystallized mylonitic rocks. The degree of recrystallization is so high that original cataclasts are not visible	**Blasto-mylonite**
Quartzites Medium to fine grained, variegated quartzite, shows extreme variations in grain size, colour (from purple to green) and texture, with concordant metabasics.	**Quartzites** Medium to fine grained, variegated quartzite, shows extreme variations in grain size, colour (from purple to green) and texture, with concordant metabasics.	

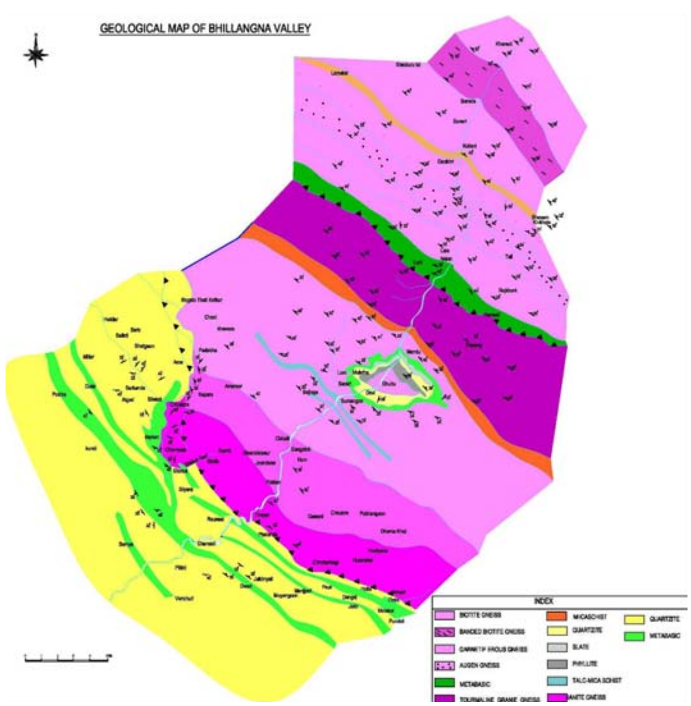


Fig. 4.23 Geological map of Bhilangna valley

Table 4.8: Lithotectonic Sequence in Various Sections of Kadernath Area.

Mandakini Valley Section (Kakda To Kedarnath)	Kaliganga Section (Guptakashi To Chaumasi)	Madhya-Maheshwar Ganga Section (Guptakashi to Madhya Maheshwar)
Coarse Crystalline Augen Gneisses Coarse augen gneisses having large porphyroblasts of feldspars and quartz. Elongated porphyroblasts are along the foliation planes, whereas euhedral porphyroblasts are oblique to foliations and cut across them. Traversed by numerous aplitic/pegmatitic veins.	____________	
Kyanite rich gneissic quartzite Medium to fine grained, grayish white to pinkish cream coloured quartzite having abundant biotite, muscovite, kyanite and garnet. Numerous veins, pockets and bands of aplititc granite and pegmatites.	____________	**Kyanite rich gneissic quartzite** Fine grained and grey coloured towards top, medium grained and grayish white coloured towards bottom having abundant biotite, muscovite, kyanite and garnet. Infrequent veins, packets and bands of aplitic granite and pegmatites. Often attain banded character. Numerous bands of coarse grained white coloured marble having large crystals of garnet.
Impure Marble Greenish coloured marble having sacchroidal grains of calcite, greenish minerals of amphiboles and pyroxenes, and subordinate grains of orthoclase, garnet etc.	____________	**Impure Marble** Light green coloured fine grained marble having calcite greenish minerals of amphiboles and pyroxenes and subordinate grains of orthoclase, garnet etc.
Micaceous Garnetiferous Quartzite Medium to fine grained grayish white to purple coloured quartzite having abundant biotite and porphyroblasts of garnet. Often show banded characters having coarse grains of quartz and larger flakes of biotite along with small laths of kyanite. Numerous bands of calc-silicate rocks with coarse grained bands of white coloured	____________	**Micaceous Garnetiferous Quartzite** Medium grained, grey to grayish white coloured quartzite having abundant biotite and porphyroblasts of garnet. Often shows banded character, having coarse grains of quartz and larger flakes of biotite along with small flakes of kyanite. These quartzites contain infrequent bands of quartz-

Mandakini Valley Section (Kakda To Kedarnath)	Kaliganga Section (Guptakashi To Chaumasi)	Madhya-Maheshwar Ganga Section (Guptakashi to Madhya Maheshwar)
marble having larger crystals of garnet and speeks of sulphide minerals.		mica-schists.
Banded Gneiss Medium to coarse grained banded greisses having alternate bands of porphyroblastic (small) quartz and feldspars and biotite flakes. Intimately associated with the quartz-chlorite-biotitie schist, quartz-chlorite-muscovite schist and fine to medium grained green coloured recrystallized quartzite.	____________	**Banded Gneiss** Medium to coarse grained banded gneisses having alternate bands of porphyroblastic (small) quartz and feldspars and biotite flakes. Intimately associated with quartz-chlorite-biotite schists and fine grained, grey coloured quartzite having abundant micaceous minerals.
Augen Gneiss Coarse grained white to grayish white greisses, having larger porphyroblasts of quartz, feldspars and occasional garnet. Few bands of quartz-mica-garnet schists are also encountered.	**Augen Gneiss** Coarse-grained white to grayish white coloured gneisses, having rounded, subrounded and rectangular porphyroblasts of quartz, feldspars and occasional garnet. Lenses and bands of matabasics are common.	____________

GEO-ENVIRONMENTAL IMPACTS OF HYDROELECTRIC PROJECTS ON ALAKNANDA AND BHAGIRATHI RIVER BASINS

Based on the size, capacity, type, location on Geotracts, nearness from thrusts, 19 HPs (11 in the Alaknanda basin and 8 in the Bhagirathi basin) were investigated. Out of these 19 HPs, 6 are reservoir based (3 in Alaknanda basin and 3 in Bhagirathi basin) and 13 HPs are the run of river projects (8 in Alaknanda basin and 5 in Bhagirathi basin). Except for 4 HPs, all other 15 HPs have installed capacity of more than 75 MW.

A. Alaknanda Basin

(I) Reservoir Based HP

i) Vishnugad – Pipalkoti HP (RoR with storage, 445 MW; Under Construction)

Located geologically in the Geotract 3 just south of MCT-1, in the Inner Lesser Himalaya, the Vishnugad – Pipalkoti HP, is also a reservoir based project with a 65m high diversion dam near Helong village downstream of Vishnugad. The water is to be diverted through a 13.4km long HRT to an underground power house near Hat village to generate 444 MW of power. The rocks exposed in the project area are dolomites, slates, quartzites and chlorite schists belonging to Garhwal Group. Since most of the structures are to be located underground, the only visible feature will be the 65 m high concrete gravity dam. The impounded water is to extend over a distance of 4km upstream of the dam site. Though the MCT may be encountered within the reservoir, the thrust will be located in the tail reaches with practically very little impoundment of water above the thrust. Since hard massive quartzites are mostly exposed within the reservoir, the instability problems may be of little magnitude. The debris and other loose materials are seen as patches of small accumulations which are not likely to cause any major instability problem in the area.

Dolomite beds dip 42° towards N20° W direction. Near Longsi Bridge along the project road, grayish black slates are exposed. The foliation planes of slates are dipping 35°–40° towards N10° E into the hill. Joints are present in dolomites dipping 60° towards S20°W. In slates, joint planes dip 80° towards S55°W. Dolomite beds are exposed with apparent dip of 32° towards NE. There is a variation of strike of foliation plane from top level upto river bed level. Near the river course the beds are more or less horizontal having strike N70°E – S70°W. Above 100m from the river course there occur slate beds having strike N80°W-S80°E with dip 30° - 35° towards N10°E. In the upstream of the Hyunda Bridge, at the left bank the foliation planes dip 20° towards S50°E. Two sets of joint are present in the slates - one dipping 72° towards S40°W and other one dipping 72° towards S65°E. Slates are foliated with the apparent dip of 18° towards NE direction along the section. Two sets of joints are present with apparent dip of 70° and 60° towards SW and NE directions respectively

Fig. 4.24 Dam site at Vishnugad – Pipalkoti HP

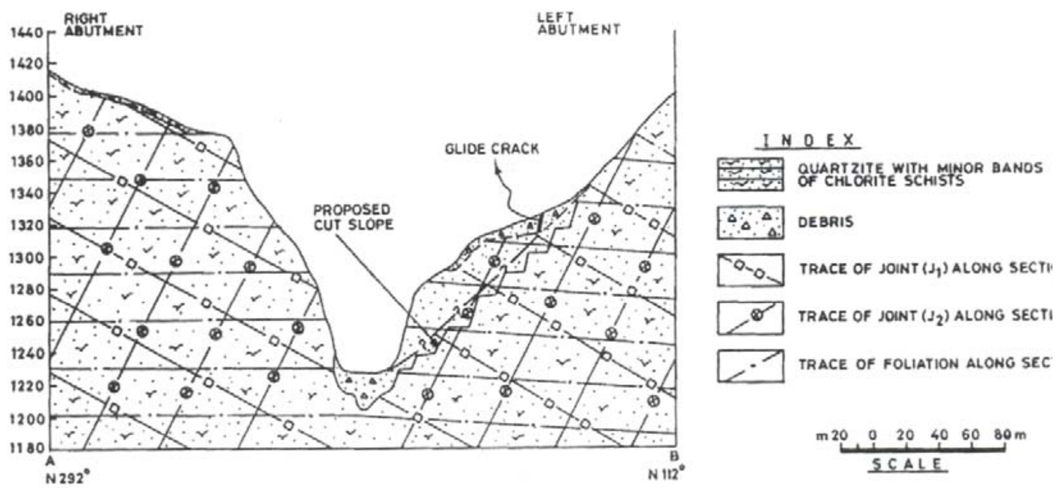


Fig. 4.25 A geological section along a profile about 50 m upstream of proposed dam axis

ii) Phata Byung HP (RoR with storage, 76 MW; Under Construction)

Located on the Geotract – 2, a 28 m high concrete straight gravity dam on the Mandakini River, just downstream of Sitapur village where the river bed level is 1610 m. The dam axis is aligned N83°W – S83°E. Based on two bore holes the bedrock is expected at about 19m below the overburden. Augen gneiss is exposed along both the abutments in the dam site. Limonitic weathered joint planes are seen in this rock unit due to seepage along joint planes. The river borne material is about 15-19 m thick.

The underground power house is located on a long terrace in between the right bank of major river Mandakini and left bank of Byung Gad, at about 100m upstream from the confluence of these two rivers. Schist/ garnatiferous schist with schistose gneiss and metabasic rocks are exposed around the power house location with very steep slope. Rocks are dipping upstream and hillside with foliation 33° - 48° in N5°E - S5°W direction with two sets of prominent joints.

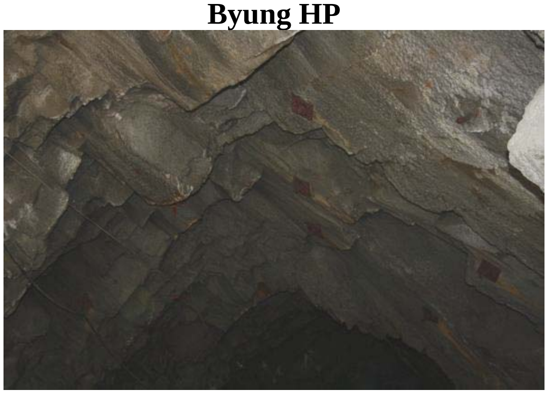
Project is located in the Crystalline Zone, rocks, the gneissic rocks, in general, except local weathered and jointed zones, Rocks are hard and compact and appear to form good base for the project components. At the dam site on both the banks, relatively sound rocks are exposed and valley is very narrow dipping upstream (Fig. 4.26).

In the tunnel as well as in the adits, gneissic rocks have not posed any major problem (Fig. 4.27, 4.28). At few places, in the sheared basic rocks may pose some problems during tunnelling.

One adit has been placed by the side of a spring. Due to tunnelling water of spring has adopted the tunnel path and has become dry. Under the prevailing conditions, no major problem is expected, However the site does not lie far off from MCT-1 and therefore needs monitoring for tectonic sensitivity. Retaining walls have been constructed at the base of muck disposal site (Fig. 4.29).

Fig. 4.26. A view of the dam site, Phata Byung HP

Fig. 4.27 A view of diversion tunnel, Phata Byung HP



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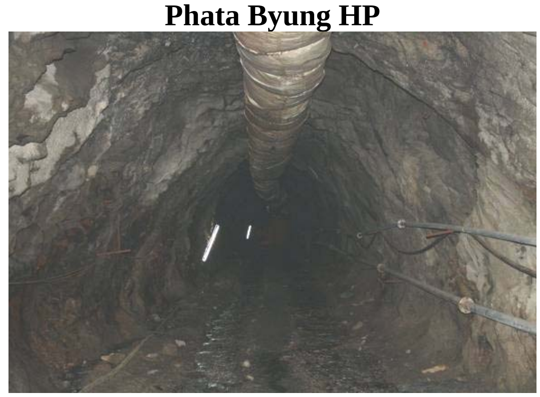


2

Fig. 4.28 Rocks at portals and in the adit/ tunnel are massive and are self supportive or have few supports of rock bolts (1). In the sheared zone (2) rocks are posing problems, Phata Byung HP

Fig. 4.29 RCC retaining walls have been constructed at the base of muck disposal site, Phata Byung HP

iii) Srinagar HP (R RoR with storage, 330 MW, Under Construction)

It is located in the Geotract 3, about 4 km north of Tons Thrust in the Alaknanda River gorge just upstream of Srinagar town. This reservoir based project includes a 65m high concrete gravity dam with reservoir extending over a distance of about 3km upstream. The water conductor system includes partly tunnel and partly open channel with a surface power house to produce 320MW of power. The major rock types exposed in the area are quartzites and metabasics mainly dolerite rocks belonging to Garhwal Group. The alignment of dam site is so chosen that the alignment falls only within the quartzites. The metabasics are present in the area in large quantity, mainly exposed at the higher levels in the dam site. Many types of quartzites are reported from the dam site with different colors. The small reservoir mainly extends over the hard, well-jointed but competent quartzites and metabasic rocks. Since rocks are mainly exposed within the reservoir with local debris at places, the draw-down conditions are not likely to cause any significant slope stability problems. However, the excavated materials from open channels and the muck from tunnel excavation have been posing major environmental problems for their disposal. They are presently disposed on the river bank without proper site selection and suitable precaution. This is causing addition of silt to the Alaknanda River throughout the year.

(II) Run of River HP

(iv) Vishnuprayag HP (RoR, 400 MW, Commissioned)

It is located and commissioned on the Geotract-1 in the Central Crystalline Zone of Greater Himalaya. In the entire area, rocks of Joshimath Formation and Pandukeshwar Formation are observed. This site is occupied by quartzites interbedded with gneisses and amphibolites. Rocks are trending N 70°E-S70° W to E-W with dip of 40° to 50° northward. Barrage site of this Run of River project is located at about 1.8 km downstream of the confluence of Alaknanda River with its tributary Khiraoganga (Fig. 4.30).

Fig. 4.30 A downstream view of diversion site, Visnuprayag HP.

Fig. 4.31 A view of Lambagarh Slide in the Palaeo-glacial deposits, Vishnuprayag HP

Fig. 4.32 Muck disposal observed in Vishnuprayag HP

The right side is a steep cliff near the barrage axis where quartzites are well exposed from river bank upwards. Here the slope has been stabilized and intake structure has been constructed. A small poundage area has developed due to this barrage. The left bank is gently sloping and is made up of fluvioglacial deposits which have been well stabilized with a number of structures.

Two underground sedimentation chambers have been constructed on the right side of the river, where quartzites are exposed. These quartzites provided good tunneling media and with the help of some support structures these chambers were constructed without any problem.

In the course of Head Race Tunnel which runs nearly perpendicular to the general foliation strike for nearly 12 km length encounters mainly quartzites, with subordinate mica schist, mica schist, and biotite gneiss with subordinate granulites and mica schist. These rocks had proved to be good tunneling media and had required nominal support structures except in the schistose zones.

Surge shaft, pressure shaft, and power house sites are located underground on the right bank of Alaknanda River near Rampur village. The rocks are generally massive gneissic and therefore, underground cavity requires only normal support.

Diversion site is considerably stable and is being maintained nicely. Slopes around the diversion site are well stabilized. Apparently due to construction of diversion structure no damage is observed at the site.

Lambagarh slide is considerably old (Fig. 4.31). This slide falls in the category of paleo – glacial deposits which consist of loose angular fragments of rocks embedded in the matrix of grit, sand, silt and clay. It is always possible that due to blasting in the area these sediments might have been loosened and during the monsoon season surface flow of water causes some flow of sediments. The muck disposal site needs protective measure (Fig. 32).

(v) Vanala (RoR; 15MW, Commissioned)

Located on the Geotract 5, on the river Nandakini the Vanala small hydro project envisages the utilisation of the hydraulic drop and discharge available in the Nandakini River between EI 1202.5m asl and 1056.00 masl. The area is encompassed by terrace deposit on both the banks of river (Fig.4.33). Thick fluvioglacial deposits which consists of boulders, cobbles, pebbles of schist, quartzites, gneisses embedded in course sandy matrix (Figs. 3.33 and 3.34). 160 m long approach channel lies in river bed hence it has been reinforced with cut & cover structure /box type to safeguard it against river erosion. Powerhouse is located on the right bank river terrace. Power channel passing through talus/slope wash terminates into Surge Tank located on shallow depth of alluvium underlain by bedrocks.

Project is of small capacity and a limited construction activity was involved. No major adverse impact is noted except that slopes have been erroded at many places due to construction of platform for head race channel (Fig. 4.35).These slopes are under restoration proccess.

Fig. 4.33 A view of diversion site, Vanala HP

Fig. 4.34 View of intake channel and desilting tank, Vanala HP

Fig. 4.35 Due to cutting of platform for head race channel slopes have been eroded at places, Vanala HP

(vi) Alaknanda HP (RoR, 300 MW, Under Construction)

This project is located 3 km downstream of Badrinath Shrine and is the uppermost project on Alaknanda River. Geologically located in the Geotract-1 in the Central Crystalline zone, it is a run of river development scheme on Alaknanda River with no storage even for diurnal peaking, and is located upstream of the operating Vishnuprayag Project. Major components of the project are underground structures.

In the project area, the Pandukeshwar and Badrinath formations of the Central Crystallines are exposed. The Badrinath Formation is well exposed around 2.5 km upstream from Hanumanchatti overlying the Pandukeshwar Formation and continues up to about north of Badrinath. In general, its foliation dips at angle 60° to 65° due N 340°. The Pandukeshwar Formation is well exposed around the power house site. The general strike direction is E-W with dips varying from 45° to 60° towards north. Two sets of joints one striking N–S with 70° to 85° dips towards east and other one striking E–W with 45° to 55° dips towards north are developed.

The right bank adjacent to river valley is occupied by thick talus and fluvioglacial material. The extent of its thickness has been investigated through drill holes. The overburden deposits are old fluvioglacial deposits. There are semi-consolidated material comprising blocks of rocks in sandy and silty matrix. In general, it appears to be stable. However, vulnerable blocks of rock have to be removed for which adequate slope protection provision has been envisaged to protect this slope from the instability during the construction activities. As such with the coming up of barrage and HRT intake structure together, it will provide very good toe support. The hill slope behind this overburden deposit and above is made up of very strong, stable gneiss rock.

The left bank of the barrage site which is mainly occupied by fluvioglacial deposits has gentle and stable slope right up to the national highway which is passing through this bank. Further upwards, the hill slope is made up of strong and stable gneiss bedrock.

The desilting galleries will be situated within the strong gneiss rock of the Badrinath Formation. The long axis of the galleries is aligned at about 60° to the strike of the foliation joints which is generally stable. The dip of the foliation joints is generally between 30° and 45°. The medium is more favourable for underground tunnel/ cavern.

From the intake, the headrace tunnel passes through the mountain range on the right banks of Alaknanda River having adequate top and lateral rock cover. Along the route of the headrace tunnel the vertical cover ranges up to 500m height and the area is free from any habitation. From the intake portal up to chainage 1700m the tunnel will be situated in the strong to very strong gneiss rock of the Badrinath Formation. Along this length the tunnel route is aligned at about 60° to the strike of the foliation joints which is generally favourable for stability of underground works.

From chainage 1700m up to the surge shaft the tunnel will be situated in the strong quartzite rock of the Pandukeshwar Formation. Along this length the tunnel route is aligned at between 70° and 85° to the strike of the foliation joints which is generally favourable for stability of underground works.

Over all, the tunnelling media being strong, bed rock are favourable to tunnel alignment. It is expected to be generally free from any major tunnelling problems.

Proposed location for the portal of the downstream construction adit, the surge shaft, the high pressure inclind shafts, the power house and tailrace tunnel are located mainly on the hard and strong quartzite & gneissic rocks. These rocks show the foliation dip of 35° to 45° towards N 335°. This construction adit will be entirely within the quartzite of the Pandukeshwar Formation. The medium is suitable for underground construction.

Geological mapping of the outcrops along the route of the tailrace tunnel shows that the foliation dips approximately 45° towards the north. The tailrace tunnel crosses beneath Khirao Ganga at an elevation of about 2295m. Drilling and Seismic refraction survey at this location have indicated that the elevation of the rock surface buried beneath the overburden is about 2360m, so the tunnel can be expected to have a minimum rock cover of about 65m.

The project area is located within Zone –V of seismic zoning map of India. The project area, lies north of MCT whose closest distance from the project is estimated to be about 15 km. It is located within the stronger rocks like gneiss and quartzite bed rock. Hence is little susceptible to any major slope failure.

The geological set up is good for the execution of the project. Rocks all over the project site are hard, compact, and massive and will provide good tunnelling media. The alignment of tunnel and the structural discontinuities are also favourable for the development of the project.

At the diversion site massive rocks are exposed, whereas all along the walls of valley, series of isolated dumps of debris are found which may fail locally specially during blasting in the massive rocks.

Power house location is on the right bank of the river (Figs. 4.36 and 4.37), and as such the road and traffic will not be affected by the construction activity. At power house location also, the rocks are very good for underground structures. A large area has been acquired for muck disposal (Fig. 4.37). Geologically, the area is not expected to experience adverse impact due to construction of the project.

Fig. 4.36 A view of power house site for the proposed Alaknanda HP.

Fig. 4.37 Large area has been acquired for muck disposal, Alaknanda HP

(vii) Khiraoganga HP (RoR, 4 MW; Under Construction)

This run of the river HP is located on the Geotract-1, at the confluence of Khiraoganga with the Alaknanda River just by the side of power house location of Alaknanda HP. This small project (4 MW), with very small length of HRT and open Power House has a geological set up similar to that of Alaknanda HP (Fig. 4.38). It is not expected to face any major slope failure problem.

Fig. 4.38 A view of the site of power house location, Khiraoganga HP

(viii) Bhyunderganga HP (RoR, 24.3 MW; Under Construction)

Geologically located in the Geotract-1 in the Central Crystallines Bhyunderganga Small Hydropower Project (24.5 MW) is located at Govind Ghat on Bhyunderganga River. Power house is located on the left side of Alaknanda River over a terrace made up of slided mass (Fig. 39). The diversion structure is located at Jungle Chatti on the way to Hemkund Saheb.

The project area falls within the Joshimath and Pandukeshwar formations of Central Crystallines. The crystalline gneiss, and quartzite rocks are massive, hard and compact and are good tunnelling / construction media.

At the proposed diversion site the river has a general NE-SW course. The bedrock is occupied by overburden. Small river terraces are present on both the banks. Bedrock is exposed near the river on the left bank as well as above the river bed. On the right bank, it is observed to occur at much higher level. Colluvium is present between the rock and the terraces on both the banks. Bedrock depth under the river bed seems to be in the range of 10 m. It has been explored by pit and shallow drill hole in the centre of river bed on the diversion axis, to confirm bedrock level in order to evaluate possibility of an economic and safer foundation on the bedrock. Considering heavy traction load, the trench diversion has been substituted by a boulder type weir.

Desilting tank is proposed on the left bank of river. There is sufficient space to accommodate this structure safely. Bedrock may be deeper at this location site than at the diversion axis. The foundation can be done on the boulder rock as well. More groundwater is expected in the lower part of the overburden at this site.

The power channel passes mostly over the fluvial terrace deposits and fairly stable colluvium upto station 600 m from the diversion axis and over the colluvial and talus deposits thereafter. Over the terraces it is likely to be fairly strong and no significant problems during construction period are expected.

In most places the debris material has a high void ratio, low consolidation with sandy matrix and the higher cut slopes. These areas need proper treatment to avoid chances to destabilize some small to medium size slides. The construction upon these deposits should consider the compositional variation of the deposit and maximum height and angle of the expected cut. Considering the topography, composition and compaction of the overburden and small cross section of the channel, the excavations are, in general, expected to be stable at 30° to 40° angles for long periods. Variations from these values will occur at some places locally due to heterogeneity of the overburden. Site specific study and investigation have been carried out in the critical reaches to ensure long term stability.

The natural slopes are relatively steep, especially below the proposed alignment, and composed of colluvial debris. The excavation in this part should be attempted carefully. The channel should be shifted towards hill side where the upper slope is more gentle and made sufficient water tight to minimise continued water saturation in this zone. Drainage structure has been designed on overburden since bedrock is expected to be lying at deeper level.

Bouldery colluvial deposit is present at tunnel intake site. The diameter of the boulders varies between 1 to 5 m. The matrix is almost absent at the surface and may be low even at depth. An exploratory pit drill hole has been made to understand the soil condition to view of stability of the rock. Bedrock depth is likely to be high, probably of the order of 30 m at this location. This structure of the discharge will therefore have to be founded on overburden. Occasional small rock falls occur at this site. The bore holes for the tunnel have been made in horizontal, vertical and axial direction, both, upstream and downstream. Inclination of bedrock formation is 23° towards the tunnel lining and will adapt very good to the inclination of the tunnel. The complete tunnel is expected to be in stable structure.

A vast river terrace deposit with agricultural areas dominates the power house site. Bedrock is expected to be lying at a depth of over 10 m below the surface at this site and it is suggested to lay the foundation of the power house inside the bedrock behind the terrace deposit itself. The bed slope will need small retaining wall, or boulder pitching. Occasional large sized boulders are present in the terrace material. They can be controlled blasted to make the site suitable for engineering construction.

The proposed project site lies in Higher Himalayan region and falls in Seismic Zone V. No structural features suggesting recent crustal adjustments have been identified in the MCT zone which is the only major feature in the Higher Himalayan region. This thrust does not pass close to the proposed project site. Therefore currently the area is expected to be free from any seismic hazard. This is valid for intake and tunnel as well.

On the inspection of the site and the description provided by the representative of M/S Super Hydro Pvt. Ltd. it seems that they have made considerable changes in the project set up. Location of diversion and power house seems to have been changed without having any detailed geological investigations at the site.

The changed location of diversion site is good and will not pose any problem. At the same time the construction of desilting tank and tunnel will also not make any significant impact.

Geologically the rocks are good for tunneling and construction purposes, but the location of power house has not been selected properly. Terrace for power house is made of the rock fall from the escarpment face of the hill. Three sets of joints on the rock face have created wedges which keep on falling (Fig.4.40). It is possible that due to blasting during the construction of the project, these wedges may become more active and fall.

Fig. 4.39 A view of power house site, Bhyunderganga HP

Fig. 4.40 Joint sets have formed wedges which keep on falling, Bhyunderganga HP

Before deciding for the location of power house at this site the developer should have carried forward detailed geological investigations at the site including slope stability studies. During construction stage the site is likely to face considerable problems.

ix) Tapovan -Vishnugad HP (RoR, 520 MW; Under Construction)

Located on the Geotract 2, the Tapovan-Vishnugad HP is a run of river project on Dhauliganga River, which is a major tributary of Alaknanda River. The barrage will be located on the Joshimath–Malari road in Chamoli district. The project envisages the construction of barrage near Tapovan with a 11.6km long HRT to an underground power house located on the left bank of Alaknanda River (Fig. 4.41) with a drop of 518m. The HRT is being excavated by Tunnel Boring Machine (TBM). It is being used for the first time in Uttarakhand Himalaya. The rocks present in the project area in Dhauliganga and Alaknanda valleys are medium to high grade metamorphic rocks, i.e.

augen gneiss, schist and quartzite with some basic intrusions at places. While the rocks on the right abutment are predominantly augen gneiss, the rocks on left abutment are predominantly schist. The reservoir environment is characterized by stable slopes of metamorphic rocks. No major landslide due to construction activity is observed. The small reservoir mostly falls within the rock slopes with debris present locally in patches. Though the valley is narrow and V-shaped in nature, the small reservoir in the valley will have little or no perceptible impact on the stability of the slopes due to draw-down conditions. The tunnel is to pass through gneisses, schistose rock which are fractured, sheared and jointed at places. The water is flowing from the tunnel portal (Fig. 4.42). The muck is disposed on the slope, however, it is supported by retaining walls (Fig. 4.43). It is likely to face some problems with respect to its construction, support and water seapage. In addition, the project lies close to MCT-1 in the Seismic Zone–IV. It, therefore, needs monitoring for tectonic/seismic activity.

Fig. 4.41 A View of Developments at power house site, Tapovan Vishnugad HP.

Fig. 4.42 A view of water flowing from tunnel portal

Fig. 4.43 A View of muck disposal site, where a number of retaining walls have been constructed.

x) Birhi Ganga – II HP (RoR, 24 MW, Under Construction)

It is located in the Geotract-3, in the Birahi Ganga River near the village Biyara. The rocks are mainly limestone with thin inter laminations of slaty limestone. Dolomite, chert marble and thin bands of quartzite belonging to Pipalkoti Formation of Garhwal Group of rocks are the main rock types in the area. The limestone as exposed on either flank of the river is fresh and hard. Left bank and right bank of the river at the proposed site has steep faces with limestone exposed whereas the river bed and the right flank are covered with overburden predominantly consisting of fluvio-and fluvio–glacial debris. Fluvial terraces are also present in the river bed at two levels. In the area rocks of Calc Zone of Chamoli are exposed.

A 25 m long raised gated weir was originally proposed across the Birhi Ganga River near Biyara village. Approach channel of about 15m is required for the above from the diversion dam to the desilting tank inlet of the tunnel. The area of the approach channel and desilting pond upto the tunnel inlet is covered with river terrace, consisting of fluvio-glacial debris. The necessary desilting basin may be located within the length of approach channel.

The terrace material is formed of loosed boulder embedded in sandy matrix. The approach channel and desilting basin may be designed with proper slope keeping the heterogeneous nature of excavations into consideration.

D-shaped head race tunnel of 3m height and 3m width and of 5.065 km length is proposed to divert 13.5 cumecs of river water to the power house location. The tunnel intake is proposed at RL 1333.28m and exit at RD 5065m. The tunnel is aligned in N9° W direction from RD 0.0 to RD 234m. A kink is provided at RD 234m and then tunnel runs in N58W direction upto RD 2.029km. Further it takes a small turn for the next 2.8 km upto surge shaft.

The limestone with thin inter laminations of chert, marble, carbonaceous shale and quartz belonging to Pipalkoti Formation of Garhwal Group of rocks is expected to be the tunneling medium. The area falls in the Seismic Zone-V. The rock formations were subjected to tectonic disturbance causing folding and refolding in several stages in the geological past, resulting in the formation of anticlines and synclines and shears.

Small pockets of weathered shear seams may also be met within the limestone. These shear seams, if they access to ground water through stream beds present on the ground surface can contribute to seepage in the tunnel to some extent. Otherwise, major portion of tunnel length will be in dry condition.

A vertical surge shaft was proposed earlier at the end of the tunnel at RD 5.35km, where the ground level is at about RL + 1400m, which amounts to 50m of vertical rock cover over the tunnel grade. The vertical shaft can be excavated which may be kept open to sky within the valley to take surge effects in the tunnel more effectively. Necessary protective measures are to be taken in the stream bed in case of the surge shaft is located there. The limestone can withstand vertical excavations, but three meter wide benches may be provided at 20m intervals. Systemic rock bolts and steel fibre reinforced shotcrete may be provided as support system.

The hill slope is too steep to provide a surface penstock, both for construction and maintenance. The disturbance to the surface for the works can trigger instability over a period. Considering these aspects, an inclined shaft is proposed for the penstock. It is aligned well within the rock mass giving adequate side cover and limestone can withstand such excavation. The bottom of the shaft will be horizontal to accommodate trifurcation and branches. An adit is also proposed for constructing this shaft parallel to the works of power house without interference with each other. Form geological consideration no difficulty is anticipated in executing this pressure shaft.

A surface power house is proposed on right bank of the Birahiganga River. Valley is covered with fluvio-glacial debries, where large boulders are embedded in sandy matrix. Rocky natural bench formed of limestone is identified on right bank of the river at about 10m height above river bed, which has sufficient length and width and the power house can be located conveniently.

The barrage is located in wide section of the valley (Fig.4.44) where fluvial deposits exist along the banks of river. In the course of tunnels, shear zones will be encountered, which will cause greater concern during the tunnelling (Fig.4.45), also a perinnial Nala, passes through it (Fig. 4.46). Fragile nature of rocks will require considerable support in the tunnel. Power house being constructed below this site further supports its suitability (Fig. 4.47).

Fig. 4.44 A view of barrage site, Birahiganga II

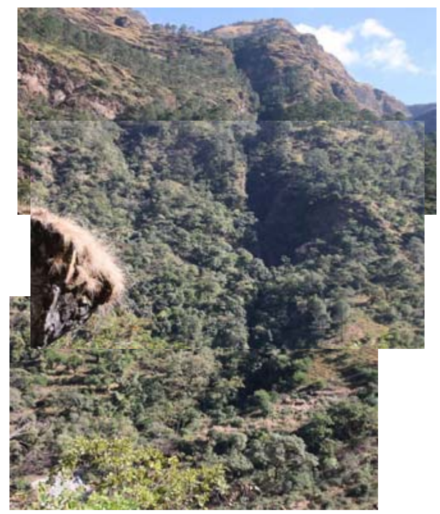


Fig. 4.45 A view of major shear / fault plane in route of tunnel, Birahiganga

Fig. 4.56 A view of perennial nala in route of tunnel, Birahiganga

Fig. 4.47 A view of power house under construction, Birahiganga

xi) Tamak Lata HP (RoR, 250, Under Construction)

Tamak Lata HP is located in the Central Crystalline Zone of Geotract I where massive gneissic rocks found exposed.

For impoundage and diversion of water, the barrage shall be constructed just upstream (160m) of the confluence of Tamak (Wauti Gadhara) with Dhauliganga.

At the barrage site along the left bank, the rock is expected to be available below thin cover of debris (2 to 5m). On the right bank, the exposures of bed rock are not observed and the area is mostly represented by fluvioglacial, terrace and colluviums deposits. On the left bank just downstream of barrage axis the bed rock is exposed and is represented by quartzite with inter bedded schist bands which dips at 25° to 35° towards NE (upstream) direction. The foliation joints are very prominent having spacing 5 to 50cm.

The intake and approach channels shall be located at the right bank on fluvioglacial and terrace deposits of the river. An open cut shall have to be made in fluvioglacial/terrace and colluvium deposits. Thickness of these deposits is not known but anticipated to be considerably high and there are almost no chances of encountering bed rock within reasonable depth. Slopes of the intake foundation shall also be in overburden and would need adequate protection.

An underground desilting chamber having the dimensions, 16m (W)× 14m (H) × 170m (L) for removal of particles 0.25 mm and above shall be located on the right bank of the river about 300m from the proposed intake. It shall be excavated in fine grained thinly bedded quartzite with inter bedded schist bands of Pandukeshwar Formation of Central Crystalline Group of rocks. Dips of the bedding plane are of order of 25° to 35°.

11.2 km long and 6m dia (fin) modified horse shoe head race tunnel shall be located on the right bank of the river and aligned roughly in NE-SW direction nearly parallel to the river flow. It shall be excavated through a sequence of granite gneiss, banded gneiss, biotite schist, muscovite schist with intermediate quartz veins and quartzite. Overall foliation dips in the area of the order of 25^0 to 35^0 towards north direction. Thus orientation of the HRT alignment is moderately favorable with reference to regional strike of the rock. Rocks are moderately jointed.

Power house and transformer caverns shall be located mostly within the rocks of the Joshimath Formation comprising augen and porphyroblastic gneiss, banded magmatite, garnet schist, kyanite schist, calc schist and quartzites. Topographical cover over this structure is of the order of 130-200m. Difficulties in excavation in such formation is controlled by the orientation, intensity and characteristics of structural features and shall depend on the orientation, intensity and characteristics of structural discontinuities, influence of underground water and in situ stresses. Keeping in view, the presence of hot spring in vicinity (about 8 km downstream), the possibility of encountering geothermal gradient in underground excavations needs due consideration and assessment. The dip of rocks varies 30^0 to 45^0 towards NE direction.

Similar geological conditions can be expected in the Surge shaft and Pressure shaft excavation. Here of course, the variation of the topographical cover vis-à-vis depth shall influence the rock mass quality and its response to the behaviour of excavation.

Water impoundage shall be extending along the valley of Dhauliganga. It is having steeper valley slopes. This is not likely to pose any problem of water leakage from the reservoir. Foliation of the bed rock dips upstream which is a favourable factor for the stability of the valley slopes along the reservoir rim

Barrage site and intake structure are not properly selected (Fig 4.48). Tunnel from intake point will pass just below the village which is located on the dip slopes (Fig. 4.49). Blasting and cutting for roads etc. may cause planar failures.

Power house is located on the upstream side of dam of Tapovan Vishnugad project. It need to be relocated as per new norms of MoEF.

Fig. 4.48 A view of barrage site, Tamak Lata HP

Fig. 4.49 Tunnel will pass below the village which is located on dip slopes, Tamak Lata HP

B Bhagirathi Valley Basin

(I) Reservoir Based HP

In Bhagirathi valley, a series of run of river projects are located in the upper reaches of the river, while in the lower reaches dam projects are reservoir based.

i) Tehri dam Project Stage-I (RB, 1000 MW; Commissioned)

Geologically located in the Geotract 4 in the Outer Lesser Himalaya at the confluence of the Bhilangana River with the Bhagirathi River, the 260.5m high Tehri dam is a 260.5 m high rock-fill and one of the biggest projects of Himalaya with power production of 2000MW total installed capacity. The first phase work of 1000MW power has already been completed and is in operation for the past few years The area lies between the southerly dipping North Almora Thrust (NAT) in the north and the northerly dipping Main Boundary Thrust (MBT) in the south. The NAT separates the Almora cryctalines in the north from the Garhwal Group in the south. The MBT forms a zone exhibiting several thrust slices. The site lies at about 10 km south of NAT. The area is tectonically active and falls in the Seismic Zone-IV. The design of the dam is accounted for this Seismic activity. The details are given in Chapter-5. Downstream of Dharasu, the Bhagirathi River has a wide valley and enters a gorge only near Tehri and the dam is located within this gorge. The valley slopes are characterized by typical phyllites of Chandpur Formation (Fig. 4.50, 4.51). The dam site exhibits mainly four lithological types:

(i) Phyllitic quartzite massive (PQM) - Grade I
(ii) Phyllitic quartzite thinly bedded (PQT) – Grade II
(iii) Quartzitic phyllite (QP) – Grade III
(iv) Sheared / schistose phyllite (SP) – Grade IV

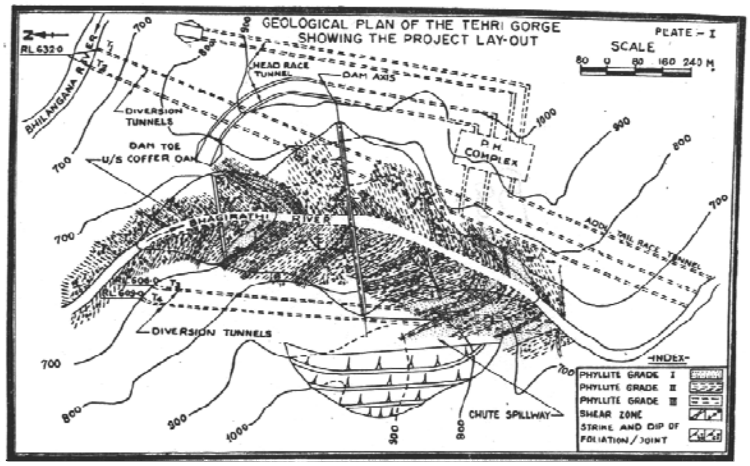


Fig. 4.50 Geological plan of Tehri Gorge showing the project layout

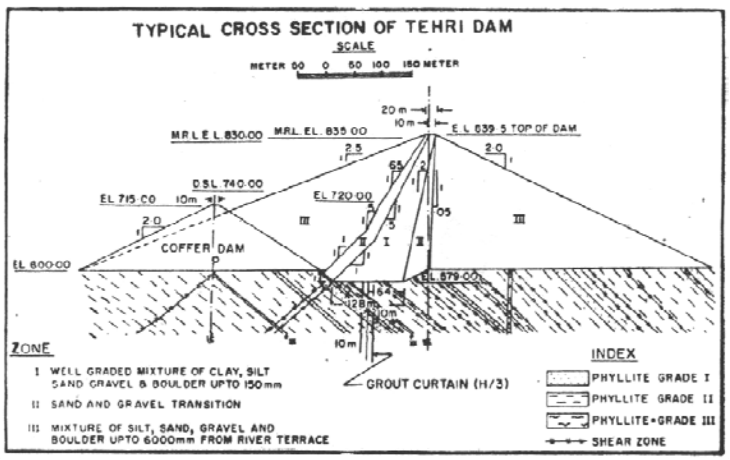


Fig. 4.51 Cross section of Tehri Dam.

On the basis of relatively argillaceaous or arenaceous composition of the bed units and their physical competence, the rocks have been grouped in four categories, namely Grade I, Grade II, Grade III and Grade IV. The phyllites Grade I are phyllitic quartzite and are the most competent rock units followed in decreasing order by the phyllite Grade II, phyllite Grade III and schistose phyllite Grade IV respectively. The argillaceous phyllites with Grade III is the least competent rock containing more of sheared materials (Fig. 4.50 & 4.51). The reservoir of Tehri dam is occupied by phyllite rocks and huge deposits of river borne material (RBM) along the bank of the river. The reservoir extends over a distance of 40km in Bhagirathi valley and 25km in Bhilangana valley. During reservoir operation and the associated draw-down conditions, the rim area of the reservoir has faced many small and shallow landsides (Fig.s 4.52 – 4.57). The rim area landslides are also observed near many villages such as Raulakot, Kangsali, Motna, Nakot, Bhainga, Chaundhar and Jangi. These surfacial landslides look to be more active and progress upslope at places. Anbalagan (1993) provides the example of Bhakra dam, another big dam in Himalaya, where the reservoir rim area showed instability during the initial years of operation for about 5-10 years, but stabilized later on due to standing water conditions.

The retaining walls have been provided to retain the slope at a number of critical places (Figs. 4.58 & 4.59). The Tehri dam reservoir is in the initial stages of operation and the tendency of slope instability will get balanced within few years of operation of the reservoir.

Fig. 4.52 Left bank of Bhilangna showing shallow slope failure at the reservoir rim,Tehri HP

Fig. 4.53 Effect of drawdown of reservoir – post monsoon slide of debris cover (Sept. 2010, Tehri-I HP)

Fig. 4.54 Demarcation of MRL and slide along rim-Bhilangna valley, Tehri-I HP

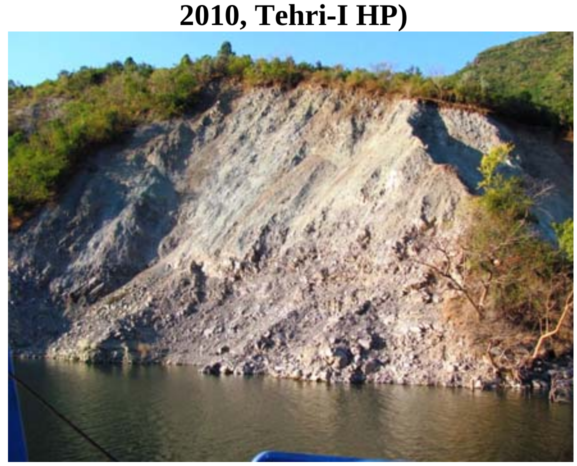


Fig. 4.55 Slides due to drawdown, thick debris cover towards Bhilangana valley part of Tehri reservoir, Tehri-I HP

Fig. 4.56 Full reservoir view–Bhagirathi valley–showing MRL and small landslide

Fig. 4.57 Slides close to reservoir rim, Bhagirathi, Tehri-I HP

Fig. 4.58 Slopes suported with retaining wall in TRT, Tehri-I H.P.

Fig. 4.59 Muck dumps –retaining walls, Tehri HP

ii) Koteshwar Dam (RB, 400 MW; Under Construction)

Located in the Geotract 4 in the Outer Lesser Himalaya, at about 18 km south of North Almora Thrust (NAT) in the Seismic Zone-IV. It is at about 15 km downstream of the Tehri on the Bhagirathi River, the Koteshwar dam envisages the construction of a 97.5m high concrete gravity dam with a power potential of 400MW. The dam construction has just been completed and the filling of the reservoir may be started soon. The dam (Fig. 4.61) as well as the reservoir (Fig. 4.62) is located on the phyllites of Chandpur Formation downstream of Tehri dam (Fig. 4.63). Rocks of Chandpur Formation of Jaunsar Group are exposed at the dam and powerhouse site. Lithologically they consist of slaty phyllites. The lithological model adopted at Tehri is also applicable here. At the dam site mainly interbedded PQM (Phyllitic quartzite massive) and PQT (Phyllitic quartzite thinly bedded) are exposed. The power house is occupied by predominantly PQM rocks, whereas the switch yard area is entirely on RBM.

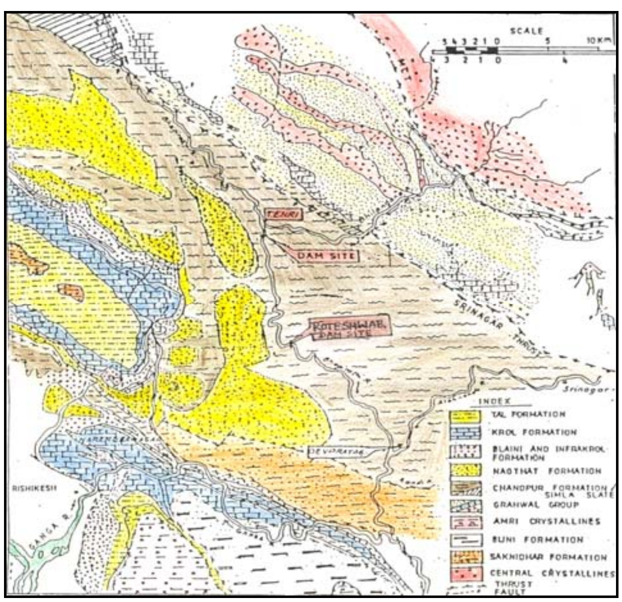


Fig. 4.60: Geological map of Tehri and Koteshwar dam sites

The bedding surface shows a great variation on either abutment, i.e. on the left abutment the bedding plane is dipping 55° - 75° / N-N20° W where as on the right abutment it is dipping 48° -70° 80°E - S30°E. This reversal in the dip direction is attributed to the antiform closure identified at the site which is plunging towards downstream direction. The primary foliation is dipping 38° - 45° / N 40°E – N70°, i.e. towards downstream direction.

The Quartzitic phyllites called Grade II phyllites are mostly exposed in the dam site with minor bands of Phyllitic quartzites called Grade I phyllite. The reservoir extends over a distance of 20km. The reservoir rim area is mainly constituted of phyllites, rocks debris and river borne materials (RBM) (Fig 4.61). The stability analysis of the entire reservoir area was carried out considering individual slopes with reservoir water at the toe (Anbalagan *et al.*, 2010). The rock slopes generally show better stability of slopes. However, wherever shallow debris are present, they show major instability problems. The approach road from Tehri to Koteshwar also may show sinking effects due to presence of thick debris in the rim area of the reservoir. Near dam site area the draw down effects seem to affect the stability of the road and the office building nearby. In general, the major landslides are not likely to take place, as the reservoir filling may cause only some shallow landslides in the area.

At the site, Bhagirathi River runs south-westerly and has asymmetric valley profile with steeper (55° -70°) left bank slopes which are rocky, and the gentler (45°-50°) right bank slopes which are covered by thick river borne material (RBM) of terrace. The right bank of the Bhagirathi River is more or less a dip slope and hence susceptible to landslides during draw-down conditions of the reservoir. On the other hand, the left bank slopes are steep with foliation dipping into the hill. As the left bank represents the strike section of the rocks, this slope is comparatively more stable.

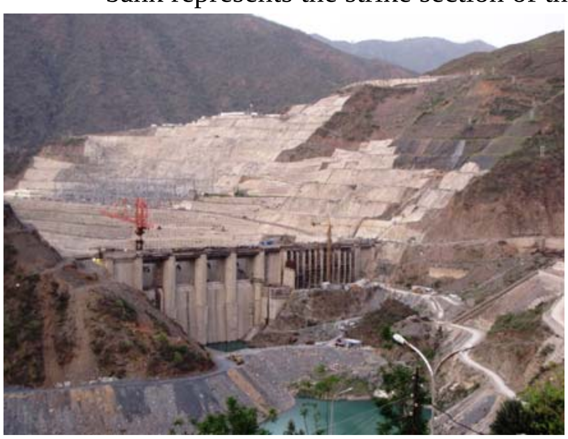


Fig. 4.61 Koteshwar dam-with reinforced slope, Koteshwar HP

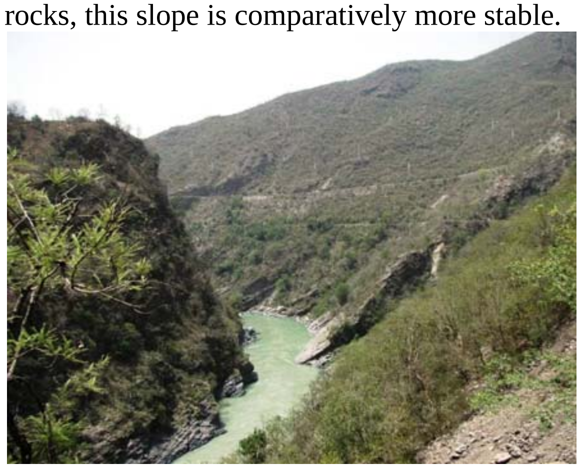


Fig. 4.62 Reservoir site of Koteshwar dam (rocks, dip in to the hill on the left bank, Koteshwar HP

II Run of River HP

iii) Maneri Bhali HP Stage I (90 MW; Commissioned)

Geologically located in the Geotract 3 in the Inner Lesser Himalaya on the Bhagirathi River, the Maneri Bhali Stage I HP is also a run of river project, which consists of a diversion dam of 39m height to divert water along a

14.28km long Head Race Tunnel to a surface power house at Uttarkashi with an output of 90MW of power. The project is in operation since 1982. The dam is located across an epigenetic gorge on quartzites intercalated with chlorite schist bands. The quartzites are dissected by a number of shear zones and shear joints. Since the construction of the dam has impounded water behind it, the reservoir rim area initially witnessed instability of hill slopes during draw down conditions. However, in the course of time all the unstable slopes have been stabilized and at present the reservoir rim shows no visible instability of hill slope in the form of active landslides. The surface excavations for dam and power house, which were treated with shotcreting and grouted anchors have been stabilized well and pose no problems to the environment.

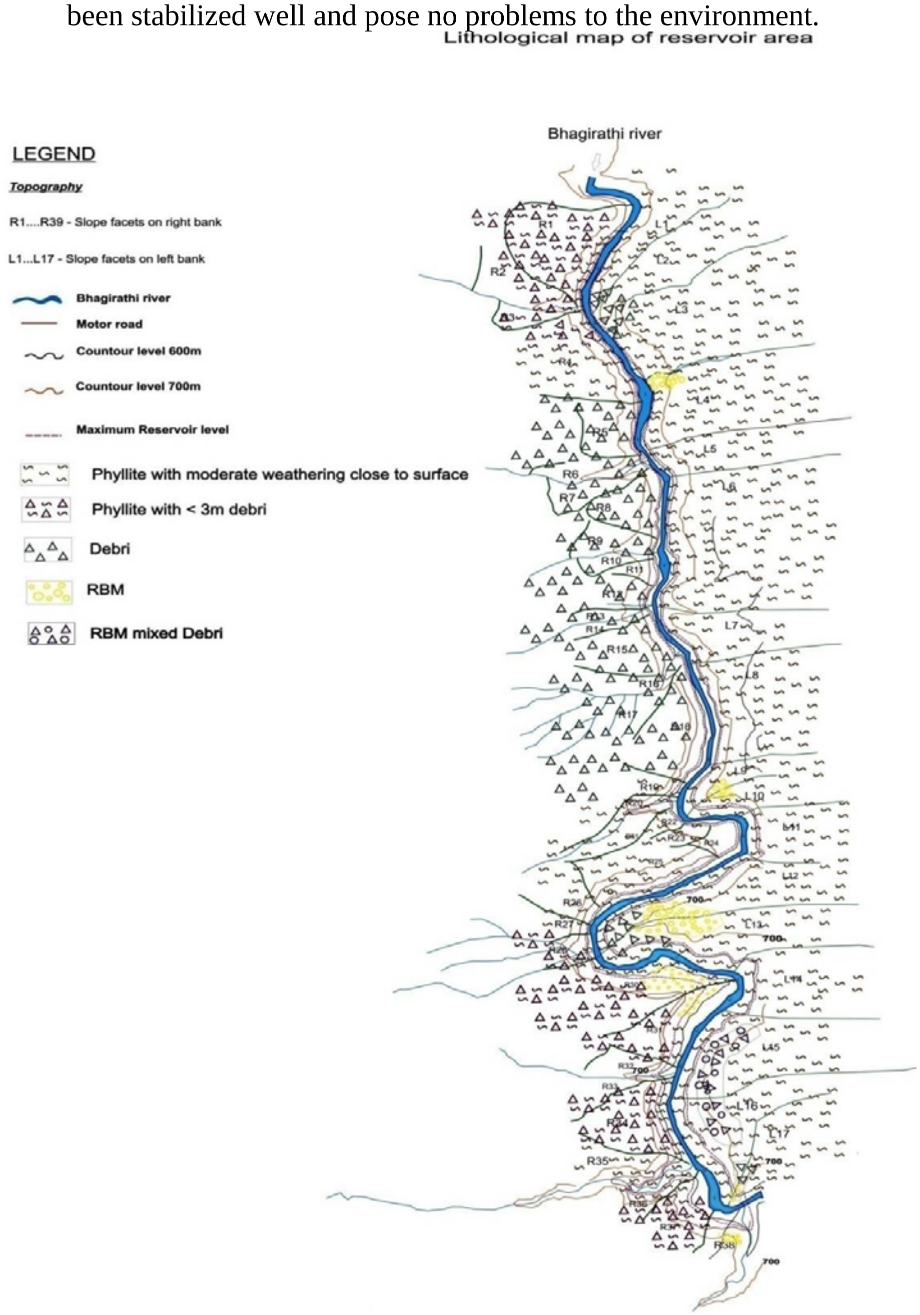


Fig. 4.63 Lithological map of Koteshwar Reservoir.

iv) **Maneri Bhali HP Stage II (RoR, 304 MW; Commissioned)**

Located downstream of Maneri Bhali Stage-I, in the Geotract 3 in the Inner Lesser Himalaya on the Bhagirathi River, the Maneri Bhali Stage II HP is also a run of river project, which consists of a barrage to divert water through Head Race Tunnel (HRT) to a surface power house at Dharasu with an output of 304 MW of power generation. The project is in operation since 2007.The rocks exposed at the project site are mainly quartzites of Nagthat-Berinag formation and phyllites of Chandpur formation belonging to Jaunsar Group (Fig. 4.64). While rocks of Nagthat-Berinag formation are exposed at the barrage site, Chandpur phyllites are present in the power house area. The HRT passes through quartzites in the initial reaches and, phyllites are encountered in the later portions. The reservoir operation of three years has resulted in a number of small shallow landslides due to draw down conditions. These landslides will get stabilized within few years due to still water conditions existing in the reservoir as in the case of Maneri Bhali stage I project due to following reasons:

a) The standing water provides toe support for the slope above
b) In the still water condition, the slided materials are carried out and hence provide toe support for the materials lying above.
c) The slope above tends to get flattened with sliding down of materials and getting accumulated at the bottom.

Fig. 4.64 Reservoir, Maneri Bhali-II HP

v) **Bhaironghati HP (RoR, 381 MW, Under Construction)**

Geologically located in the Geotract 1 of Greater Himalaya on the Bhagirathi River, the Bhaironghati HP is run of river project which is planned to utilize a drop of 2615m potential with a barrage as a diversion structure. The project is under construction in future. The rocks exposed at the site include various types of gneisses and schistose rocks. Intrusives in the county rock are represented essentially by granite – gneiss, with subordinate bands of schists, quartzite, phyllite and amphibolite. These rocks generally dip 45° – 50° northward. The right abutment is predominantly schistose in nature, interbanded with gneissic rocks. The rocks are highly weathered and suitable investigations are required to be carried out to identify the extent of weathering. The left abutment is more steep and constituted of hard gneissic rocks with minor bands of schists that are lenticular in nature. Just downstream of the dam location site, pegmatite dyke of about 8 m width occurs. Alluvial and gacio-fluvial deposits occupy the river bed area. The Head Race Tunnel would be driven at angle of 20° – 30° with respect to the strike of the rocks.

In view of barrage as diversion structure, the reservoir to be formed will be very limited in height. Since predominantly gneissic rocks with foliation oblique to the valley slope are exposed on the banks, slope instability problems are likely to be less in the reservoir area. In view of steep river banks in the dam area, the stability problems due to cuttings of slopes by blasting may have to be tackled in a systematic way. The road construction on steep hill slopes may face problems of instability, at places.

At the site, tourmaline granite traversed by pegmatite veins is exposed on both the banks of the river upto a height of nearly 60-70m. At this height, both the banks will have detached/transported blocks of rocks with soil. Both the banks of the river are covered with forest with less exposed rock along the alignment of the dam. Dumping of excavated earthmass in this area is a serious cause of concern. Necessary steps for proper dumping need to be taken.

The site lies about 10 kms north of MCT-II. Besides this thrust, there is a nearby zone of normal faulting with splays, known as Kaurik fault system (KFS). The area is tectonically active and falls in the Seismic Zone-IV. The region has experienced many earthquakes in the past. Therefore the area needs continual seismic monitoring.

vi) Loharinag-Pala HP (RoR, 600 MW; Under Construction)

Located geologically in the Geotract 2 at about 5 km south of MCT-1 on the Bhagirathi River, the Loharinag-Pala HP is run of river project which utilizes a drop of 482m with a barrage as a diversion structure. The project is in construction stage with an output of 150 X 4MW of power. This project is also located within the Higher Himalayan Crystallines, consisting of quartz felspathic and biotite gneiss, mica schist, metabasics and migmatites. Most of the project units are planned within the hills including power house except the barrage and a small reservoir. In view of small height of the reservoir extending for a distance of about an half a kilometre mainly through the dense and hard gneissic rocks on the slopes, the slope instability problems are likely to be of small order and may cause little geo-environmental problems. No major landslides are observed due to underground and surface constructions. However, the road construction on steep hill slopes may face problems of instability at places. It falls in the Seismic Zone-IV. Also, it lies close to MCT-1, in a zone which is tectonically sensitive and need continual monitoring for seismic activities, specially the footwall of MCT-1.

vii) Pala – Maneri HP (RoR, 480 MW; Under Construction)

Located in the Geotract 2 of Himalaya on the Bhagirathi run of river, the Pala – Maneri HP is a run of river project with a barrage as a diversion structure. It lies on the rocks of central crystallines and the Garhwal Group which is included by granite and basaltic rocks. The gneissic rocks lie below 25.3 m of alluvium in the river bed. On the northern side, the barrage and a part of Head Race Tunnel (HRT) are located within the Greater Himalayan Crystallines, consisting of quartz felspathic and biotite gneiss, mylonitic mica schist, metabasics, quartzites and magmatites. The tunnel alignment cuts through fault (thrust) near Bhatwari. Further south, quartzites of Nagthat-Berinag formation are exposed upto the underground power house. Since most of the structures will be located within the hills including power house, except the barrage and a small reservoir, there will be minor surfacial excavations and attendant instability problems. Moreover, in view of small height of the reservoir behind the barrage, which will fall within the rock slopes, the slope instability concerns are likely to be less with no visible geo-environmental problems. The road construction on steep hill slopes may face problems of instability at places. The tunnel excavation around the thrust may lead to high over break conditions, which does not appear to cause any major geological instability problems, on the whole.

The site lies in the MCT zone between MCT-I and MCT-II, characterised here by Seismic Zone-IV. The region is tectonically active and has experienced many earthquakes. It, therefore, needs continual monitoring for geotectonic activity.

viii) Singoli Bhatvari HP (RoR, 99 MW, Under Construction)

The site is located on the Gestract 3 in the Bhagirathi River. The area lies in the Seismic Zone IV. The rocks exposed in and around the project belong to Garhwal Group. The Lithological sequence exposed from north (Barrage site) to south (Power house site) is as follows:

The project area is mostly covered with colluvium and fluvioglacial material. The outcrops are few and sparse and generally occur in the road section, river and nala sections. Schistose quartzite is fine to medium grained gray, quartz predominant rock, it is discernible in field by prominent current bedding which shows normal order of superposition. Calc-silicate is a fine granulose aggregate in calc-magnesian-silicates along with calcite and shows solution cavities.

Chandrapur Granite gneiss is medium to coarse grained generally gray in colour. The predominant minerals are quartz and feldspar, which occur as augen. Quartz-biotite schist is a quartz predominant rock (74%) with subordinate biotite (15%), plagioclase (about 5%), microperthite (about 3%) and accessory minerals (about 1%). The felspar grains show cracks at some places indicating strain effect.

In the amphibolites predominant mineral is hornblende/actinolite 5% to 55%, plagioclase felspar 35% to 40% and accessory minerals 5% to 20%. As the rock shows foliation it is termed as amphibolite schist.

Mylonite occurs at the contact of units 3 and 4 and indicates a sheared contact. The main mineral is quartz (about 50%) which shows shearing and recrystallisation, Next in abundance is felspar (about 45%) which forms prophyroblasts and shows alteration and fracture. About 5% of mica is also present.

Rocks exposed from upstream to downstream are schistose-quartzite, calc-silicate, granite gneiss. The bedding of calc-silicate dips at 37° to 45° in N 5° E to N 70° W and the schistose quartzite and granite gneiss foliation dip at 25° to 55° in N 15° E to N 55° E (Fig. 4.65 and 4.66). The rocks on either bank do not match when projected along the strike which is indicative of a river bed fault. The inferred fault trends N 27° W- S 27° E and is probably steeply dipping to vertical.

The bedrock as explored through bore holes is schistose quartzite with interbeds of calc-silicate, amphibolite and biotite schist. In view of the thick cover of loose overburden (fluvioglacial deposit) over the bedrock, the barrage is proposed to be designed for a permeable foundation.

The geological map of the HRT depicts that the HRT alignment runs through mostly colluvial terrain with intervening scanty and scattered outcrops (Fig. 4.67). This is a major constraint in evaluating the geological and geotechnical features. However to supplement the data, lithological and structural projections have been made on the alignment from its vicinity, and based on the projections the lithology to be encountered is as follows:

Unit No.	Lithology	App. % upto surge shaft
1	Chandrapuri granite gneiss with subordinate chlorite schist and amphibolite schist bands.	41%
	Sheared contact Inferred at chainage 4820m of HRT	
	Quartz biotite schist with subordinate amphibolite schist and schistose Quartzite bands	59 %

In unit I foliation dips at 29° to 34° due N17° to 50°W. From intake to chainage 5650m the rocks dip towards upstream. Thereafter the rocks are folded into broad anticline and syncline. In case tunnel intersects an anticline, the vertical pressure on the lining is relieved and if the rocks are water charged it will have water flowing from it. Conversely in case of tunnel through a syncline there will be an increase in pressure on the lining and water will tend to flow into the tunnel (Fig.4.68).

The present H.R.T alignment intersects the Damar nala obliquely there by the nala overburden material (fluvioglacial) would be encountered for about 35m length. The H.R.T. is sub parallel to the contours on both flanks. On the left flank quartz-biotite schist is exposed whereas on the right side, the bedrock is covered under fluvioglacial material. The tunnel on the left flank is inferred to encounter quartz-biotite schist whereas on the right flank the loose overburden is inferred to be met with at about 35m along the alignment. Rock foliation dips at 28° to 35° in N5° E to N 40°E directions.

The H.R.T, alignment intersects the Dangi nala at an angle of *25°* to the flow direction. On the left flank schistose quartzite and quartz-biotite schist are exposed whereas on the right flank quartz biotite schist is exposed in the form of a narrow ledge with colluvial covering most of the area. The foliation of the rocks dip at 30° to *35°* in N55° to 80°E direction.

Surge Shaft is located in the quartzite rocks exposed along the long terrace made up of fluvial deposits. This terrace is quite wide and long to house the power house and other infrastructures (Fig. 4.69).

The construction of the project is in progress without causing any geological disturbance. Within massive rocks in the adits and tunnel only rock bolting has been adopted, whereas in the fluvio-glacial and sheared zones considerable heavy support has been provided. In the initial reaches of tunnel water has been encountered to the tune of 100 lps. At the outlet sedimentation chamber has been provided to arrest the suspended solids (fig. 4.70). Any kind of subsidence or land slide has not taken place so far.

Muck is being disposed properly. Wire crated retaining walls have been erected all along the disposal sites (Fig. 4.71).

Fig.4.65 A view of coffer dam at diversion site, Singoli Bhatwari HP

Fig. 4.66 A view of diversion channel, Singoli Bhatwari HP

Fig.4. 67 A view of inlet portal at intake, Singoli Bhatwari HP

Fig. 4.68.A view of different portals of adits, Singoli Bhatwari HP

Fig. 4.69 A view of long and wide terrace for power house site and other infrastructures, Singoli Bhatwari HP

Fig.4.70 A view of sedimentation chamber, Singoli Bhatwari HP

Fig. 4.71 Wire-crated retaining walls have been provided at the base of dumping yards, Singoli Bhatwari HP

CHAPTER 5

SEISMOLOGICAL ASPECTS

5.1 INTRODUCTION

Uttarakhand Himalayas are one of the seismically active regions of the world and have experienced earthquakes since times immemorial. The region has also experienced tectonic movements. This is evident from the several thrusts and faults present in and around the state. Two regional tectonic features in Uttarakhand, which have earthquake potential, are the Main Central Thrust (MCT) and the Main Boundary Thrust (MBT). In fact, these tectonic features are present all along the entire Himalayan tectonic belt.

As per the seismic zoning map of India, as incorporated in Indian Standard Criteria for Earthquake Resistant Design of Structures IS:1893-(Part I) 2002 : General Provisions and Buildings; the entire state of Uttarakhand has been assigned to seismic zones IV and V, which are the two most seismo-tectonically active zones on the map. Most parts of Alaknanda valley are in seismic zone V whereas the Bhagirathi valley is in seismic zone IV (Fig.5.1a and 5.1b). As such the presence of several hydro power projects in the region warrants investigations in terms of seismotectonic activity.

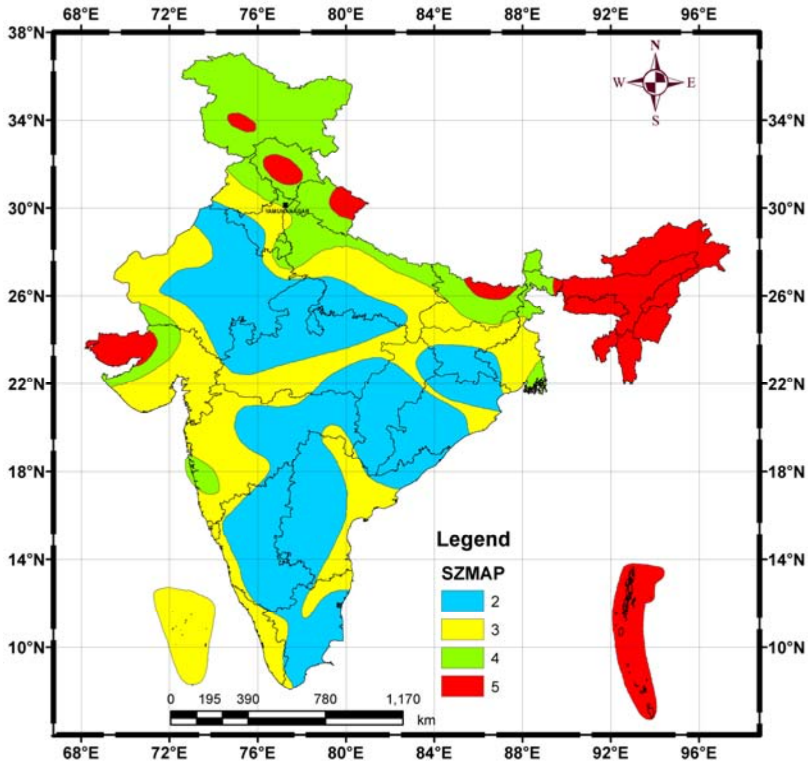


Fig. 5.1a Seismic zoning map of India, as per BIS, 1893- 2002.

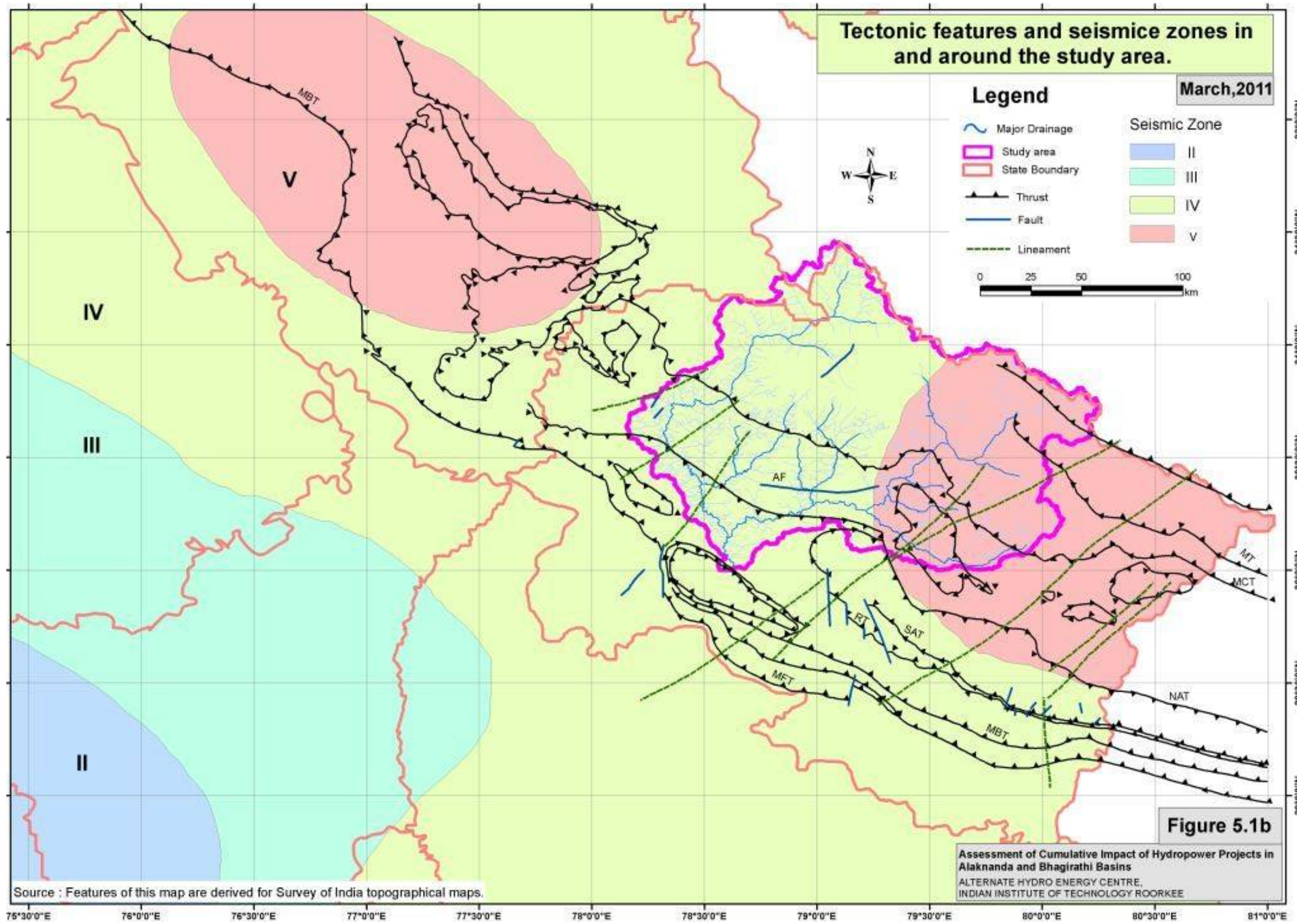


***Figure** 5.1b Map of area in and around the catchment area of Alaknanda and Bhagirathi basins, with seismic zones V, IV, III and II; and tectonic features. AF - Alaknanda Fault. MBT-Main Boundary Thrust, MCT-Main Central Thrust, MFT-Main Frontal Thrust, MT-Martoli Thrust, NAT-North Almora Thrust, RT-Ramgarh Thrust, SAT-South Almora Thrust.*

5.2 OBJECTIVE

With this background this study has the following objectives:

a. Study of available historical, reported, recorded and locally monitored earthquakes, seismo tectonic models and reservoir induced seismicity.
b. Assessment of cumulative impact of existing, proposed and under construction large hydropower projects in Alaknanda and Bhagirathi basins in terms of seismic design parameters.

5.3 METHODOLOGY ADOPTED

It is imperative that all hydropower projects in Alaknanda and Bhagirathi basins have a firm design so that these can withstand future earthquakes. This has been done with a two pronged strategy, viz. deterministic seismic hazard analysis (DSHA) and reservoir induced seismicity (RIS). The DSHA, i.e., the design part, can be addressed by adopting a set of procedures that are being practiced worldwide and are constrained by present technology and wisdom. The approach adopted was as follows: seismic design of each project was based on local and regional geological conditions, earthquake occurrences and seismo tectonic set up of the region. Structures designed as per recommended design earthquake parameters for this region would generally prevent loss of human life and only repairable damage could occur. Maximum Considered Earthquake (MCE) was evaluated on the basis of above studies using deterministic approach and the same was recommended for consideration in design of structures, (hydropower projects).

Data used

A wide area around the project site was considered for study. This encompassed an area of 6° × 6°, with the hydropower project site at its center. The earthquake catalogue containing location, time of occurrence and size of earthquakes (provided by India Meteorological Department, New Delhi), together with tectonic data, as per GSI Atlas, (2000), was used for this study.

5.4 SEISMICITY OF THE STUDY AREA

Several earthquakes, of medium to large size, have occurred in this region, as per data based on historical and instrumental records, reported by India Meteorological Department (IMD). Annexure 5.1 contains a list of earthquakes that have occurred around the study area. The catalogue provided by IMD reported earthquakes occurring between latitude 27.00 to 33.00 degrees north and longitude 75.00 to 83.00 degrees east, between the period July 1720 to January 2009. These earthquakes ranged in magnitude from 1.1 to 8.0. One hundred and sixty earthquakes in this list were not assigned any magnitude. Seventeen earthquakes were in the magnitude range 6.1 - 7.0, hundred in the range 5.1 - 6.0, 402 in the range 4.1 - 5.0, 595 in the range 3.1 - 4.0 and 1778 had magnitude less than 3.0. Epicentral data of the region in and around Alaknanda and Bhagirathi basin is shown in Fig. 5.2.

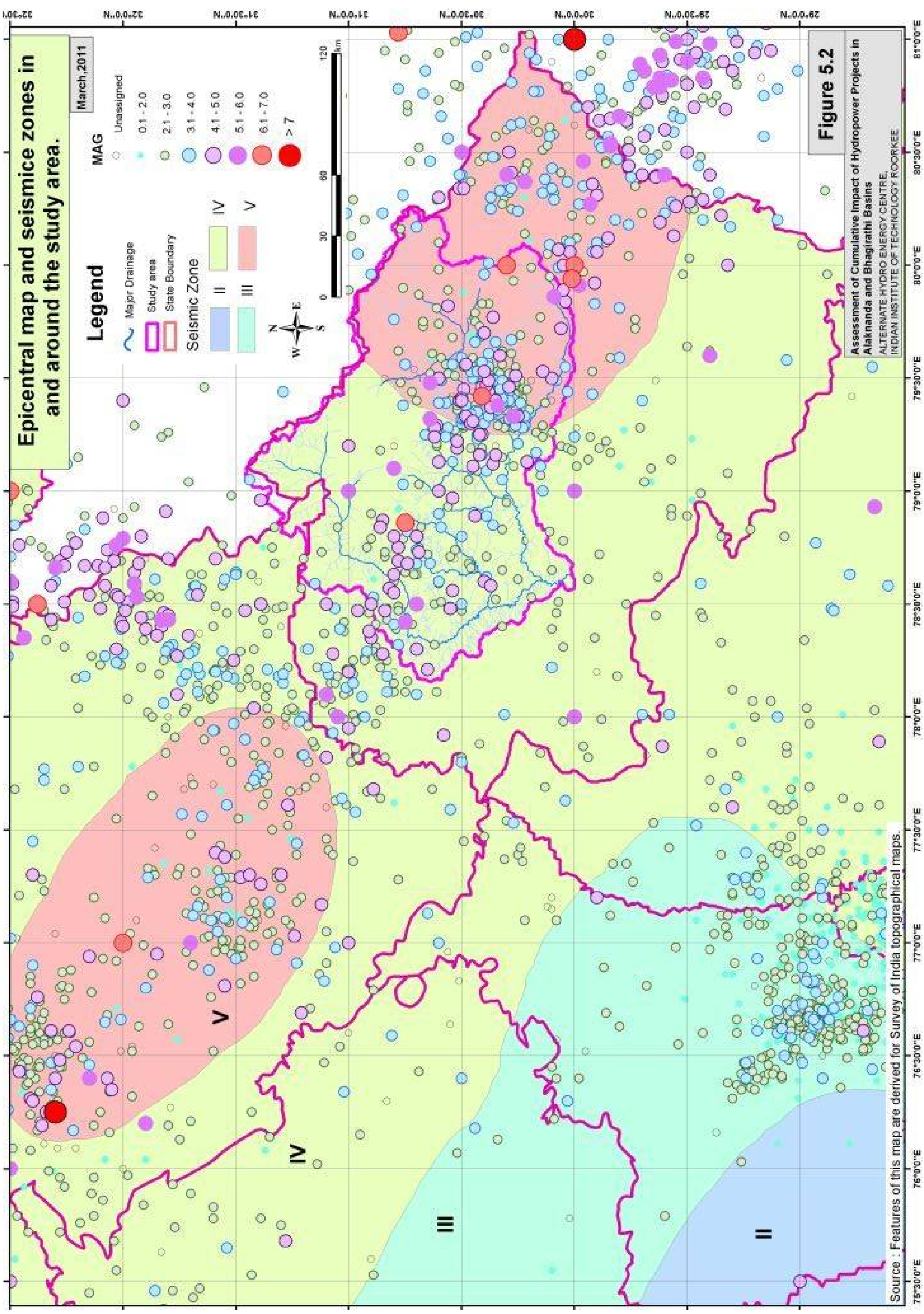


Figure *5.2 Epicentral map of the area in and around Alaknanda and Bhagirathi valleys, for the period from 15.07.1720 to 31.01.2009 (Source IMD).*

One of the earliest disastrous earthquakes reported in Uttarakhand by IMD was of magnitude 6.5, which occurred on July 15, 1720 at Latitude 28.37° N and Longitude 77.1° E. Other prominent earthquakes experienced in this region were (i) the Feb 28, 1906 earthquake with magnitude 7.0, (ii) the June 04, 1945 earthquake with magnitude 6.5, (iii) the Feb 23, 1953 earthquake with magnitude 6.0, (iv) the July 14, 1962 earthquake with magnitude 5.5, (v) the July 29, 1980 Dharchula earthquake with magnitude 6.1 (vi) the Uttarkashi earthquake of Oct 20, 1991 with magnitude 6.4 and (vii) Chamoli earthquake of March 29, 1999 of magnitude 6.8. The earthquake of 14.07.1962, with magnitude 5.5, was felt strongly at Mukteshwar and triggered landslides near Joshimath. Nearly 200 people were killed in Nepal and India due to Dharchula earthquake of 29.07.1980. Damage to buildings was reported at Dharchula, Pithoragarh and nearby areas.

The Uttarkashi earthquake of 20th October 1991 affected various parts of Uttarkashi and nearby areas. It took a toll of more than 727 human lives, injured several thousand people and caused severe to partial damage to about 100,000 houses. Maximum damage was characterized by complete destruction of mud, adobe, and stone masonry houses, damage to RCC columns, heavy damage to partition walls, development of wide open ground fissures on valley side of slopes, road cuts in overburden material and initiation of innumerable landslides, rock dislodgements and failure of terraced slopes. These were observed in an area of 440 sq km. This includes the meizoseismal area around Maneri – Jamak and Dedsari villages, wherein complete collapse of most poorly constructed houses, development of wide open ground fissures in flat topography, shaving of terraces and occasional collapse of pillar structures were observed (Geological Society of India, 1995). The degree of damage progressively decreased in all directions. Maximum intensity in the epicentral tract was estimated to be IX on the Modified Mercalli Intensity scale and encompassed an area of about 20 sq km. Damage surveys also indicated areas of isolated intensity highs of VI within V, around Kunihar and Timbi in Himachal Pradesh, and in Dehradun and Duggadda in Uttarakhand. An anomalous high of V within isoseismal IV was observed around Delhi. The earthquake was followed by a large number of aftershocks.

The severe Chamoli earthquake on 29th March 1999 caused extensive damage to life and property in the meizoseismal area of Chamoli and Rudraprayag districts of Garhwal region. According to official estimates the earthquake took a toll of 103 human lives. Effects of this earthquake were spread in varying degrees in four more districts of Uttarakhand, viz., Tehri, Bageshwar, Uttarkashi and Pauri. Maximum epicentral intensity was close to VIII on MMI scale. Epicentral location of several reported earthquakes are clustered in and around Chamoli region, (Reconnaissance Report, 2000). In view of this it may be inferred that this part is undergoing more tectonic movements in comparison to other parts of the study area.

5.5 SEISMO TECTONIC MODELS OF HIMALAYAS

To explain the cause of occurrence of earthquakes and to understand seismo tectonics of the Himalayan collision zone, various models have been proposed for evolution of the Himalayas. Of these, two models namely, the steady state model and the evolutionary model have gained considerable importance. These models suggest that the contemporary deformation styles in the Himalayas are guided by under thrusting of the Indian plate along the detachment surface.

The steady state model (Seeber and Armbruster, 1981) postulates that the active low angle contemporary thrusts i.e. Main Central Thrust, (MCT) and main Boundary Thrust, (MBT), converge with the plane of detachment, which marks the interface between the sub-ducting Indian slab and overlying sedimentary wedge (Fig. 5.3a). Part of the shallow dipping detachment surface is considered as basement thrust where the MCT merges with the detachment surface. According to this model the great Himalayan earthquakes are related to the detachment surface.

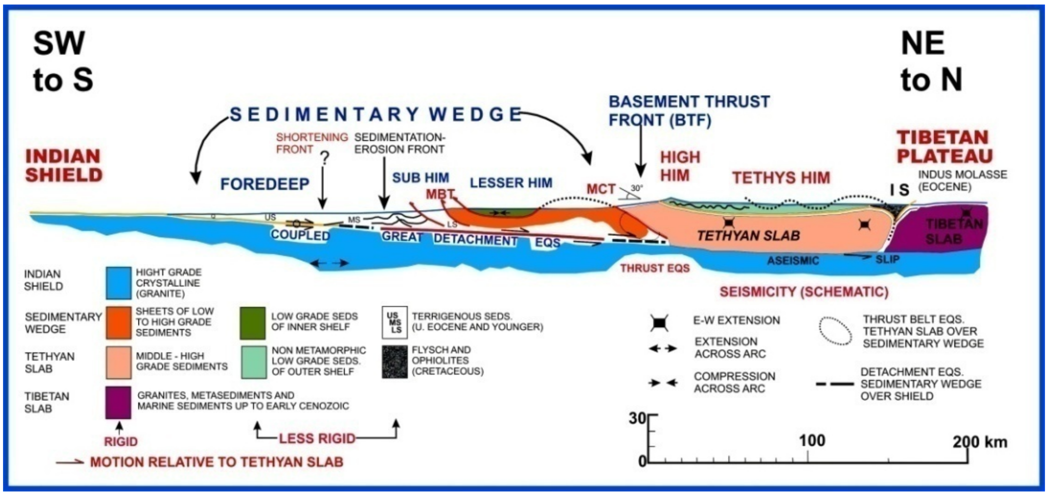


FIG. 5.3a Steady State Tectonic Model of Himalaya
(After Seeber & Armbruster, 1981)

The evolutionary model of Ni and Barazangi, (1984) postulates that the zone of plate convergence has progressively shifted south by formation of intra crustal thrusts. It hypothesizes that the MBT is the most active tectonic surface and that seismicity is concentrated in a 50 km wide zone between the map trace of MBT and MCT (Fig. 5.3b). This model suggests that the rupture of Great Himalayan earthquakes may have started in the interplate thrust zone, which propagated south along the detachment to the MBT and further south to the subsidiary blind thrusts, making MBT the most active thrust rooted in the detachment.

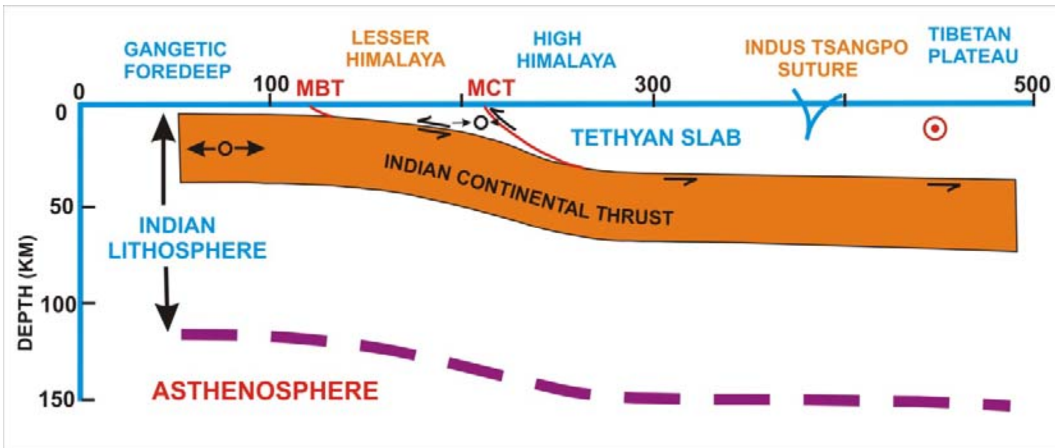


FIG. 5.3b Evolutionary Tectonic Model of Himalaya (Ni and Barazangi, 1984)

5.6 ESTIMATION OF MAXIMUM CONSIDERED EARTHQUAKE (MCE) FOR A HYDROPOWER PROJECT SITE

The area encompassed by Alaknanda and Bhagirathi valleys falls in western part of the Himalayan orogenic belt. It is affected by several tectonic features. In order to evaluate earthquake hazard for any hydropower project site, various important earthquake sources around each site were considered.

Based on geology and seismotectonics of a region parameters of a Maximum Probable Earthquake which can be generated from a potential seismogenic source around a site can be estimated for deterministic analysis. MCE is defined as the earthquake that can cause the most severe ground motion capable of being produced at the site under the currently known seismotectonic framework. It is a rational and believable event, which can be supported by all known geological and seismological data. It is determined by judgment based on maximum earthquake that a tectonic region can produce considering the geological evidence on past movement and recorded seismic history of the area. Design Basis Earthquake, (DBE), is defined as that earthquake which can reasonably be expected to occur during the economic life of the structure (say 100 years). In the event of exposure to earthquake hazards it will not cause loss of life and the structure will undergo permissible deformations and repairable damage such that the structure, equipment facilities and services will remain functional after the earthquake. As design criteria the resulting ground accelerations at the site under DBE may be taken as a fraction of MCE based on engineering judgment for adopted design methodology.

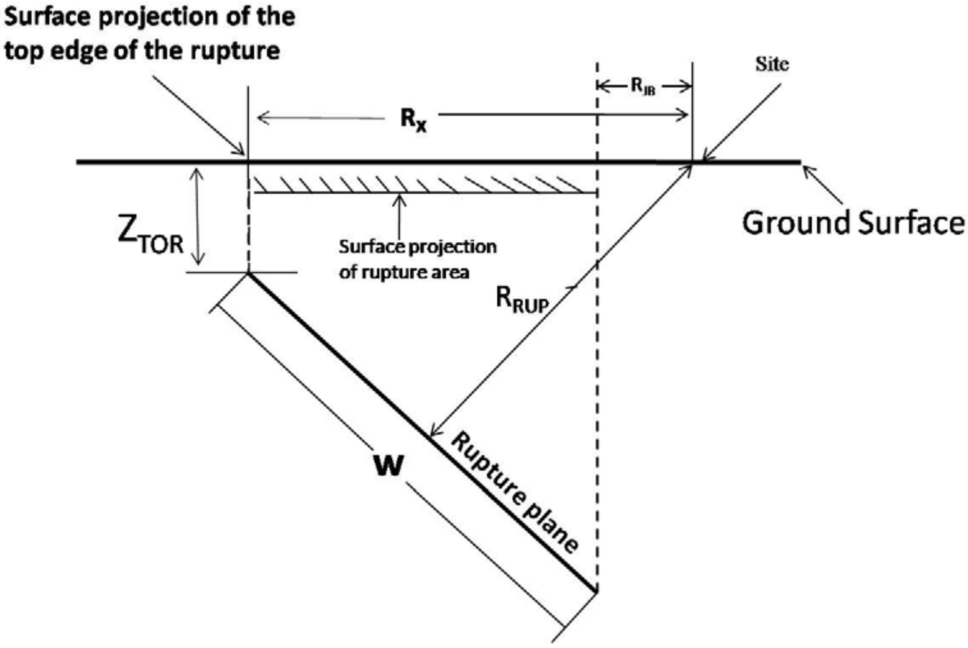
Estimates of peak ground horizontal acceleration are made using empirical formulae worked out by several research workers for various tectonic environments. Attenuation relationships are derived by regression analysis using different distance measures and magnitude measures. Thus, different relationships provide different estimates of probable ground acceleration and a judicious decision to estimate ground acceleration is therefore required for adoption in any particular situation. ICOLD Bulletin 72 (1989) recommends use of some empirical relationships like that of Campbell (1981) and Joyner and Boore (1981). Subsequently, Abrahamson and Litehiser (1989), using a formulation similar to the above, made comprehensive recommendations based on analysis of 585 records from 76 worldwide earthquakes. For the present study attenuation relationship proposed by Abrahamson and Litehiser (1989) was used. Regression used a two-step procedure that is a hybrid of Joyner and Boore (1981) and Campbell (1981) regression methods. The horizontal acceleration attenuation relation is as follows:

$$\log(a) = -0.62 + 0.177\,M - 0.982\log(r + e^{0.284\,M}) + 0.132\,F - 0.0008\,Er \qquad (5.1)$$

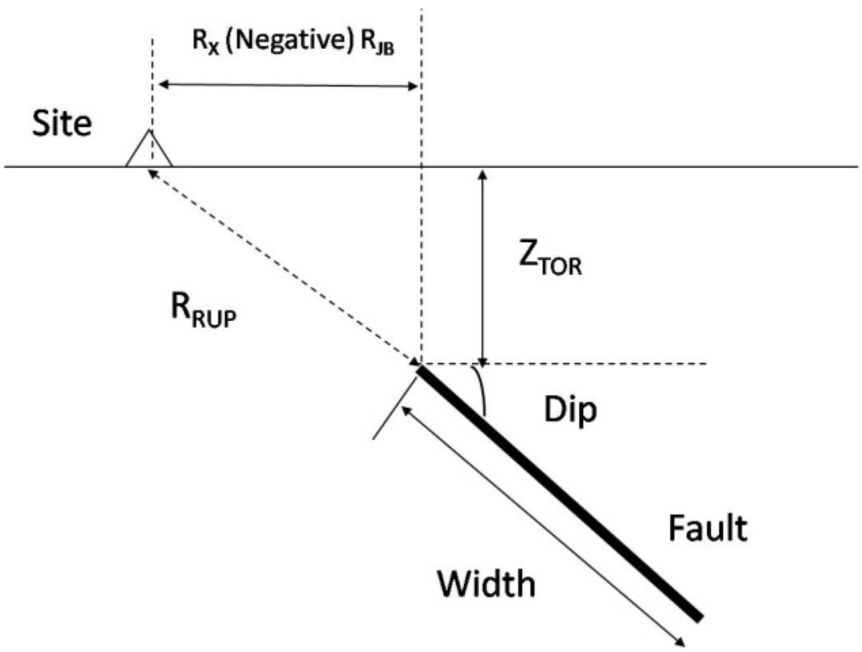
where, a is peak horizontal acceleration, r is the closest distance (in km) between the site and zone of energy release, M is magnitude {($M_L < 6.0$ and $M_S > 6.0$), following Campbell (1981), Ms is used if it is greater than or equal to 6.)}, F is a dummy variable that is 1 for reverse or reverse oblique fault otherwise 0, and E is a dummy variable that is 1 for inter-plate and 0 for intra-plate events.

5.6.1 Style of faulting

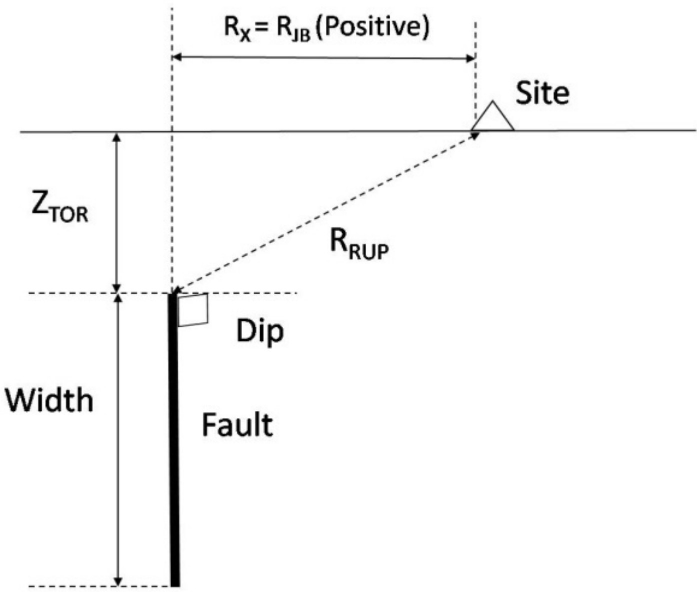
For crustal earthquakes, ground motions systematically differ when generated by strike slip, thrust, or normal mechanisms. For the same conditions ground motion from thrust earthquakes tends to be larger than ground motions from strike slip earthquakes (about 20 - 30% larger), and ground motion from normal faulting earthquakes tend to be smaller than ground motion from strike slip earthquakes (about 20% smaller). It is of utmost importance to know the location of the site with respect to faults and thrusts in the region. Several possible situations exist; three of these are shown in Figs. 5.4a, b and c. Fig. 5.4a depicts reverse or normal faults when the site is on the hanging wall side, Fig. 5.4b is for reverse or normal fault when the site is on the foot wall side, and Fig. 5.4c is for strike-slip faulting, (Kaklamanos et al., 2010).



(a)



(b)



(c)

FIG. 5.4: (a) Reverse or normal faulting - hanging wall site **(b)** Reverse or normal faulting, foot-wall site, **(c)** Strike-Slip Faulting. Comparison of different distance measures found in ground motion prediction equations, using a vertical cross section through a fault rupture plane is also shown in this Fig.. The rupture distance, (R_{RUP}), is the slant distance to the closest point on rupture plane; Joyner and Boore distance, (R_{JB}), is horizontal distance to surface projection of rupture; (R_X), is horizontal distance to surface projection of top edge of rupture, measured perpendicular to strike. Geometric parameters of rupture plane are: depth to top of rupture (Z_{TOR}), down dip rupture width (W), and fault dip (δ). These terms are illustrated for a hypothetical site.

Rupture width, RW, is estimated by using the Wells and Coppersmith, (1994) relationship

$$\log(RW) = -1.01 + 0.32M \qquad (5.2)$$

In case rupture width is less than general focal depths in the region (FD) then depth to zone of energy release (Dz) is estimated as

$$Dz = NSD + (FD - \frac{RW}{2}\sin\alpha) \qquad (5.3)$$

where NSD is non seismo-genic depth and α is the dip angle.
When rupture width is more than FD depth to zone of energy release is estimated as

$$Dz = NSD + \frac{RW}{2}\sin\alpha \qquad (5.4)$$

Distance to zone of energy release, De, is estimated using depth to zone of energy release, Dz, and epicentral distance Ep as

$$De = \sqrt{Ep^2 + Dz^2} \qquad (5.5)$$

If the site is on the hanging wall of a thrust type of seismo-genic feature, epicentral distance is considered as zero and distance to zone of energy release is taken as depth to zone of energy release i.e., Dz. This is shown in Fig. 5.5. Angle α is taken as 15° for thrust type of seismo-genic features which are necessarily low angle reverse faults. In case of normal/strike slip α is taken as 90°.

Estimation of general depth of focus is based on depth section of earthquake occurrences. The relationship given by Wells and Coppersmith uses moment magnitude, which is approximately equal to surface wave magnitude in the range 5.0 – 7.5 (Kanamori, 1983). Therefore, the same magnitudes are used to compute rupture width. Magnitudes are assigned to seismic sources based on past seismicity associated with individual seismo-genic features.

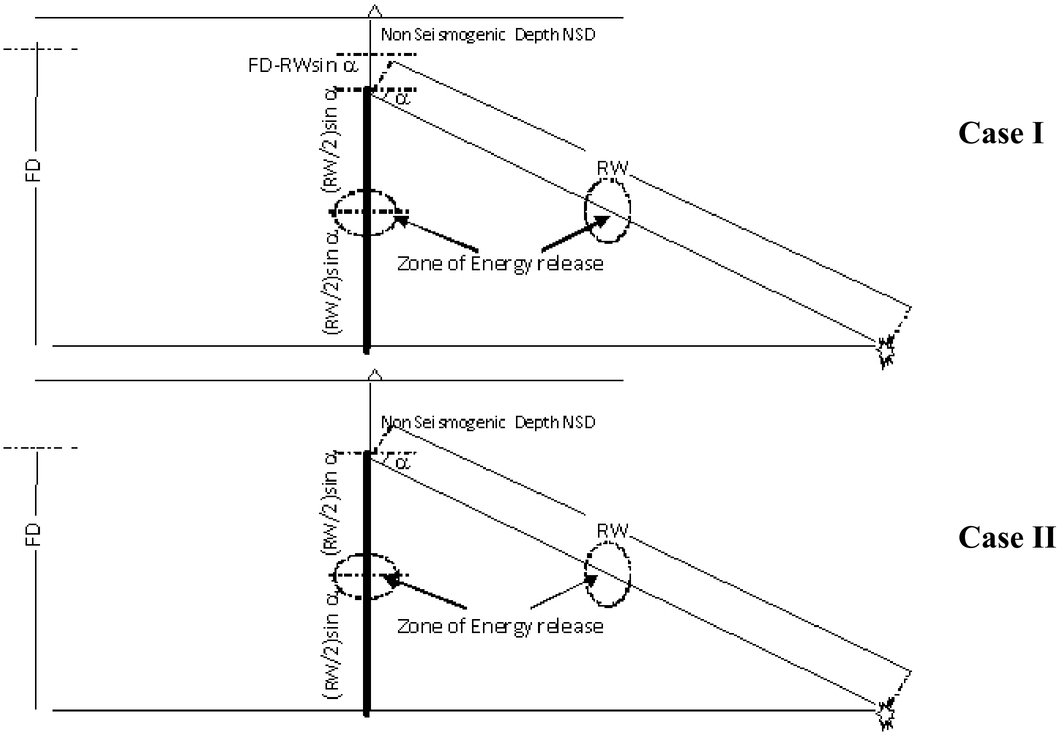


Fig. 5.5 Geometry of the source showing calculation of depth of energy release. Case I: when vertical width of rupture is less than focal depth, and Case II: when vertical width of rupture is more than focal depth.

5.6.2 Estimation of Ground Motion

Predictive relationships for parameters that decrease with increasing distance (such as peak acceleration) are often referred to as attenuation relationships. For engineering applications, peak ground acceleration (PGA) and response spectra are needed for a site. For quantifying seismic hazard at a site, or to prepare a seismic zoning map, one needs to know the attenuation and scaling characteristic of various strong motion parameters with distance, earthquake size and geological condition. Selection of an appropriate ground motion attenuation relationship is an important aspect as it directly influences the estimation of expected ground motion at a site. The accuracy of ground motion attenuation relationship depends on data, function taken and methodology used to derive it. Ground motion attenuation relations can be classified into three categories of seismic environments: shallow crustal earthquakes in active tectonic regions, shallow crustal earthquakes in stable continental regions, and subduction zones. Various attenuation relationships are proposed for estimation of ground motion for specific regions and for general areas by different workers. For this work attenuation relationship formulated by Abrahamson and Litehiser (1989) was used.

5.6.3 Parameters for attenuation relationship

The most common source, ray path, and site parameters are: kind of fault, magnitude, distance, and site classification. Different measures of earthquake magnitude are used in different regions of the world. Mostly, moment magnitude is universally adopted as a measure of earthquake size. Various measures of distance are used in strong motion attenuation relationships.

Some commonly used measures of distance are shown in Fig. 5.6. D_1 and D_2 are hypo-central and epicentral distances, which are the simplest distances to determine after an earthquake. D_3 is distance to the energy zone, or zone of high localized stress drop such as an asperity. It is the best measure in that an extensive analysis is needed to determine where these zones were located for those selected earthquakes for which a large amount of data is available, and it is almost impossible to determine where these would be located in a future earthquake. Campbell (1987) proposed and defined D_4 as the closest distance to the seismo-genic rupture. D_5 is the closest distance to the surface projection of the fault rupture.

Douglas (2003) provided an excellent review of various definitions of source to site distance that were used in ground motion prediction equations (GMPE) released in 2008 as a part of the next generation attenuation of ground motion ("NGA-West", or "NGA") project (Kaklamanos and Baise, 2011). The NGA relationships predict peak ground acceleration (PGA), peak ground velocity (PGV), and 5% damped elastic pseudo response spectral acceleration (Sa) for shallow crustal earthquakes in active tectonic regions.

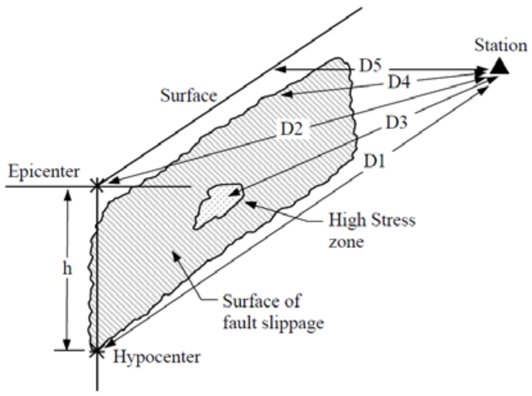


Fig. 5.6: Some commonly used measures of source to site distance, (Reiter, 1990). D_1 and D_2 are hypo-central and epicentral distances, which are the simplest distances to determine after an earthquake. D_3 is distance to the energy zone, or zone of high localized stress drop such as an asperity. Campbell (1987) proposed and defined D_4 as the closest distance to the seismo-genic rupture. D_5 is the closest distance to the surface projection of the fault rupture.

5.6.4 Ground Motion Characteristics

Time history of ground motion is worked out from the shape of target acceleration response spectra, which in turn depends on parameters of the earthquake, predominant period of ground motion, and amplification of spectral acceleration at various periods. Shape of design response spectrum is based on subjective judgment of local geology and bed rock conditions.

It is imperative that the above approach be adopted for design of hydropower projects in a seismically active region. It is reasonable to believe that dams designed according to the above methodology would withstand future earthquakes without suffering considerable damage. This work was done for several commissioned and under construction hydropower projects in the region and the list is given in Table 5.1. Seismotectonic map of the area in and around the Alaknanda and Bhagirathi basins is shown in Figs. 5.7 and 5.8. The case for a few dams is illustrated here. Table 5.2 shows maximum accelerations estimated for different hydropower projects.

Table 5.1 Hydropower Projects located in Uttarakhand for which design parameter studies were carried out by the Department of Earthquake Engineering.

S. No.	Name of the project
1.	Alaknanda
2.	Bhairon Ghati
3.	Dhauliganga, Pithoragarh
4.	Jakhol-Sankri
5.	Jamrani
6.	Jamrani, Nainital
7.	Jelam Tamak
8.	Kishau, Dehradun
9.	Koteshwar
10.	Koteshwar, Tehri
11.	Kotlibhel IA
12.	Kotlibhel IB
13.	Kotlibhel II
14.	Lakhwar, Dehradun
15.	Loharinag Pala
16.	Malari Jelam
17.	Pipalkoti
18.	Rupsiabagar
19.	Shrinagar
20.	Singoli-Bhatwari
21.	Srinagar, Garhwal
22.	Tapovan Vishnugad
23.	Tehri
24.	Vyasi

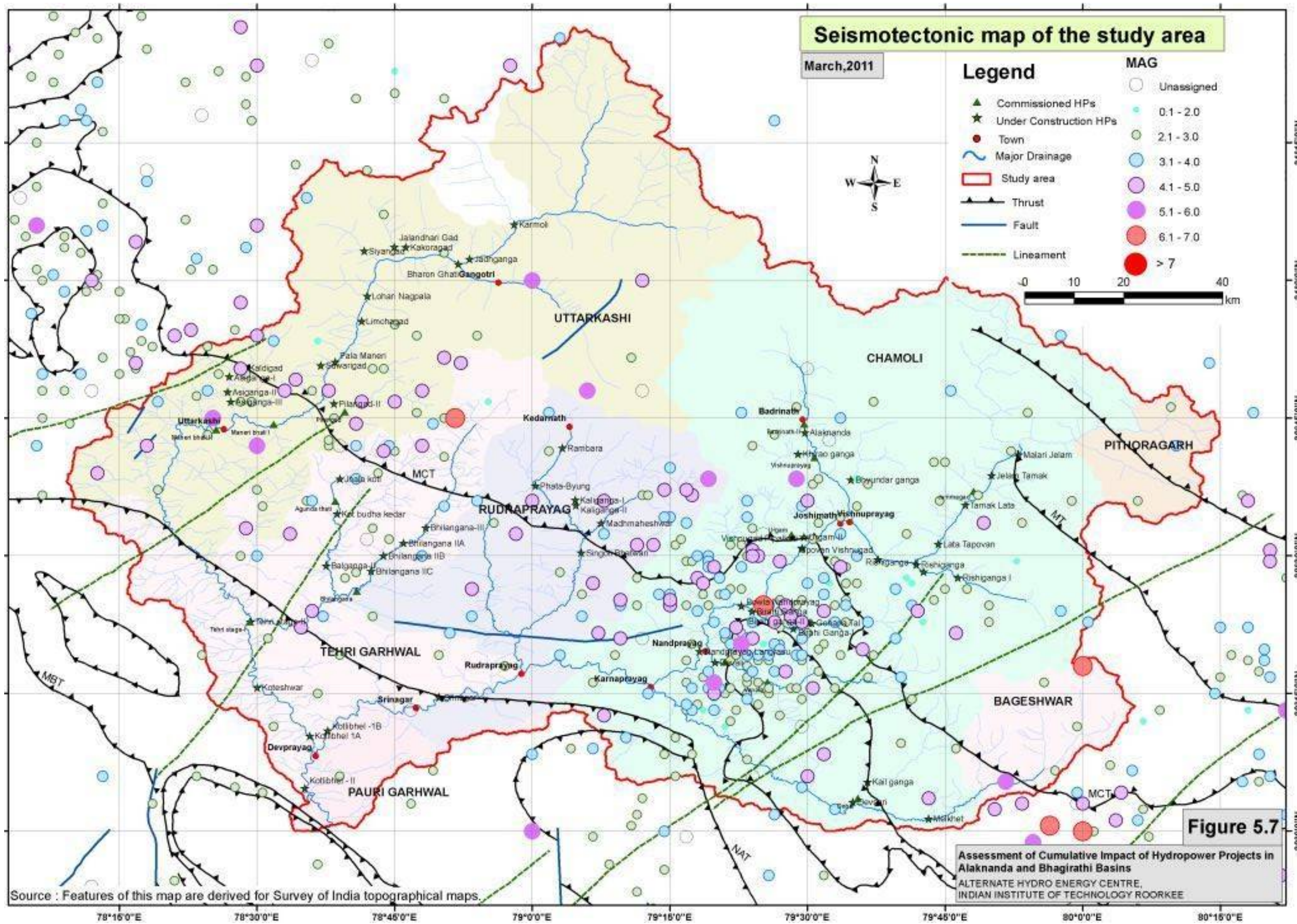


Figure 5.7 Seismotectonic map of the area in and around the Alaknanda and Bhagirathi basins. Epicentral data is same as for Figure 5.2. Tectonic features shown in the map are: AF-Alaknanda Fault. MBT-Main Boundary Thrust, MCT-Main Central Thrust, MFT-Main Frontal Thrust, MT-Martoli Thrust, NAT-North Almora Thrust, RT-Ramgarh Thrust, SAT-South Almora Thrust.

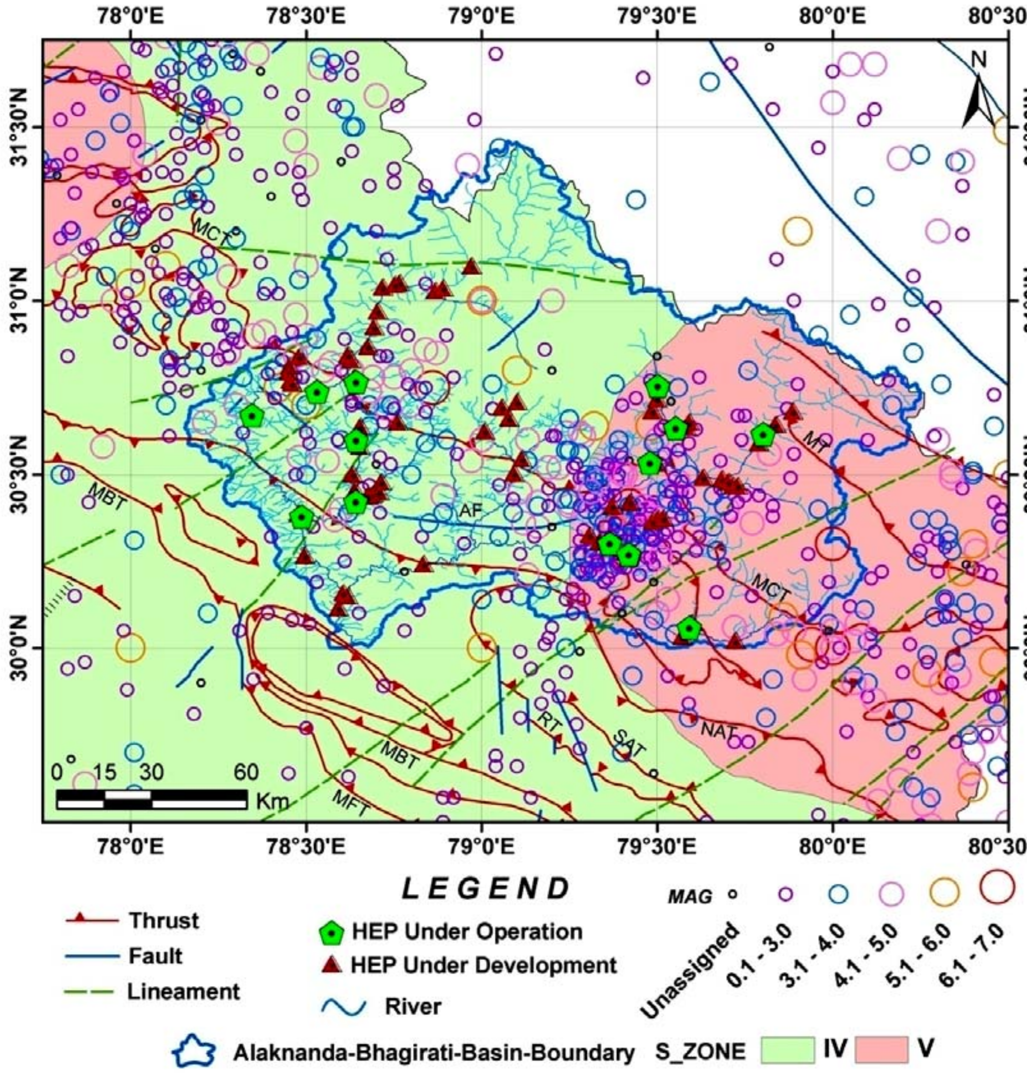


Fig. 5.8. Seismotectonic map of area around Alaknanda and Bhagirathi Basins

Table 5.2 Maximum accelerations estimated for hydropower projects on the basis of seismotectonics.

Project	Sources	Magnitude	Focal Depth (km)	Hypocentral distance (km)	Max. Accl. (g)
Tehri	Srinagar Thrust	6.5	20	26	0.19
	MBT	7.0	20	27	0.25
Kotlibhel	Main Boundary Thrust	7.5		Distance to zone of energy release 15	0.31

Project	Sources	Magnitude	Focal Depth (km)	Hypocentral distance (km)	Max. Accl. (g)
Bowala Nandprayag	Main Central Thrust	8.0		Distance to zone of energy release 15	0.36 at bed rock 0.49 at River bed level
Bhairon-Ghati	Main Central Thrust	8.0		Distance to zone of energy release 15	0.36
Pala Maneri	Main Central Thrust	8.0		Distance to zone of energy release 15	0.36
Tapovan Vishnugad	Main Central Thrust	8.0		Distance to zone of energy release 14	0.38
Koteshwar	Main Boundary Thrust	7.5		Distance to zone of energy release 15	0.31

5.6.5 Tehri Hydropower Project

The Tehri project, located at old Tehri town, is a 261 meter high rock fill dam across the Bhagirathi River. This project site lies in seismic zone IV of the seismic zoning map of India, BIS:1893-2002, (Part I). Studies related to seismic design of the project were based on local and regional geological conditions, earthquake occurrences and seismo-tectonic set up of the region. This project is located south of Srinagar Thrust (North Almora Thrust) and north of MBT.

Seismogenic sources nearest to the Tehri hydropower project site are Srinagar or North Almora Thrust and Main Boundary Thrust. This feature has a southerly dip which varies from moderate to steep. The North Almora Thrust (NAT) dips southward towards the project site and lies beneath the site. An earthquake of magnitude 6.5 was assigned to this thrust. The Main Boundary Thrust (MBT) marks the northern boundary of the Siwalik belt, separating it from the Lesser Himalayas. The Lesser Himalayan meta-sedimentaries have been brought over the sub Himalayan successions through large-scale movement that took place along the MBT. The MBT is not a single tectonic plane; instead it is represented by several thrust slices. The project site lies NE of the MBT and as the tectonic feature dips northward the thrust plane also lies beneath the site. An earthquake of magnitude 7.0 is assigned to this feature. Peak ground horizontal acceleration (PGA) for MCE condition was estimated to be 0.25g.

Project	Sources	Magnitude	Focal Depth (km)	Hypocentral distance (km)	Max. Accl. (g)
Tehri	Srinagar Thrust /Hydropower	6.5	20	26	0.19
	MBT	7.0	20	27	0.25

5.6.6 Kotlibhel (I A) Hydropower Project

The Kotlibhel hydropower project Stage IA, proposed to be located near Muneth village, involves construction of a 75.6 meter high concrete gravity dam across the Bhagirathi River. This hydropower project site lies in seismic zone IV of the seismic zoning map of India, BIS:1893 - 2002. Studies related to seismic design of the project were based on local and regional geological conditions, earthquake occurrences and seismo-tectonic set up of the region. Maximum Considered Earthquake (MCE) was evaluated on the basis of above studies using the deterministic approach, and the same was recommended for consideration in design of structures. This project is located south of Srinagar Thrust (North Almora Thrust) and north of MBT.

Seismogenic sources nearest to the site are the Main Boundary Thrust and North Almora Thrust. The MBT marks the northern boundary of the Siwalik belt, separating it from the Lesser Himalayas. The Lesser Himalayan meta-sedimentaries have been brought over the Sub Himalayan successions through large-scale movement that took place along the MBT. The MBT is not a single tectonic plane; instead it is represented by several thrust slices. The project site lies NE of the MBT and as the tectonic feature dips northward the thrust plane also lies beneath the site. Earthquakes of magnitude 7.0 or more have been reported in the study area around the site, which could be associated with this feature. Based on the above a magnitude 7.5 earthquake was assigned to this feature.

The Srinagar Thrust/North Almora Thrust (NAT) delimits high grade complex Almora crystallines towards north and defines the tectonic boundary between the Almora Crystalline and the Garhwal Group in Almora and Pithoragarh area. This feature has a southerly dip which varies from moderate to steep. This feature dips southward towards the project site and lies beneath the site. The PGA values for MCE and DBE conditions at the site are estimated to be 0.31g and 0.16g respectively.

Source	Magnitude	Distance to zone of energy release (km)	Max. Accl. (g)
Main Boundary Thrust	7.5	15	0.31

5.6.7 Bowala Nandprayag Hydropower Project

This barrage site is located in Chamoli district of Uttarakhand on river Alaknanda and the site lies in seismic zone IV, as per BIS: 1893-2002, (Part I). Studies related to seismic design of the project were carried out based on local and regional geological conditions, earthquake occurrences and seismotectonic set up of the region. Maximum Considered Earthquake (MCE) was evaluated on the basis of above studies using the deterministic approach and the same was recommended for consideration in design of structures. The project site lies south of MCT and geologically it is represented by gneissic rocks belonging to Central Himalayan crystalline.

The nearest seismo-genic sources around the site are the Main Central Thrust, Martoli Thrust and Main Boundary Thrust. The project area is seismically active as several earthquakes originated in this region. The NW-SE trending MCT is located about 7 km north of the project site. The maximum observed earthquake magnitude which can be associated with the MCT in the region around the site is 7.5. However, the MCT is a regional feature and is capable of generating higher magnitude earthquakes. Further, as the site lies south of northward dipping MCT it is considered that the seismo-genic feature extends beneath the project site. Features like the MCT are weak planes for future activity in the region. A magnitude 8.0 earthquake has been assigned to this regional feature for assessment of seismic hazard using the deterministic approach. A dip of 15° (due to gently dipping part of thrust plane at depth) was assumed while estimating distance to the zone of energy release.

The Main Boundary Thrust (MBT) marks the northern boundary of the Siwalik belt, separating it from the Lesser Himalayas. The Lesser Himalayan meta-sedimentaries have been brought over the sub Himalayan successions through large-scale movement that took place along the MBT. The MBT is not a single tectonic plane; instead it is represented by several thrust slices. The project site lies NE of the MBT and as the tectonic feature dips northward the thrust plane also lies beneath the site. Earthquakes of magnitudes 7.0 or more have been reported in the study area around the site, which could be associated with this feature. Based on the above a magnitude 7.5 earthquake was assigned to this feature. The peak ground horizontal acceleration (PGA) values for MCE and DBE conditions at the site were estimated to be 0.49g and 0.25g respectively.

Sources	Magnitude	Distance to zone of energy release (km)	Max. Accl. (g)
Main Central Thrust	8.0	15	0.36 at bed rock 0.49 at River bed level

5.6.8 Bhairon-Ghati Hydropower Project

The Bhairon Ghati hydropower project is a run of the river scheme across the Bhagirathi River. The project envisages utilizing a 280 m drop available in Bhagirathi river. The scheme involves construction of a barrage on river Bhagirathi. The proposed Bhairon Ghati hydropower project site lies in seismic zone IV and is located north of the MCT. Studies related to seismic design of the project were carried out based on local and regional geological conditions, earthquake occurrences and seismo-tectonic set up of the region. Maximum Considered Earthquake (MCE) was evaluated on the basis of above studies using deterministic approach and the same was recommended for consideration in the design of structures.

Seismo-genic sources nearest to the site are Main Central Thrust and Kaurik Fault System. The latter is not shown on the map as this feature is out of range in Fig. 5.7, towards NW. The project area is seismically active as several earthquakes were reported from this region. The Main Central Thrust (MCT) trends NE-SW and is located SW of the project site. The maximum observed earthquake magnitude which could be associated in the region around the site with this feature is 8.0. However, the MCT is a regional feature and is capable of generating higher magnitude earthquakes. Features like the MCT are weak planes for future activity in the region. A magnitude 8.0 was assigned to this regional feature for assessment of seismic hazard using the deterministic approach. The project site lies northeast of this thrust and as the tectonic feature dips northward the thrust plane also lies beneath the site.

The Kaurik Fault System (KFS) of Higher Himalaya is characterized by normal faulting exhibiting splays. This structural discontinuity trends sub-parallel to the Himalayan trend and might have ruptured during Kinnaur earthquake of 1975 (GSI, 2000). Ground Motion was characterized by horizontal PGA values for MCE and DBE conditions and was estimated to be 0.36 g and 0.18 g, respectively.

Source	Magnitude	Distance to zone of energy release (Km)	Max Accl (g)
Main Central Thrust	8.0	15	0.36

5.6.9 Pala Maneri Hydropower Project

This project is located across the Bhagirathi River in Uttarkashi district and the site lies in seismic zone IV. Studies related to seismic design of this hydropower project were based on local and regional geological conditions, earthquake occurrences and seismo-tectonic set up of the region. Maximum Considered Earthquake (MCE) was evaluated on basis of the above studies using the deterministic approach and the same was recommended for consideration in the design of structures. The project site is located north of the MCT, and geologically it is represented by medium to high grade metamorphic rocks belonging to the central Himalayan crystalline.

The seismo-genic source nearest to the site is the Main Central Thrust. The project area is seismically active as several earthquakes were reported from this region. The Main Central Thrust (MCT) trends NW-SE and is located about 24 km SW of the project site. The maximum observed earthquake magnitude which could be associated with MCT in the region around the site is 7.5. However, the MCT is a regional feature and is capable of generating higher magnitude earthquakes. Further, as the site lies north of northward dipping MCT it is considered that the seismo-genic feature extends beneath the project site. Features like the MCT are weak planes for future activity in the region. A magnitude 8.0 was assigned to this regional feature for assessment of seismic hazard using the deterministic approach. A dip of 15° was assumed while estimating distance to the zone of energy release. Ground Motion was characterized by peak ground horizontal acceleration values for MCE and DBE conditions. It was estimated to be 0.36g and 0.18g, respectively.

Source	Magnitude	Distance to zone of energy release (Km)	Max. Accl. (g)
Main Central Thrust	8.0	15	0.36

5.6.10 Tapovan Vishnugad Hydropower Project

The Tapovan Vishnugad hydropower project is a run of the river scheme across the Dhauliganga River. It is located at Tapovan village, about 15 km from Joshimath, on Joshimath – Malari road, in district Chamoli. The project envisages utilizing a 494 m drop available in the Dhauliganga River. The scheme involves construction of a barrage on river Dhauliganga near village Tapovan, with a 4.08 m diameter, 11.65 km long head race tunnel, and an underground powerhouse. This project site lies in seismic zone V of the seismic zoning map of India. Studies related to seismic design of the project were based on local and regional geological conditions, earthquake occurrences and seismo-tectonic set up of the region. Maximum Considered Earthquake (MCE) was evaluated on basis of the above studies using the deterministic approach and the same was recommended for consideration in the design of structures. The project site is located north of the MCT and geologically it is represented by gneissic rocks belonging to Central Himalayan crystalline.

The seismo-genic sources nearest to the site are the Main Central Thrust, Alaknanda Fault, Main Boundary Thrust and the Indus Suture Zone. The project area is seismically active as several earthquakes were reported from this region. The NW-SE trending Main Central Thrust (MCT) is located about 24 km SW of the project site. The maximum observed earthquake magnitude which could be associated with MCT in the region around the site is 7.5. However, the MCT is a regional feature and is capable of generating higher magnitude earthquakes. Further, as the site lies north of the northward dipping MCT it is considered that the seismogenic feature extends beneath the project site. Features like the MCT are weak planes for future activity in the region. A magnitude 8.0 was assigned to this regional feature for assessment of seismic hazard using a deterministic approach. A dip of 15° was assumed while estimating distance to the zone of energy release. Ground Motion was characterized by estimation of peak ground horizontal acceleration. The PGA values for MCE and DBE conditions were estimated to be 0.38g and 0.19g respectively.

Source	Magnitude	Distance to zone of energy release (Km)	Max. Accl. (g)
Main Central Thrust	8.0	15	0.38

5.6.11 Koteshwar Hydropower Project

The Koteshwar hydropower project involves construction of a concrete gravity dam on Bhagirathi River. The project site is located south of Srinagar Thrust (North Almora Thrust) and north of the MBT. Studies related to seismic design of the project were based on local and regional geological conditions, earthquake occurrences and seismotectonic set up of the region. Maximum Considered Earthquake (MCE) was evaluated on the basis of above studies using a deterministic approach and the same was recommended for consideration in the design of structures.

Seismogenic sources nearest to the site are the Main Boundary Thrust and North Almora Thrust. The Main Boundary Thrust (MBT) marks the northern boundary of the Siwalik belt separating it from the Lesser Himalayas. The Lesser Himalayan meta-sedimentaries have been brought over the Sub Himalayan successions through large-scale movement that took place along the MBT. The MBT is not a single tectonic plane; instead it is represented by several thrust slices. The project site lies NE of the MBT and as the tectonic feature dips northward the thrust plane also lies beneath the site. Earthquakes of magnitude 7.0 or more were reported in the study area around the site, which could be associated with this feature. Based on the above a magnitude 7.5 was assigned to this feature.

The Srinagar Thrust / North Almora Thrust (NAT) has a southerly dip which varies from moderate to steep. This feature dips southward towards the project site and lies beneath the site. Ground motion characteristics were estimated by peak ground horizontal acceleration. The PGA values for MCE and DBE conditions were estimated to be 0.31g and 0.16g respectively.

Source	Magnitude	Distance to zone of energy release (Km)	Max. Accl. (g)
Main Boundary Thrust	7.5	15	0.31

5.7 POSSIBILITY OF RESERVOIR INDUCED SEISMICITY ASSOCIATED WITH HYDROPOWER PROJECTS IN ALAKNANDA AND BHAGIRATHI BASINS

It is of utmost importance to examine the seismicity pattern after impoundment of the reservoir and evaluate any change of seismicity. This is referred to as Reservoir Induced Seismicity (RIS). The following section attempts to answer this question.

Reservoir induced seismicity (RIS) was first noticed at Lake Mead (Hoover Dam) in 1930's; thereafter a few other isolated cases occurred before 1960. Moderate earthquakes followed the impoundment of six reservoirs and at least in two of these cases namely, Kremsata and Koyna, death, injury and damage were caused. In 1963, a major landslide at Vajont Dam (Italy) claimed nearly 2000 lives. These cases of induced seismicity stimulated considerable interest because of social and economic implication and also due to the role which water load played in the occurrence of these earthquakes. As of today, in more than 100 cases, the seismic regime has been modified by impounding of large reservoirs. A number of reviews are now available on reservoir induced seismicity (e. g., Simpson, 1976). Changes in seismicity due to reservoir impounding have been grouped into six categories namely, major induced earthquakes, minor induced earthquakes, changes in micro-earthquake activity, transient changes in seismicity, decrease in seismic activity after reservoir filling and possible cases of reservoir induced seismicity.

5.7.1 Characteristics of Reservoir Induced Seismicity

Rothe (1973) found that RIS is most common in reservoirs greater than 100 m deep and hence depth of water appears to be more important than total volume of water. But Simpson (1976) demonstrated that this is neither a necessary nor a sufficient condition for the existence of RIS. There are many reservoirs with dams greater than 100 m high with no noticeable seismicity whereas dams less than 100 m high have observable activity. It has been established, based on available data on reservoir induced earthquakes, that the size of major earthquake does not increase with the height of the dam or volume of reservoir and no relationship is suggested between height and magnitude by the available data.

5.7.2 Mechanism of Reservoir Induced Seismicity

Impounding of large reservoirs creates a stress field which is superimposed on the ambient tectonic stress field around a reservoir site. The way in which these induced stresses interact with the framework of tectonic, geological and hydrological environment would determine as to whether or not Reservoir Induced Seismicity would result. To the first approximation it has been recognized that loading of reservoirs affects the ambient environment in two ways: (a) an increase in vertical stress due to weight of the water mass (b) Decrease in effective stress caused by increased pore pressure.

5.7.3 Types of Reservoir Induced Seismicity

Comparison of well documented case histories of seismicity at reservoirs suggests that induced seismicity is of two types: (i) Rapid response, (ii) Delayed response (Simpson, et. al., 1988). A brief description of these is as follows:

Rapid Response: In the case of rapid response, induced seismicity is primarily confined to low magnitude swarm-like seismicity located in the immediate reservoir area and is closely correlated with changes in water-level in the reservoir. This pattern of induced seismicity is attributed to elastic response due to load of the reservoir. This response occurs both through an increase in elastic stress and/or an increase in pore-pressure induced by elastic compression of pore space (i.e., not through transfer of water from the reservoir).

Delayed Response: In this case seismicity occurs with significant delay, after the first time reservoir impounding, and is often associated with large magnitude earthquakes. Seismicity may occur significantly beyond the confines of the reservoir and may not show an immediate correlation with major changes of water level in reservoir. Often, the reservoir water level may go through a number of apparently similar annual cycles in water-level between first loading and onset of significant seismicity.

The dominant mechanism which leads to delayed response is by diffusion of pressure from reservoir to hypocentral depths. Cases of delayed response differ from rapid response in that the dominant seismicity occurs relatively late in the life of the reservoir. A typical example of delayed response is the Oroville dam, a 235 m high earth dam with maximum capacity of 4.3 km^3, located in foothills of Sierra Nevada, California. The dam was impounded in 1968 and after a period of seven years a magnitude 5.7 earthquake occurred 12 km south (downstream) of the dam on 1^{st} August1975.

Mixed Response: Although at some sites it is possible to categorize induced seismicity as belonging to one of the two types, yet both types of responses may occur at one site. For example, at Koyna and Lake Mead, low magnitude seismicity occurred soon after the reservoir filling started. However, major bursts of seismicity occurred after a number of annual cycles had passed. Some cases show a delayed response to initial filling and a strong component of rapid response to short term variation in water level.

5.7.4 Induced Seismicity associated with impounding of reservoirs in the Himalayan Region

A number of dams have been built over Himalayan rivers for the purpose of hydropower generation, irrigation and flood control. Several of these reservoirs have water depth exceeding 100 meters and reservoir volume exceeding 10^9 m^3. Gupta and Rajendran (1986) examined reservoir induced seismicity associated with some of these reservoirs which are located in the Lesser Himalaya and the Sub Himalaya in vicinity of Main Boundary Thrust and Main Central Thrust, the two major tectonic boundary thrusts related to Himalayan orogeny. Out of eleven 1arge reservoirs only two were adequately instrumented for seismological observations. Out of nine large reservoirs that were impounded, local seismological network of sensitive seismographs existed at Mangla and Tarbela reservoirs only. A brief description of seismicity changes observed with the impoundment of four dams is given below.

Mangla: The dam, with a storage volume of 7250 million m^3 and a height of 118 m, is situated on Jhelum River. Several major earthquakes, including the devastating Mangla earthquake of June 4, 1669 which might be associated with Main Boundary Thrust have occurred in the immediate vicinity of this reservoir. Based on temporal variation of local seismicity from 1966 to 1973, it was concluded that since impounding of the Mangla reservoir, seismicity in the vicinity has not increased but may have decreased after five years. No relationship was found between the frequency of occurrence of events and rate of change of water-level in the reservoir.

Tarbela: Tarbela reservoir, with a dam height of 143 meters and a storage volume 1367 million m^3, is located on the Indus River in the Lesser Himalaya of northern Pakistan. The reservoir is located very close to Main Central Thrust. Several major and moderate earthquakes have occurred in the region around Tarbela reservoir in the past. In August 1973, a tele-metered seismic array was installed which provided one year of local seismicity data prior to reservoir loading. Reservoir was filled during summer 1974, but had to be drained. The reservoir was fully impounded during the summer of 1975 and a decrease in seismicity was observed during the two month period of impounding. Further, the region assumed average background seismic activity during the drawdown period and frequency of average activity decreased from 1.1 events to 0.5 events per day during the period of rising water level. During the drawdown period events migrated closer to the reservoir. It was concluded that initial filling of Tarbela reservoir resulted in minor decrease in seismicity within a distance of 100 km from dam site (Jacob et. al, 1979).

Bhakra: Bhakra dam, built on Sutlej River, is located between Main Boundary Thrust and Main Central Thrust in the Himachal Lesser Himalaya. Govind Sagar Reservoir created by the dam has a storage volume of 9868 million m^3 and height 226 m. Reservoir impounding began in 1958 and maximum depth of 115 meters was reached in 1963. Several earthquakes occurred in the immediate vicinity of Bhakra dam in the past. From 1930 to 1958, six moderate earthquakes of magnitude ≥ 5 occurred in the region. Several small earthquakes associated with Main Central Thrust have also occurred. However, only one moderate earthquake ($M \geq 5$) occurred within 100 km of

Bhakra Dam during this period and no such event was located within 50 km of the dam.

At Bhakra most earthquakes occurred north of the reservoir and seem to be associated with the Main Central Thrust. Seismic activity was more during post monsoon months when the reservoir level was high. However, during 1975 no seismic activity occurred though the reservoir level was the highest. It has been concluded that there seems to be no relationship between seismic activity and Govind Sagar Reservoir (Chaudhary and Srivastava, 1978).

Ramganga Reservoir: This is an earth and rock-fill dam across river Ramganga at Kalagarh. It is a 125.6 m high dam with a storage capacity of 2.49 x 10 m^3. The reservoir was partially filled for first time during 1974 summer monsoon. Distribution of events within hypocentral distance of 200 km from dam site obtained from monitoring of micro-earthquake activity from July 15 to Sept. 13, 1974, did not indicate any statistical trend in variation of local events with time. Further, no correlation was observed between filling of the reservoir and number of recorded events. On the basis of this short-term monitoring of local seismicity during the filling of Ramganga reservoir no possible influence of reservoir filling on seismic activity of the region could be brought out (Singh et al., 1976).

5.7.5 Prediction of Reservoir Induced Seismicity Associated with Hydropower Projects in Alaknanda and Bhagirathi Basins

For the purpose of predicting reservoir induced seismicity associated with hydropower projects in Alaknanda and Bhagirathi basins, the statistical model developed by Baecher and Kenney (1982) has been adopted. This model, based on discriminant analysis, has been calibrated by the available worldwide data on induced seismicity and provides approximate estimates of probability of RIS for specific reservoir sites. To calibrate the model, data of 29 worldwide reservoirs that exhibited RIS and 205 reservoirs that did not show RIS, were used. Details of calibration procedure are described in the paper. For predicting RIS, five reservoir attributes were used. These attributes are reservoir depth, reservoir volume, states of stress, fault activity and geology. Each attribute has different states. For example the depth attribute is divided into three states namely, very deep reservoirs (over 150 m), deep reservoirs (90-150 m), and shallow reservoirs (less than 92m). Similarly, volume attribute is divided into three attributes namely, very large, large, and small reservoirs. State of stress refers to the orientation of principle stresses and can be extensional, compressional and shear, depending upon the direction of major principle stresses. Fault activity is classified into two categories based on whether faulting is observed, or not observed in the vicinity of reservoir before the reported RIS. Geological environment has three states depending upon the presence of sedimentary, igneous and metamorphic rocks. Study of relationship between single attribute states and the occurrence of RIS have brought out significant correlations between RIS and reservoir depth, and RIS and reservoir volume.

Reservoir induced seismicity (RIS) was estimated for specific case studies from the Himalayan region, and the probability of occurrence of RIS was worked out on the basis of published empirical relations. Locally monitored earthquakes, recorded through deployment of an earthquake network, were analyzed for this purpose.

Based on analysis of available data, a preliminary model of RIS was developed to assess the probability of RIS given various attribute states. This model has several characteristic features and variants like single attribute model, based on the state of one attribute, multi attribute model that considers all attributes simultaneously. Models of RIS also assume independence among all attributes and assuming dependence between depth and volume. Further, this model can be applied for discrete data set as well as treating volume and depth as continuous variables. IN this study the discrete version of the model was used to compute the probability of occurrence of RIS for Alaknanda and Bhagirathi valleys.

The Model

Predicting the occurrence of reservoir induced earthquakes is a difficult problem due to the complexity of the phenomena of reservoir induced seismicity (RIS). Data set on occurrence of such earthquakes is scanty compared to natural tectonic earthquakes. In view of this our understanding of attributes of reservoir induced earthquakes are limited.

For the purpose of discriminant analysis these reservoirs were characterized by five attributes namely, depth (d), volume (v), stress states (s), presence of active faulting (f) and geology (g); Baecher and Keeney (1982). Considering all the attributes simultaneously, we have:

$$P(RIS,|d,v,s,f,g) = \frac{P(RIS)P(d,v,s,f,g|RIS)}{P(RIS)P(d,v,s,f,g|RIS) + P(\overline{RIS})P(d,v,s,f,g\,|\overline{RIS})}$$

$$P(\overline{RIS},|d,v,s,f,g) = \frac{P(\overline{RIS})P(d,v,s,f,g|\overline{RIS})}{P(RIS)P(d,v,s,f,g|RIS) + P(\overline{RIS})P(d,v,s,f,g\,|\overline{RIS})}$$

$P\,(RIS)\,and\,P(\,\overline{RIS}\,)$ are the prior probabilities of RIs and non-RIS

Where $P(RIS,|d,v,s,f,g)$ is the conditional probability of RIS given the combination of states d, v, s, f, g.

Dividing the above equations we have

$$\frac{P(RIS,|d,v,s,f,g)}{P(\overline{RIS},|d,v,s,f,g)} = \left[\frac{P(RIS)}{P(\overline{RIS})}\right] = \left[\frac{P(d,v,s,f,g|RIS)}{P(d,v,s,f,g|\overline{RIS})}\right] = \frac{P(RIS)}{P(\overline{RIS})}\,LR\,(d,v,s,f,g)$$

The above equation means conditional odds of RIS equals the prior odds of RIS multiplied by the likelihood ratio (LR) for the given states. This equation has been adopted for computing conditional Probabilities.

5.7.6 Computation of Conditional Probability of RIS

Five attributes and their states for various dam sites, based on the definition of reservoir attribute states given by Baecher and Keeney (1982), are as follows:

1. If the depth of proposed reservoir is above 150 m the state of depth attribute is d_1. If the depth lies between 92 to 150 m, the state of depth attribute is d_2 and in case the depth is less than 92 m, the state of depth attribute is d_3.

2. If the volume of proposed reservoir is very large, the state of volume attribute is v1 and in case the volume is large the state of volume attribute is v2. Similarly if the volume is small, the state of volume attribute is v3.

3. If the dam site falls in extensional tectonic environment, the state of stress attribute is taken as s1. If the dam site falls in compressional tectonic environment, the state of stress attribute is taken as s2. Similarly, if the dam site falls in shear tectonic environment, the state of stress attributes is s3.

4. If the area is seismically active, the state of fault activity is taken as f1. If the area is seismically inactive, the state of fault activity is taken as f2. If fault activity is not known, the state of fault activity is f3.

5. If geological formations comprise sedimentary rocks, the state of geology is taken as g_1. If the geological formations comprise metamorphic rocks, the state of geology is taken as g_2. If the geological formations comprise igneous rocks, the state of geology is taken as g_3.

Using the above attribute states, computations of two conditional probabilities of RIS assuming: a) probabilistic independence of all attributes; and b) dependence between depth and volume has been carried out. Two typical examples of computations made for Kotlibhel (Stage -1B) and Srinagar hydropower projects are described below.

5.7.7 Conditional Probability of RIS for Kotlibhel Hydropower Project (Stage -1B)

Five attributes and their states for the site of Kotlibhel hydropower (Stage -1B) project based on definitions of reservoir attribute states are as follows:

1. As the proposed reservoir will be shallow, (less than 92 m), the state of depth attribute is d_3.

2. As the proposed reservoir is small, the state of volume attribute is taken as $v_{3.}$

3. The dam site falls in compressional tectonic environment and state of stress attribute is taken as s_2 .

4. The area is seismically active and state of fault activity is taken as $f_{1.}$

5. The geological formations comprise metamorphic rocks and state of geology is taken as g_2.

Table 5.3 provides the attribute likelihood ratios considering probabilistic independence between various attributes and considering probabilistic dependence between depth and volume.

Table 5.3 Conditional Probabilities of RIS for Kotlibhel Hydropower (Stage -1B) Project Site

Attributes likelihood ratios		
Attribute states	**Independent**	**Dependent between depth and volume**
Depth: shallow	0.21	-
Volume: small	0.66	0.66
Stress: Compressional	0.91	0.91
Fault activity	1.50	1.50
Geology: metamorphic	0.74	0.74
(Π) Product of all values in range of series	0.13	-

Prior odd ratio =0.13

Conditional odd ratio = 0.13 x 0.13 =0.0169

Conditional probability of RIS = $\frac{0.0169}{1 + 0.0169}$ = 0.016 = 0.02 (approx)

5.7.8 Conditional probability of RIS for Srinagar Hydropower Project

Five attributes and their states for the site of Srinagar Hydropower project, based on definitions of reservoir attribute states, are as follows:

1. As the proposed reservoir will be shallow (less than 92 m) the state of depth attribute is d_3.

2. As the proposed reservoir is small, the state of volume attribute is taken as v3.

3. The dam site falls in compressional tectonic environment and state of stress attribute is taken as s2.

4. The area is seismically active and state of fault activity is taken as f1.

5. The geological formations comprise metamorphic rocks and state of geology is taken as g_2.

The attribute likelihood ratios considering probabilistic independence between various attributes and considering probabilistic dependence between depth and volume are listed in Table 5.4.

Table 5.4 Conditional Probabilities of RIS for Srinagar Hydropower Project Site

Attributes likelihood ratios		
Attribute states	**Independent**	**Dependent between depth and volume**
Depth: shallow	0.21	-
Volume: small	0.66	0.66
Stress: Compressional	0.91	0.91
Fault activity	1.50	1.50
Geology: metamorphic	0.74	0.74
(Π) (Product of all values in range of series)	0.13	-

Prior odd ratio =0.13
Conditional odd ratio = 0.13 x 0.13 =0.0169
Conditional probability of RIS = $\frac{0.0169}{1+0.0169}$ = 0.016 = 0.02 (approx)

The attributes for the Kotlibhel stage 1-B and Srinagar hydropower projects are the same and hence the tables 5.3 and 5.4 show similar values.

On similar lines, conditional probabilities can be computed taking into account the different attribute states by grouping the hydropower projects having similar attribute states. A large number of proposed dams have shallow depths and small reservoir volume and in view of this the conditional probability is very small, of the order of 0.02. Some proposed dams in this category are located north of the Main Central Thrust and on account of this the state of geological attribute changes and becomes igneous (g_3). This will bring about slight change in the value of conditional probability which becomes (0.03).

Because reservoir attributes fall into different states, efforts have been made to compute conditional probabilities taking different combinations of the attribute states. Conditional probabilities have been computed for nine combinations and are listed below.

Attribute States		**Conditional probability**
Depth	Volume	Independent
Very deep	Very large	0.25
Very deep	Large	0.43
Very deep	Small	0.18
Deep	Very large	0.09
Deep	Large	0.19
Deep	Small	0.07
Shallow	Very large	0.02
Shallow	Large	0.06
Shallow	Small	0.02

Critical probabilities of the probabilistic model have been estimated based on an almost similar data set of reservoir induced earthquakes and it has been inferred that if the occurrence probability predicted by model is greater than the critical probability then an induced earthquake can occur after filling of reservoir (Baoqi, 1992). However, in case the occurrence probability is less than the critical probability no induced earthquake can be considered to occur. The critical probability estimated by Baoqi (1992) falls between 0.2 and 0.3. The maximum occurrence probabilities estimated for the various hydro-electric project sites falling in the Alaknanda – Bhagirathi basins have values less than 0.2, which is less than the critical probability. In view of this the cumulative risk of reservoir induced earthquakes, as a random event, seems to be very unlikely.

A review of reported cases of reservoir induced seismicity for large reservoirs located in the Sub-Himalaya and the Lesser Himalaya having volume more than 10^9 cubic meters and/or the height of the dams above 100 meter has brought out that none of these reservoir sites exhibit reservoir induced seismicity. Nine of these reservoirs were fully impounded. Local networks of seismological instruments were deployed at some of these reservoirs to monitor local seismic activity. Non occurrence of induced seismicity phenomenon is primarily attributed to the thrust fault environment prevalent in the Himalaya region as this faulting environment is not conducive to reservoir induced seismicity. However, if normal and strike slip faults fall in the reservoir area induced seismicity might occur. Tarbela reservoir is located on Indus River in the Lesser Himalaya of northern Pakistan with a volume of 1367 million cubic meters and dam height of 143 m. A telemetry seismic array was deployed prior to reservoir filling to collect pre-impounding data. Comparison of this pre-impounding data with the post –impounding seismicity data showed that there was minor decrease in seismicity within a distance of 100 km from dam site during initial filling of Tarbela reservoir. Most dam sites in the Garhwal Lesser Himalaya fall in an almost similar tectonic environment and it can be concluded that chances of occurrence of reservoir induced seismicity are minimal.

5.8 PATTERN OF LOCAL SEISMICITY IN ENVIRONS OF ALAKNANDA AND BHAGIRATHI BASINS

5.8.1 Background Information

For the purpose of monitoring of local seismicity in the environs of Tehri dam covering the reservoir area, the Department of Earthquake Engineering at IIT Roorkee deployed a twelve station radio-linked local seismological network with the central recording station (CRS) at New Tehri. This network became operational in 1994 and initially, digital data was continuously transmitted from six remote stations to the central recording station where it was collected in an analog mode using smoked paper analog seismographs (MEQ-800 systems). From 1994 to 2007 local earthquake data in the form of seismograms was collected at central recording station and was continuously analyzed and interpreted to study attributes of local seismicity of the region.

Since December 2007 the above local network was expanded and replaced by a state-of-the-art 12 station radio-linked digital seismological network. This greatly improved the timing accuracy of incoming data and also allowed estimation of source parameters in addition to the regular hypocenter parameters of local earthquakes. Location of 12 stations of the local seismological network is shown in Fig. 5.9.

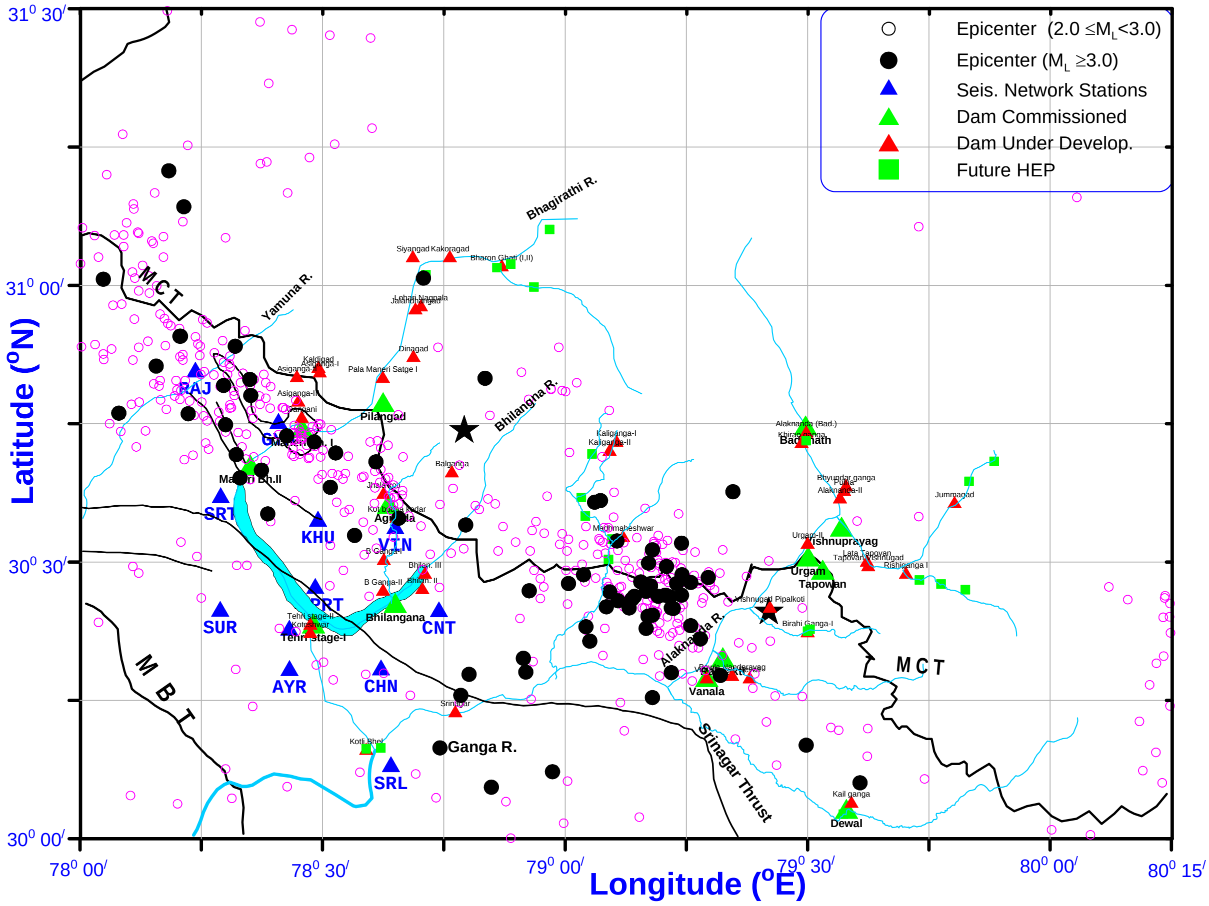


Fig. 5.9. Local seismicity in the Alaknanda Bhagirathi basin during the period 1994-2009.

5.8.2 Data Processing and Analysis

Analog records obtained at Central Recording Station (CRS) were scanned for identification of micro earthquakes and small earthquakes. Events were identified as seismic in origin because of their sudden beginning distinct P and S phases and slow decaying coda (viz., signal duration). Events recorded at three or more stations were located using the well known Hypo71PC computer program given by Lee and Lahar (1975). Events having local magnitude (M_L) two and above have been considered for analysis.

5.8.3 Interpretation of Local Earthquake Data

From the point of view of hydropower projects there are two main purposes for monitoring local seismicity. Firstly, it allows one to study the level of contemporary local seismicity and to delineate active fault source zones. Secondly, samples of local seismicity collected before reservoir filling allows one to study changes in local seismicity during and after reservoir impounding.

Fig. 5.9 depicts the pattern of local seismicity, i.e. distribution of epicenters of earthquakes located during period 1994 to 2009 in the region. Spatial distribution of epicenters has revealed a 100 km long and 30 km wide zone of local seismicity that extends from 30 km northwest of Barkot town to Chamoli town. Distribution of seismicity in this zone is non-uniform but, by and large, follows the trend of the MCT. Location of hydropower projects, both commissioned and those under development and planned in future, have been superimposed on the local seismicity map. This shows that the region falling north of the MCT, where a number of proposed hydropower projects are located both along the river Bhagirathi and Alaknanda, exhibit a low level of contemporary local seismicity. No change in the pattern of local seismicity, within 40 km of Tehri dam, has been observed after the filling of Tehri dam reservoir. The focal depth distribution of located events shows that the entire activity falls in the depth range of 5 to 50 km. However, majority of events occur at depths up to 20 km.

5.9 CONCLUSIONS

Seismic activity of the study area is considerably high and earthquakes with maximum magnitude 6.8 occurred in the region. Noteworthy earthquakes in the region are 1991 Uttarkashi (M=6.6) and 1999 Chamoli (M=6.8) earthquakes. In view of earthquake occurrence and the prevailing seismotectonic models, standard procedures have been adopted to estimate ground motions (conservatively) for the various project sites for design purpose. It is rational to believe that dams can withstand future earthquakes with the present design.

Study of local seismicity around Tehri region, employing a seismological network since 1994, has provided useful information on the pattern of local seismicity in the vicinity of proposed hydropower projects. Region falling north of the MCT, where most proposed hydropower project sites are located, both along the Alakananda and Bhagirathi rivers, exhibit a low level of contemporary local seismicity. No change in the pattern of local seismicity, within 40 km of Tehri dam, has been observed after filling of the Tehri dam reservoir.

The maximum occurrence probabilities estimated for various hydropower project sites falling in the Alakhnanda and Bhagirathi basins have values less than 0.2, which is the critical probability. In view of this the cumulative risk of occurrence of reservoir induced earthquakes, as a random event, seems to be very unlikely.

Most dam sites in the Garhwal Lesser Himalaya fall in a compressional tectonic environment, and based on available case histories of Bhakra, Mangla, Tarbela and Tehri from the Himalayan region on RIS, it can be concluded that chances of occurrence of reservoir induced seismicity are minimal.

Many hydropower projects fall under run of the river scheme and do not have reservoirs, in view of this there are least chances that these will bring about any change in the prevailing seismic status of the region.

5.10 RECOMMENDATIONS

As geological and seismotectonic conditions are highly variable in the study area no generalized design parameters for dams can be suggested. In view of this wherever a new hydropower project is planned or established it is recommended that a detailed site specific geological, seismological and seismotectonic study be carried out for design, as is the normal practice.

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CHAPTER – 6

WATER QUALITY, BIODIVERSITY AND RIVER ECOLOGY

6.1 INTRODUCTION

Information on the hydrology and associated water quality is very important for evaluating management strategies at a watershed level. Water quality has become a very big issue today, partly because of the tremendous growth in population, changes in land use and urban expansion and development. Rural areas also contribute to water-quality problems. The excess nutrients have the potential to degrade water quality if incorporated into runoff from farms into streams. All this growth puts great stress on the natural water resources.

Limited data on water quality of Bhagirathi and Alaknanda and their tributaries is available in the public domain. Based on bio-monitoring assessment of the rivers of Uttarakhand, Semwal and Akolkar of CPCB (2006) evolved biological water quality criteria for various uses and their respective characteristics. In the water quality report on EIA of Alaknanda River [2009], assessment of water quality of Alaknanda River has been made. There is an EIA report of NTPC (2007). NTPC has tested water samples taken in post-monsoon season from Tapovan Vishnugad HP situated on Dhauliganga, a tributary of Alaknanda River and Lohari Nagpala hydropower project situated on Bhagirathi River. The above information is discussed in detail in the section dealing with the comparison of the results of water quality assessment done under this study and the water quality results available in previous studies.

The present study has been carried out on the water sampling for estimating the water quality in undisturbed state (Baseline) and assessing the impact of HPs at the upstream (u/s) and the downstream (d/s) of hydropower projects (HP) in Alaknanda and Bhagirathi Basins. The list of HPs is given in Table 6.3 and the drainage network map of the study area showing the locations of sampling points is given in the map (Fig. 6.1). Both water quality and water quantity characteristics have effect on ecosystem. Although, the minimum flow guidelines focus on water quantity, the water quality factors should not be ignored.

Changes in water quality may occur due to the location of a dam/barrage in a river and its effects are often experienced both upstream and downstream. Some of the effects can be increase or decrease the dissolved oxygen, increase in the total dissolved gases, modify nutrient levels, and modify the thermal levels. Relatively few reservoirs have acute problems and mitigation measures can be adopted if necessary.

6.1.1 Scope of Work

- To determine baseline water quality of the rivers.
- To carry out water quality analysis of selected parameters at HP projects under operation i.e., projects that have been commissioned.
- To carry out water quality analysis of some HP projects under development.
- To carry out water quality analysis at HP Future projects.

6.1.2 Considerations for Selection of Sampling Sites for Testing Water Quality

i. Since the projects are located both on Bhagirathi and Alaknanda rivers and their tributaries, the sites selected covered both the rivers and their tributaries.
ii. For baseline water quality, samples were collected from stretches of rivers where there are no HPs and which are largely not influenced by human activity.
iii. Projects with capacity smaller than 10 MW do not have significant impact. Hence consideration for selection of sites was limited to projects with capacity exceeding 10 MW.
iv. Out of 70 Hydro Electric Projects only 40 HP sites in Alaknanda and Bhagirathi Basins were selected to find out the impact on water quality. In this, 6 HPs are in operation, 27 are under construction and 07 projects are future sites. Nineteen samples were taken to determine the Baseline water quality of rivers i.e., river stretches which are largely left in natural state.

6.1.3 Parameters Measured

The parameters have been selected keeping in view their influence on the sustainability of aquatic life. The following parameters have been measured at selected locations of hydroelectric projects:

(i). Temperature (°C)
(ii). pH
(iii). Dissolved Oxygen (mg/l)
(iv). Conductivity (µs/cm)
(v). Total Dissolved Solids (mg/l)
(vi). Turbidity (NTU)
(vii). BOD (mg/l)
(viii). Fecal Coliform (MPN/100 ml)
(ix). Total Phosphates (mg/l)
(x). Nitrate- Nitrogen (mg/l)

6.1.4 Number of Samples Collected

The sampling was done in the following manner:

i. For Commissioned Hydropower Projects two samples were drawn one or more from upstream and one from downstream of the project site.
ii. For Under Construction Hydropower Projects one or two samples were drawn at each project selected.
iii. For Proposed Hydropower projects one sample was taken from each project site
iv. A number of samples were collected from different rivers in the basins for the purpose of generating baseline data (Table 6.1).

Table 6.1. Samples for baseline data collection

River Basin	No. of Samples
Alaknanda	04
Mandakini	04
Bhagirathi	05
Bhilangna	06
Total	**19**

The HP sites are classified in 3 categories (Table 6.2)**:**

Table 6.2. Sampling plan for water samples from project sites

S. No.	HP Project	No. of HPs	No. of Samples
1	Commissioned	06	15
2	Under Construction	27	48
3	Proposed	07	07
Total		**40**	**70**

The list of HP sites where samples were collected is given in Table 6.3 and location is shown on the map (Fig. 6.1).

Table 6.3. List of sampling locations of hydropower projects

(A) Commissioned Hydropower Projects

S. No.	Name of PR	Name of ST	Long	Lat	Altitude (m)
1	Tehri stage-I	Bhagirathi	78.481	30.389	640
2	Visnuprayag	Alaknanda	79.578	30.564	1488
3	Maneri Bhali-I	Bhagirathi	78.503	30.706	0
4	Vanala	Nandakini	79.292	30.292	816
5	Bhilangana	Bhilangna	78.650	30.426	820
6	Maneri bhali-II	Bhagirathi	78.353	30.667	919

B) Under Construction Hydropower Projects

S. No.	Name of PR	Name of ST	Long.	Lat.	Altitude (m)
1	Alaknanda	Alaknanda	79.497	30.736	2800
2	Bhilangna-III	Bilangna	78.706	30.453	1060
3	Bowla Nandprayag	Alaknanda	79.344	30.296	1300
4	Tapovan Vishnugad	Dhauliganga (A)	79.625	30.494	1780
5	Tehri Stage-II	Bhagirathi	78.475	30.389	640
6	Vishnugad Pipalkoti	Alaknanda (A)	79.414	30.419	1005
7	Bhilangana II	Bhilangna			
8	Srinagar	Alaknanda	78.774	30.231	560
9	Koteshwar	Bhagirathi	78.475	30.374	620
10	Kotli Bhel II	Ganga	78.590	30.163	680
11	Lata Tapovan	Dhauliganga (A)	79.622	30.503	1780
12	Rishi Ganga	Rishi Ganga			

S. No.	Name of PR	Name of ST	Long.	Lat.	Altitude (m)
13	Lohari Nagpala	Bhagirathi	78.703	30.964	2151
14	Madhmaheshwar	Madhma-heshwar	79.119	30.547	1400
15	Pala Maneri Stage-I	Bhagirathi	78.539	30.742	1615
16	Kotlibhel H.E. (Stage-1B)	Alaknanda	30.1639	78.6200	670
17	Kotlibhel H.E. (Stage-1A)	Bhagirathi	30.1625	78.5900	680
18	Phata-Byung	Mandakini	30.5333	79.0333	1240
19	Singoli Bhatwari	Mandakini	30.5047	79.0894	760
20	Devsari H.E.	Pindar	30.0444	79.5736	1320
21	Jelam Tamak	Dhauli ganga	30.6458	79.8327	2420
22	Malari Jelam H.E.	Dhauli ganga	30.6819	79.8846	2760
23	Bharon Ghati	Bhagirathi	78.869	31.036	2640
24	Birahi Ganga-I	Birahi Ganga			
25	Birahi Ganga	Birahi Ganga	30.3750	79.5000	1476
26	Nandprayag Lagasu	Alaknanda			
27	Tamak lata	Dhali ganga			

(C) Proposed Hydropower Projects

S. No.	Project Name	Name of ST	Lat.	Long.	Altitude (m)
1	Melkhet	Pindar			
2	Bhyundar Ganga	Bhyundar Ganga	79.579	30.639	2080
3	Jalandharigad	Jalandarigad	78.692	30.958	2160
4	Pulna	Alaknanda			
5	Gohana Tal	Birahi Ganga	30.3786	79.5050	1200
6	Rambara	Bhagirathi	30.6953	79.0556	2040
7	Karmoli	Jahnvi			

The sampling locations for Baseline water quality data and for impact of hydropower Projects are and shown in Tables 6.7 &6. 8. The sampling points for these base line data were selected on the river stretch upstream of the first HP on the tributary of the river.

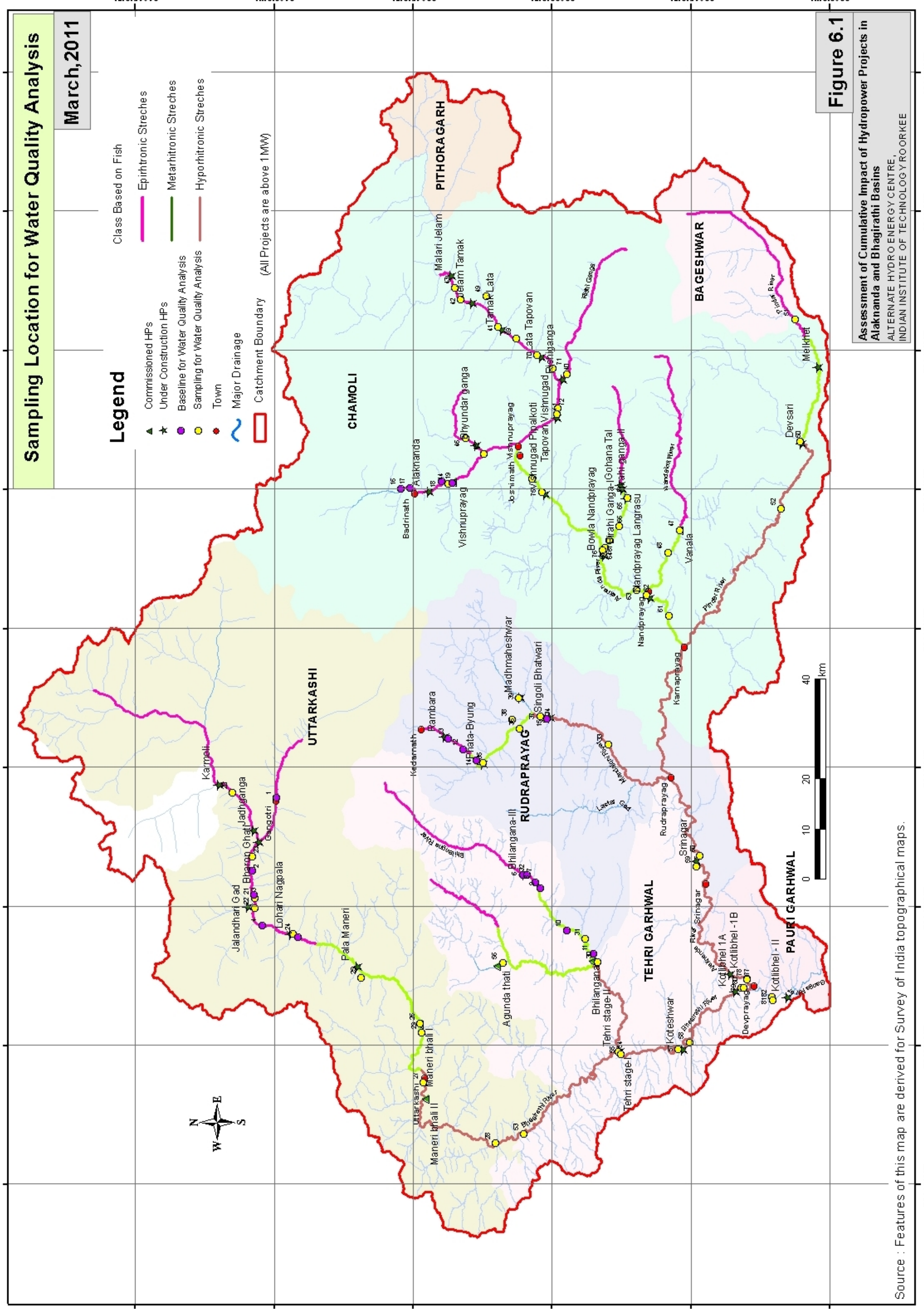

Fig. 6.1. Map showing location of sampling points for water quality

6.2 SAMPLING METHODOLOGY

The sampling and analysis were done as per APHA (20th Edition) Water samples were collected from Alaknanda and Bhagirathi rivers during four visits organized from the end of October, 2010 to middle February 2011. They were taken 0.50 m below the surface. The samples were stored in polyethylene bottles.

In the field, five, water quality in-situ parameters namely pH, conductivity, TDS, DO and Temperature were measured at the site itself by means of portable instrument (HACH). For other parameters, samples were preserved by adding appropriate reagent, followed by storage at 4°C in ice and brought to the laboratory for analysis. Analysis was conducted as per standard methods prescribed in APHA (20th Edition). A brief description of the analytical methods used is given in Table 6.4.

Tables 6.4. Analytical procedures Adopted for different water quality parameters

S. No.	Parameter	Method	Make / Model	Accuracy (%)
1	Temperature	Thermometric method	-	± 1
2	pH	Electrometric method	Hach	± 5
3	Conductivity	Electrometric method	Hach	± 5
4	TDS	Electrometric method	Hach	± 5
5	DO	Electrometric method	Hach	± 5
6	Turbidity	Electrometric method	Hach	± 5
7	Nitrate nitrogen	Spectrophotometric method	Spectrophotometer Hach	± 5
8	Total Phosphorous	Spectrophotometric method	Spectrophotometer Hach	± 5
9	BOD	Titrometric method	APHA (20th Edition)	-
10	Fecal coliform	Via- media method	APHA (20th Edition)	-

6.2.1 Significance of Parameters Tested

The parameters of water quality were selected which are likely to be affected by hydropower projects and are critical to the aquatic life or for various other uses. The significance of these parameters is briefly discussed:

(a) Temperature

Water gets stored in the reservoir or the barrage and also passes through a long tunnel. It may undergo changes in temperature in the process of storage or in travel to the power house. Aquatic life is sensitive to temperature.

(b) pH

The balance of positive hydrogen ions (H+) and negative hydroxide ions (OH-) in water determines how acidic or basic the water is. It indicates which 'ions', with a positive or negative electrical charge dominate.

The pH scale ranges from 0 (high concentration of positive hydrogen ions, strongly acidic) to 14 (high concentration of negative hydroxide ions, strongly basic).

In pure water, the concentration of positive hydrogen ions is in equilibrium with the concentration of negative hydroxide ions, and the pH measures exactly 7 [Anonym 1972].

(c) Conductivity

Conductivity is a measure of the ability of water to pass an electrical current. Conductivity in water is caused by the presence of inorganic dissolved solids such as chloride, nitrate, sulfate, and phosphate anions (ions that carry a negative charge) and sodium, magnesium, calcium, iron, and aluminum cations (ions that carry a positive charge). Conductivity is also affected by temperature: the warmer the water, the higher the conductivity.

Conductivity in streams and rivers is affected primarily by the geology of the area through which the water flows. Streams that run through areas with granite bedrock tend to have lower conductivity because granite is composed of more inert materials that do not ionize (dissolve into ionic components) when washed into the water.

streams that run through areas with clay soils tend to have higher conductivity because of the presence of materials that ionize when washed into the water. Ground water inflows can have the same effects depending on the bedrock they flow through. Discharges to streams can change the conductivity depending on their make-up. Inflow of sewage would raise the conductivity because of the presence of chloride, phosphate, and nitrate; an oil spill would lower the conductivity. [APHA 1992].

(d) TDS

It refers to the total amount of all inorganic and organic substances – including minerals, salts, metals, cations or anions – that are dispersed within a volume of water. While TDS is not considered a primary pollutant, high TDS levels typically indicate hard water and may lead to scale buildup in pipes, reduced efficiency of water filters, hot water heaters, etc., and aesthetic problems such as a bitter or salty taste. TDS in drinking-water originate from natural sources, sewage, urban run-off, industrial wastewater, and chemicals used in the water treatment process, and the nature of the piping or hardware used to convey the water, i.e., the plumbing.. The United States Environmental Protection Agency (EPA) recommends treatment when TDS concentrations exceed 500 mg/L, or 500 parts per million (ppm). The TDS concentration is considered a Secondary Drinking Water Standard, which means that it is not a health hazard. However, further testing may be warranted, as water with a high TDS concentration may indicate elevated levels of ions that do pose a health concern, such as aluminum, arsenic, copper, lead, nitrate and others. [Bruvold and Ongerth 1969, WHO 1989].

(e) Dissolved Oxygen

DO vary in natural water depending on the temperature as well as saturation values. As DO levels in water drop below 5.0 mg/l, aquatic life comes under stress.

(f) Turbidity

Turbidity refers to how clear the water is. Turbidity is a measure of the degree to which the water loses its transparency due to the presence of suspended particulates. The more total suspended solids in the water, the murkier it seems and the higher the turbidity. Turbidity is considered as a good measure of the quality of water. The WHO (World Health Organization), establishes that the turbidity of drinking water should not be more than 5 NTU, and should ideally be below 1 NTU [Michaud 1991]. The major effect turbidity has on humans might be simply aesthetic - people don't like the look of dirty water. However, turbidity also adds real costs to the treatment of surface water supplies used for drinking water. Pollution tends to reduce water clarity. Watershed development and poor land use practices cause increases in erosion, organic matter, and nutrients, all of which cause increase in suspended particulates and algal growth [Anonym, 1989]. During the rainy season when mud and silt are washed into rivers and streams, high turbidity can quickly block filters and stop them from working effectively. High turbidity will also fill tanks and pipes with mud and silt, and can damage valves and taps. Where chlorination of water is practiced, even quite low turbidity will prevent the chlorine killing the germs in the water efficiently.

(g) Nitrate – Nitrogen (NO_3-N)

Nitrate in water is undetectable without testing because it is colorless, odorless, and tasteless. Nitrogen occurs naturally in the soil in organic forms from decaying plant and animal residues. In the soil, bacteria convert various forms of nitrogen to nitrate, (NO_3-N). Nitrate is a major ingredient of farm fertilizer and is necessary for crop production. When it rains, varying nitrate amounts wash from farmland into nearby waterways. Nitrates also get into waterways from lawn fertilizer run-off. The Environmental Protection Agency (EPA) has since adopted the 10 mg/L standard as the maximum contaminant level (MCL) for nitrate-nitrogen and 1 mg/L for nitrite-nitrogen for regulated public water systems. It is difficult to establish an exact level at which nitrogen concentrations in water are safe or unsafe [Knepp and Arkin 1973, Moore 1989].

(h) Total Phosphate (TP)

Phosphorus is usually present in natural water as phosphates (orthophosphates, polyphosphates, and organically bound phosphates). Phosphorus is a plant nutrient needed for growth and a fundamental element in the metabolic reactions of plants and animals (hence its use in fertilizers). Sources of phosphorus include human and animal wastes (i.e., sewage), industrial wastes, soil erosion, and fertilizers.

Ortho forms are produced by natural processes and are found in wastewater. Poly forms are used for treating boiler waters and in detergents; they can change to the ortho form in water. Organic phosphates are important in nature and also may result from the breakdown of organic pesticides which contain phosphates [Anonym 1963].

(i) BOD

Biochemical oxygen demand or BOD is a chemical procedure for determining the amount of dissolved oxygen needed by aerobic biological organisms in a body of water to break down organic material present in a given water sample at certain temperature over a specific time period. It is not a precise quantitative test, although it is widely used as an indication of the organic quality of water. Clair et.al. 2003 It is most commonly expressed in milligrams of oxygen consumed per liter of sample during 5 days of incubation at 20 °C or 3 days at 27°C and is often used as a robust surrogate of the degree of organic pollution of water.

(j) Fecal Coliform

The presence of fecal coliform bacteria in aquatic environments indicates that the water is contaminated with the fecal material of human being or other animals. These can enter river through direct discharge of waste from man, animals and birds or through drainage from the watershed. It is an indicator of potential health risk for individuals exposed to this water. Untreated organic matter that contains fecal coli form can be harmful to the environment. Aerobic decomposition of this material can reduce dissolved oxygen levels if discharged into the rivers or waterways. This may reduce the oxygen to a level that kill the fish and affect other aquatic life. Fecal coli form in wastewater can be reduced by the use of chlorine and other disinfectant chemicals.

The Central Pollution Control Board has classified water in five classes on the basis of water quality as given in the Table 6.5.

Table 6.5. Water quality standards prescribed by CPCB.

S. No.	Designated-Best-Use	Class of water	Criteria
1	**Drinking Water Source thout conventional treatment but after disinfection**	A	Total coliforms organism MPN/100ml shall be 50 or less pH between 6.5 and 8.5 Dissolved Oxygen 6mg/l or more Biochemical oxygen Demand 5 days 20°C 2mg/l or less
2	**Outdoor bathing (Organized)**	B	Total Coliforms Organism MPN/100ml shall be 500 or less pH between 6.5 and 8.5 Dissolved Oxygen 5mg/l or more Biochemical Oxygen Demand 5 days 20°C 3mg/l or less
3	**Drinking water source after conventional treatment and disinfection**	C	Total Coliforms Organism MPN/100ml shall be 5000 or less pH between 6 to 9 Dissolved Oxygen 4mg/l or more Biochemical Oxygen Demand 5 days 20°C 3mg/l or less
4	**Propagation of Wild life and Fisheries**	D	pH between 6.5 to 8.5 Dissolved Oxygen 4mg/l or more Free Ammonia (as N) 1.2 mg/l or less
5	**Irrigation, Industrial Cooling, Controlled Waste disposal**	E	pH betwwn 6.0 to 8.5 Electrical Conductivity at 25°C micro mhos/cm Max.2250 Sodium absorption Ratio Max. 26 ,Boron Max. 2mg/l

* Below-E Not Meeting A, B, C, D & E Criteria.

6.2.1 Time Period of Visit for Sampling

The details of visits for sampling, nature of samples drawn and the locations are given in Table 6.

Table 6.6. Details of water sampling schedule

S. No.	Visits	Date of Visits	Area	Nature of Sampling	HP Projects						Total samples
					In operation		Under development			Future projects	
					u/s	d/s	u/s	d/s			
1	1st Visit	19th – 28th Oct. 2010	u/s of HP on Alaknanda & Bhagirathi River Basin	Baseline data *WQ Sampling	-		-			-	19
2	2nd Visit	11th – 17th Nov. 2010	Bhagirathi river basin	HP WQ Sampling	3	3	2	2	4	3	17
3	3rd Visit	02nd - 15th Dec. 2010	Alaknanda river basin	HP WQ Sampling	2	2	4	4	6	4	22
4	4th Visit	29th Jan.- 10th Feb. 2011	Alaknanda & Bhagirathi River Basin	HP WQ Sampling	4	1	13	13	-		31
Total											89

For sampling and analysis, the CPCB guidelines were followed.
*WQ stands for samples drawn from hydropower project sites.

6.2.2 Data Collection

Two samples were collected from each Commissioned HP i.e. one from upstream and another from downstream of each project. Two samples were also collected from each HP (under construction) one from u/s and another from d/s. From a hydropower project site where construction work had not started only one sample was collected. The water quality data of samples collected above are given in Tables 6.7 and 6.8. The trend of different parameters is shown in Figs. 6.2a, 6.2b, 6.3a, 6.3b, 6.4a, 6.4b, 6.5a, 6.5b and 6.6a, 6.6b, 6.7a, 6.7b, 6.8a, 6.8b and 6.9a, 6.9b.

6.3 RESULTS AND DISCUSSIONS

The water quality data has been classified into three categories, namely

- Baseline stations,
- Stations at commissioned HP sites
- Stations at HP sites under development

6.3.1 Baseline Data

(a) Bhagirathi River

The samples BG 1 to BG 5 are from u/s to d/s. The results indicate that the temperature ranges from 6.6°C – 9.3°C, at the time of sampling while the pH remains between 7.2 – 7.6 which is lower than the prescribed limits for class ‘A’ of water i.e., (6.5 – 8.5). The DO ranges from 8.30 – 8.94 mg/l which satisfies the prescribed value of (6 mg/l or more).

The turbidity ranged from 1.79 – 7.95 mg/l which is less than the standard limit of 10 mg/l and indicates the availability of natural water having less sediments/ silts and water of class A (Table 5).

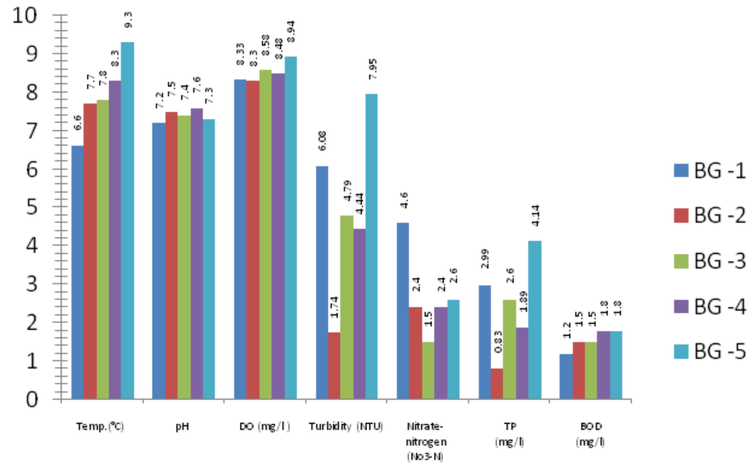

Fig. 6.2 (a) Baseline data of Bhagirathi River (from upstream to downstream)

Nitrate - nitrogen (NO_3-N) range from 1.5 – 4.6 mg/l. The highest value is 4.6 at BG 1 and lowest at BG 3 (1.5). The high values may be attributed to the more human activities related to the agriculture/ artificial forest using synthetic nitrogen fertilizer which appears through the runoff into the stream. The TP range from 0.832 – 4.14 mg/l . The high TP in BG 5 followed by BG 1 may be due to the flow of human waste into the stream. This is supported by the presence of temple in that area.

The BOD range from 1.2 – 2.8 mg/l which are lower than the prescribed limit of drinking water.

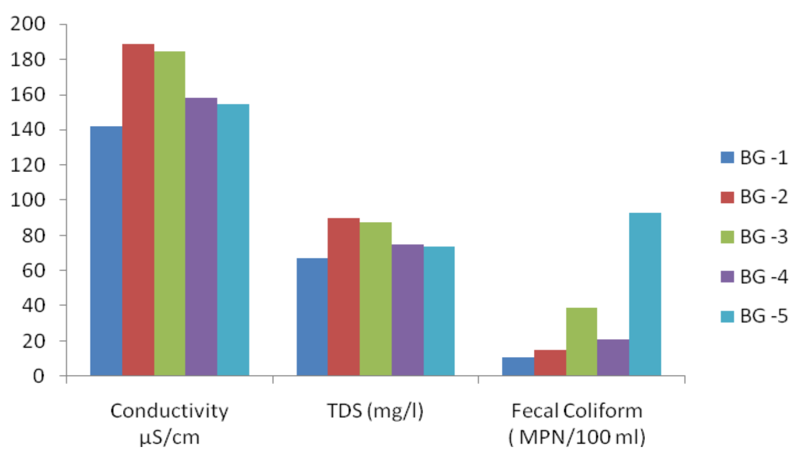

Fig.6.2 (b) Baseline Data of Bhagirathi River (From upstream to downstream)

(* **where,** BG -1- BG-5 = Bhagirathi sample 1- 5.)

The conductivity ranges from 142 – 189 µs/cm. There is an increase in the conductivity at BG 2 and BG 3 as compared to BG 1 indicating the mixing of mineral rich water. The trend indicates that there is a significat increase in conductivity from BG 1 – BG 3 and then slight decrease from 87.4 – 73.7 over 75 µs/cm (BG 4).

The FC ranges from 71 to 93MPN/100ml which are under the standard limits of class A water (50 or more). The increase in FC from BG1 – BG 3 and further from BG 4 – BG 5 is attributed to the increase in the amount of human waste as we go from BG 1 to BG 5.

These findings show that the baseline data of Bhagirathi River are within the limit of drinking water specification except for FC which is higher than the limit in all the 5 sites. The quality water is suitable for aquatic life corresponding to the cold temperatures prevailing in the area of sampling. This data can be used as baseline data for comparison of the water quality with the samples collected from HP sites.

(b) Alaknanda River

The temperature shows an increase from 2.1°C to 6.7°C indicating the lowest temperature (2.1°C) in the higher altitude site which increases as we go downstream. The pH in all the four baseline sites is not exceeding the permissible limit for water class A (Table 6).

The DO ranges from 8.1 (AK-2) to 9.74 mg/l (AK-1). These values are in the range of drinking water standards. The variations in the turbidity are not very large and are under the standard limit. However, at site AK-2 turbidity is high giving 9.99 NTU against the low value of 1.2 mg/l at AK-4 location indicating considerable human activity.

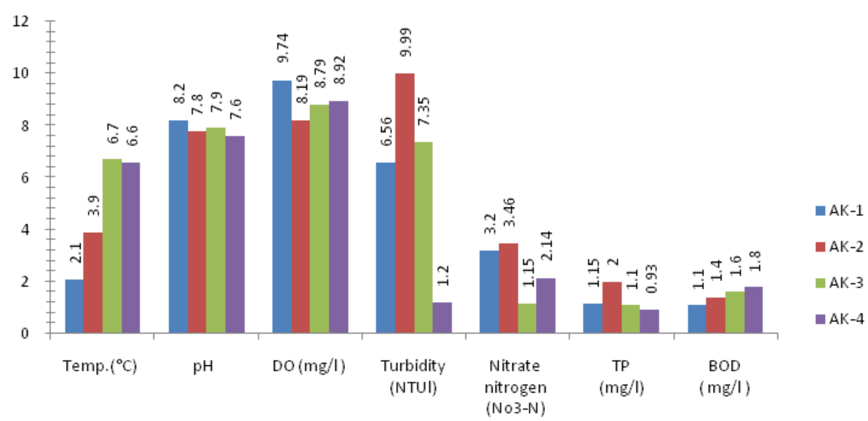

Fig. 6.3 (a). Baseline data of Alaknanda River (from upstream to downstream)

The NO_3-N ranges from 1.15 mg/l (AK-3) to 3.46mg/l (AK-2). These values indicate anthropogenic activity near the sampling location and the flow of nutrients from the watershed. The BOD ranges from 1.1 to 1.8 mg/l. These values are lower than the drinking water specifications (< 2 mg/l. The conductivity on all the four sites ranges from 67.2 to 81.4 µs/cm which is contributed by the chemical weathering of the rocks is the catchment. The Turbidity and TDS are also low and range from 9.99 to 1.2 NTU and 31.5 to 38.3 mg/l respectively.

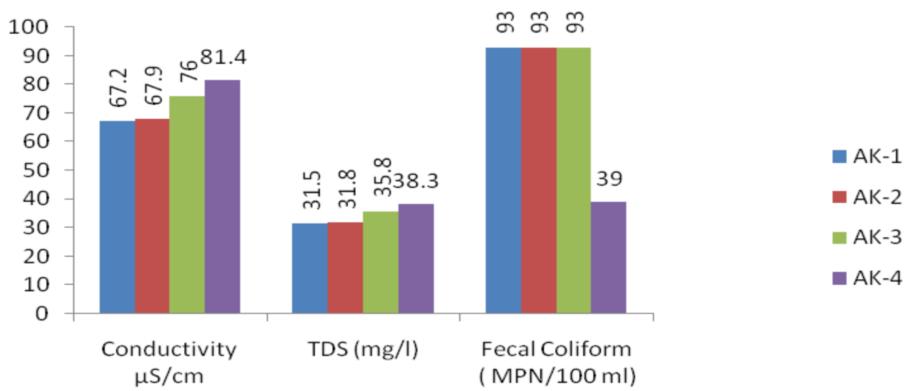

Fig. 6.3 (b). Baseline data of Alaknanda River (from upstream to downstream)

(* where, AK- 1 – AK -4 = Alaknanda Sample 1-4).

The fecal coliform in all the sites (except AK-4) were more than the standard prescribed for water class A (Drinking purpose). This is due to the anthropogenic activity in the vicinity of the sampling locations. In the case AK-4 site the FC were found as 39 MPN/100 ml due to the least human impact in the area.

In view of the above data, it is concluded that baseline parameters of all the four sites are meeting the drinking water requirements except FC which are marginqally higher than the specified value except AK-4. The quality of water is suitable for aquatic life corresponding to the cold temperatures prevailing in the area of sampling.

(c) Mandakini River

Four samples were collected on the upper stretch of Mandakini River from Kedarnath to Okhimath. The results shows that the temperature ranges from 4.7°C to 11.9°C as one goes in downstream direction.

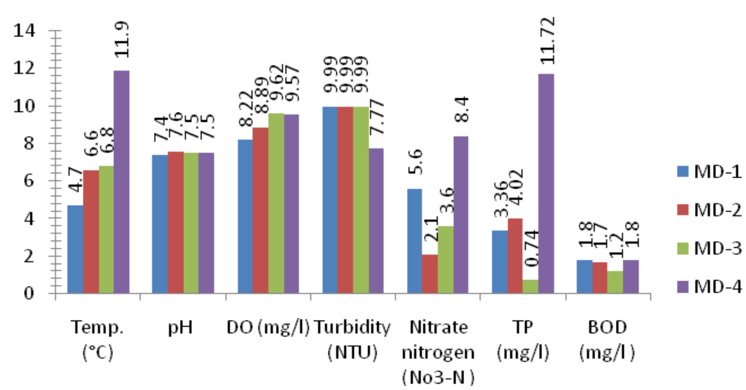

Fig. 6.4 (a). Baseline data of Mandakini River (from upstream to downstream)

The pH was found in the river water of sampled stretch in the range of 7.4 to 7.6. The DO was in the range of 8.22 to 9.62 mg/l. This increase in the DO towards downstream may be due to the natural aeration occurring during the flow

The turbidity level is 9.99 to 6.56. The NO_3-N ranges from 2.1(MD-2) to 8.4 mg/l (MD-4). There seems to be4 some contribution of runoff from agricultural fields.

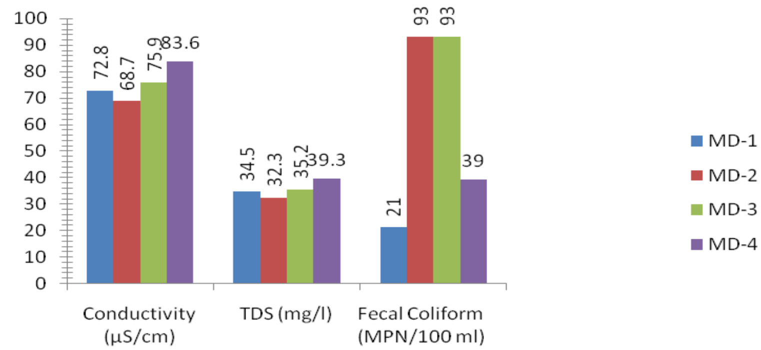

Fig. 6.4 (b). Baseline data of Mandakini River (from upstream to downstream)

* (**where**, MD-1 to MD- 4 = Mandakini Sample 1-4).

High TP (11.72 mg/l) was found due to anthropogenic impact in the river water downstream to the Gaurikund. The BOD ranges from 1.2 to 1.8 mg/l. Slightly higher BOD values in the downstream of both the towns (MD-1 and MD-4) is due to impact of human activities. The conductivity ranges from 68.7 to 83.6 µs/cm and increases along the streamflow in the Mandakini river water. The FC varies from 21 to 93 MPN/100ml increasing downstream. Aeration takes place from Gaurikund to Okhimath to reduce the FC count.

The Mandakini River carries drinkable water (CPCB class 'A') in its upper stretch except in Rambara and Gaurikund. It is suitable for aquatic life.

(d) Bhilangna River

The samples of BL1 to BL6 are from u/s and d/s, where temperature ranges from 9.5°C to 17.3°C during the month of October while the pH remains in range of 7.3-7.6 mg/l. The DO ranges from 8.6 - 9.34 mg/l. the turbidity ranges from 1.08 – 9.99 NTU.

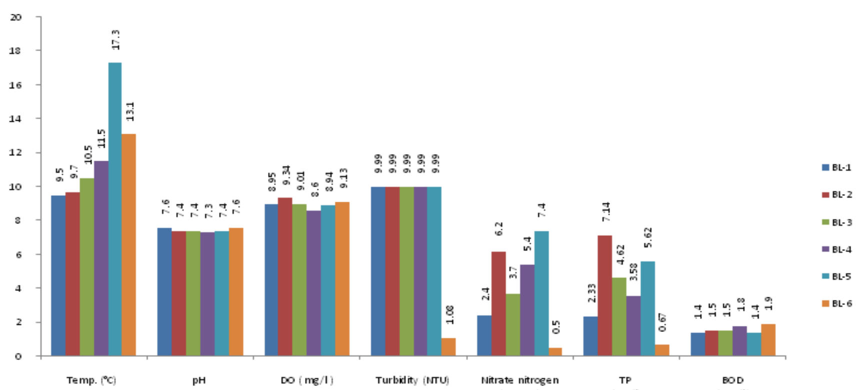

Fig. 6.5 (a). Baseline data of Bhilangna River (from upstream to downstream)

The Nitrate- Nitrogen (NO_3-N) ranged from 0.5 – 7.4 mg/l, the high values are due to more forest area in the catchment region. The TP values range between 0.67 – 7.14 mg/l mainly due to human activity.

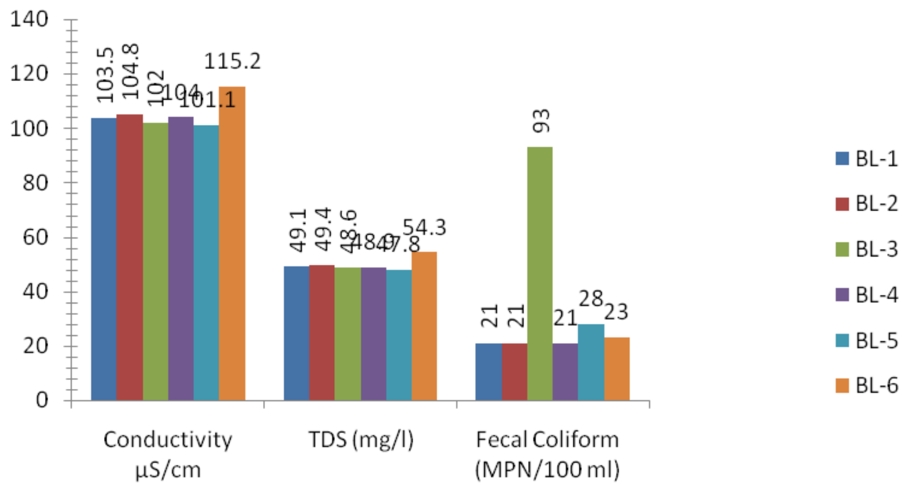

Fig. 6.5 (b). Baseline data of Bhilangna River (from upstream to downstream)

(* **where,** BL-1 to BL-6 = Bhilangna Sample 1-6)

The BOD ranges from 1.4 -1.9 mg/l, the conductivity ranges from 101-115 µs/cm.

The FC ranged from 28 to 93 MPN/100ml, the higher values are due to the increase in human waste. The water in baseline stations is good drinking water, and suitable for aquatic life corresponding to the cold temperatures prevailing in the area.

6.3.2 Commissioned Hydropower Projects

Fifteen samples were collected from the 6 (in operation) HPs. Four samples were drawn from Tehri reservoir, one from the tail race of the power house and 10 from 5 other HP projects. Tehri stage 1 and Tehri stage-II were treated as one HP because Tehri II is under construction and not in operation.

(a) Maneri Bhalli I HP (MB I)

No change in the pH was found but there was a decrease in DO from 10.03mg/l at inlet (u/s) to 9.3mg/l at outlet (d/s) of the project. This may be due to the passage of water through the tunnel. The increase in the BOD is from 1.2-1.6 mg/l from upstream to downstream but is under the drinkable water standards (2 mg/l or less). The FC were 23 (u/s) and 75 MPN/100ml (d/s). This increase is due to the mixing of wastewater from both the towns (Maneri and Tiloth) at d/s side and meeting of Asiganga tributary with Bhagirathi.

(b) Maneri Bhalli II HP (MB II)

In this case, there is no appreciable change in DO. The FC in the upstream was 290 MPN/100 ml which may be due to the mixing of wastewater of Uttarkashi city while the FC in the downstream was 75 MPN/100 ml. This reduction in FC is due to the 16.5 km long tunnel.

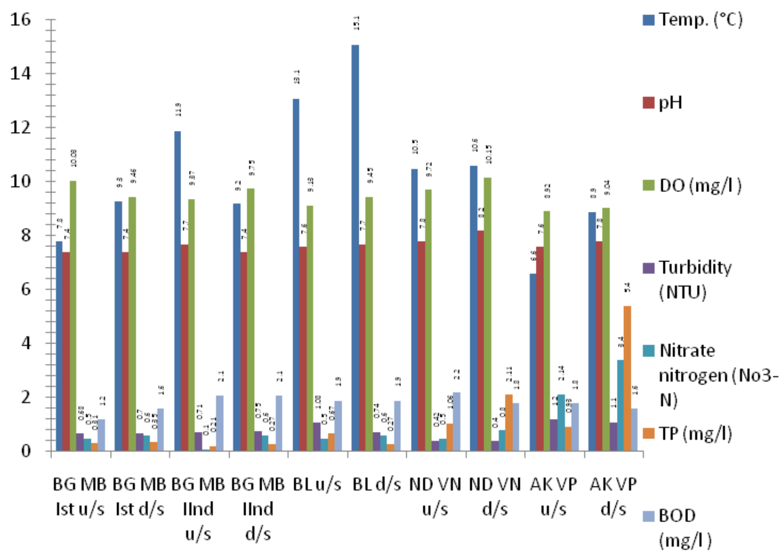

Fig. 6.6(a). Water quality data from HP projects (from upstream to downstreak)

(c) Bhilangna HP

Bhilangna HP is located upstream of Ghansali town on the Bhilangna River. The BOD and DO are unchanged indicating that there is no impact of HP on these parameters. FC values change from 23 (u/s) to 39 MPN/100 ml (d/s) due to the wastewater coming from surrounding colonies. No significant change in the values of TDS and conductivity was observed.

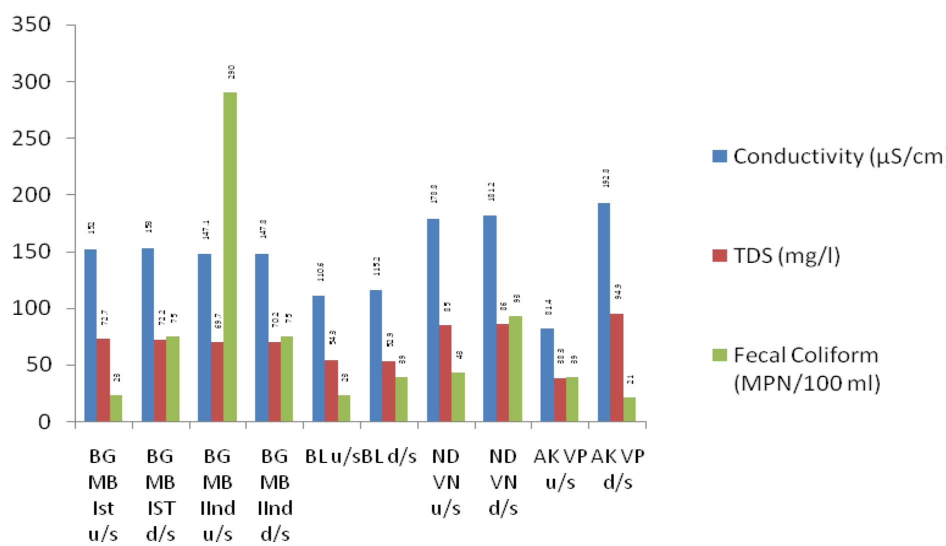

Fig. 6.6(b). Water quality data from HP projects (from upstream to downstream)

***where,**

BG MB 1^{st}	=	Maneri Bhalli Ist HP at Bhagirathi River,
BG MB 2^{nd}	=	Maneri Bhalli IInd at Bhagirathi River,
BL	=	Bhilangna HP at Bhilangna River,
ND VN	=	Vanala HP at Nandakini River,
AK VP	=	Vishnuprayag HP at Alaknanda River.

(d) **Vanala HP**

Vanala HP is located in the vicinity of Nandakini River. DO shows slight increase from 9.72 (u/s) to 10.15 mg/l (d/s). There is no appreciable change in pH, NO_3-N, TP and turbidity, TDS and conductivity. There is also little decrease in BOD from 2.2 mg/l (u/s) and 1.8 mg/l (d/s). The increase in FC is found due to the mixing of waste water from the local residential population.

(e) **Vishnuprayag HP**

Vishnuprayag HP (400 MW) located in the upper reaches of Alaknanda River has about 15.5 km long tunnel. Whereas the tributary Dhauliganga also joins Alaknanda River at the point. DO was found as 8.92 (u/s) and 9.04 mg/l (d/s) indicating negligible impact on water passing through tunnel. The TP and Nitrate - Nitrogen (NO_3-N) ranges 0.93 to 5.4mg/l and 2.14 to 3.4 mg/l from u/s – d/s. The changes observed may be on account of the mixing of wastewater from surrounding population and run offs from the agricultural forestry practices in the area and the confluence of Dhauliganga. Conductivity increased from 81.4 (u/s) to 192.8 µs/cm (d/s) indicating the possibility of excavation activities in the upper stretches as we go downward .

TDS values are observed to change from 38.3 to 94.9 mg/l. The decrease in the FC count was found from 39 MPN/100 ml to 21 MPN/100 ml as a result of long tunneling action. Moreover, improved water quality was found in the downstream of the project.

(f) **Tehri HP**

Tehri Dam is across Bhagirathi River about 1.5 km d/s of Tehri town where the Bhilangna River joins the Bhagirathi River. Out of the total of 7400 million m^3 of storable water in the valley, Tehri Dam will store about 2615 million m^3 as live storage. The lake spread at full supply level of reservoir is about 42 km^2 with reservoir extending up to 25 km along Bhilangna River and upto 44 km along Bhagirathi River (DPR of Tehri Project).

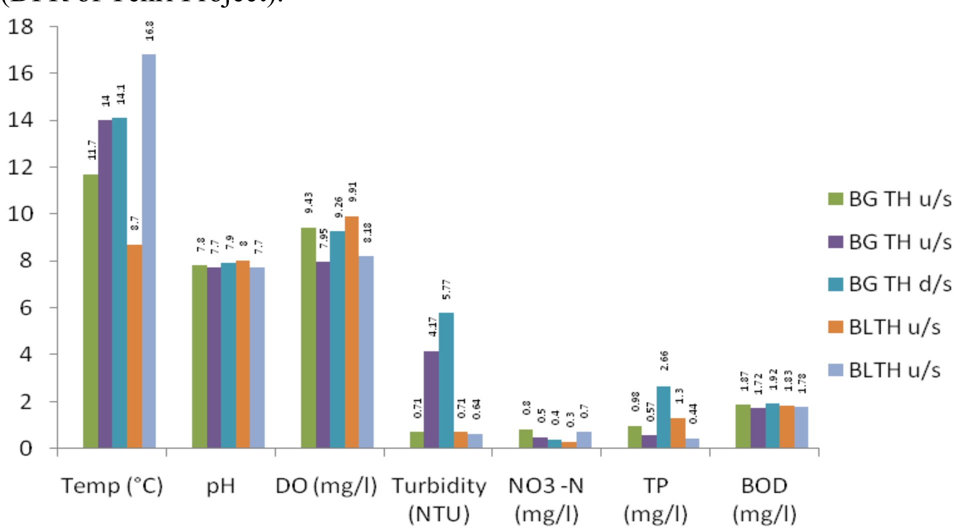

Fig. 6.7(a). Water quality data of Tehri HP

For analysis, 4 samples were taken from the reservoir first from Chinyalisaur, second from boat club, third from downstream to Gansli and fourth from Tehri (Dam site). The DO was measured 9.43 mg/l in Chinyalisaur which reduced to 7.95 mg/l in Tehri.

The DO reduces from 9.91 to 8.18 mg/l along the Bhilangna River, the conductivity reduces from 169.9 to 113.5 µs/cm along Bhilangna River. TDS reduces from 80.4 to 53.8 mg/l along Bhagirathi River and from 65.6 to 50.9 along Bhilangana River.

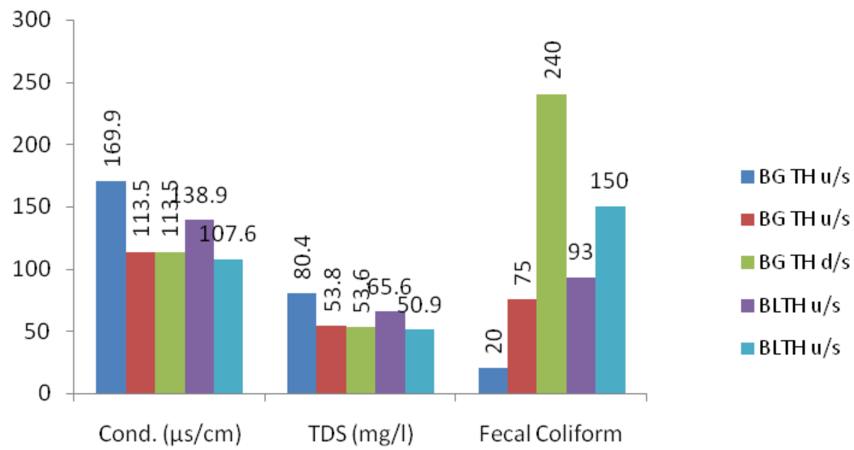

Fig. 6.7 (b). Water Quality data at Tehri HP

*** Where,**
BG TH = Tehri HP at Bhagirathi River,
BLTH = Tehri HP at Bhilangna River.

Increase in turbidity was found from 0.71 to 4.17 NTU along Bhagirathi River but decrease was found along Bhilangna River. BOD reduction was observed along both the rivers (Bhagirathi River, 1.87 to 1.72 mg/l) and Bhilangna River 1.83 to 1.78 mg/)l. fecal coliform show increase from 20 to 75 MPN/100ml in Bhagirathi River and 93 to 150 in Bhilangna River MPN/100ml. The parameters of DO, Conductivity, TDS and N03-N did not show appreciable change; but turbidity was found to increase from 0.417 to 5.77 mg/l. Total Phosphate decreases along both rivers but further increase up to 2.66 at the end of the project. FC and BOD increased to 240 MPN/100ml and 1.92 mg/l in the d/s of the project.

6.3.3 Under Development Hydropower Projects

(a) Loharinagpala HP

The project is designed to have a capacity of 600 MW and a long tunnel. There was no construction activity in the vicinity of the project at the time of sampling. The turbidity changed from 7.95 (u/s) to 0.52 NTU (d/s), BOD increased from 1.8 (µ/s) to 2.02 mg/l (d/s), Nitrate nitrogen (NO_3-N) decreased from 2.6 (u/s) to 0.3 mg/l (d/s). Total phosphate (TP) decreased from 4.14 (u/s) to 0.41 mg/l (d/s). FC also reduced from 93 to 39 MPN/100 ml. No significant change was observed in DO, pH and TDS.

The changes in the values have occurred because rains intervened between the sampling u/s and d/s.

(b) Bhilangna III HP

The project is located in the upper reaches of the Bhilangna River. The project area starts from upstream of Ghuttu where diversion structure has been planned. The project was under construction; but no impact on turbidity, pH and DO values are observed. The NO_3-N and TP were observed to change from 2.4 u/s to 3.7 mg/l (d/s) and 2.33 to 4.62 mg/l (d/s) respectively. BOD value ranges between 1.4 mg/l at u/s and 1.5 at d/s. No significant change was found in conductivity and TDS. Fecal coliform ranged from 21 to 93 MPN/100 ml showing the impact of mixing of untreated waste from Ghuttu town. No impact of HP on the water quality was observed.

(c) Singoli Bhatwari HP

pH value range from 7.5 to 8.1, TP from 3.25 to 0.3 mg/l. BOD was measured 1.9 (d/s) and 2.2 mg/l (u/s). No change in the FC was observed. Hence there is no impact of HP on water quality.

The water quality data is depicted in Fig. 8a.

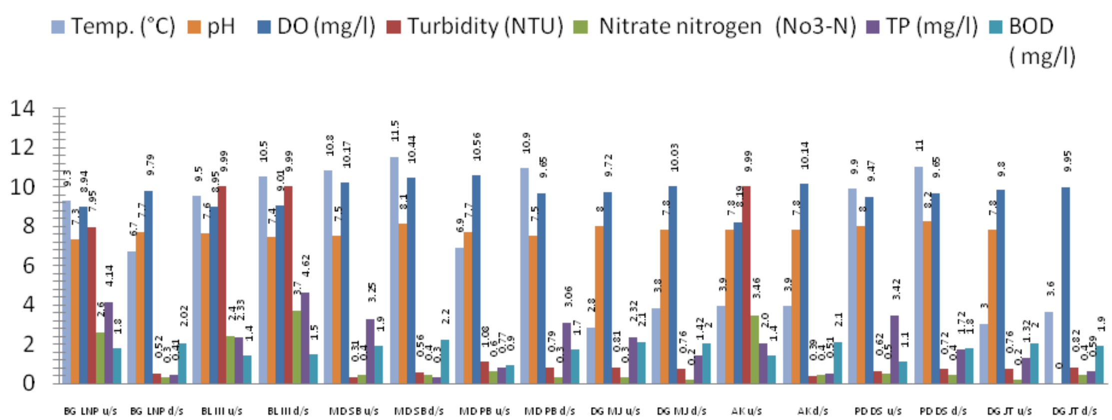

Fig. 6.8 (a). Water quality data for HP projects (from upstream to downstream)

(d) Phata Bhyung HP

BOD was measured as 1.7 in u/s and 2.1 mg/l in d/s. FC increased from 23 to 43 MPN/100 ml. No considerable change was found in any of the other parameters.

Table 6.7: Water Quality Analysis.
(Project Name: Cumulative impact of Hydro Electric Power Projects in Alaknanda and Bhagirathi River Basin**)**
Baseline WQ Data

S. No.	River	Sample No.	Name of Place	Distance (km)	Date (D/M/Y)	Time (24 Hrs)	WQ Parameter									
							Temp.	pH	DO (mg/l)	Conductivity (µS/cm)	TDS (mg/l)	Turbidity (NTU)	Nitrate nitrogen (NO_3-N) (mg/l)	TP (mg/l)	BOD (mg/l)	Fecal Coliform MPN/100ml
1.	Bhagirathi	BG -1	Gangotri temple	0	20/10/10	14:00	6.6	7.2	8.33	142.1	67.3	6.08	4.6	2.99	1.2	11
2.	Bhagirathi	BG -2	Lanka (u/s)	7.5 (d/s)	20/10/10	16:30	7.7	7.5	8.3	188.8	89.7	1.74	2.4	0.83	1.5	15
3.	Bhagirathi	BG -3	Lanka (d/s)	12 (d/s)	20/10/10	17:10	7.8	7.4	8.58	184.2	87.4	4.79	1.5	2.6	1.5	39
4.	Bhagirathi	BG -4	Harsil	19 (d/s)	20/10/10	17:50	8.3	7.6	8.48	158.2	75	4.44	2.4	1.89	1.8	21
5.	Bhagirathi	BG -5	Inlet of L.N.P. HP	37 (d/s)	20/10/10	18:50	9.3	7.3	8.94	154.3	73.7	7.95	2.6	4.14	1.8	93
6.	Bhilangana	BL-1	Inlet of Bhilangana III HP	0	22/10/10	13:05	9.5	7.6	8.95	103.5	49.1	9.99	2.4	2.33	1.4	21
7.	Bhilangana	BL-2	Ghuttu (u/s)	1 (d/s)	22/10/10	13:25	9.7	7.4	9.34	104.8	49.4	9.99	6.2	7.14	1.5	21
8.	Bhilangana	BL-3	Outlet of Bhilangana III HP	4 (d/s)	22/10/10	14:10	10.5	7.4	9.01	102	48.6	9.99	3.7	4.62	1.5	93
9.	Bhilangana	BL-4	Ghuttu (d/s)	8 (d/s)	22/10/10	15:30	11.5	7.3	8.6	104	48.9	9.99	5.4	3.58	1.8	21
10.	Bhilangana	BL-5	Bhilangana II HP	20 (d/s)	22/10/10	17:05	17.3	7.4	8.94	101.1	47.8	9.99	7.4	5.62	1.4	28
11.	Bhilangana	BL-6	Inlet of bhilangna HP	30 (d/s)	23/10/10	10:10	13.1	7.6	9.13	115.2	54.3	1.08	0.5	0.67	1.9	23
12.	Mandakini	MD-1	Kedarnath Temple	0	24/10/10	14:20	4.7	7.4	8.22	72.8	34.5	9.99	5.6	3.36	1.8	21
13.	Mandakini	MD-2	Rambara	7 (d/s)	24/10/10	17:15	6.6	7.6	8.89	68.7	32.3	9.99	2.1	4.02	1.7	93
14.	Mandakini	MD-3	Gauri kund	17 (d/s)	25/10/10	9:40	6.8	7.5	9.62	75.9	35.2	9.99	3.6	0.74	1.2	93
15.	Mandakini	MD-4	Singoli Bhatwari HP	31 (d/s)	25/10/10	12:25	11.9	7.5	9.57	83.6	39.3	7.77	8.4	11.72	1.8	39
16.	Alaknanda	AK-1	Mana (bhim bridge)	0	27/10/10	11:00	2.1	8.2	9.74	67.2	31.5	6.56	3.2	1.15	1.1	93
17.	Alaknanda	AK-2	Badrinath Temple	5 (d/s)	27/10/10	12:05	3.9	7.8	8.19	67.9	31.8	9.99	3.46	2	1.4	93
18.	Alaknanda	AK-3	Hanuman chatti	10 (d/s)	27/10/10	14:50	6.7	7.9	8.79	76	35.8	7.35	1.15	1.1	1.6	93
19.	Alaknanda	AK-4	Inlet of Vishnuprayag HP	15 (d/s)	27/10/10	15:20	6.6	7.6	8.92	81.4	38.3	1.2	2.14	0.93	1.8	39

- **The COD has not been done of baseline water samples.**

Table 6.8: HP WQ Data

S. No.	Name of HP	River	HP Status	Capacity (MW)	Inlet/ Outlet	Date (D/M/Y)	Time (24 Hrs)	WQ Parameter									
								Temp. (0C)	pH	DO (mg/l)	Conductivity (µS/cm)	TDS (mg/l)	Turbidity (NTU)	Nitrate nitrogen (NO_3-N) (mg/l)	TP (mg/l)	BOD (mg/l)	Fecal Coliform MPN/100ml
1	MB Ist	Bhagirathi	EP	90	u/s	15/11/10	10:35	7.8	7.4	10.03	152	72.7	0.68	0.5	0.31	1.2	23
					d/s	15/11/10	12:45	9.3	7.4	9.46	153	72.2	0.7	0.6	0.35	1.6	75
2	MB IInd	Bhagirathi	EP	304	u/s	15/11/10	18:05	11.9	7.7	9.37	147.1	69.7	0.71	0.1	0.21	2.1	290
					d/s	15/11/10	15:45	9.2	7.4	9.75	147.8	70.2	0.75	0.6	0.27	2.1	75
3	Bhilangna	Bhilangna	EP	22.5	u/s	16/11/10	17:30	13.1	7.6	9.13	110.6	54.3	1.08	0.5	0.67	1.9	23
					d/s	16/11/10	16:45	15.1	7.7	9.45	115.2	52.9	0.74	0.6	0.27	1.9	39
4	Vanala	Nandakini	EP	15	u/s	11/12/10	12:30	10.5	7.8	9.72	178.8	85	0.42	0.5	1.06	2.2	43
					d/s	11/12/10	13:15	10.6	8.2	10.15	181.2	86	0.4	0.8	2.11	1.8	93
5	Vishnuprayag	Alaknanda	EP	400	u/s	27/10/10	15:20	6.6	7.6	8.92	81.4	38.3	1.2	2.14	0.93	1.8	39
					d/s	26/10/10	12:15	8.9	7.8	9.04	192.8	94.9	1.1	3.4	5.4	1.6	21
6	Lohari nagpala	Bhagirathi	DP	600	u/s	13/10/10	18:50	9.3	7.3	8.94	154.3	73.7	7.95	2.6	4.14	1.8	93
					d/s	14/11/10	15:30	6.7	7.7	9.79	162	77.4	0.52	0.3	0.41	2.02	39
7	Bhilangna III	Bhilangna	DP	24	u/s	14/11/10	12:05	9.5	7.6	8.95	103.5	49.1	9.99	2.4	2.33	1.4	21
					d/s	14/11/10	14:10	10.5	7.4	9.01	102	48.6	9.99	3.7	4.62	1.5	93
8	Singoli Bhatwari	Mandakini	DP	99	u/s	3/12/10	14:20	10.8	7.5	10.17	93.8	44	0.31	0.4	3.25	1.9	23
					d/s	3/12/10	13:15	11.5	8.1	10.44	101.2	47.8	0.56	0.4	0.3	2.2	23
9	Phata Bhayung	Mandakin	DP	76	u/s	4/12/10	10:00	6.9	7.7	10.56	75.4	35.5	1.08	0.6	0.77	0.9	75
					d/s	4/12/10	15:10	10.9	7.5	9.65	82.1	38.7	0.79	0.3	3.06	1.7	43
10	Malari Jhelem	Dhauli ganga	DP	55	u/s	8/12/10	15:15	2.8	8	9.72	308	147	0.81	0.3	2.32	2.1	93

S. No.	Name of HP	River	HP Status	Capacity (MW)	Inlet/ Outlet	Date (D/M/Y)	Time (24 Hrs)	WQ Parameter									
								Temp. (0C)	pH	DO (mg/l)	Conductivity (µS/cm)	TDS (mg/l)	Turbidity (NTU)	Nitrate nitrogen (NO_3-N) (mg/l)	TP (mg/l)	BOD (mg/l)	Fecal Coliform MPN/100ml
					d/s	8/12/10	14:10	3.8	7.8	10.03	306	147.2	0.76	0.2	1.42	2	43
11	Alkananda	Alaknanda	DP	300	u/s	9/12/10	12:05	3.9	7.8	8.19	67.9	31.8	9.99	3.46	2	1.4	93
					d/s	9/12/10	13:00	3.9	7.8	10.14	83	39.2	0.39	0.4	0.51	2.1	23
12	Devsari	Pindar	DP	252	u/s	14/12/10	15:00	9.9	8	9.47	182.2	56.2	0.62	0.5	3.42	1.1	43
					d/s	14/12/10	15:55	11	8.2	9.65	175.2	83.3	0.72	0.4	1.72	1.8	75
13	Jelem Tamak	Dhauli ganga	DP	60	u/s	8/12/2010		3	7.8	9.8	304	147.2	0.76	0.2	1.32	2	43
					d/s	8/12/2010	12:50	3.6	7.8	9.95	275	131.1	0.82	0.4	0.59	1.9	21
14	Bhilangana II	Bhilangna	DP	24	-	22/10/10	17:05	17.3	7.4	8.94	101.1	47.8	9.99	7.4	5.62	1.4	28
15	Bharaoghati	Bhagirathi	DP	381	u/s	14/11/10	11:50	8.3	7.6	8.48	158.2	75	4.44	2.4	1.89	1.8	21
					d/s	14/11/10	13:30	2.7	7.5	9.73	200	94.8	0.64	0.7	0.28	1.9	93
16	Pala maneri	Bhagirathi	DP	480	-	14/11/10	16:35	7.5	7.4	9.93	161	76.2	0.8	0.6	0.41	1.8	150
17	Madhmahesgwar	Madhuganga	DP	15	-	6/12/10	10:15	9.1	7.8	10.59	93.4	44	0.46	0.5	1.79	2.1	28
18	Rishi ganga	Rishiganga	DP	13.2	-	7/12/10	13:40	3.3	7.5	10.66	224	106.5	0.71	0.1	0.29	0.8	9
19	Jalandarigad	Jalandari	FP	12	-	13/11/10	14:20	6.7	7.8	8.82	124	59.2	0.58	0.3	0.21	1.2	43
20	Bhayundar Ganga	Bhayundar ganga	FP	72	-	9/12/10	15:00	7.4	8	9.82	47.3	22.1	0.51	0.4	0.71	2	43
21	Rambara HP	Mandakini	FP	24	-	24/10/10	17:15	6.6	7.6	8.89	68.7	32.3	9.99	2.1	4.02	1.7	93
22	Karmoli	Jahnavi	FP	140	-	13/11/10	16:20	6.2	7.4	9.2	161	72.1	0.39	1.0	1.34	1.8	43
23	Pulna	Alaknanda	FP	13	-	10/12/10	11:45	10.6	8.5	9.96	185.7	88.2	0.94	0.4	2.43	1.9	28
24	Gohanatal	Birahiganga	FP	60	-	12/12/2010	13:00	13.8	8.1	9.1	171.9	81.6	0.71	0.9	2.99	2.1	20
25	Melkhet	Pindar	FP	15	-	13/12/10	14:30	10.1	7.8	9.58	199.1	94.9	0.42	0.1	2.98	2	9

S.No.	Name of HP	River	HP Status	Capacity (MW)	Inlet/ Outlet	Date	Time (24 Hrs)	WQ Parameter									
								Temp (°C)	pH	DO (mg/l)	Cond. (µS/cm)	TDS (mg/l)	Turbidity (NTU)	NO_3-N (mg/l)	TP (mg/l)	BOD (mg/l)	Fecal Coliform
26	Tehri (Chinyalisaur)	Bhagirathi	EP	1000	u/s	1/30/2011	14:05	11.7	7.8	9.43	169.9	80.4	0.71	0.8	0.98	1.87	20
	Tehri (dam site)				u/s	1/30/2011	18:05	14	7.7	7.95	113.5	53.8	4.17	0.5	0.57	1.72	75
	Tehri (Outlet)				d/s	1/31/2011	12:05	14.1	7.9	9.26	113.5	53.6	5.77	0.4	2.66	1.92	240
27	Tehri reservoir	Bhilangna			u/s	1/31/2011	14:10	8.7	8	9.91	138.9	65.6	0.71	0.3	1.3	1.83	93
	Tehri reservoir (uthad)				u/s	1/31/2011	16:23	16.8	7.7	8.18	107.6	50.9	0.64	0.7	0.44	1.78	150
28	Koteshwar	Bhagirathi	DP	400	u/s	2/1/2011	11:10	17.5	7.7	9.16	116.7	55.1	4.24	0.5	0.48	1.71	93
					d/s	2/1/2011	12:30	15.5	7.7	9.6	115.7	54.5	10	0.8	11.6	2.02	1100
29	Srinagar	Alaknanda	DP	330	u/s	2/2/2011	11:35	10.4	7.8	10.2	181.5	86.2	0.91	0.3	0.68	2.07	43
					d/s	2/2/2011	11:05	10.4	8	11.1	181.8	86.7	6.52	0.4	1.08	1.95	150
30	Nandprayag Lagasu	Alaknanda	DP	100	u/s	2/4/2011	11:05	9.2	7.9	10.64	197.4	94	0.54	0.7	1.21	2.03	93
					d/s	2/4/2011	10:15	9.2	7.8	10.68	199.7	94.7	0.73	0.4	0.31	1.95	150
31	Bowla Nandprayag	Alaknanda	DP	300	u/s	2/4/2011	15:30	8.9	7.9	10.16	202.1	96.2	0.7	0.4	0.4	2.16	75
					d/s	2/4/2011	11:45	9	8	10.36	195.9	93	0.9	0.5	1.35	2.86	150
32	Birahiganga I	Birahi ganga	DP	24	u/s	2/5/2011	11:00	8.5	7.9	9.63	247	117.4	0.47	0.2	0.93	1.92	28
					d/s	2/5/2011	12:05	13	8	8.99	319	153.1	0.55	0.4	0.58	1.92	93
33	Birahiganga II	Birahi ganga	DP	24	u/s	2/5/2011	13:15	14	7.9	8.91	324	155.1	0.36	0.2	0.39	1.68	7
					d/s	2/5/2011	13:40	14.1	8.1	8.95	322	154.5	0.49	0.3	0.6	1.86	28
34	Tamak lata	Dhauliganga	DP	250	u/s	2/6/2011	13:10	5	7.8	9.4	284	135	1.64	0.3	4.94	1.62	93
					d/s	2/6/2011	13:40	5.5	7.9	9.81	265	126.8	1.44	0.5	0.96	1.96	150

S.No.	Name of HP	River	HP Status	Capacity (MW)	Inlet/ Outlet	Date	Time (24 Hrs)	WQ Parameter									
								Temp (°C)	pH	DO (mg/l)	Cond. (µS/cm)	TDS (mg/l)	Turbidity (NTU)	NO_3-N (mg/l)	TP (mg/l)	BOD (mg/l)	Fecal Coliform
35	Lata tapovan	Dhauliganga	DP	310	u/s	2/6/2011	14:10	6	7.7	9.65	275	131.4	2	0.4	0.76	1.96	120
					d/s	2/6/2011	15:05	6.5	7.9	9.88	261	124.6	1.81	0.4	2.94	1.92	93
36	Tapovan Vishnugad	Dhauliganga	DP	520	u/s	2/6/2011	15:25	6.7	7.7	9.97	261	124.8	1.6	0.4	1.95	1.58	120
					d/s	2/6/2011	13:35	7	7.9	10.23	178	84.5	5.2	0.5	0.77	1.74	460
37	Vishnugad Pipalkoti	Alaknanda	DP	444	u/s	2/8/2011	12:00	7.5	7.9	10.16	177.3	85.2	4.71	0.5	0.67	1.73	290
					d/s	2/8/2011	16:45	8.5	7.9	10.08	187.7	89.5	9.87	0.6	2.60	1.88	460
38	Kotlibhel I B	Alaknanda	DP	320	u/s	2/9/2011	16:00	12.3	8	10.39	183.5	86.6	1.71	0.5	5.56	1.66	290
					d/s	2/9/2011	16:15	16.6	7.9	10.3	183.7	86.9	1.66	0.6	3.41	2.02	460
39	Kotlibhel I A	Bhagirathi	DP	195	u/s	2/10/2011	11:15	17.4	7.9	9.72	118.6	56.3	9.99	0.9	2.36	1.73	460
					d/s	2/10/2011	11:50	16.4	7.9	9.64	119.3	56.4	10.2	0.9	3.59	2	460
40	Kotlibhel II	Ganga	DP	530	u/s	2/10/2011	13:40	15.8	7.8	9.17	139.3	65.5	9.76	0.7	4.20	1.92	1100
					d/s	2/10/2011	14:45	14.7	7.7	9.65	65.1	138.14	9.01	0.7	2.59	1.91	1100

(e) Malari Jhelum HP

The pH, DO, NO_3-N, TP and Turbidity values were 8 – 7.8, 9.72 – 10.03 mg/l, 0.3 – 0.2 mg/l, 2.32 – 1.42 mg/l and 0.81 – 0.76 NTU respectively from u/s to d/s. Conductivity was very high with values of 308 u/s and 306 µs/cm d/s. TDS values also were high. FC reduces from 93 to 43 MPN/100 ml. As a result, improved water quality was found downstream of the project. As the river has high slope and water flows with high speed considerable aeration takes place in the water which results in the improved water quality in downstream reaches.

All the construction activities were on hold at the time of sampling. However, no impact of HP was found on the water quality of the river.

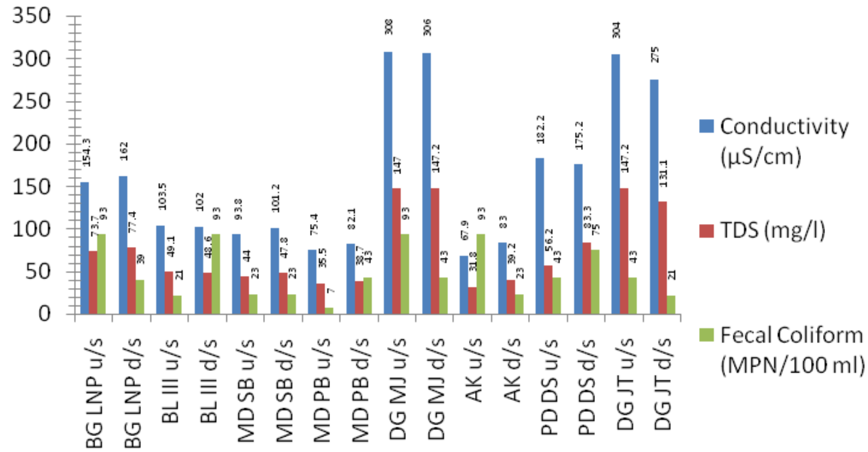

Fig. 6.8 (b). Water quality data of HP projects (from upsstream to downstream)

*** where,**

BG LNP	= Lohari nagpala HP at Bhagirathi River,
BL III	= Bhilangna III HP at Bhilangna River,
MD SB	= Singoli Bhatwari HP at Mandakini River,
MD PB	= Phata Bhyung HP at Mandakini River,
DG MJ	= Maleri Jhelum HP at Dhauli Ganga River,
AK	= Alaknanda HP at Alaknanda River,
PD DS	= Devsari HP at Pindar River,
DG JT	= Jelum Tamak HP at Dhauli Ganga River.

(f) Devsari HP

Devsari HP is located in upper reaches of Pinder River. Diversion site is located between Dewal and Tharali. The power house is located in downstream of Tharali. The project has 15 km long tunnel. At the time of sampling no construction activity was found. BOD increases from 1.1 to 1.8 mg/l, the total phosphate decreases from 3.42 to 1.72 mg/l (d/s). FC and TDS changes from 43 to 75 and 39.2 to 56.2 NTU toward downstream respectively. The increase in FC is marginal and may be the result of waste water mixing from Tharali town.

(g) Alaknanda HP

Alaknanda HP is located in the upper reaches of Alaknanda River having barrage site at 2.5 km d/s of confluence of Rishi Ganga with Alaknanda River. Badrinath shrine is situated on the left on the left bank of Alaknanda River approximate 3 km u/s from barrage site. Project area covers 9 villages/ town including

Badrinath having population more than 4550 and 500 households. No significant change was found in pH, Temperature and TDS. DO changes from 8.19 – 10.14 mg/l and BOD changes from 1.4 – 2.1 mg/l. Total nitrate (NO_3-N) decreases from 3.46 – 0.4. Turbidity was very high (9.99 NTU) at u/s point of the project and reduces significantly to 0.39 NTU. Total phosphate decrease from 2.02 - 0.51 mg/l. Fecal Coliform also reduce from 93 – 23 MPU/100 ml. The quality of waters improves downward as the river stretch has very high slope and velocity of flow, resulting in natural aeration in the flow.

(h) Koteshwar HP

The project is situated downstream of Tehri town, the impact of pollution from Tehri town was found in the Koteshwar reservoir. The construction works were going on at the time of sampling, effecting the increase in turbidity from 4.24 – 10 NTU. The pH was 7.7 at both the sampling locations. DO changed from 9.96 – 9.6 mg/l, BOD increased from 1.71 – 2.02 mg/l. Total phosphate and Nitrate- nitrogen increases from 0.46 – 11.6 and 0.5 – 0.8 mg/l respectively. The increase in NO_3-N and TP may be due to the result of ongoing infrastructural activities and excavation. Fecal Coliform was found at the u/s as 93 and 1100 MPN/100 ml at d/s. This increase may be due to the human activities and waste water coming from project colonies and nearby towns. These data are depicted in Fig. 6.9(a).

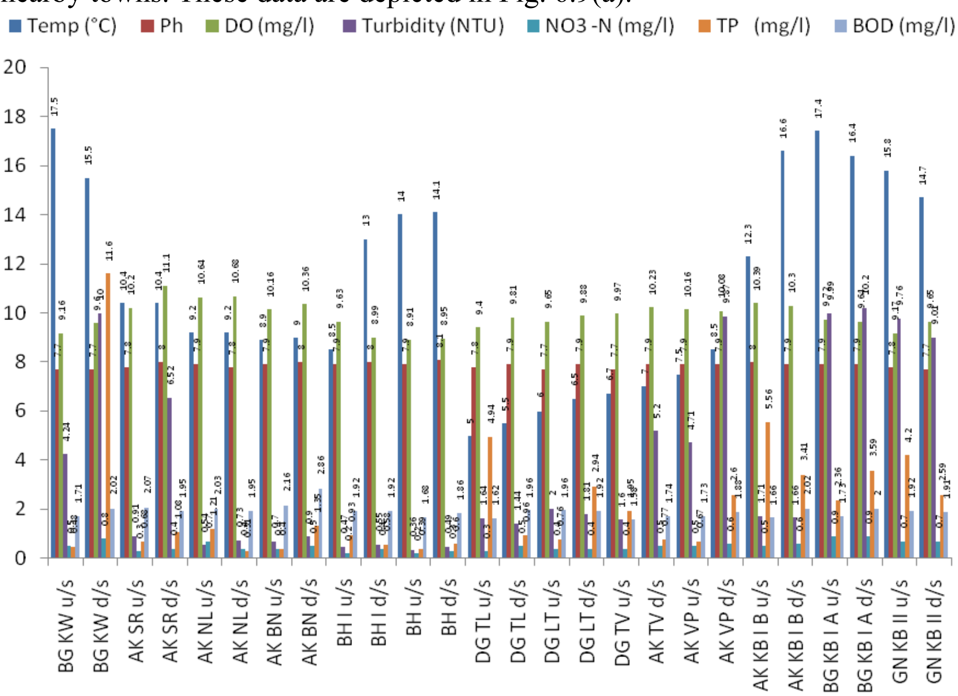

Fig. 6.9(a). Water quality data of HP projects

(i) Bowla Nandprayag HP

This project is situated in the d/s of the confluence of the Birahi Ganga River with Alaknanda River. No significant changes were found in pH, TDS, Turbidity, NO_3-N and conductivity. Total phosphates and BOD increase from 0.4 – 1.35 mg/l and 2.2 – 2.9 mg/l respectively downstream. The increase was found in the Fecal coliform from 75 – 150 MPN/100 ml d/s. Since no project activities were going on at the time of sampling, the observed values and changes are due to natural processes.

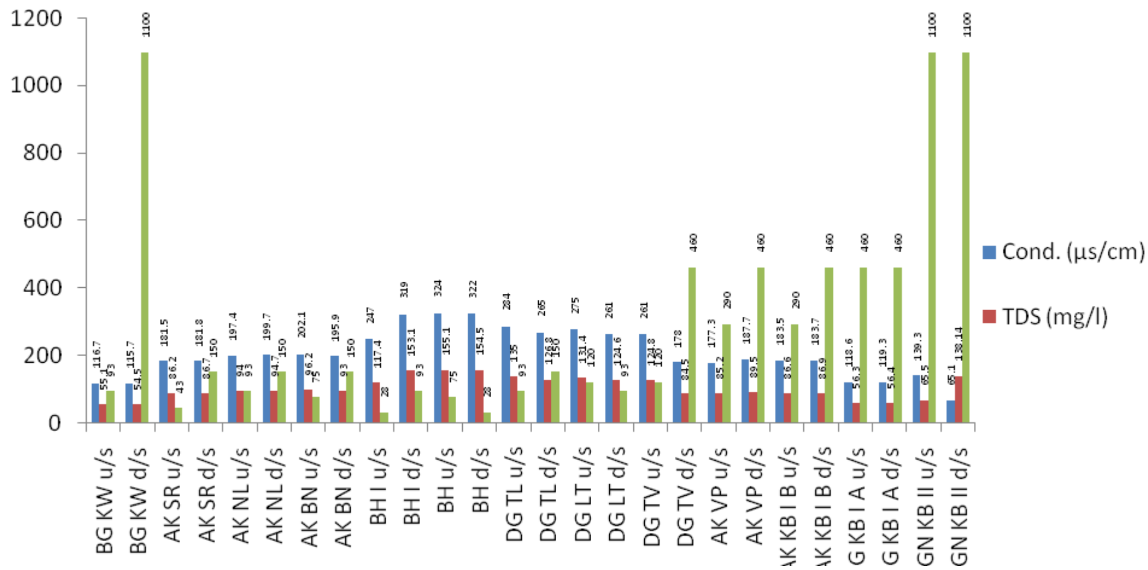

Fig. 6.9 (b). Water quality data of HP projects

*** Where,**

BG KW	= Koteshwar HP at Bhagirathi River,
AK SR	= Srinagar HP at Alaknanda River,
AK NL	= Nandprayag Lagasu HP at Alaknanda River,
AK BN	= Bowla Nandprayag at Alaknanda River,
BH I	= Birahiganga I HP at Birahi ganga River,
BH II	= Birahiganga II HP at Birahiganga River,
DG TL	= Tamaklata HP at Dhauli ganga River,
DG LT	= Latatapovan HP at Dhauliganga River,
DG TV	= Tapovan Vishnugad HP at Dhauliganga River,
AK VP	= Vishnugad Pipalkoti HP at Alaknanda River,
AK KB IB	= Kotlibhel IB HP at Alaknanda River,
BG KB IA	= Kotlibhel IA HP at Bhagirathi River,
GN KB II	= Kotlibhel II HP at Ganga River.

(j) Nandprayag Lagasu HP

This project is situated d/s of the confluence of Nandakini River with Alaknanda River. NO_3-N and Total Phosphate decreases from 0.7 – 0.4 and 1.21 – 0.31 mg/l respectively. Fecal coliform increases from 93 – 150 MPN/100 ml waste water from the towns in the project vicinity. No perceivable change was found on other parameters.

(k) Tamak Lata HP

The project is situated between the town Tamak and Lata on Dhauliganga River. The DO increased from 9.42 – 9.81 mg/l, the BOD from 1.62 upstream to 1.9 mg/l downstream. The change in turbidity, TDS and conductivity was found to range from 0.3 – 0.5 NTU, 1.64 – 1.44 mg/l and 284 – 265 µs/cm respectively. Fecal coliform was measured 93 u/s and 150 at d/s MPN/100 ml.

As the project area covers low population density and no construction activities was ongoing at the time of sampling the values are due to natural processes except increase in Fecal coliform due to human activity.

(l) **Lata Tapovan HP**

The project is situated downstream of Tamak Lata HP on Dhauliganga River. The DO and pH increases from 9.65 – 9.88 mg/l, 7.7 – 7.9 respectively. Conductivity decreases from 275 – 261 μs/cm and TDS changes from 131.4 – 124.6 mg/l without any change in NO_3-N and TP. The reduction in BOD and Fecal coliform was found as 2.0 – 1.9 mg/l and 120 – 93 MPN/100 ml respectively in d/s of the stream.

(m) **Tapovan Vishnugad HP**

The barrage site of the project is situated just downward of the confluence of the Rishi Ganga River with Dhauliganga River. The decrease in conductivity and TDS is observed from 261 – 178 μs/cm and 124.8 – 84.5 mg/l respectively. The increase in DO, Turbidity, BOD and Fecal coliform from 9.97 – 10.23 mg/l, 1.6 – 5.2 NTU, 1.58 – 1.74 mg/l and 120 – 460 MPN/100 ml respectively.

No appreciable changes occur in pH and Total NO_3-N. The increase in Turbidity and Fecal coliform may be due to construction work and waste water coming from Joshimath town and nearby villages.

(n) **Vishnugad Pipalkoti HP**

The barrage site of the project is situated d/s of Tapovan Vishnugad HP on Alaknanda River. The BOD increased from 1.7 – 1.9 mg/l and turbidity from 4.71 – 9.87 NTU. Fecal coliform was found as 460 d/s and 290 u/s MPN/100 ml. This may be the due to heavy anthropogenic impact of the population living in Pipalkoti. No significant impact on other parameters was found.

(o) **Srinagar HP**

The project is located u/s of the Srinagar town on Alaknanda River. The construction was going on at the time of sampling. The DO was measured 10.2 mg/l at u/s and 11.1 mg/l at d/s of the project. The increase in TP was found from 0.68 to 1.08 mg/l and Nitrate – nitrogen from 0.3 to 0.4 mg/l. FC was measured 43 MPN/100ml at u/s and 150 MPN/100ml at d/s. This increase in FC may be due to the waste water coming from project colonies. The turbidity increased from 0.91 to 6.52 NTU. This increase in turbidity was due to the mixing of muck produced from constructional activities.

In the case of Koteshwar, Srinagar, Kotlibhel and Vishnugad Pipalkoti hydropower projects, the fecal coliforms was found to increase while moving u/s to d/s. This may be due to the mixing of flow of wastewater from the catchment between upstream site and downstream site. However, there is no impact of the HP project on the FC.

6.4 IMPACT OF HPS ON TROPHIC STATUS OF RIVER WATER

The trophic status refers to the level of productivity in a lake and river water as measured by phosphorous, algae abundance and depth of light penetration. Trophic Status Index (TSI) rates water bodies based on the amount of biological productivity occurring in the water [Carlson 1977]. Indiana Trophic State Index (ITSI), a modified version of the BonHomme Index was developed for Indiana in 1972. In contrast, Carlson's Trophic State Index is a simpler, but statistically valid means of representing direct linear relationships between three parameters: water clarity (Secchi depth), Nutrients (phosphorus) and overall algal biomass (chlorophyll-a) [Sharma et. al 2010]. The trophic status of Alaknanda and Bhagirathi river waters using two parameters i.e. TP and Nitrate nitrogen is Oligotrphic.

Table 6.9. Indiana Trophic State Index (ITSI).

S. No.	Indiana TSI Scores	Trophic Class
1	0-15	Oligotrophic
2	16-31	Mesotrophic
3	32 - 46	Eutrophy
4	47 - 75	Hypertrophic

6.5 COMPARISON OF WATER QUALITY DATA COLLECTED BY OTHER AGENCIES

Search was made of water quality data collected by other agencies. The following publications were considered:

(i) CPCB yearly data, 2006
(ii) Water Quality report on Alaknanda River, 2009
(iii) EIA report of NTPC, 2007

(i) CPCB yearly data, [Semwal and Akolkar, 2006]

Based on bio-monitoring assessment of the rivers of Uttarakhand, [Semwal and Akolkar of CPCB (2006)] evolved biological water quality criteria for various uses and their respective characteristics. They also worked out the average physico-chemical water quality levels at different water quality classes of rivers in Uttarakhand, and developed Bio-monitoring based classes of river water. Clean Water quality Class A, Slightly polluted class B, Moderately polluted class C, Highly polluted class D, Severely polluted Class E. Benthic macroinvertebrates were considered as the most suitable biological parameters for water quality evaluation. They also made ecological assessment of various river stretches in Uttarakhand based on the range of saprobic score, range of diversity score and water quality class. This paper gives sampling location wise figures of physico- chemical water quality parameters.

The investigation under the present study was undertaken to assess the water quality in a mountainous watershed of Alaknanda and Bhagirathi Basins upstream of Devprayag, the confluence of Bhagirathi and Alaknanda Rivers in order to assess the impact of hydropower projects on river water quality. Some hydropower projects are commissioned, some are under construction and many more are proposed. Hydropower dams can cause several environmental problems. Damming rivers may permanently alter river systems and biological habitats. It is apprehended that hydropower plants operations may also affect water quality through increase in silting, change of water temperatures, and lowering the dissolved oxygen concentration. Both upstream and downstream of HPs.

Out of 60 stretches of 19 rivers, 41 stretches indicated clean water quality of Class 'A', five stretches were slightly polluted (class 'B'), six were moderately polluted (class 'C'), one stretch was highly polluted (class 'D') and there were altogether seven severely polluted (class 'E') stretches. The list of biological taxas / family of benthic macro invertebrates commonly called water bodies present in river water and contain class A and B are given in table 10.

Table 6.10. Clean water stretches based on macro invertebrates

S.No.	Rivers	Location	Tax on	Class
1	Bhagirathi	District Uttarkashi Downstream Lohari Nag-pala Hydroelectric Project U/s Maneri Bhali, Phase-I, Near Jhulapul Inlet Maneri Bhali, Phase-I, Keshavpuram Outlet Maneri Bhali, Phase-I Inlet Maneri Bhali, Phase-II 2 km downstream Maneri Bhali, Phase II Upstream Uttarkashi Downstream Uttarkashi Upstream Nagon Gadhera, Dharasu Bhagirathi Upstream Old Tehri, Malideval	Ephemeroptera: Heptageniidae, Ephemerellidae, Pothaminthidae, Ephemeridae, Siphonuridae, Caenidae, Baetidae Plecoptera: Perlidae, Nemouridae, Leuctridae, Capniidae, Taeniopterygidae, Perlodidae, Cryptoperla Trichoptera: Hydropsychidae, Leptoceridae, Georidae, Sericostomatidae, Rhyacophilidae, Polycentropodidae, Philopotamidae, Brachycentridae, Hydroptilidae	A
2	Alaknanda	Badrinath, Second Hydel Project, Bamni 250 m upstream Vishnuprayag Barrage, access on NH-58 In front of Switch Yard, Downstream Power House of Vishnuprayag Hydroelectric Project Birahi, after confluence of Birahiganga Rudraprayag, opposite temple, upstream of sangam Rudraprayag, after confluence to River, Mandakini, GMVN Guest House	Hemiptera: Aphelocheiridae Coleoptera: Psephenidae, Dytiscidae, Gyrinidae, Hydrophilidae Planaria: Planariidae Diptera: Blepharoceridae, Simulidae, Tipulidae, Chironomidae, Tabanidae	A

S.No.	Rivers	Location	Tax on	Class
		Alaknanda Kaliyasaur, Near Dhari Devi Temple		
3	Dhauli ganga	Tapovan village, Vishnugad barrage site District Joshimath	Diptera: Blepharoceridae, Simulidae, Tipulidae, Chironomidae, Tabanidae	A
4	Birahi ganga	Birahi, before confluence to River Alaknanda, 6 km from Chamoli	Mollusca/Viviparidae, Lymnaeidae	A
5	Pindar	Meeng, near bridge Karanprayag, before confluence to River Alaknanda	Megaloptera/Cordyladidae	A
6	Nandakini	Nandprayag, near bridge, before confluence to River Alaknanda	Hirudinea/Erpobdellidae, Hirudidae, Glossiphonidae	A
7	Mandakini	Before confluence to River Alaknanda 2 km from Tilwara, upstream Rudraprayag	Polychaeta/Gordiidae	A
8	Ganga	Muni Ki Reti, Rishikesh	Mollusca: Lymnaeidae Coleoptera: Hydrophilidae, Dytiscidae, Psephenidae Hemiptera: Aphelocheiridae, Gerridae Diptera: Simulidae, Chironomidae Megaloptera: Corydalidae Crustacea: Grabsidae Hirudinea: Glossiphonidae	B

The physic-chemical analysis was also done by them; the primary source of water for rivers in Uttarakhand is rainfall and snowmelt, which makes their composition an important component of river water chemistry. Total dissolved solids (TDS) in Himalayan rivers ranged from 35 to 151 mg/l compared with our observation is 35 – 147 mg/l, In unpolluted hill streams, the range of NO3-N has been reported to be nil to0.13 mg/l, whereas our observation is > 4 mg/l and Total phosphates, 0.21–6.0 mg/l. In upland hill streams, BOD ranges are from almost nil to around 3 mg/l whereas our ranges less than 2 mg/l. The DO value ranges from 8 – 12 mg/l and in our observation it is 8 to 10 mg/l.

The results of this physic chemical analysis of the rivers of Uttarakhand are similar to our results.

(ii) Water Quality report on Alaknanda River, 2009

In the water quality report on EIA of Alaknanda River (2009), assessment of water quality of Alaknanda River has been made. According to this assessment, the river waters has high levels of dissolved oxygen throughout, while the pH changes slightly from neutral to slightly alkaline as it descends from the upper reaches. Lower reaches of the river show slightly higher total dissolved solids indicating the solution of minerals as the water passes along the river but even at lower reaches the levels are not much elevated. The concentration of nutrients such as nitrate and phosphate do not differ considerably along the Alaknanda and its tributaries ranging from 0.01 to 0.15mg/l. Slightly elevated levels of nutrient have been found in the Mandakini and Dhauliganga rivers (up to 1.5 mg/l and 3.5 mg/l respectively) (CISHME, 2008).

As measured at specific points the Biological Water Class is uniformly Grade A except for immediately downstream of the Vishnuprayag barrage where it is Grade C. Alaknanda River water in general belongs to Biomonitoring Class 'A' with a few stretches in Class 'B' and some in Class 'C' . The same applies to the entire length of the Dhauliganga River. As the river flows downstream, there is an increase in the population centres, such as Srinagar and Karnaprayag on the Alaknanda River and associated activities such as domestic sewage discharge and agricultural run-off that will increase the concentration of nitrogen and phosphorus.

(iii) EIA report of NTPC, 2007

NTPC- has tested water samples taken in post monsoon from Tapovan Vishnugad HP and Lohari nagpala HP the results of analysis are given in below table 11 and 12 respoectively which are similar to our results. Tapovan Vishnugad HP is situated on Dhauliganga River, tributary of Alaknanda River and Lohari nagpala HP is situated on Bhagirathi River.

Table 6.11. Water quality of the Tapovan Vishnugad HP on Dhauliganga River

S.No.	Parameter	Unit	Sampling Sites		
			W1	W2	W3
1	pH	-	7.6	7.4	7.5
2	Temperature	°C	7.5	8.1	7.9
3	DO	mg/l	8.0	8.2	8.2
4	Conductivity	µS/cm	64	65	66
5	TDS	mg/l	46	47	46
6	Turbidity	NTU	10	11	12
7	BOD	mg/l	1.0	1.0	1.0
8	Nitrate nitrogen	mg/l	3.4	3.5	3.4

* Where,
W1 = Dhauliganga River u/s (barrage site)
W2 = Dhauliganga River d/s (barrage site)
W3 = Alaknanda River d/s

The results of both HPs are within limits of prescribed water class A. The samples were taken in post monsoon in year 2007, that was the initial stage of projects. Our data is similar with their data except conductivity and TDS respectively.

The conductivity and TDS are slightly high in our study in comparision of NTPC data but this is due to some constructional activities and nature of bed rock present in water flow.

Table 6.12. Water Quality of the Lohari nagpala HP on Bhagirathi River (After NTPC 2007)

S. No.	Parameter	Unit	Sampling sites					
			W1	W2	W3	W4	W5	W6
1	pH	-	7.7	7.6	7.7	7.7	7.7	7.7
2	Temperature	°C	7.4	7.6	7.6	7.6	7.5	7.6
3	DO	mg/l	8.4	8.5	8.6	8.7	8.4	8.7
4	Conductivity	µS/cm	77	76	74	81	77	78
5	TDS	mg/l	56	53	53	57	53	54
6	Turbidity	NTU	12	15	12	13	15	12
7	BOD	mg/l	1.0	1.0	1.0	1.0	1.0	1.0
8	Nitrate nitrogen	mg/l	4.2	4.2	4.1	4.0	4.1	4.1

*Where,
W1 = Tributry in confluene with the Bhagirathi river u/s (barrage site)
W2 = Tributry in confluene with the Bhagirathi river d/s (barrage site)
W3 = Bhagirathi River d/s (barrage site)
W4 = Bhagirathi River u/s (barrage site)
W5 = Bhagirathi River u/s (power house site)
W6 = Bhagirathi River d/s (power house site)

6.6 SELF PRESERVATIVE PROPERTY OF BHAGIRATHI RIVER WATER

A study carried out by NEERI (2004) for self purification capacity of Bhagirathi River give following values for various water quality parameters in its upper reaches.

pH	-	6.4 – 8.0
DO	-	7.1 – 19.85 mg/l
Total Suspended Solids	-	4 – 276 mg/l
Total Dissolved Solids	-	24 – 143 mg/l
COD	–	Below 10 mg/l
BOD	–	Less than 1 mg/l
Total Nitrogen	–	0.22 – 4.12 mg/l
Total Phosphorus	–	0.001 – 0.070 mg/l

Total Coliforms (TC) counts are low in upper reaches, but show are increase in downstream direction. The water quality was considered to be good.

NEERI (2004) also made are assessment of self preserving property of the Bhagirathi River water. Antibacterial activity in the Ganga River water are ascribed to the phage activity and they are termed as bacteriophages. Coliphages are inhabitant to humans and other mammals and excreted along with fecal matter. Different types of phages have been detected in the Ganga River water and its sediments. The coliphages might be adhering to the sediment suspended in Ganga River water and settling to the bottom along with the silt. The coliphages adsorbed to the sediment appear to be responsible for predating coliforms in the overlaying water column when the sediment and water co-exist in a container under static conditions.

The self preservative property of Bhagirathi River water under static condition might be enhanced by the release of metal ions from the sediment and suspended solids. The interaction of Cr^{+6} and Cu^{+2} is known to be synergistic and both are released from the sediment (demonstrated in the experiment); bactericidal impact of these metals is a strong possibility.

The sediment of Ganga water has potential to absorb the phases which are likely to increase in number under static conditions. These phages may play an important role in preserving property of Ganga River water. Thus, suspended sediment particles in the Ganga River water play very important role in self preservation property.

The Ganga River water and sediments have rather high concentration of heavy metals, volatile matters, radioactive elements. These parameters may have some role to play in self preservation property of the Ganga River water.

The study concluded that construction of Tehri Dam shall not have any adverse affect on the purification capacity of Bhagirathi River water. Thus, it may be emphasized that construction HPs shall not have any effect on the purification property of the Ganga River water.

6.7 BIODIVERSITY IN ALAKNANDA AND BHAGIRATHI BASINS

The Uttarakhand region is characterized by rich biodiversity and several unique ecological domains. The biological components can be identified into distinct broad categories, namely terrestrial flora, terrestrial fauna, aquatic flora and aquatic fauna. Riverine habitats generally occupy a small proportion in the total landscape, yet play a critical role as corridors and migration pathways for several faunal and floral species. They also serve as ‘edge’ habitats, facilitate river courses and also assist in prevention of soil erosion. They are often designated as ‘sensitive habitats’. The courses of Bhagirathi and Alaknanda rivers support a number of forest formations which are typically riverine in nature. Among the faunal groups several species of herpetofauna, riverine birds such as laughing thrushes, red starts, forktails, whistling thrush and mammals especially otters and fishing cats are of high conservation significance. Among fishes, there are several threatened species including golden mahseer, snow trout, etc. that breed in this landscape. Many species of fish require the uninterrupted riverine habitats as well as the floodplains for their breeding.

The construction of HP plants affects the river ecosystem and the adjacent areas including lower part of the river valley. In general, effect of a HP on the terrestrial biodiversity may be minimum but its impact on aquatic biodiversity could be severe. In case of a HP project consisting of a dam with large reservoir, the terrestrial biodiversity in the lower parts of the valley slopes adjacent to the river channel shall also be adversely affected. This has been the case with the Tehri HP project.

Most of the projects in the study area, commissioned and under construction are run of river projects where reservoirs are not constructed. However, these projects may affect the aquatic flora and fauna due to reduction of flow in the river channel or acting as barriers for migratory aquatic fauna. For example, endangered golden mahseer which is migratory in nature will be adversely affected if any barrier which is more than 15 m in height is placed across their migratory route. To understand the impact of HP projects on the aquatic fauna and flora, it is necessary to have a systematic documentation of various genera and species in the different segments of the river system. Moreover, record of temporal changes in the aquatic life is also required to assess the natural changes and changes due to HP projects. However, such kind of information is not yet available. HP projects, both reservoir type and run of river type may divert large amount of water, leaving little water in the river channel. Lately, concept of environmental flows has been developed, which requires that sufficient river flow be maintained in the river channel (after diversion of water) to maintain the aquatic ecosystem downstream. This aspect is discussed in greater details in chapter on Hydrology. We do not have any systematic record of biodiversity of rivers in Alaknanda and Bhagirathi basins. Data on the threatened fish species and their habitat is made available by the Wildlife Institute of India (WII) largely based on secondary sources and also with some primary data (Table 6.2.1). WII has initiated a study titled 'Assessment of Cumulative Impacts of Hydroelectric Projects on Aquatic and Terrestrial Biodiversity in Alaknanda and Bhagirathi Basins, Uttarakhand' during January 2011. Therefore, the complete riverine biodiversity profile along with impact details and minimum ecological flows required etc. would be made available by WII at the end of this project. However, they have provided some data on the requirement of water flow velocity and depth in natural observation. Preliminary review of WII's data shows that Nayar River has maximum species richness (Spp. Rich = 56); hence it may be considered the most important fish breeding river of the area. It may be mentioned that Nayar River is located south of the study area.

Further, potential habitat of Smooth Coated Otter (the only aquatic mammal in the study area) has been recorded from two locations:

1- Near Malysu village (30°15′43.9″ N, 78°55′11.7″ E)
2- Near Papdasu village (30°15′06.9″N, 78°53′37.8″ E)

The Wildlife Institute of India has also provided list of rare, endangered and threatened (RET) species of plants (Table 6.2.2), list of RET mammals (Table 6.2.3), and list of RET birds (Table 6.2.4) in Alaknanda and Bhagirathi basins, however, this data might be revised after the completion of their study mentioned above.

To evaluate the impact of HP on aquatic life, much more detailed and quantitative data than available at present on the fauna and flora is required. Thus, at present it is not possible to give any firm assessment on the impact of HP on the biodiversity of the Alaknanda and Bhagirathi basins. However, it is necessary to maintain the minimum environmental flows at each HP project to sustain the biodiversity of the rivers.

Construction of a dam with reservoir changes the domain of a flowing water (River) to a standing water (lake) domain. This change makes significant changes in the physio-chemical characteristics which affect the ecological parameters. The new standing water body would have its own ecology and biodiversity. So far, we do not have any study of changes in the aquatic life from river to reservoir.

Table 6.13. Distribution of fish population in different rivers of Alaknanda and Bhagirathi basins.

S. No.	Site	Latitude	Longitude	Altitude (m)	Min. No. of RET spp. (Primary data)	Breeding Habitat	Species Richness
1	Srinagar, Pauri Garhwal	N 30° 13. 140', N 30° 13.195'	E 078° 47.565', E 078° 47.386'	639.47, 630.94	5	Y	48
2	Khanda, Garhwal	N 30° 13. 142', N 30° 13.233'	E 078° 49.562', E 078° 49.472'	642.82, 643.13	2	Y	48
3	Tehri Dam	N 30° 24. 569', N 30° 24.176'	E 078° 27.212', E 078° 27.685'	640.08, 821.74	4	Y	41
4	Bagh Boila	N 30° 24. 176', N 30° 24.382'	E 078° 27.686', E 078° 27.533'	819.00, 800.10	3	y	4
5	Nagini	N 30° 19. 550', N 30° 19.335'	E 078° 21.305', E 078° 21.521'	1074.72, 1090.57	3	y	6
6	Dugadda Gad, Tehri	N 30° 12.137',	E 078° 46.005'	675.44	3	y	6
7	Khankaria Gad, Pauri Garwal	N 30° 14.563'	E 078° 55.116'	709.27	**3**	y	5
8	Rudra Prayag	N 30° 17.281'	E 078° 58.745'	638.56	4	y	48
9	Amshera Bidoon	N 30° 07.1734'	E 078° 21.271'	897.03	5	y	6
10	Banderkot	N 30° 44.610'	E 078° 21.534'	1057.96	4	y	6
11	Varungad	N 30° 44.338'	E 078° 24.487'	1118.31	3	y	5
12	Uttarkashi	N 33° 43.793'	E 078° 26.792'	1115.87	2	y	41
13	Ganeshpur	N 30° 45.206'	E 078° 28.400'	1118.31	3	y	4
14	Harsil	N 31° 02.355'	E 078° 47.685'	2448.76	1	y	41
15	Gangotri	N 30° 59.616'	E 078° 56.474'	3061.72	2	y	7
16	Phata	N 30° 35.490'	E 079°	1114.96	3	y	48

S. No.	Site	Latitude	Longitude	Altitude (m)	Min. No. of RET spp. (Primary data)	Breeding Habitat	Species Richness
			02.118'				
17	Karan prayag	N 30° 13.690'	E 079° 15.598'	822.66	2	y	48
18	Shimili	N 30° 13.336'	E 079° 15.244'	825.40	3	y	38
19	Nao Gaon (Chapta God)	N 30° 13.347'	E 079° 20.582'	936.96	5	y	38
20	Kaudiyala (Garhwal)	N 30° 14.026'	E 078° 42.190'		2	y	3
21	Vishnu Prayag (Garhwal)	N 30° 33.449'	E 079° 34.324'		One time sampling (no fish found)		
22	Pandukesvar (Garhwal)	N 30° 38.099'	E 079° 32.444'		One time sampling (no fish found)		
23	Nand Prayag (Garhwal)	N 30° 20.060'	E 079° 19.080'		3	y	48
24	Ghansigad (Pipalkoti)	N 30° 25.070'	E 079° 25.470'		3		48
25	Kaliasod (Near Srinagar Garhwal)	N 30° 14.491'	E 078° 53.527'		2	y	48
26	Jwalpa, Pauri Garhwal	N 29° 59.558'	E 078° 48.437'		3	y	5
27	Banghat , Pauri Garhwal	N 29° 56.571'	E 078° 41.257'		2	y	5
28	Vyasghat, pauri garhwal	N 30° 03.446'	E 078° 34.547'		2	y	5
29	Mana (Badrinath)	N 30° 45.261'	E 079° 29.590'		One time sampling (no fish found)		
30	Nayar	Entire river			9	y	56

Note:
Nayar River meets the Ganga River 5 km downstream of Devprayag.
Min. No. of RET spp.: This is the minimum number of threatened (vulnerable and endangered) species reported during our one or two time samplings, many more RET species might be here.
Spp Rich: Total number of species reported.
Breeding Habitat: Y-Yes (Fry and Fingerlings were found).

Explanation to the Table 6.123

1. A total of 30 sampling points including entire Nayar River were sampled for fishes
2. Site: Name of Sites mentioned in the first column, where fish were sampled.
3. Latitude and Longitude of sampled site are in subsequent columns.
4. Altitude are in the scale of ‘meters’. For some sites altitude data was not collected.
5. Min. No. of RET spp. (Primary data): Minimum number of threatened species recorded during our one time sampling. There may be more number of threatened species at each site which can be confirmed only by repeated sampling covering all seasons.
6. Breeding Habitat: The site recorded with juveniles (fry and fingerlings) were considered as conducive for breeding.
7. Species Richness: Number of possible species may occur or use this site. Total number of 48, 41, 38 and 56 species are reported in Alaknanda, Bhagirathi, Pindar and Nayar rivers respectively Single digit numbers of species mentioned in this column are actual number of species recorded by us during our one time sampling.
8. Except for species richness, all other data are primary data collected by WII
9. RET species covered in this list largely belong to Tor spp, Schizothorax spp., Barilius spp., Nemacheilus spp
10. Data on number of individuals of each species caught in each sampling site is also available with WII.
11. Nayar River is found to be one of most important fish breeding river of Uttarakhand. During one time sampling, WII could collect 9 species belonging to threatened species (Vulnerable and Endangered) out of total 15 species recorded; however, 56 species are reported here by earlier studies. The Nayar River meets the Ganga River at about 7 km downstream of Devprayag. It is very close to the Devprayag project, which may affect the fish population of Nayar River.

Table 6.14. **Rare, Endangered and Threatened species (RET) of plants, listed in the Red Data Book of Indian Plants recorded in the SEA Area, Bhagirathi and Alaknanda Catchments, Garhwal Himalaya.**

Sr. No.	Plant Name	Localities	Habitat	Altitude (m)	Habit	*Uses
1	*Acer caesium* Wall. ex Brandis	Hanuman chatti, Harsil, Kanchula-Kharak (30°27'36.13"N, 79°13'41.55"E), Bansinarayan, Above Silla (way to Kushkalyani) 30°44'35.0"N, 78°37'48.7"E)	Sub-alpine forests	2600 - 3400	H	M
2	*Aconitum hetrophyllum* Wall	Dayara, Kandara, Gidara (30°56'28.61"N, 78°36'33.74"E), Bedini-Ali, Mandani, Tungnath, Khedatal	Alpine Meadows	2700-4000	H	M
3	*Acorus calamus* L.	Pindar Valley, Akash Kamini (Mandal 30°27'13.10"N, 79°16'49.14"E), Phata (30°35'56.3"N, 79°1'36.5"E)	Fresh water swamps	up to 2000	H	M
4	*Allium stacheyi* Baker	Dayara, Gidara, Bedini-Ali, Badrinath, Rudranath, Khedatal, Kyarkoti (Syanagad)	Alpine Meadows	3300-4800	H	EB
5	*Allium humile* Kunth	Gidara, Kandara, Valley of Flowers NP, Tungnath	Alpine Meadows	3400-4000	H	M
6	*Arnebia benthamii* (Wall. ex D. Don) Johnston	Dayara, Gidara (30°56'31.58"N, 78°36'44.05"E), Kandara, Kyarkoti-Syanagad (31°5'47.1"N, 78°40'12.4"E)	Sub-alpine/Alpine bouldery areas	3200-4500	H	M
7	*Berberis osmastonii* Dunn.	Kheta (30° 2'43.04"N, 79°44'17.74"E), Kedarnath	Sub-alpine forests	2800-3800	S	-
8	*Caragana sukiensis* Schn.	Sukhi (31°0'13.81"N, 78°42'7.00"E), Jhala (near to Sukhi)	Upper temperate bouldery areas	2400-2700	S	SR
9	*Catamixis baccharoides* Thoms.	Saknidhar near Deoprayag, Only one population	Sandstone rocks	800 - 1000	S	BC
10	*Coleus barbatus* (Andr.) Benth.	Before Kirtinagar, East Khirsu (30°12'8.3"N, 78°55'32.6"E), Khetaswami (30°21'46.8"N, 79°6'1.9"E), Chirbatiya, Narayanbagarh (pinder valley)	Open slopes	800-2200	H	M
11	*Cyananthus integer* Wall. ex Benth.	Tungnath (30°29'10.61"N, 79°13'6.64"E), Mandani, Rudranath	Alpine rocky slopes	3200-4000	H	-

Sr. No.	Plant Name	Localities	Habitat	Altitude (m)	Habit	*Uses
12	*Datisca cannabina* L.	Harsil, Tharali (Pinder valley), Maneri (Bhagirathi valley), Naugaun (Yamuna valley)	Temperate loose slpoes	800-2000	S	M
13	*Dioscorea deltoidea* Wall. ex Griseb.	Kedarnath, ahead Bhangeli (way to Gidara), Badiyargad (upper Yamuna FD)	Temperate forests	1200-2200	C	-
14	*Epipogium aphyllum* (Schm.) Swartz	Gangotri, Ghangarea	Sub-alpine forests	2400-4000	H	BC
15	*Lilium polyphyllum* D. Don ex Royle	Gangotri, Ahead Bhairavghati, Radi top	Upper temperate bouldery areas	1500-3200	H	M
16	*Mahonia borealis* Takeda	Mussourie, Ghesh (pindar valley)	Temperate forest	1300-2500	S	BC
17	*Nardostachys jatamansi* DC.	Tungnath, Kedarnath, Mandani, Gidara, Kanasar, Dodital (30°54'12.3"N, 78°31'58.9"), Kushkalyani (way to Sahasratal)	Moist sub-alpine/Alpines rocky slopes	2400-3800	H	-
18	*Picrorhiza kurrooa* Royle ex Benth.	Tiungnath, Kedarnath, Mandani, Gomukh, Badrinath, Dodital (30°54'12.3"N, 78°31'58.9")	Moist sub-alpine/Alpines rocky slopes	2400-4200	H	-
19	*Saussurea gnaphalodes* D. Don	Chhaya Bugyal, Near Kandara	Sub-nival zone, Snowline	Above 4000	H	BC
20	*Trillidium govanianum* (D. Don) Kunth	Tungnath(30°29'19.82"N, 79°12'24.08"E), Mandani, Yamunotri (on the way to Saptarishi)	Alpine/Sub-alpine bouldery areas	2500-3500	H	M

M= Medicinal
EB = Ethnobotanical Use
BC = Botanical Curiosity
SR = Soil Enrichment

Table 6.15: RET Mammals in Alaknanda and Bhagirathi Basins (including a few Least Concern (LC) species listed in Schedule I/II of IWPA)

Common Name	Scientific Name	Altitude Range (m)	Habitats	IUCN	IWPA Schedule
Asiatic black bear	*Ursus thibentanus*	1000-3400	CPF,STMF,TF,SAF	VU	I
Himalayan brown bear	*Ursus arctos isabellinus*	above 3600	AS, AMR	VU	I
Himalayan masked palm civet	*Paguma larvata*	up to 2800	STMF,CPF,TF	LC	II
Jungle cat	*Felis chaus*	up to 2000	STMF,TF	LC	I
Fishing cat	*Prionailurus viverrilus*	up to 1500	Riverine, STMF	EN	I
Common leopard	*Panthera pardus*	up to 4000	STMF,CPF,TF,SAF,AS,AMR	NT	I
Snow leopard	*Panthera uncia*	up to 3000	AS, AMR	EN	I
Red fox	*Vulpes vulpes*	2500-5000	TF,SAF,AS, AMR	LC	II
Blue sheep*	*Psuedois nayaur*	above 3000	AS, AMR (Trans-Himalayan only)	LC	I
Himalayan musk deer	*Moschus chryogaster*	2450-4000	TF,SAF,AS, AMR	EN	I
Sambar	*Rusa unicolor*	up to 3200	TF,SAF	VU	III
Himalayan goral	*Nemorhedus goral*	up to 3500	TF,CPF,TSTS, SAF,AS, AMR	NT	III
Himalayan Serow	*Nemorhedus sumatraensis*	2000-3000	TSTS,SAF,AS	NT	I
Himalayan tahr	*Hemitragus jemlahicus*	1300-4000	TSTS,SAF,AS	NT	I
Smooth coated otter	*Lutrogale perspicillata*	up to 1500	Riverine	VU	II
Habitats			**IUCN Categories**		
STMF	Subtropical Mixed Forests		E - Endangered		
CPF	Chir Pine Forests		V - Vulnerable		
TF	Temperate Forests		NT - Near Threatened		
TSTS	Temperate Scattered Tree & Scrub+open rocky slopes		LC - Least Concern		
SAF	Subalpine Forests				
AS	Alpine Scrub				
AMR	Alpine Meadows & Open rocky slopes				
* only in the Trans-Himalayan regions of the Bhagirathi & Alaknanda catchments					

Table 6.16: RET Birds in Alaknanda and Bhagirathi Basins (including a LC species listed in Schedule I of IWPA)

Common Name	**Scientific Name**	**Altitude Range (m)**	**Habitats**	**IUCN**	**IWPA Schedule**
Indian White-backed Vulture	*Gyps bengalensis*	up to 2500	OF,HH	CE	I
Red-headed Vulture	*Sarcogyps calvus*	up to 2500	STMF,HH	CE	I
Egyptian Vulture	*Neophron percnopterus*	up to 2500	OF,HH	EN	I
Cinereous Vulture	*Aegypius monachus*	up to 3000	OF,HH	NT	I
Himalayan Monal	*Lophophorus impejanus*	2700-4000	TF,SAF,AS, AMR	LC	I
Cheer Pheasant	*Catreus wallichii*	1500-3000	CPF, OF,TSTS	VU	I
Habitats				**IUCN Categories**	
STMF	Subtropical Mixed Forests			CE - Critically endangered	
CPF	Chir Pine Forests			EN - Endangered	
TF	Temperate Forests			VU - Vulnerable	
TSTS	Temperate Scattered Tree & Scrub+open rocky slopes			NT - Near Threatened	
SAF	Subalpine Forests			LC - Least Concern	
AS	Alpine Scrub				
AMR	Alpine Meadows & Open rocky slopes				
OF	Open Forest (Subtropical/Temperate)				
HH	Around Human Habitation				

6.8 RIVER ECOLOGY AND HYDROLOGY REQUIREMENT

An appropriate environmental river flow is required for maintaining the health, function and integrity of the river ecosystems through the protection of aquatic organisms dwelling in these fluvial ecosystems. The major biotic components of Alaknanda-Bhagirathi basin up to Deoprayag are periphyton, phytoplankton, macrophytes, zooplankton, benthic macroinvertebrates, fish and fish otter. However, changed environmental flow regime caused by the construction of hydropower projects should not adversely influence phytoplankton, zooplankton and macrophytes.

Thus, the major biotic valued ecosystem components (VECs) of Alaknanda-Bhagirathi basin up to Deoprayag are benthic macroinvertebrates, fish and fish otter. The protection of these valued ecosystem components is very important for the integrity of the ecosystems of these rivers. Therefore, it is very much essential to know the hydrological requirements (hydromedian depth and water velocity) of these freshwater organisms for ensuring the sustainability of these aquatic life and proper functioning of the riverine ecosystem. A considerable work has been done on the water quality and aquatic biodiversity of Bhagirathi (Sharma 1983; 1984, 1985, 1986; Sharma *et al.* 2008a; Sharma and Bahuguna 2009), Bhilangana (Sharma *et al.* 1990), Alaknanda (Singh and Sharma 1998, Kala and Sharma 2001), Dahuliganga (Sharma *et al.* 2004), Tons (Sharma *et al.* 2008b) and Asan (Sharma and Rawat 2009).

Direct information on the precise hydrological requirements of the organisms dwelling habitats of the upper Ganga is not available. The data on the hydromedian depth (HMD) and water velocity and various stages of these organisms in the natural environment are available. Thus, it is possible to provide minimum hydrological requirement (HMD and water velocity) on the basis of long working experience on these organisms and their life stages. The hydrological requirements of these valued ecosystem components (VECs) will be instrumental for determining the environmental flow requirement at each site of the hydropower project in Alaknanda –Bhagirathi basin up to Deoprayag.

6.8.1 Study Area

The study focuses on on-going and proposed hydropower developments on the Alaknanda and its tributaries (Dhauliganga, Rishiganga, Birhiganga, Pindar, Nandakini, Mandakini) and Bhagirathi and its tributaries (Asiganga, Bhilangana, Balganga) up to Devprayag. An important spring-fed river Nayar, which meets the Ganges at Vyasghat, 5km downstream to Deoprayag, has also been included under the study area. This river provides a favourable habitat for some of the fishes, especially Mahseer for breeding.

6.8.2 Study Approach

The entire study area was divided into different stretches/zones on the basis of the habitat characteristics (geological/morphological/hydrological and biological). The primary data on collection of biotic valued ecosystem components (macroinvertebrates, fish and fish otter) were made after visiting all the major river zones of study area. The secondary data related with biotic components were also collected from the published literature. Benthic macorinvertebrate data were derived from samples taken following standard protocols outlined in Wetzel and Likens (1991) and APHA (1998). These techniques timed 3 min. kick/sweep net sampling of all habitats and habitats were sampled in proportion to their occurrence.

The data on fishes and fish otter were collected through primary and secondary sources. Data on important basin ecological indicators were also collected for assessing the environmental management class of the rivers.

Hydrological requirements (water depth and water velocity) of macro invertebrates, fish and fish otter were also collected on the analysis of the characteristics of their natural habitat and their life activities in the Alaknanda and Bhagirathi Basin. The published literature was also consulted extensively for assessing the hydrological requirements of these organisms. Hynes (1970) and Decamp (1971) have done a pioneer work on the hydrological requirement of freshwater of aquatic biota. These were also consulted for assessing the hydrological requirements of the organisms dwelling the study area.

6.8.3 Environmental Management Class of Rivers

There are various approaches for classifying the rivers on the basis of biotic communities or various basin ecological indicators. Therefore, an attempt has been made to classify the different stretches of Alaknanda-Bhagirathi basin up to Deoprayag (Table 6.15).

Table 6.17 Environmental management class (EMC) of Alaknanda and Bhagirathi rivers and their tributaries

S. No.	Class based on basin ecological indicators	Illies and Botosaneanu (1963)	Class Based on Fish	Holmes *et al.* (1998)	Trophic Status Class
1.	B	Epirhithron	No Fish Zone	D2	Ultra-oligotrophic
2.	C	Metarhithron	Trout Zone	D1	Oligotrophic
3.	D	Hyporhithron	Mahseer Zone	C2	Oligo-mesotrophic

(a) Illies and Botossaneanu (1963) Classification:

According to the classification of Illies and Botossaneanu (1963), the Alaknanda-Bhagirathi basin can be classified into a rithronic stretch which has mean monthly temperature up to 20°C with high dissolved Oxygen, fast and turbulent water velocity and the river bed is composed of rocks, stones with occasional sandy/silty patches. This rithronic stretch is again divided into three sub-types- Epirhithron (dominated by rapids, waterfalls and cascades), Meta-rhithron (alternation of riffles and pools) and hyporhithron (relatively less riffles). The stretches classified under epirhithronic stretch have been presented in Table 6.16, metarhithronic in Table 6.17 and hyporhithronic in Table 6.18.

Table 6.18 Epirhithronic stretches of Alaknanda-Bhagirathi basin EMC B (No Fish Zone)

S. No.	River	Stretch
1	Alaknanda	Mana -Vishnuprayag
2	Dhauliganga	Malari-Tapovan
3	Rishiganga	Entire stretch
4	Bhuyandar Ganga	Entire stretch
5	Birahi ganga	Source –Guhana Tal
6	Mandakini	Kedarnath-Gaurikund
7	Nandakini	Source-Vanala
8	Pindar	Source-Melkhet
9	Bhagirathi	Gangotri-Dabrani
10	Bhilangana	Source-Ghuttoo
11	Jahnvi	Entire stretch
12	Balganga	Source-Jhalakoti
13	Asiganga	Source-Singoli
14	East Nayar	Doodhatoli-Thalisain
15	West Nayar	Doodhatoli-Tirpalisain

Table 6.19 Metarhithronic stretches of Alaknanda-Bhagirathi basin EMC C (Trout Zone)

S.N.	River	Stretch
1	Alaknanda	Vishnuprayag-Karnaprayag
2	Dhauliganga	Tapovan-Vishnuprayag
3	Birahi ganga	Guhana Tal - Pipalkoti
4	Mandakini	Gaurikund-Guptkashi
5	Nandakini	Vanala-Nandprayag
6	Pindar	Melkhet-Debal
7	Bhagirathi	Dabrani-Uttarkashi
8	Bhilangana	Ghuttoo-Ghansali
9	Balganga	Jhalakoti-Ghansali
10	Asiganga	Singoli-Bhatwari
11	East Nayar	Thalisain-Satpuli
12	West Nayar	Tirpalisain-Satpuli

Table 6.20 Hyporhithronic stretches of Alaknanda-Bhagirathi basin EMC D (Mahseer Zone)

S.N.	River	Stretch
1	Alaknanda	Karnaprayag – Devprayag
2	Bhagirathi	Uttarkashi -Deoprayag
3	Bhilangana	Ghansali -Tehri
4	Mandakini	Guptkashi -Rudraprayag
5	Pindar	Debal–Karnaprayag
6	Nayar	Satpuli-Deoprayag

(b) Classification Based Upon the Presence of Fish Communities:

The classification of the river water bodies based on the presence of fish communities was initially devised by Cowx *et al.* (2004) into 8 major types. This typology was reviewed for classifying Alaknanda-Bhagirathi basin. Thus, the entire study area can be divided into three major types - No fish zone, Trout zone and Mahseer zone. 'No fish zone' is the epirhithronic, while the trout zone is metarhithronic. The Mahseer zone is hyporhithronic stretch. These segments are depicted for different rivers of the basin in Fig. 6.10.

(c) Classification by Holmes *et al.* (1998):

On the basis of the classification given by Holmes *et al.* (1998), the study area can be divided in the three categories: High altitude (D2), high altitude (D1) and middle altitude (C2) category. The high altitude (D2) category is characterized by the presence of hard rocks, steep slopes, presence of cobble, boulder bed rock with torrential water current and ultra-oligotrohic status of ecosystem with high gradient. This stretch is part of the epirhithron. High altitude D1 category is of moderate gradient of altitude with oligotrophic status of ecosystem which can be categorized under meta-rhithron. The third category is Medium Altitude (C2 category), which is characterized by presence of pebbles, cobble, boulder bed with smooth flow with abundant riffles and the trophic status of the ecosystem is oligo-mesotrophic which can be designated under hyporhithronic stretch.

(d) Classification Based Upon Basin Ecological Indicator:

This classification is based on 14 basin ecological indicators including the presence of rare and endangered aquatic biota, endemic species, habitat diversity, presence of protected areas, sensitivity of aquatic ecosystem, percentage of natural percentage cover, percentage of flood-plain vegetation cover, degree of flow regulation; fragmentation of aquatic habitats, degree of flow fragmentation, percentage of exotic species, relative richness of aquatic biodiversity, human population density and overall water quality in the basin. On the basis of these indicators the entire study area can be classified into three environmental management classes- B, C and D which will be epirhithron, metarhithron and hyporhithron, respectively.

6.9 AQAUTIC ECOSYSTEM INTEGRITY AND NATURAL FLOW PARADIGM

Endemic riverine species possesses life history traits that enable individuals to survive and reproduce within a certain range of environmental variation. A myriad of environmental attributes are known to shape the habitat templates that control aquatic and riparian species distributions including flow depth and velocity, temperature, bottom substrate size distributions, oxygen content, turbidity soil moisture/ saturation, and other physical and chemical conditions and biotic influences. Hydrological variation plays a major part in structuring the biotic diversity within river ecosystems as it controls key habitat conditions within the river channel, the flood plain, and hyporheic (stream-influenced groundwater) zones. The often strong connections between stream flow, floodplain inundation, alluvial groundwater movement, and water table fluctuation mediate the exchange of organisms, particulate matter, energy, and dissolved substances along the upstream- downstream, river floodplain river – hyporheic, and temporal dimensions of riverine ecosystems.

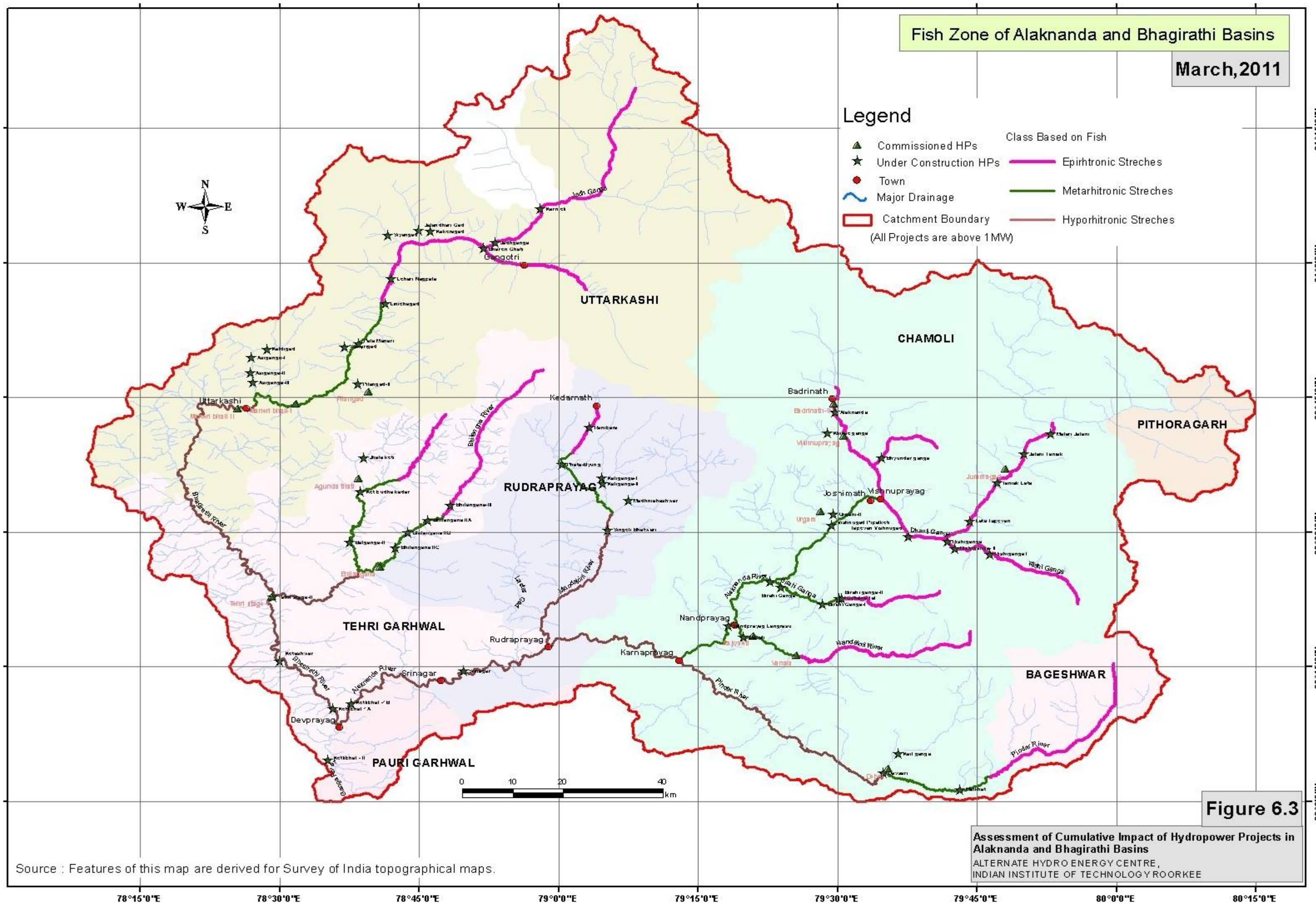

Fig. 6.10. Fish Zone of Alaknanda and Bhagirathi Basins

An in-depth study on the relationship between hydrological variability and river ecosystem integrity overwhelmingly suggests a natural flow paradigm, states: the full range of natural intra- and interannual variation of hydrological regimes, and associated characteristics of timing, duration, frequency and rate of change are critical in sustaining the full native biodiversity and integrity of aquatic ecosystems.

6.10 PRESCRIBING ENVIRONMENTAL FLOWS FOR INTEGRITY OF RIVER ECOSYSTEM

An “environmental flow” is the minimum discharge required to be left within a river at a point of abstraction to satisfy a special level of environmental goods and services. Thus, the objective of this concept is to prescribe the minimum flow required for maintenance the integrity of aquatic ecosystem within the river channel below the offtake.

In recent years, there have been a number of methods that have been proposed for the purposes of estimating the environmental water requirements of rivers. These methods are based on some dominant characteristics of approach –hydrological approach, hydraulic based approach, holistic approach, the Flow Stressor-Response (FSR) approach, the Downstream Response to imposed Flow transformations (DRIFT) approach, and Instream Flow Incremental Methodology (IFIM) approach. Many of these approaches focus on different aspects of the problem, while few of them consider all of the issues associated with the eventual implementation environmental water requirement as part of the integrated water management. Thus, the integrated framework based on integrating the impacts of changing flow regimes on different ecosystem response components. This framework will be flexible enough to be used with different approaches to analyzing ecosystem responses, ranging from complex hydraulic habitat assessments to the interpretation of expert opinion and therefore, would be widely applicable at all points in Alaknanda-Bhagirathi basin upto Deoprayag.

6.11 MAJOR COMPONETS OF AHEC, IITR FLEXIBLE ENVIRONMENTAL FLOWS DETERMINATION METHOD

Hughes and Louw (2010) have presented the various components of an integrated environmental water requirement (EWR) determination framework for rivers integrating hydrology, hydraulics, and ecological response into a flexible approach (Fig.6.11). The top part of the diagram suggests that the two main ecosystem response drivers (water quantity and quality) need to be integrated with all the ecosystem response components and that this integration will normally occur through a hydraulic sub-model that uses the hydrological (water quantity) information as part of the input. The lower part of the diagram suggests that the outputs from the integration need to be explored in a format that is useful for the design of future adaptive management practices in terms of setting abstraction of water.

At the very least, the monitoring programme should be designed to assess whether the recommended managed flow and water quality regimes are being attained, as well as checking that these are achieving the required ecological objectives through biomonitoring or environmental assessments.

The proposed framework does not restrict the type of method that should be used for individual sub-components, merely that they are (or can be made to be) compatible with the integration approach. This should make the complete framework reasonably flexible such that it can be applied in a wide variety of situations including those where very few data are available and where there might be a strong reliance on expert opinion.

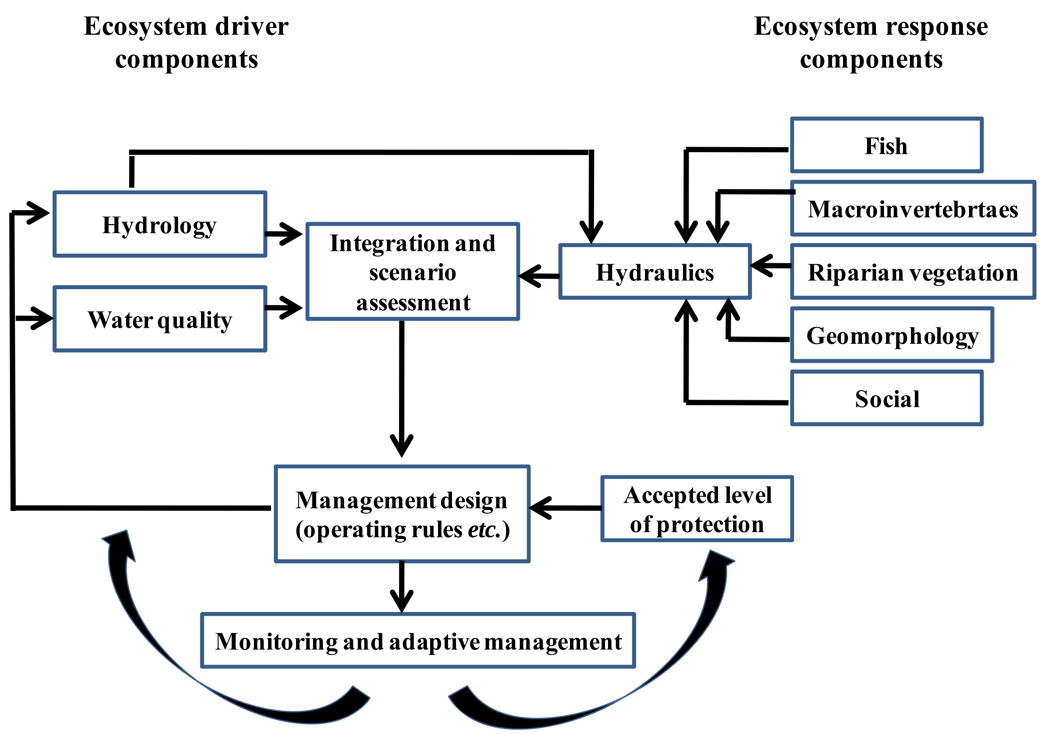

Fig. 6.11 Components of an EWR determination and implementation approach (adapted from Hughes and Louw, 2010)

6.12 MAJOR ECOSYSTEM BIOTIC RESPONSE COMPONENTS AND THEIR MINIMUM HYDROLOGICAL REQUIREMENTS

Internationally, there already exists a wide range of different methods that can be used to assess the effects of various ecosystem drivers (water quantity and quality) on different response components. The most important biotic response components which are also acting as valued ecosystem components (VECs) in the Alaknanda-Bhagirathi basin up to Deoprayag are macro invertebrates, fish and fish otter. The species of these biotic response components dwelling the various sites of hydropower projects and their flow groups and hydrological requirements (water depth; water velocity) in the Alaknanda-Bhagirathi basin have been presented. Many freshwater organisms have precise requirements for particular current velocities or flow ranges and certain taxa may be ideal indicators for prevailing flow conditions. On the basis of primary and secondary information, an overview on the hydrological requirements of important biotic valued ecosystem components (macro invertebrates, fish and fish otter) has been presented in Table 6.3.5.

Table 6.21 Freshwater macro invertebrate and fish flow group, ecological flow associations and minimum hydrological requirements (water depth and water velocity)

Flow group	Ecological Flow Association	Minimum Hydrological Requirement	
		HMD (cm)	Water Velocity (cm s^{-1})
I	Taxa associated with rapid flows	15-20cm	>100
II	Taxa associated with moderate to fast flows	20-30 cm	50-100
III	Taxa associated with slow to moderate flows	30-50cm	25-50

Explicit attempt to connect macroinvertebrate populations with flow conditions are less prevalent, although two decades ago Jones and Peters (1977) made some headway in linking flows in unpolluted British rivers to invertebrate community structure. Armitage (1995) has associated community response with variable current velocities in experimental situations. Petts and Bickerson (1997) provided a summary of detailed investigations into invertebrate/flow relationships in the River Wissey, Norfolk.

Despite these advances, there is still a need for straightforward and reliable ecological assessment method which is sensitive and responsive to varying flow patterns and that can be used with the existing data.

6.12.1 Macroinvertebrates

Many freshwater invertebrates have precise hydrological requirements (water depth and water velocity). Quantitative responses to flow changes, site specific studies also show that most taxa associated with slow flow lead to increase in abundance as flow declines, whereas most species associated with faster flows exhibit the opposite response. Alterations in community structure may occur as a direct consequence of varying flow patterns or indirectly through associated habitat change. Benthic macroinvertebrates will be adversely impacted due to change in environmental flow regimes on river bed and river bank ecology as a consequence of the construction of hydropower projects in the Alaknanda-Bhagirathi basin. However, phytoplankton, zooplankton and macrophytes will not be adversely affected.

In case of uncertainty or ambiguity on ecological assessment and the lack of straightforward data on the hydrological requirements of macroinvertebrates, most of the flow group associations have been derived from published work, from the professional experience of freshwater biologists and the personal experience working on these organisms during the last three decades. Typical mean current velocities associated with various benthic freshwater macroinvertebrates flow groups and ecological associated have been outlined in Macan (1963) and Hynes (1970). Many invertebrates have an inherent need for current either because they rely on it for feeding purpose or because their respiratory requirements demand it. These are typical rheostenic species and many workers have found that particular species have been confined to fairly definite range of water velocity.

The benthic freshwater macroinvertebrate flow groups and their hydrological requirements dwelling epirhithronic, metarhithronic and hyporhithronic stretches of the Alaknanda-Bhagirathi basin have been presented in Tables 6.20 – 6.22. Where species data are unavailable, the requirements have been assessed at the family level. The use of family level data may result in a loss of precision, since a number of families contain species with fairly wide ranging flow requirements.Ubiquitous taxa such as Chironomidae and Oligochaeta are not used, since there appears to be no definitive relationship between the Chironomid/Oligochaete abundance and flow requirement.

Table 6.22 Diversity of macroinvertebrates and their minimum hydrological requirements dwelling epirhithronic stretch of Alaknanda-Bhagirathi basin

S. No.	Macroinverebrates			Flow group	Minimum Hydrological requirement	
	Order	**Family**	**Taxon**		**HMD (cm)**	**Water Velocity (cm s^{-1})**
1	Ephemeroptera	Baetidae	*Baetis niger*	II	20-30	50-100
			B.muticus	II	20-30	50-100
			B. rhodani	II	20-30	50-100
			Centroptilum luteolum	II	20-30	50-100
		Heptageniidae	*Rhithrogena*	I	15-20	>100
			Heptagenia	I	15-20	>100
		Ephemerellidae	*Ephemerella ignita*	II	20-30	50-100
2	Diptera	Tendipidae	*Tendipes tentans*	II	20-30	50-100
3	Trichoptera	Hydropsychidae	*Hydropsyche*	II	20-30	50-100
4	Plecoptera	Perlidae	*Perla*	I	15-20	>100
		Perlodidae	*Isoperla*	I	15-20	>100

Table 6.23 Diversity of macroinvertebrates and their minimum hydrological requirements dwelling metarhithronic stretch of Alaknanda-Bhagirathi basin

Macroinvertebrates			Flow group	Minimum Hydrological requirement	
Order	**Family**	**Taxon**		**HMD (cm)**	**Water Velocity (cm s^{-1})**
Ephemeroptera					
	Heptageniidae	*Heptagenia*	I	15-20	>100
	Baetidae	*Baetis niger*	II	20-30	50-100
	Baetidae	*B. muticus*	II	20-30	50-100

	Baetidae	*B. rhodani*	II	20-30	50-100
	Baetidae	*Cloeon*	II	20-30	50-100
	Caenidae	*Caenis*	III	30-50	25-50
	Ephemerellidae	*Ephemerella ignita*	II	20-30	50-100
	Heptageniidae	*Rhithrogena*	I	15-20	>100
Trichoptera					
	Rhyacophilidae	*Rhyacophila*	I	15-20	>100
	Hydropsychidae	*Hydropsyche*	II	20-30	50-100
	Glossosomatidae	*Glossosoma*	II	20-30	50-100
	Hydroptilidae	*Hydroptila*	III	30-50	25-50
Diptera					
	Tabanidae	*Tabanus*	II	20-30	50-100
	Tipulidae	*Antocha*	III	30-50	25-50
Coleoptera					
	Amphizoidae	*Amphizoa lecontei*	II	20-30	50-100

Table 6.24 Diversity of macroinvertebrates and their minimum hydrological requirements dwelling hyporhithronic stretch of Alaknanda-Bhagirathi basin

S. No.	Macroinverebrates			Flow group	Minimum Hydrological requirement	
	Order	Family	Taxon		HMD (cm)	Water Velocity (cm s^{-1})
1.	Ephemeroptera					
		Ephemerellidae	*Ephemerella*	II	20-30	50-100
		Caenidae	*Caenis*	III	30-50 cm	25-50
		Heptageniidae	*Heptagenia*	I	15-20	>100
			Rithrogena	I	15-20	>100
		Baetidae	*Baetis*	II	20-30	50-100
			Cloeon	II	20-30	50-100
2.	Trichoptera					
		Hydropsychidae	*Hydropsyche*	II	20-30	50-100
		Psychomyiidae	*Psychomyia*	II	20-30	50-100
			Polycentropus	II	20-30	50-100
		Leptoceridae	*Leptocella*	III	30-50cm	25-50
			Mystacides	III	30-50cm	25-50
		Glossosomatidae	*Glossosoma*	II	20-30	50-100
		Hydroptilidae	*Hydroptila*	III		
		Rhyacophilidae	*Rhyacophila*	I	15-20	>100
		Limniphilidae	*Limniphilius*	II	20-30	50-100
3.	Diptera					
		Syrphidae	*Chrysogaster*	III	30-50cm	25-50
		Blepharoceridae	*Philorus*	III	30-50cm	25-50
		Musidae	*Limnophora*	III	30-50cm	25-50

S. No.	Macroinverebrates			Flow group	Minimum Hydrological requirement	
	Order	Family	Taxon		HMD (cm)	Water Velocity (cm s^{-1})
		Tabanidae	*Tabanus*	II	20-30	50-100
		Simuliidae	*Simulium*	II	20-30	50-100
		Dixidae	*Dixa (pupa)*	II	20-30	50-100
		Rhagionidae	*Atherix*	III	30-50cm	25-50
		Tipulidae	*Antocha*	III	30-50cm	25-50
4.	Coleoptera					
		Psephenidae	*Psephanus*	III	30-50cm	25-50
		Elmidae	*Heterlimnius*	II	20-30	50-100
		Gyrinidae	*Dineutes*	III	30-50cm	25-50
5.	Odonata					
		Lestidae	*Archilestes*	III	30-50cm	25-50
		Gomphidae	*Octagomphus*	II	20-30	50-100
		Libelludidae	*Epicordulia*	III	30-50cm	25-50
		Libelludidae	*Sympetrum*	III	30-50cm	<25-50
6.	Plecoptera					
		Perlidae	*Perla*	I	15-20	>100
		Perlodidae	*Isoperla*	I	15-20	>100

6.12.2 Fishes

Fish is also one of the most valued ecosystem components (VECs) of the Bhagirathi-Alaknanda basin up to Deoprayag. As a consequence of cascade of hydropower projects in operation, under construction, or under development this valued ecosystem component will be adversely affected. The magnitude, timing and duration of flow events determine *inter alia* the temporal and spatial availability as well as the connectivity of different physical habitats required by riverine fish during their various life history stages.

With respect to fish in perennial rivers, there may be several critical habitat conditions including the effects of reducing flow on the availability of marginal habitat caused by a reduction of wetted parameter, a reduction in fast and deep habitats in favour of either slow and deep or fast and shallow habitats, or a reduction in fish mobility due to insufficient depth of water flowing over shallow riffle areas. If these conditions persist for extended lengths of time they may impact on the capacity of a specific species of fish to successfully feed, spawn or compete with other species and therefore affect abundance and dynamics. Many of these effects will be seasonally dependent and therefore extended periods of high “stress” in some months may be normal, while in the other months may be detrimental to ecological functioning.

Periodic high, flushing flows are desirable to prevent settling of fine, clogging interstitial spaces in the substratum (Wood and Armitage 1997). Upland rivers are more sensitive to change in flow than those in lowland, thus, they need more stringent standards of protection.

Spawning fish require a minimum area of suitable habitat and flows sufficient to keep gravel free from fines; thus most of the fish species have threshold levels of depth and velocity. During incubation fish eggs must be submerged and well oxygenated by water percolating through the gravels; pan survival rates are density dependent so sufficient flow is required to maintain adequate habitat. The viability of the spawning habitat is dependent on the magnitude of sand deposition. A change of substrate comparison from a primarily cobble to a sand-cobble bed mixture could result in the elimination of preferred spawning habitat, suffocation of eggs or entrapment of the larvae. A minimum stream flow is required that will sustain all the life stages of fish species.

The effect on fish habitat of the deposition of excessive amounts of sands and fine material on the cobble substrate can be severe, limiting the aquatic insect population, reducing the opportunity for spawning and reducing the channel carrying capacity. Reduced or altered flow patterns and corresponding reductions in sediment transport capacity could threaten the fish population. Entry of Mahseer fish into headwater tributaries is particularly flow dependent.

The data on the fish diversity and their hydrological requirements (water depth and water velocity) dwelling metarhithronic and hyporhithronic stretches of Alaknanda-Bahgirathi basin have been presented in Tables 6.23 – 6.24. The epirhithronic stretch has no fish due to very cold temperature and turbulent water current. However, metarhithroic stretch has a natural favourite habitat for snow trout (Trout zone). The hyporhithronic stretch is a natural habitat for Himalayan Mahseer (*Tor tor* and *Tor putitora*). Thus, this can be aptly called as Mahseer zone.

Some of the fishes, especially Barils (*Barilius spp*) and laoches (*Noemacheilus spp*) use to prefer to stay in the small tributaries having fast currents. However, the adult big fishes like snow trout and Mahseers stay most of the time in the main rivers. The rare cat fishes including *Glyptothorax* sp and *Pseudoecheneis* sp prefer very fast current and are adapted to cling to the stones with their suckers and adhesive pads. Most of the cold water fish species particularly rheophilic cyprinids are very sensitive to modified flows. However, coarse fishes exhibit greater plasticity towards modified flows. The hydrological requirements of the fishes dwelling metarhithronic and hyporhithronic stretches can be met provided a suitably designed environmental flow release programme is implemented.

Table 6.25: Diversity of fish and their minimum hydrological requirements dwelling metarhithronic stretch of Alaknanda-Bhagirathi basin (EMC-C)

S. No.	Name of the Fish	Flow group	Minimum Hydrological requirement	
			HMD (cm)	Water Velocity ($cm\ s^{-1}$)
	Family Cyprinidae			
1.	*Schizothorax richardsonii* Gray	II	20-30	50-100

2.	*Schizothorax plagiostomus* Heckel	II	20-30	50-100
3.	*Schizothorax sinuatus* Heckel	II	20-30	50-100
4.	*Schizothoraichthys progastus* McClelland	II	20-30	50-100
5.	*Garra lamta* Hamilton	II	20-30	50-100
6.	*Garra gotyla gotyla* Gray	II	20-30	50-100
7.	*Crossocheilus latius* Hamilton	II	20-30	50-100
8.	*Barilius bola* Hamilton	II	20-30	520-100
9.	*Barilius bendelisis* Hamilton	II	20-30	50-100
10.	*Barilius barna* Hamilton	II	20-30	50-100
11.	*Barilius vagra* Hamilton	II	20-30	50-100
12.	*Barilius barila* Hamilton	II	20-30	50-100
	Family Cobitidae			
13.	*Noemacheilus montanus* McClelland	II	20-30	50-100
14.	*Noemacheilus rupicola* McClelland	II	20-30	50-100
	Family Sisoridae			
15.	*Glyptothorax pectinopterus* McClelland	I	15-20	>100
16.	*Pseudoecheneis sulcatus* McClelland	I	15-20	>100

Table 6.26. Diversity of fish and their minimum hydrological requirements dwelling hyporhithronic stretch of Alaknanda-Bhagirathi basin (EMC-D)

S. No.	**Fish**	**Flow group**	**Minimum Hydrological requirement**	
			HMD (cm)	**Water Velocity (cm s^{-1})**
	Family Cyprinidae			
1.	*Tor tor* (Ham.-Buch.)	III	30-50cm	25-50
2.	*Tor putitora* (Ham.-Buch.)	III	30-50cm	25-50
3.	*Labeo dero* (Ham.-Buch.)	III	30-50cm	25-50
4.	*Labeo dyochelius* (McClleland)	III	30-50cm	25-50
5.	*Schizothorax richardsonii* (Gray)	II	20-30	50-100
6.	*Schizothorax sinuatus* (Heckel)	II	20-30	50-100
7.	*Schizothorax niger* (Heckel)	II	20-30	50-100
8.	*Schizothoraichtys progastus* (McClelland)	II	20-30	50-100
9.	*Danio danio* (Ham.-Buch.)	II	20-30	50-100
	Family: Cobitidae			
10.	*Lepidocephalichthys guntea* (Ham-Buch.)	III	30-50cm	25-50
11.	*Botia geto* (Ham.-Buch)	III	30-50cm	25-50
12.	*Botia dario* (Ham-Buch.)	III	30-50cm	25-50
	Family Amblycepidae			
13.	*Amblyceps mangois* (Ham.-	III	30-50cm	25-50

	Buch.)			
	Family:Schilbeidae			
14.	*Clupisoma garua* (Ham.-buch.)	II	20-30	50-100

6.12.3 Fish Otter

Fish otter is also as important biotic valued ecosystem component and top predator of the Alaknanda-Bhagirathi basin. Fish otter occupies the highest trophic level in the riverine ecosystem. The Smooth-coated otter (*Lutrogale perspicillata*) of family Mustelidae and sub-family Lutrinae dwells the hyporhithronic stretch of the study area. The species is vulnerable (Vu) under the IUCN Category and is protected under Wildlife Protection Act 1972 (Schedule II (II) an CITES Appendix II. The fish otter can be placed under flow group III which requires hydro median depth of 30-50 cm and water velocity 25-50cm s^{-1}. The data related with the diversity of macroinvertebrates, fish species and fish otter and their hydrological requirements have revealed that some of the species are natural inhabitants of a specific stretch of river and need specific hydrological requirements. But, they may move in upstream or downstream direction in search of food or fulfilling the requirements of their life stages. Thus, there is a no demarcation line among the three stretches of epirhithron, metarhithron and hyporhithron. However, the data on hydrological requirements of these biotic VECs will be of paramount importance for determining the environmental flow requirements at each site of the hydropower projects in Alaknanda-Bhagirathi basin up to Deoprayag.

6.13 FOREST AND PROTECTED AREAS

The basin is home to a number of protected areas and reserve forests. These areas and hydropower projects are shown in Fig. 6.12. It can be seen that about seven projects are located in the protected areas.

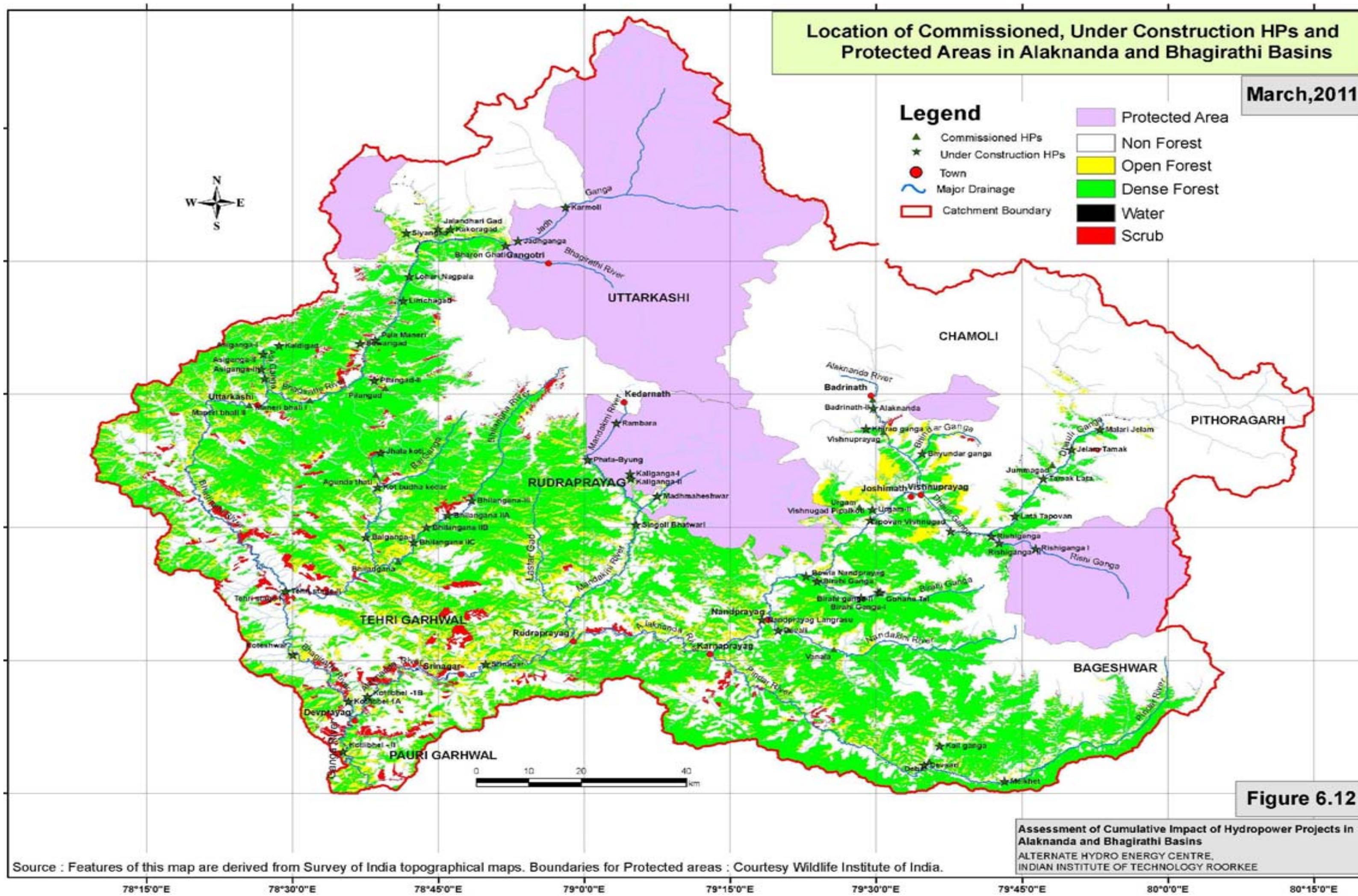

Fig. 6.12. Location of Commissioned, Under Construction HPs and Protected areas in Alaknanda and Bhagirathi Basins

6.14 CONCLUSION

The water quality of Manei Bhali I & II, Bhilangana, Tehri on Bhagirathi River and Vishnuprayag, Rajwakti and Vanala on Alaknanda River. (Table 8) has been compared with base line water quality.

The impact on the DO is negligible, the BOD remains unchanged as the water passes through the tunnels/channels. FC is higher u/s in some cases (MB I and MB II) which undergoes some reduction while passing through a long tunnel. The other parameters do not show significant change.

Based upon the analysis of the data, it is concluded that the impact of the hydropower projects that have been commissioned and are under operation on water quality is not significant. However, there is a caveat. Within the reservoir which is deep, the water quality may change significantly from the surface to the bed and from near the dam to the point where the submergence due to dam ends and would have implications for biotic life.

On the basis of the analysis reported in this chapter it may be concluded that there is no significant impact of the Hydropower Projects on the water quality in run of river projects. Out of 10 parameters only five namely, viz temperature, DO, BOD and FC and conductivity show minor changes in the vicinity of the hydropower projects. As water is transported from the dam/barrage to the powerhouse, DO decreases marginally, but it recovers soon after it comes out of the tail race. BOD increases but this is not significant. Fecal coliforms show marginal increase or decrease and that too is insignificant. However, where habitations have come up because of the projects and waste water flows to the rivers, the parameters change. In most cases the habitations do not have very large population and so the impact also is small.

For the data in respect of six commissioned project from where samples were drawn for testing, temperature was found to increase in reservoir based projects, the change taking place mainly in the reservoir. The water quality may change drastically from the bed to the surface in a reservoir. In the case of Tehri dam, the temperature rises from 11.7° to 14°C from the beginning of the reservoir to dam on the Bhagirathi side of the reservoir. On the downstream the temperature is almost the same as at the dam. Likewise the sample drawn from Bhilangna part of Tehri dam shows the temperature rise from 8.7°C to 14°C between the beginning of the reservoir to the dam site. In this study detailed analysis of the changes in the water quality within the reservoir were not done.

In RoR projects conductivity generally shows little change in values. Only in one project, Vishnuprayag at Alaknanda, it shows an increase from 81.2 μS/cm to 192.8 μS/cm. In Tehri project, which is a reservoir based project, there is difference in conductivity in the sample drawn from the beginning of the reservoir to that drawn from the dam the value changing from 169.9 μS/cm to 113.5 μS/cm.

The conductivity, TDS of Bhagirathi River and its tributaries is much higher in comparison to that in Alaknanda River and its tributaries. This is primarily controlled by the nature of rocks and intensity of chemical weathering. A plausible explanation for this significant difference in conductivity of water is given in Chapter 4, Section 4.2.9 under the head Geotract – 2. This may be due to the presence of granite bedrock in the area through which Alaknanda River runs, in contrast with the softer rocks of the Bhagirathi River catchment.

In so far as nutrients are concerned, Nitrate nitrogen decreases as the river runs from u/s to d/s. However, the tributaries of Bhagirathi and Alaknanda show a trend of increasing nitrate from u/s to d/s. TP increases when one moves from u/s to d/s of Bhagirathi, Bhilangna and Mandakini rivers, while it decreases from u/s to d/s of Alaknanda River. The sources of phosphates include: natural decomposition of rocks and minerals, storm water and agricultural runoff, erosion and sedimentation, atmospheric deposition, and direct input by animals/wildlife. Where human habitations come up wastewater contributes phosphates and nitrates to river water.

Water quality of the study area conforms to the standards prescribed for the designated best use “Source without Conventional Treatment but after Disinfection”i.e., it satisfies standards prescribed for CPCB class ‘A’. In some places the Fecal Coliforms exceed the value of 50/100ml, but is lower than 100mg/100ml. Disinfection will be necessary before it is used for drinking. The quality of water everywhere is suitable for aquatic life corresponding to the cold temperatures prevailing in the area of sampling. However, turbidity levels in many places were found to be rather high.

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CHAPTER 7

HYDROLOGICAL STUDIES

7.1 General Appraisal of Hydrology of the Study Area

Although the headwaters region of Ganga in the Himalaya is dotted by a number of mighty tributaries, the Bhagirathi River that rises from the Gangotri glacier at Gomukh at an elevation of about 4000 m is traditionally considered to be the source of Ganga River. The other main stream that originates in the Ganga basin in Uttarakhand is the Alaknanda originating from Satopanth and Bhagirath Kherag glaciers. Flowing downhill, Bhagirathi and Alaknanda river meet at Devprayag to form Ganga River. Thus, the Ganga river basin up to Devprayag has two distinct sub-basins: Bhagirathi and Alaknanda basins. The Alaknanda – Bhagirathi river basins up to Devprayag cover a catchment area of 19,600 sq. km. A map showing the main rivers and their catchment areas in the basin is given in Fig. 7.1.

To understand the hydrologic behavior of the area, it is important to describe its physiography. Fig. 7.2 shows the physiography of the study area and a description of the same follows.

7.1.1 Physiography of the Bhagirathi Basin

A channel emerging from the Gangotri glacier at Gomukh is considered to be the source of the Ganga River. Gangotri glacier is located at an elevation above 4000 m in Uttarkashi district. The Ganga River bed up to Gangotri is filled up with debris left behind due to recession of glaciers. Further downstream of Gangotri, the evidence of broad U shaped valley of glacial origin is seen only at the higher elevation and the river has cut a narrow V-shaped fluvial valley at the lower evlevation up to Kharali. The bed slope is steep in the upper reaches and is of the order of 50.0 m to 3.0 m per km from Gangotri to Loharinag Dingad. It decreases to 20.0 m per km in its descent from Loharinag to Tehri. The total catchment area of Bhagirathi River is 8846.64 sq. km and lies in Uttarkashi and Tehri Garhwal districts.This catchment can be sub-divided into the watershed of the Bhagirathi, Bhilangana and Asi Ganga rivers.

In the Bhagirathi sub-basin, the highest and the most fascinating zone is above 4000 m elevation. Most of it is snowbound. This zone is the principal source of water and major tributaries of Ganga River emanate from this zone. No vegetation grows in this area. This zone is not inhabited by man. Occasionally shepherds visit some places with flocks of sheep. Between 4000 m and 3000 m elevation the valleys and amphitheatres are filled with glacial debris which is being slowly removed by rivers. This zone has plenty of alpine meadows which provide pastures for semi-nomadic tribes. This zone supports sub-alpine type trees.

Between elevation 3000 m and 2000 m occur tremendous gorges. Truncated spurs rise steeply to dizzy heights. Over them descend water falls from hanging valleys. This zone is also sparsely populated. The habitation and communication lie along valley bottom. The area is extremely rugged. This zone has some of rich temperate forests and generally good vegetation. It has reasonable concentration of

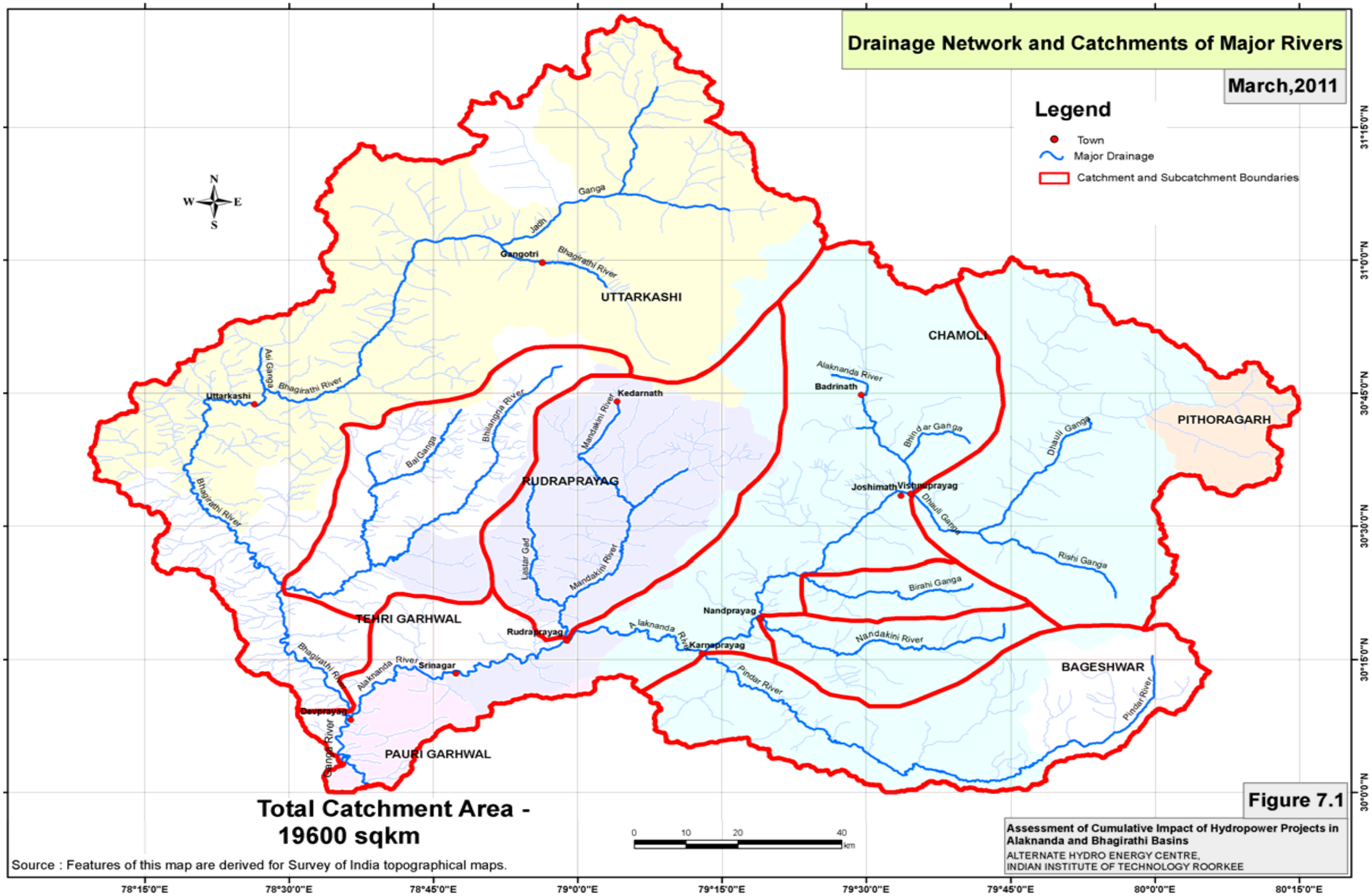


Fig. 7.1 Drainage Network and Catchments of Major Rivers

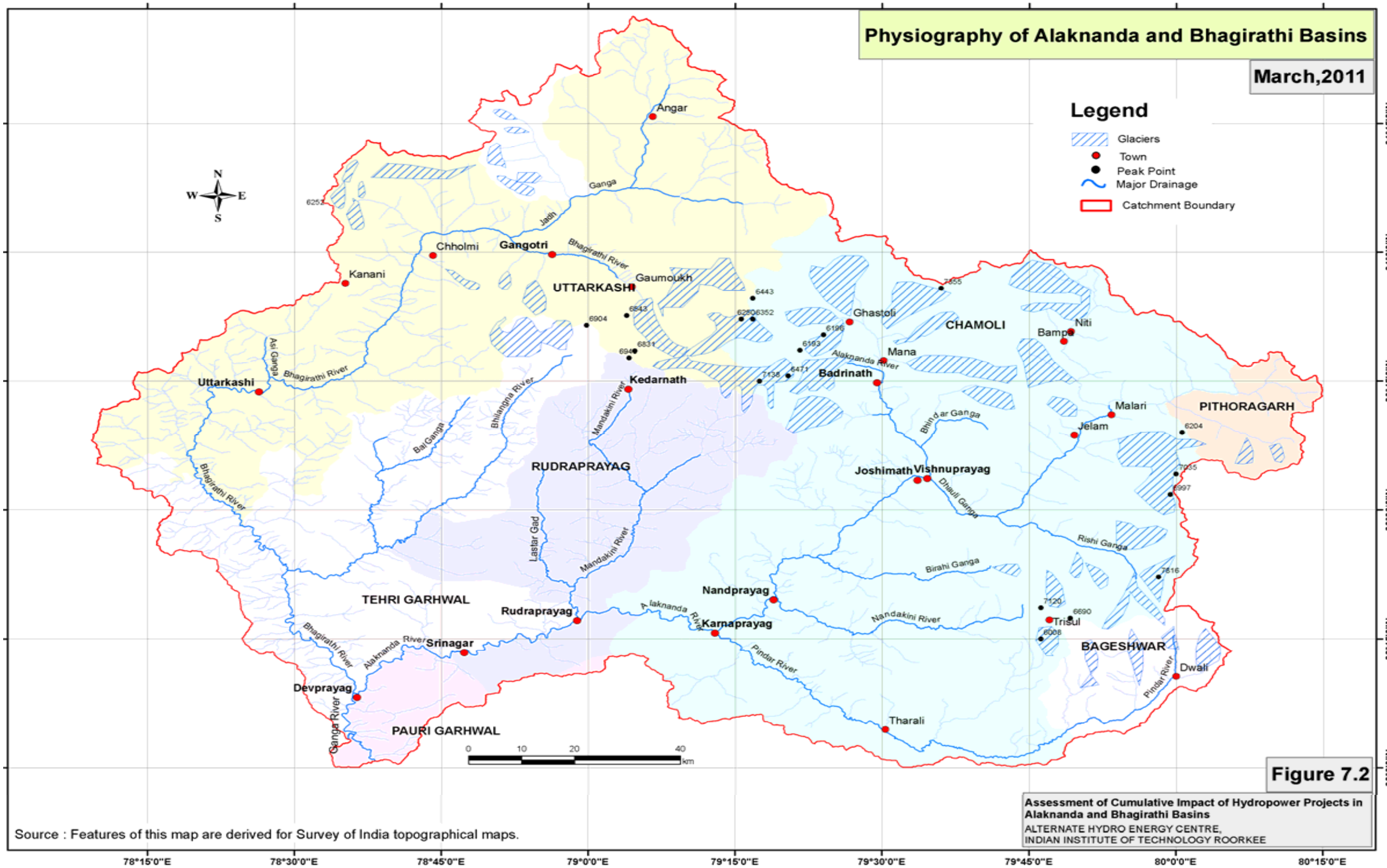


Fig. 7.2 Physiography of Alaknanda and Bhagirathi Basin

trees. The fields are generally scattered, small and in steps. Between elevation 2000 m and 1000 m river terraces are quite common. The valleys are open. Terraces provide fertile land for intensive cultivation and as such this zone has comparatively high density of population. This zone also supports sub-tropical chir forests. Most of the project area falls between the slope 33% to 100%. This reflects its vulnerability to soil erosion and thus emphasizes the need to protect the area against soil erosion.

Bhilangana and Asiganga are the major tributaries of Bhagirathi River. Asiganga joins Bhagirathi River upstream of Uttarkashi. Bhilangana River originates from Khatling glacier and joins Bhagirathi River at Tehri. It has its own sub-tributaries, namely Balganga and Dharni Ganga.

7.1.1.1 Glaciers

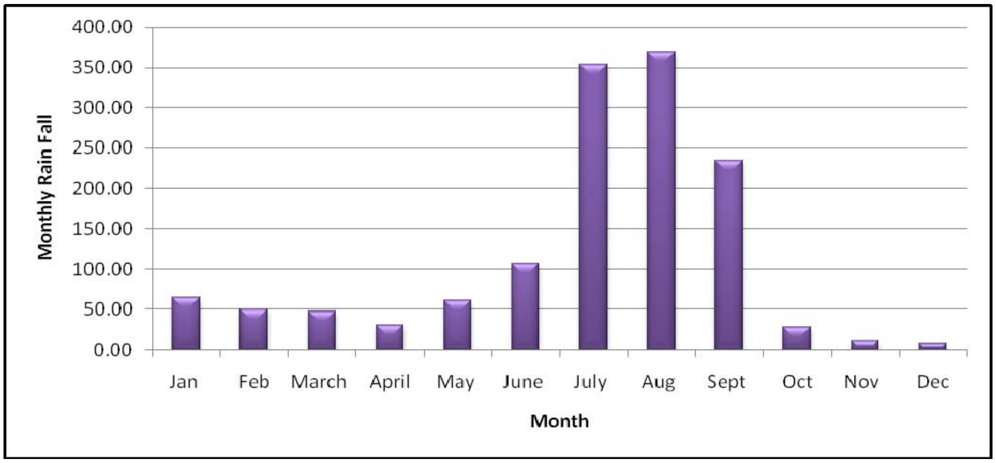
Very large number of glaciers exist above the snow line. The factors controlling the glacierization of an area include the height of ridges, the orientation of slopes and the amount and type of precipitation in the area. The Gangotri system is a cluster of glaciers comprising the main Gangotri glacier (length: 30.2 km; width: 0.20-2.35 km; area: 86.32 km^2) as trunk part of the system. The other major glaciers of the system are: Raktvarn (55.30 km^2), Chaturangi (67.70 km^2), Kirti (33.14 km^2), Swachand (16.71 km^2), Ghanohim (12.97 km^2), and a few others (13 km^2). Depth of the glacier is about 200 m and the elevation varies from 4,000-7,000 m. Satopanth and Bhagirath Kharak glaciers in upper Alaknanda basin originate from the peaks of Chaukhamba and Badrinath range. These glaciers are 13 and 18 km long respectively with snouts at an altitude of 3800m.

Because of the large size of the Gangotri glacier, its melt water stream, the Bhagirathi River is full-fledged river even as it emerges from the sub-glacial tunnel at the glacier terminus the Gaumukh (Cow’s mouth).

7.1.1.2 Rainfall

The basic pattern of climate of our country is governed by summer and winter monsoon systems of Asia. The winter rains are brought by the ‘Western disturbances’ and the summer rains by the summer monsoon winds. For all the seasonal regularity of monsoon winds and rainfall, local climates (over much of the area) are quite variable. Sometimes, the rains may come at the expected time or rainfall over an entire monsoon season may be considerably diminished. By contrast, there will be time when the rainfall is unusually heavy leading often to disastrous floods. In the interior region of catchment, rainfall is very low. Annual rainfall is about 1500-2000 mm. Fig. 7.3 shows monthly rainfall at Uttarkashi and Tehri stations in the Bhagirathi basin.

The maximum rainfall is observed in monsoon months due to south west monsoon which normally strikes the Garhwal Himalayas towards the end of June and withdraws from the region towards the end of September. The precipitation is due to the passage of depressions and or cyclonic storms from the Bay of Bengal over the region. After originating from the Bay of Bengal, the monsoon winds move in north west direction and strike the Garhwal Himalayas. The winter precipitation in the basin is due to western disturbances advancing from Afghanistan and West Pakistan.



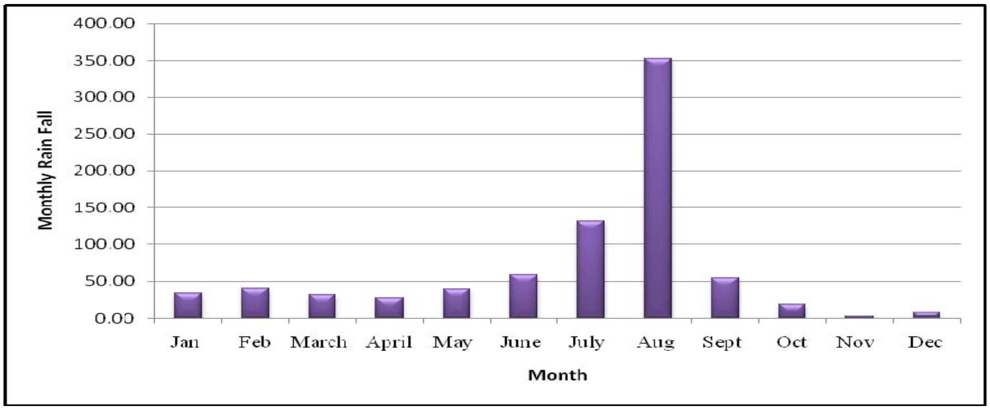


Fig. 7.3 Monthly rainfall at Uttarkashi (upper) and Tehri (lower) stations in the Bhagirathi basin.

7.1.1.3 Temperature

Temperature varies greatly from place to place and from month to month. Maximum temperature ranges from 30^{o}C to 36^{o}C while minimum between 0^{o}C to 6^{o}C. For every 1000 m rise in elevation, the mean temperature falls by approximately 6^{o}C.

7.1.1.4 Wind

The wind pattern in the area is extremely complicated. The general direction of the flow over the mountains in winter is from North-East to North-West. Over mountains the actual wind may show considerable deviation due to local influences. At higher levels, the winds are westerly of about 120 km per hour reaching 160 km per hour or more. At low levels they are about 50-60 km per hour.

7.1.2 Physiography of the Alaknanda Basin

The Bhagirath Kharak and Satopanth glaciers serve as the major source of the Alaknanda River. Besides this, Luri Glacier and Bhagnyu glacier feed the Alaknanda channel. The Alaknanda flows from Mana just upstream of Badrinath and the

Dhauliganga flows from Malari to its confluence with the Alaknanda immediately downstream of Joshimath. Most of the catchment areas of the Alaknanda River and its tributaries in the headwater regions are covered with snow and glaciers.

The Alaknanda catchment, upstream of Vishnuprayag, represents an asymmetrical basin in which the right bank slopes cover larger land area. The river flows from west to east from Satopanth/ Kharak Bhagirath glaciers and turns towards south near Mana. On the other hand, its major tributary, the Saraswati river, flows from north to south and confluences with the Alaknanda River on its left bank near Mana at 3,120 m.

The major glaciers present in the catchment are Khular Bank, Khuliagarvia Gal, Anadeb Gal, Dakhni Nakthoni Gal, Uttar Nakthoni Gal, Paschimi Kamet Glacier, Dakhni Chamrao Glacier, Uttar Chamrao Glacier, Balbala Bank, Tara Bank, Arwa bank, Kalandani Bank, Vidum Bank, Bhagnyu Bank, Bhagirath Kharak and Satopanth Bank. Arwa Tal, Rishi Kund, Sankunni and Satopanth Tal are four major lakes present in the catchment.

In general, radial and rectangular drainage networks characterize the catchment region and the small order basins show dendritic pattern. In particular a radial drainage pattern is present around the important lake, Arwa Tal, in the Alaknanda catchment.

The Saraswati River, which rises in the Tara glacier, is the major left bank tributary of the Alaknanda River in its headwater region. Most part of the Saraswati River catchment upstream of the confluence of Arwa nala (4,016 m) is covered with snow. Glaciers and snow avalanches descend up to the river bed in this stretch. Downstream of Mana, Kanchan Ganga, Rishi Ganga, Ghrit Ganga and Khirao Ganga are important tributary streams of the Alaknanda River.

Rishiganga is a big tributary joining Alaknanda River on its right bank downstream of Mana. Rishiganga has its source in the glaciated area and snowfields on the northern flank of Nilkanth (6,596 m) peak. Flowing eastward, it confluences with Alaknanda River on its right bank near Badrinath. Most parts of the catchment of Rishiganga below 4200 m are either barren or covered with glacial moraines.

Originating from Khular bank glacier above 5400 m elevation Ghrit Ganga joins the Alaknanda River at 2470 m near Hanuman Chhati. The Khirao Ganga flowing from Panpatia glacier at 3800 m elevation joins the Alaknanda River on its right bank at 2330 m elevation opposite to Benakulli village.

The Dhauliganga originates from Ganesh Parbat glacier lying above 6000 m. At Phatatoli, the Dhauliganga receives water from the Silakangla (Urla) glacier. Downstream, it maintains its south-westward course until it reaches Khal Kurans. In this stretch the river receives a substantial input of water from a right bank tributary near Shepak Kharak. This right bank tributary receives water from Uttari Raikana, Raikana, Purbi Kamet, Deoban and Semkharak Ka glaciers. Upstream of Khal Kurans the river receives water on its right bank from a small glacier which lies in the south of Semkharak ka glacier. Downstream of Khal Kurans the river turns towards southeast and flows following the northern flank of Ramkhulta Dhar till Janti Ghat. At

Gamsali, Amrit Ganga rising in the Bankund glacier drains into the Dhauliganga River on its right bank. At Kuikuti, the river receives water from Girthiganga on its left bank.

Girthiganga is a major tributary of Dhauliganga. The river originates from Naijgaon Peak and confluences with the Dhauliganga at Kurkuti. Dhauliganga, after taking a hair-pin bend near the Bunga Peak (4331 m), flows towards the southwest from Malari to Reni. At Reni, Rishi Ganga joins Dhauliganga River on its left bank. Most parts of the catchment of the Dhauliganga River are either barren or covered with snow and glaciers.

Birahi Ganga flows for 35 km up to its confluence point with Alaknanda River. In its total length from Nanda Glacier to confluence with Alaknanda, it has a drop of about 4950 m before joining Alaknanda. There are several important nallahs joining this river from both banks. The main important left bank nallahs are Gudiyar Gadhera, Biori Gadhera and Begar nalla. The main streams joining it from right bank are Dhadhali gad, Shyam gad, Rogila gad and Pui Gadhera etc.

Nandakini River is also an important tributary of Alaknanda River and meets it on its left bank at an elevation of 870 m at Nandprayag. The Nandakini River has its origin at an elevation of 6620 m in Nanda Ghungti glacier. The east to west drainage is formed by the Nandadevi mountain range that is characterized by steep slopes covered with dense forests. All these constitute water sources for the Nandakini River. Nandakini flows from east to west direction till its confluence with Alaknanda. The basin has a rectangular shape. The catchment of the Nandakini River lies between the latitudes 30° 10' to 30° 21' N and longitudes 79° 25' to 79° 46' E. The highest elevation in the basin is about 6620 m. Areas of the basin above 4000m are considered to the permanent snow covered whereas those between 4000 to 2200 m are dominated by forest. The areas below 2200 m are dominated by forest and agricultural lands. The gradient of Nandakini River in initial reach is steep and becomes moderate in later stages. There is no consumptive use of water in between the proposed intake and powerhouse site.

Precipitation in the Nandakini catchment area is in the form of snow and rain. The catchment receives moderate to heavy rainfall during monsoon whereas during winter, it receives moderate snowfall at higher altitude and rainfall at lower altitude. The Nandakini River runoff during monsoon is very high due to the heavy and prolonged rains. The runoff during March to June is predominantly snow melt.

The Pinder River originates from Pindari Glacier at an elevation of 5,200 m. The glacier lies between the Nanda Devi and Nanda Kot peaks and its snout is at an elevation of 3,627 m. The glacier is 5 km long and 300 to 400 m wide. The permanent snow cover is reported to be above EL 4,600 m. High elevation zone in catchment area rises up to about EL 6,600 m. About 20% of the catchment area is covered by snow/glacier, about 50 % is open forest, 12% dense forest. In its initial course, the Pinder River flows through sedimentary rocks and then it meanders through quart schists. Granite is found in abundance in this area. The Pinder River has cut a gorge in thick glacial deposits up to nearly 10 km. The total length of the river is 124 km flowing from east to west and drainage area is 1688 km^2 till the confluence with Alaknanda River at Karanprayag. The main tributaries of Pinder are Kail Ganga, Pranmati Gad, Meing, Gadhera, Kewar Gadhera, Chopta Gad and Ata Gad. Besides these, there are many small streams and natural springs adding discharge in Pinder River.

The Mandakini River is an important tributary of the Alaknanda River which joins the latter at Rudraprayag. The length of Alaknanda River up to Rudraprayag is 180 km with an average slope of 24.0 m per km. The Mandakini river runs for a length of 80.0 km up to the confluence at Rudraprayag with an average slope of 42.0 m per km. The famous shrine of Kedarnath is located in Mandakini sub-basin.

Flowing past the town of Srinagar, Alaknanda River meets Bhagirathi River at Devprayag to form Ganga River. The total catchment area of Alaknanda River is 12587.23 sq. km and lies in Chamoli, Pithoragarh, Bageshwar, and Pauri Garhwal districts. The total catchment area at Devprayag is 19600 sq. km. Some more information about physiography of the area is given in Chapter 8.

7.1.2.1 Climate and Rainfall

The mountain topography plays a vital role in the weather and climate of the area. The climate is 'tropical monsoon' type with most of the rainfall occurring in the summer monsoon of June through October due to tropical storms and depressions originating in the Bay of Bengal. The mean annual rainfall over the Alaknanda catchment above Rudraprayag varies between 1000 mm and 2000 mm.

The annual rainfall in the Alaknanda basin ranges from 1000 to 1600 mm and nearly 75% of the rainfall occurs during the monsoon months. Fig. 7.4 shows the average monthly rainfall at Joshimath. Most river channels in this sub-basin are deeply incised with steep valley slopes. Valley slopes in some segments, particularly in the upper reaches are very steep and unstable. Landslides and sediment movement as debris flow are frequent in these reaches. The mean annual rainfalls at Joshimath, Munsyari, Rudraprayag, Okimath, Pauri, Chaukri and Tijjam are 1044 mm, 3005 mm, 1225 mm, 1757 mm, 1080 mm, 1729 mm and 2571 mm respectively. The annual maximum temperature recorded at Rudraprayag is 45^{o}C and the minimum temperature is 2.5^{o}C.

In the higher elevations of the Greater Himalayas, the snow accumulation starts from the beginning of November and reaches maximum in January / February. The snow-melt begins in March and reaches the maximum value in May-June contributing substantially to the river flows. In winter snow-line comes down to near about 2000 m – 3000 m rising to about 5000 m in August – September. The contribution of the snow and glacier melt to the volume of river flows is rather limited in the study area and progressively the contribution from rainfall increases as one moves downstream. The rivers of the region show strong seasonal fluctuation in the discharge.

The maximum and minimum discharges of the Ganga River at Devprayag during 1990-91 were 4061 and 125 cumec, respectively (Singh and Hasnain, 1998). During this period, the maximum and minimum contribution of the Alaknanda to the total discharge was 3000 and 85 cumec, respectively. The flow of Alaknanda River at Devprayag is nearly twice as big as that of Bhagirathi River.

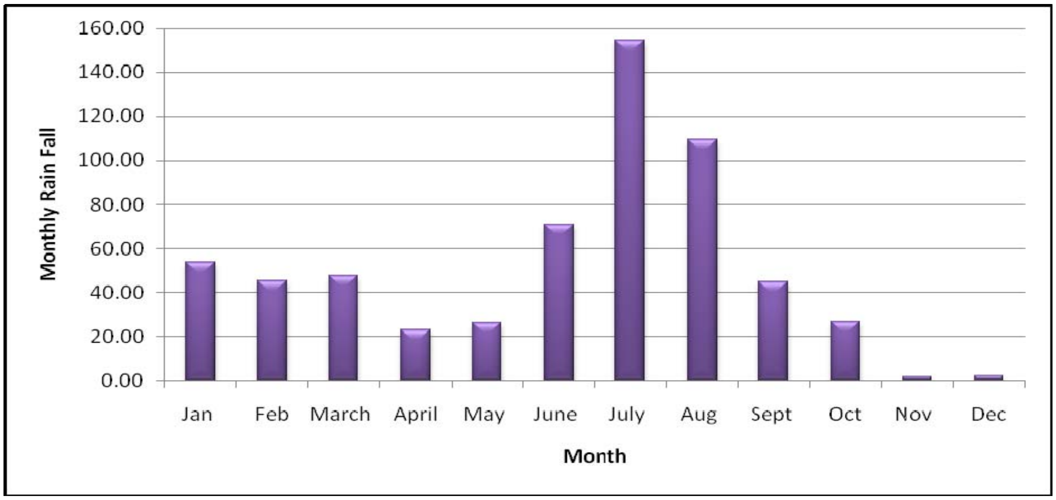


Fig. 7.4: Distribution of annual rainfall at Joshimath.

Figure 7.5 shows a line diagram of Ganga and its major tributaries (numbers in the figure are average annual flows in MCM or million cubic meters) in virgin conditions.

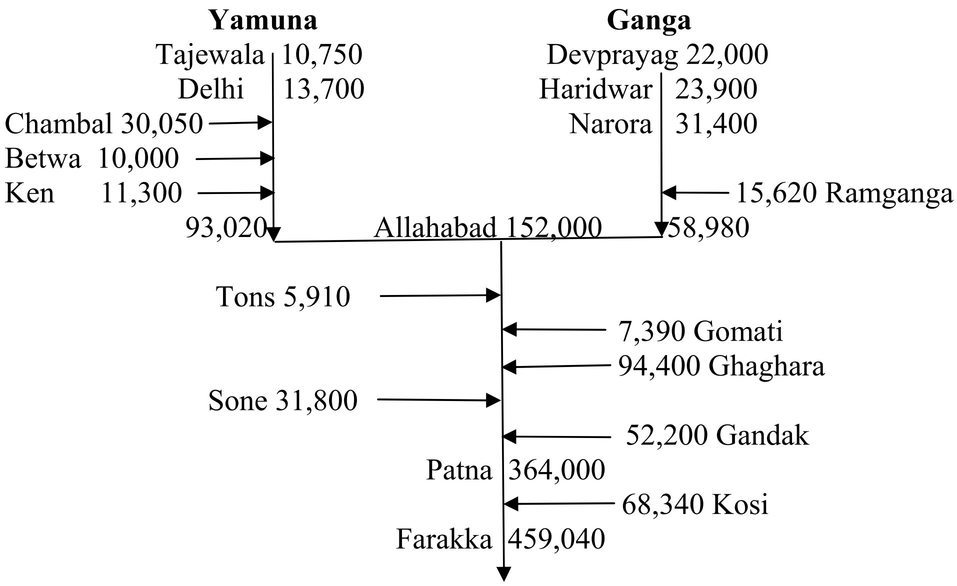


Fig. 7.5 Line diagram of Ganga and its major tributaries.
Numbers are average annual flows in MCM (million cubic meters).

7.1.3 Appraisal of Surface Water Resources

The purpose of appraising water resources is to determine the source, extent and dependability of supply. Estimation of surface water availability (surface water potential in the basin) is one of the prime requirements for planning and design of works on any river system. Quantity of flow and associated dependability are the key considerations.

7.1.4 Data Availability

A line diagram of the Alaknanda and Bhagirathi basin up to Devprayag river basin showing the locations of various river gauging stations is given in Fig. 7.11. A water-year is defined as the period from the month of June to May in the following year.

7.1.4.1 River gauging stations

Daily gauge and discharge data of 16 stations were collected from the Central Water Commission (CWC), New Delhi. Fig. 7.6 shows location of the gauging sites of CWC in the study area. After preliminary scrutiny of the data, length of time-series and locating the gaps, it was seen that the data of only 9 gauging sites could be used in the study. Out of these, two sites fall on the tributaries and the rest are on the two main rivers Alaknanda and Bhagirathi basins.

Daily observed discharges data at nine stations as per details in Table 7.1 were used for estimation of various quantities of interest.

Table 7.1 Availability of discharge data obtained from CWC

S. No.	Name of Discharge Gauging Station	Name of River	Catchment area (sq. km)	Period of Record	Range of discharge (cumec)
1	Uttarkashi	Bhagirathi	4555	1989-90 to 2008-09	1.8 to 1011
2	Tehri-G5	Bhagirathi	7208	1989-90 to 2008-09	0.8 to 1907
3	Deoprayag-A1	Bhagirathi	7813	1989-90 to 2008-09	0.5 to 8255
4	Badrinath	Alaknanda	1285	1989-90 to 2008-09	--
5	Joshimath	Alaknanda	4508	1989-90 to 2008-09	7.3 to 960
6	Karnaprayag	Pinder	2294	1989-90 to 2008-09	11.5 to 1640
7	Chandrapuri	Mandakini	1297	1989-90 to 2004-05	11.2 to 1028
8	Rudraprayag -A5 (before confluence)	Mandakini	1644	1989-90 to 2008-09	49 to 2873
9	Rudraprayag -G5 (after confluence)	Alaknanda	10675	1989-90 to 2008-09	50.7 to 3762

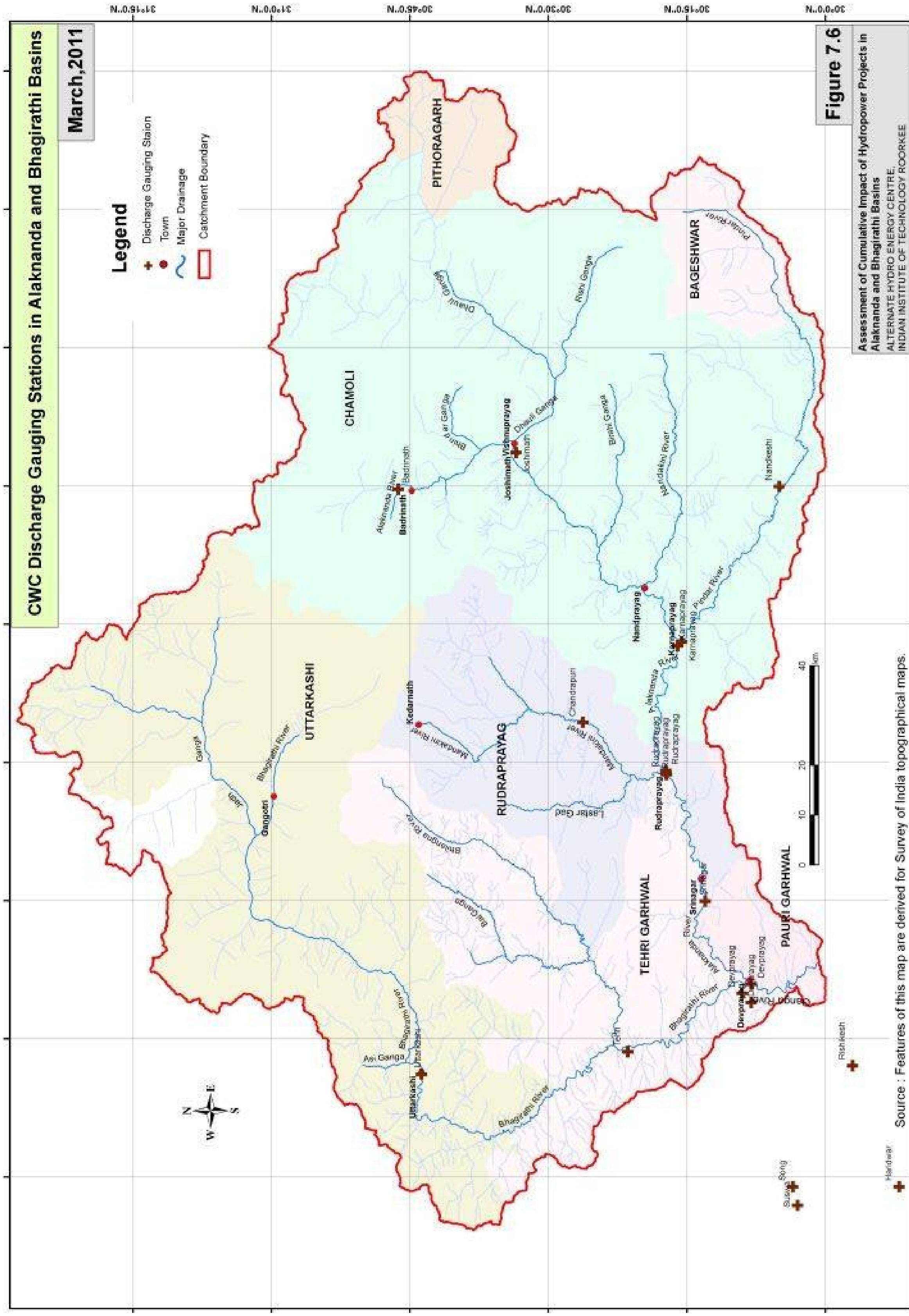


Fig. 7.6 CWC discharge gauging stations in Alaknanda and Bhagirathi Basins

According to the norms of the World Meteorological Organization (WMO), there should be one river gauging station per 1000 sq. km of the catchment area. Hence, this area should have at least 22 river gauging stations. Further, keeping in view the importance of the study area both from conservation and development points-of-view, a denser network of river gauging stations would be required.

7.1.4.2 Rain Gauge Data

Rainfall data for the study area were collected from the India Meteorological Department (IMD). IMD has 5 stations in the study area. The situation regarding the meteorological stations was not encouraging. Long-term series at only five stations could be obtained. Location of the rain gauge stations is shown in Fig. **7.7** and the details of daily observed rainfall data is as given in Table 7.2.

Table 7.2 Availability of rainfall data obtained from IMD

S. No.	Index Number of Rain gauge Station	Location	Name of River Basin	Period of Record
1	05211	Mukhim	Bhagirathi	1988-89 to 2007-08
2	42108	Uttarkashi	Bhagirathi	1973-74 to 1979-80
3	42114	Tehri	Bhagirathi	1969-70 to 1983-84 2002-03 to 2007-08
4	42115		Alaknanda	1975-76
5	42116	Joshimath	Alaknanda	1969-70 to 1980-81 1982-83 to 1986-87

7.1.5 Methodology for Surface Water Resource Estimation

The appraisal of surface water resources generally includes estimation of (i) annual run-off and its monthly / ten daily / daily distributions, and (ii) aerial distribution of water resources within the basin. For a reliable appraisal of water resources, stream flow records for at least 20 years are desirable. In case of short records, temporal extrapolation is required using suitable techniques. Gauge-discharge observation taken once a day is sufficient for most yield studies.

Processing of surface water data in the present study was completed in the following steps:

(i) The study area was sub-divided into sub-basins (sub catchments/ watersheds) keeping in view the existing and proposed storage / diversion schemes, size of watersheds and demand areas (towns, agriculture land etc.).

(ii) Suitable gap-filling techniques are employed where the discharge data records were incomplete.

(iii) Estimation of water-year runoff (daily / 10-daily/ monthly / annual) in sub-basins was made as follows:

a) Estimate water-year rainfalls in sub-basins,

b) Estimate total flow at a river gauge site / sub-basin, and

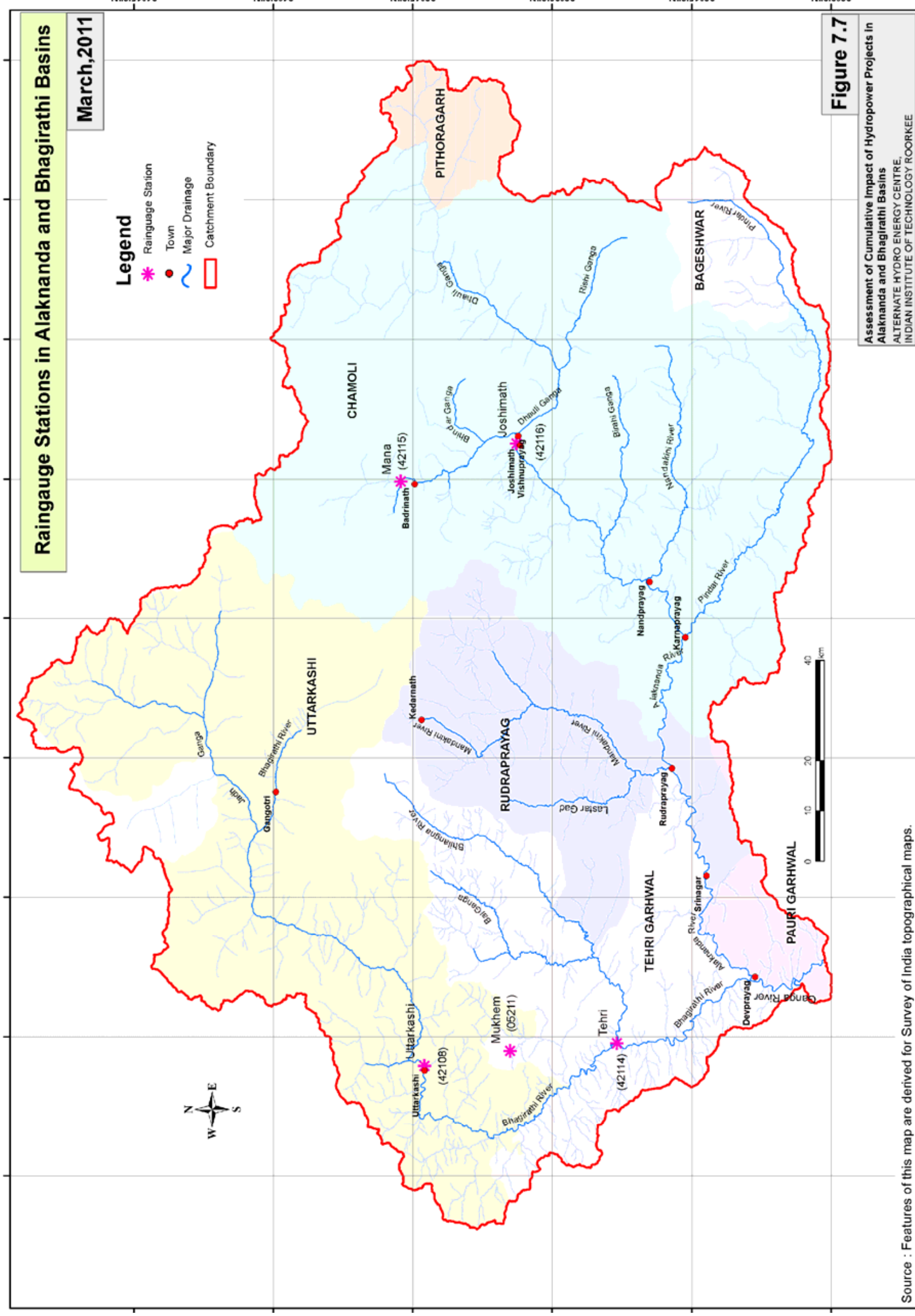


Fig. 7.7 Raingauge Stations in Alaknanda and Bhagirathi Basins

c) Estimate water-year dependable yields in each un-gauged gauge site / sub basin: Compute the total flow at an un-gauged site based on proportionate catchment area and weighted rainfall. For hydropower and environmental purposes surface water of 75% and 90% water-year project dependability criteria is required. In addition, flows with 50%, 60%, and 90% were also computed.

Weighted rainfalls within various sub-catchments in the basin were estimated. In the absence of inflow data available at the identified proposed / existing project sites, the total flow series at an un-gauged site was estimated by proportionate catchment area and weighted rainfall procedure using discharge data at nearby discharge gauging site, as follows:

Flow at un-gauged site = (Flow at gauged site)* $(Ca_i * R_i)/(Ca_g * R_g)$ … (7.1)

where Ca_i = catchment area of un-gauged site, R_i = weighted rainfall on catchment of free or intervening area of un-gauged site, Ca_g = catchment area of gauged site, and R_g = weighted total rainfall on catchment area of gauged site.

Each of the sub-basins (Bhagirathi and Alaknanda) has only 2 to 3 rain gauges (i.e., Nos. 05211, 42108 and 42114 in Bhagirathi basin and Nos. 42115 and 42116 in Alaknanda basin) but except for one location in each sub-basin which has longer period rainfalls with some missing data; remaining rain gauges have data for a few years only. Thus, data for only one rain gauge station in each sub basin was available which was not sufficient for analysis. Moreover, the discharge data from CWC are for the years 1989 to 2008. Therefore, the discharges at un-gauged sites were estimated from discharge data of CWC only on the basis of catchment area ratios.

7.2 Natural Stream Flow Variability in the Bhagirathi-Alaknanda Basin

The two major streams in the study area are Bhagirathi and Alaknanda rivers. Streamflow variability of the basin in these two sub-basins is discussed below.

7.2.1 Bhagirathi Basin

Fig. 7.8 shows the variation of flows in the Bhagirathi sub-basin at two sites: Uttarkashi and Tehri. Hydrographs of the years corresponding to 50 %, 60%, 75%, 90%, and 95% dependabilities and the flow duration curves at these dependabilities have been plotted.

In the Bhagirathi and Alaknanda rivers, the dominant hydrologic process contributing to the flow change with respect to time of the year. During April to June, most of the flow comes from snowmelt and there is some contribution from ground water. Rain water dominates the flow during July to October. Post season, the contribution of rainfall decreases progressively and most of the flow is due to base flow.

It can be seen from this figure that most of the flow in a water year takes place between the days 40 to 90, i.e., 10th July to the end of Sept.

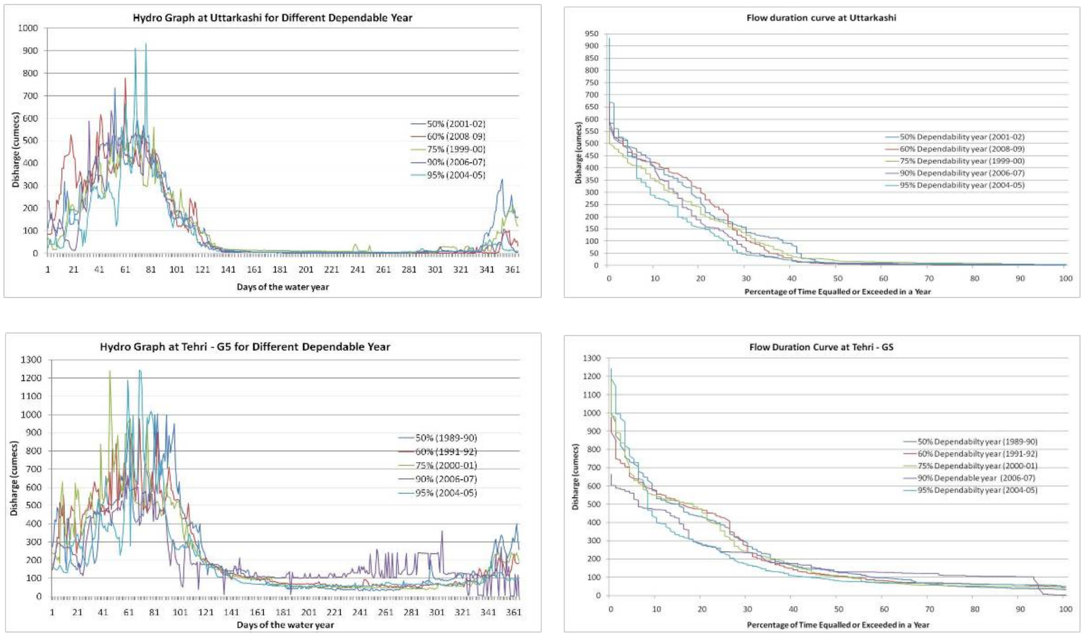
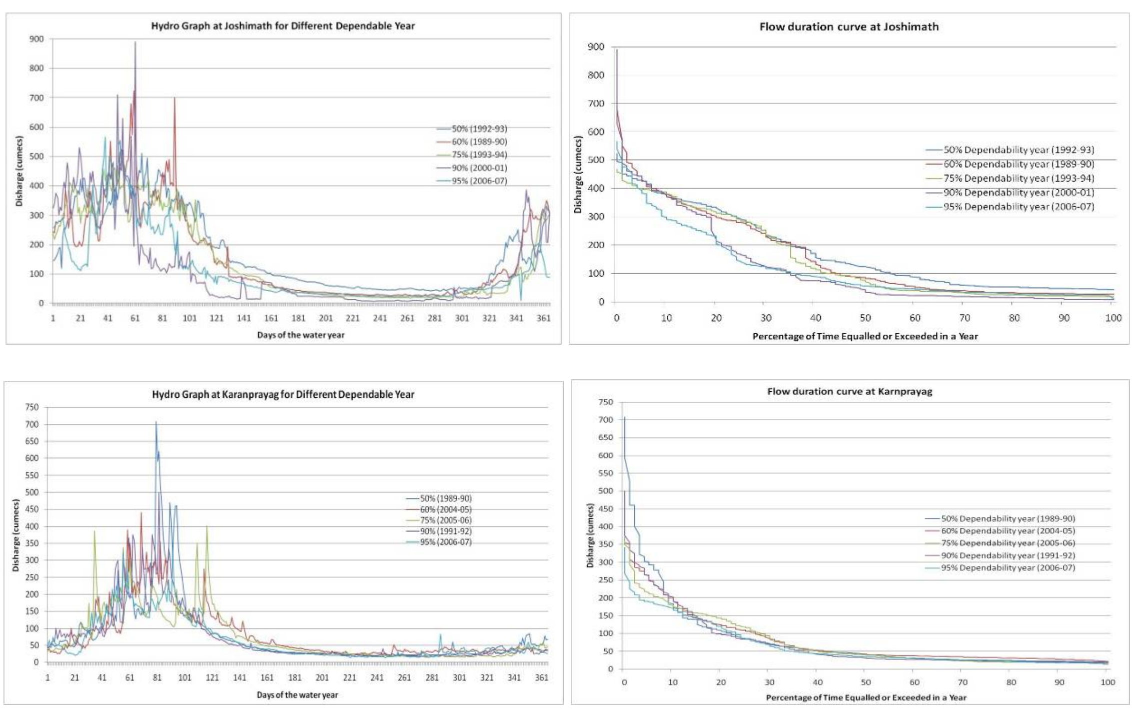


Fig. 7.8 Hydrographs and FDCs at Uttarkashi and Tehri in the Bhagirathi sub-basin at five dependabilities.

7.2.2 Alaknanda Basin

Fig. 7.9 shows the variation of flows in the Alaknanda sub-basin at five sites: Joshimath, Karnaprayag (Pinder), Chandrapuri (Mandakini), Rudraprayag (before confluence), and Rudraprayag (after confluence). The hydrographs of the years corresponding to 50 %, 60%, 75%, 90%, and 95% dependabilities and the flow duration curves at these dependabilities have been plotted.



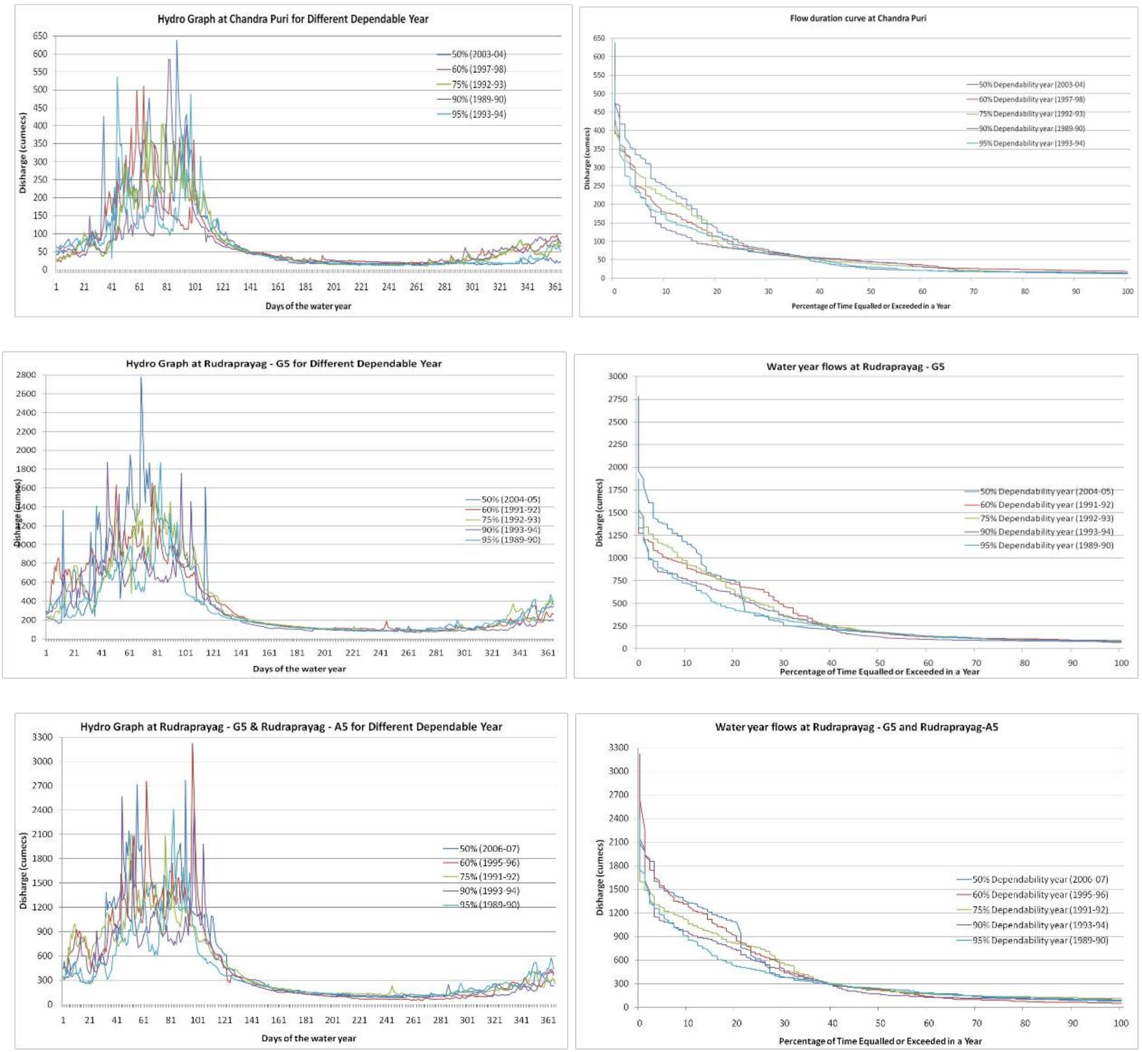


Fig. 7.9 Variation of flows in the Alaknanda sub-basin with respect to dependabilities for five sites.

All the FDCs show a steep fall in the initial stages (up to 10% mark on the x-axis). FDC at Joshimath is somewhat flat while the FDC at Karnprayag is quite steep.

Finally, the hydrograph and FDC for Devprayag site is plotted in Fig. 7.10.

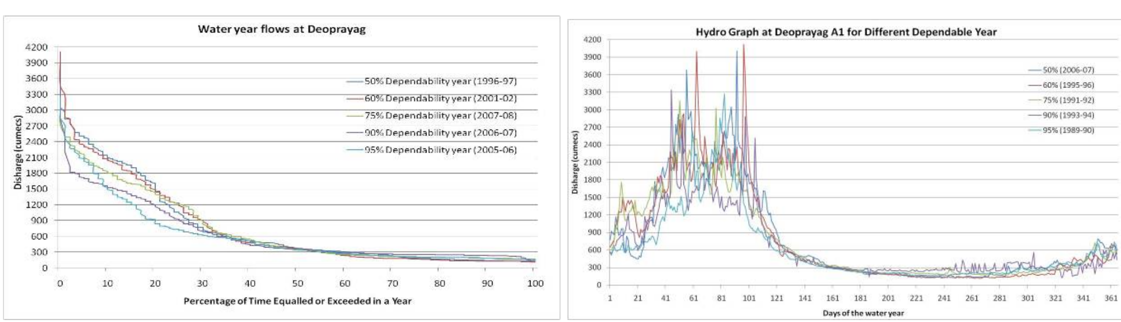


Fig. 7.10 Variation of flows at Devprayag with respect to dependabilities.

The FDC at Devprayag is quite flat compared to other FDCs. This is expected since this site receives flow contribution from a large area and the flows come from snowmelt as well as glacier melt.

7.3 ENVIRONMENTAL FLOW REQUIREMENTS

The increasing demand withdrawal water for agricultural, domestic and industrial uses has reduced the flow in vast segments of rivers, thereby adversely affecting the river ecosystem and river health. Health of a river ecosystem is determined based on many factors. According to Norris and Thoms (1999), the factors are: discharge in the river, physical structure of the channel and riparian zone, quality of water, channel management such as macrophyte cutting and dredging, level of exploitation (e.g. fishing) and the presence of physical barriers (e.g. dams) to connectivity. The concept of Environmental Flow Requirement (EFR) has been developed to minimize the impact of large withdrawals on the river ecosystem and the uses to which the river is put. Environmental flows is a term to denote the quantity, timing, duration, frequency and quality of water flows required to sustain freshwater, estuarine, and near share ecosystems and the human livelihoods and well being that depend on them (Acreman & Ferguson, 2010). EFR is necessary to maintain the health and biodiversity of downstream water bodies, including coastal waters, wetlands (mangroves, sea grass beds, floodplains) and estuaries.

Environmental flow requirements are those that are needed to help maintain downstream ecosystems, renewable natural resource production systems and associated livelihoods. As such, environmental flow requirement is a compromise between water resources development and maintenance of a river in ecologically acceptable or agreed conditions. In brief Environmental Flows are required for (i) Maintaining flow regime, (ii) Enabling the river to purity itself (iii) Maintaining aquatic biodiversity (iv) Recharging ground water (v) Supporting livelihoods (vi) Maintaining sediment movement (vii) Allowing the river to be used for meeting natural and religious needs of the people (viii) Prevailing recreation. Realizing the importance of EFR, many countries have now formulated policies and laws to ensure priority allocation of water to river ecosystems after the basic human needs have been satisfied. These countries have made ensuring environmental flows mandatory. For example, The Mekong River Agreement, 1995; South Africa's National Water Act, 1998 and the Swiss Water Protection Act.

7.3.1 Perspective

In the 1970s, the concept of minimum flow in the rivers came into practice. It was based on the premise that the health of a river ecosystem deteriorates if the flow falls below a certain minimum value. Hence, as long as the discharge in the river exceeds a critical value, the river ecosystem will be able to function satisfactorily. Subsequent detailed studies on the different components of river ecosystems led to the understanding that ensuring minimum flow alone is not sufficient and all elements of a flow regime, including high, medium and low flows are important (Poff et al., 1997). Thus, any changes in the flow regime will have some influence on the river ecosystem and if the natural river ecosystem is to be maintained in a pristine condition, the environmental flow will have to be set to closely follow the natural flow regime. However, this will not always be possible and most river ecosystems are managed to different degrees to meet the needs of the society. Certain needs, e.g., water supply for municipal uses, irrigation, require removal of water from the river. Societal needs, such as bathing in the river, do not require that water be removed from the river. Generation of electricity by the use of stream flows may require diversion of water or may be accomplished without diversion, depending upon the topographic conditions. In some uses (hydropower generation or cooling of a thermal power plant), diverted water is returned to the river after use. This type of use of water is termed as non-consumptive use.

Coming to the generation of electricity using the river flows, there may be little effect on flow magnitudes and pattern by run of river hydropower projects, although flow velocities may be affected and the river connectivity could be disrupted. If a run of river project diverts water for hydropower generation, the time pattern of flows downstream of the point where the diverted water joins back the river will be slightly altered; of course flows in the bypassed section will be significantly less.

Numerous attempts have been made to link EFR for a particular stretch of river simply by specifying a certain number. But this is a rather simplistic approach which fails to appreciate the basic idea behind the EFR concept. Environmental flow requirement of rivers depends on a number of factors, including:

- Size of the river,
- Natural state of the river, 'type' or perceived sensitivity,
- The desired state of the river, and
- The uses of river water.

Consequently, before defining EFR, broader objectives must be determined to indicate the type of river desired. For some rivers, EFR are set to achieve specific pre-defined ecological, economic or social objectives. This is called objective-based flow setting (Acreman and Dunbar, 2004). In India, river water extensively is used for many social and religious rituals. This is particularly true for the Ganga River, especially in the study area.

The concept of reference status for all rivers (also lakes, estuaries and coastal waters) has come from the Water Framework Directive (WFD) of the European Union. It is a useful concept. To define the reference state, an assemblage of component species is required that would be found in an 'undisturbed' state. WFD requires EU member states to achieve 'Good Status' (GS) in all surfaces and ground waters. Good status of a river is a combination of good Chemical Status and good Ecological Status (ES). ES is defined qualitatively as slight deviation from the reference status, based on populations and communities of fish, macro-invertebrates, macrophytes and phytobenthos, and phytoplankton.

7.3.2 Baseline Conditions for River Ecosystems

Most Indian rivers are currently in highly degraded condition. In all the discussions and attempts to restore the river ecosystems, we talk of the river conditions at some earlier time. A question that naturally arises is how far back one must look? In looking back, one should not go so much back that the relevance of the subject is lost. For instance, in the context of river flood plains in the Ganga basin, IWMI (Smakhtin et. al., 2007, page 25) laments, “Less than approximately 10 percent of the original (i.e., 10,000 years ago) floodplains still remain”. We feel that benchmarking the current status of the flood plains with the conditions 10,000 years ago is not reasonable.

One of the reasons behind the steep rise in the withdrawal and use of river water is rapid increase in population and industrial activities. Recall that the population of India at the beginning of the 20th century was about 20 million. It was 683.3 million in 1981 and at present (year 2011), the population of India is around 1150 million. Further, the growth trajectory of Indian GDP experienced a rapid rise from mid 1990s onwards.

7.3.3 Methodology for Assessment of Environmental Flows Requirement

Since the mid-1970s, there has been a rapid proliferation of methods for estimating environmental flow for a given river, ranging from relatively simple, low-confidence, desktop approaches, to resource-intensive, high-confidence approaches (Tharme, 2003). The comprehensive methods are based on detailed multi-disciplinary studies that often involve expert discussions and collection of large amounts of geomorphological and ecological data (e.g. King and Louw, 1998). Typically they take many months, sometimes years, to complete. A key constraint to the application of comprehensive methods in many countries is the lack of data linking ecological conditions to specific flows. To compensate for this, several methods of estimating environmental flows have been developed that are based solely on hydrological indices derived from historical data (Tharme, 2003). Although it is recognized that a myriad of factors influence the ecology of aquatic ecosystems (e.g. temperature, water quality and turbidity), the common supposition of these approaches is that the flow regime is the primary driving force (Richter et al., 1997).

The last couple of decades have seen evolution of various methods, approaches and frameworks for estimating environmental flows. ‘Methods’ typically deal with specific assessments of the ecological requirement. ‘Approaches’ are ways of working to derive the assessments, e.g. through expert teams. ‘Frameworks’ for flow management provide a broader strategy for environmental flow assessment. Choice of a particular method depends on the type of issue (abstraction, dam, run of river scheme), the management objective (e.g. pristine or working river), expertise, time and money available and the legislative framework within which the flows must be set.

The various approaches developed as described above to estimate environmental flow requirements can be divided into four broad categories:

- **Hydrological Index Methods**- such as Look-up tables, Tennant Method, Desktop Reserve Model(DRM), Desktop analysis (Range of variability approach (RVA), Flow Duration Curve (FDC) based approach, Environmental Management Class (EMC) based approach, etc.
- **Hydraulic Rating Methods**- such as Wetted Perimeter Method
- **Habitat Simulation Methodologies**

- **Holistic Methodologies-** such as Holistic Approach, Instream Flow Incremental Methodologies (IFIM), Downstream Response to Imposed Flow Transformation (DRIFT), and Building Block Methodologies (BBM).

7.3.3.1 Hydrological Index Method

This method is based on simple indices. The environmental flow is usually given as percentage of average annual flow or a percentile from the flow duration curve (FDC) on monthly basis. The indices used for environmental flow assessment in various places of the world are discussed below.

i) **France:** A hydrological index is used in France, where the freshwater fishing law (June, 1984) required that residual flows in bypassed sections of river must be a minimum of 1/40 of the mean flow for existing schemes and 1/10 of the mean flow for new scheme (Souchon and Keith, 2001).

ii) **UK:** In regulating abstraction in UK, an index of natural low flow has been employed to define the environmental flow. Q95 (i.e. that flow which is equaled or exceeded for 95% of the time) is often used. However, in other cases, indices of rarer events (such as mean annual minimum flow) have been used. The figure of Q95 was chosen purely on hydrological grounds. However, the implementation of this approach often includes ecological information (Barker and Kirmond, 1998).

iii) **USA (Tennant method):** Tennant (1976) developed a method using calibration data from hundreds of sites on rivers in the mid-western states of the USA to specify minimum flows to protect a healthy river environment. Percentages of the mean flow are specified that provide different quality habitat for fish, e.g. 10% for poor quality (survival), 30% for moderate habitat (satisfactory) and 60% for excellent habitat. The indices have been adopted for other climatic regions in North America and have been widely used in planning at the river basin level.

Indices based purely on hydrological data are more readily calculated for any new region, as flow data tend to be generally available. Look up tables do not necessarily take account of site specific conditions. Therefore, these are particularly appropriate for low controversy situation. They also tend to be precautionary. Since this method is frequently mentioned, it is being described in more details.

Tennant (1976) considered the three factors of wetted width, depth and velocity as being crucial for fish well being. He measured variables concerning physical, biological and chemical parameters along 58 transect from 11 different streams at 38 different discharges. Tennant proposed that certain flow could achieve the maintenance of particular amounts of habitat as given in Table 7.3.

Table 7.3 Flow release by tenent method

Description of Flow	Flow to be released during	
	April to September	October to March
Flushing flow (from 48 – 96 hours)	200% MAF (Mean Annual Flow)	Not Applicable
Optimum range of flow	60 - 100% MAF	60 - 100% MAF
Outstanding habitat	60% MAF	40% MAF
Excellent habitat	50% MAF	30% MAF
Good habitat	40% MAF	20% MAF
Fair or degrading habitat	30% MAF	10% MAF
Poor or minimum habitat	10% MAF	10% MAF
Severe degradation	<10% MAF	<10% MAF

This means that if the quantity of water that the basin managers can provide for EFR is ≤ 20% of MAF (10% during April to September and 10% during October to March) then the environmental quality of the habitat in that reach will be "Severe degradation". If a "Good" habitat is desired, then at least 60% of the MAF must be allocated for EFR, 40% during April-September and 20% during October to March.

The Tennant method was modified by Tessman and it resulted in an approach called as Modified Tennant Method or Tessman Method. Tessman adopted Tennant seasonal flow recommendation to calibrate the percentage of Mean Annual flow (MAF) to local hydrologic and biological conditions including monthly variability. Under these changes, the following rules were formulated.

i) Monthly minimum equals the mean monthly flow (MMF), if MMF < 40% of MAF
ii) If MMF > 40% MAF, then monthly minimum equals 40% MAF
iii) If 40% MMF > 40% MAF, then monthly minimum equals 40% MAF
iv) The flushing flow criterion is still a requirement to be met on an annual basis.

iv) Desktop Reserve Model

Hughes and Munusler (2000) and Hughes and Hannart (2003) developed a desktop method for rivers in South Africa. The user calculates a hydrological index (i.e. coefficient of variation of flows divided by the base flow index (CV/BFI) using river flow data at the site. Hence, the base flow index curves are employed to define the percentages of mean annual runoff (MAR) volume that is required for different components of the environmental flow regime. It is intended to quantify environmental flow requirements in situations when a rapid appraisal is required and data availability is limited (Hughes and Hannart, 2003). The model is built on the concepts of the building block method, which was developed by South African scientists over several years (King *et al*., 2000), and is widely recognized as a scientifically legitimate approach to setting environmental flow requirements (Hughes and Hannart, 2003). The model comprises empirically derived statistical relationships developed through an analysis of comprehensive environmental flow studies conducted in South Africa. It is found that rivers with more stable flow regimes have relatively higher flow requirements than rivers with more variable flow regimes. This is because in highly variable flow regimes the biota would have adjusted to relative scarcity of water, while in more reliably flowing rivers, the biota are more sensitive to reduction in flow (Hughes and Hannart, 2003).

The Building Block Method is underpinned by the premise that, under natural conditions, different flows play different roles in the ecological functioning of a river. Consequently, to ensure sustainability, it is necessary to retain key elements of natural flow variation. Hence, the so-called Building Blocks are different components of flow which, when combined, comprise a regime that facilitates the maintenance of the river in a pre-specified condition. The flow blocks comprise low flows, as well as high flows, required for channel maintenance and differ between 'normal years' and 'drought years'. The flow needs in normal years are referred to as 'maintenance requirements' and divided between high and low flow components. The flow needs in drought years are referred to as 'drought requirements' (Hughes, 2001). The DRM provides estimates of these building blocks for each month of the year.

(v) Desktop Analysis

Desktop analysis can be sub-divided into (i) those based purely on hydrological data, and (ii) those that employ both hydrological and ecological data.

Desktop methods based on hydrological data

(a) Flow Duration Curve Based Method

A flow duration curve (FDC) is a plot of flow vs. percentage time equaled or exceeded. FDC can be prepared using the entire time series data of flow or the flow data pertaining to a specific period (such as a month) in different years. Further, it can be developed for a particular site or combining data for different sites on per unit catchment area basis in a hydro meteorologically homogeneous region.

(b) Environmental Management Class (EMC) based FDC Approach

Smakhtin and Anputhas (2006) reviewed various hydrology based environmental flow assessment methodologies and their applicability in Indian context. Based on the study, they suggested a flow duration curve based approach which links environmental flow requirement with environmental management classes.

This EFA method is built around a period-of-record FDC and includes several subsequent steps. The first step is the calculation of a representative FDC for each site where the environmental water requirement (EWR) is to be calculated. In this study, the sites where EF is calculated coincide with the major flow diversion. The sites with observed flow data are further referred to as 'source' sites. The sites where reference FDC and time series are needed for the EF estimation are referred to as 'destination' sites. All FDCs are represented by a table of flows corresponding to the 17 fixed percentage points. For each destination site, a FDC table was calculated using a source FDC table from either the nearest or the only available observation flow station upstream. To account for land-use impacts, flow withdrawal, etc., and for the differences between the size of a source and a destination basin, the source FDC is scaled up by the ratio of 'natural' long term mean annual runoff (MAR) at the outlet and the actual MAR calculated from the source record.

Environmental flow aim to maintain an ecosystem in, or upgrade it to, some prescribed or negotiated condition/status also referred to as "environmental management class (EMC)". The higher the EMC, the more water will need to be allocated for ecosystem maintenance or conservation and more flow variability will need to be preserved. Generally, six EMCs are used and corresponding default levels of EWR may be defined. The set of EMCs is similar to the one described in DWAF (1997) and given below Table 7.4.

Table 7.4 Environmental Management Classes (EMC)

EMC	Description	Management perspective
A	Natural rivers with minor modification of in-stream and riparian habitat.	Protected rivers and basins. Reserves and national parks. No new water projects (dams, diversions etc.) allowed.
B	Slightly modified and/or ecologically important rivers with largely intact biodiversity and habitats despite water resources development and/or basin modifications.	Water supply schemes or irrigation development present and / or allowed.
C	The habitats and dynamics of the biota have been disturbed, but basic ecosystem functions are still intact. Some sensitive species are lost and/or reduced in extent. Alien species present.	Multiple disturbances associated with the need for socio-economic development, e.g. dams, diversions, habitat modification and reduced water quality
D	Large changes in natural habitat, biota and basic ecosystem functions have occurred. A clearly lower than expected species richness. Much lowered presence of intolerant species. Alien species prevail	Significant and clearly visible disturbances associated with basin and water resources development, including dams, diversions, transfers, habitat modification and water quality degradation
E	Habitat diversity and availability have declined. A strikingly lower than expected species richness. Only tolerant species remain. Indigenous species can no longer breed. Alien species have invaded the ecosystem.	High human population density and extensive water resources exploitation. Generally this status should not be acceptable as a management goal. Management interventions are necessary to restore flow pattern and to "move" a river to a higher management category.
F	Modifications have reached a critical level and ecosystem has been completely modified with almost total loss of natural habitat and biota. In the worst case, the basic ecosystem functions have been destroyed and the changes are irreversible	This status is not acceptable from the management perspective. Management interventions are necessary to restore flow pattern, river habitats etc (if still possible / feasible). - to "move" a river to a higher class.

Placing a river into a certain EMC is normally accomplished by expert judgment using a scoring system. Alternatively, the EMCs may be used as default 'scenarios' of environmental protection and corresponding EWR and EF- as 'scenarios' of environmental water demand.

7.3.3.2 Hydraulic Rating Methods

In the previous EFR methodologies, difficulties exist in relating changes in the flow regime directly to the response of species and communities. Hence, approaches have been developed that use habitat for target species as an intermediate step. Hydraulic Rating Method (HRM) is combined desktop-field method requiring limited hydrological, hydraulic modeling and ecological data and expertise. HRM also uses the hydrological record and linked this data to simple cross-section data in the river of interest. This method uses the relationship between the flow of the river and simple hydraulic characteristics such as water depth, velocity or wetted perimeter to calculate an acceptable flow. These methods are an improvement on empirical or hydrological index method, since these require measurement of the river channel and so are more sensitive than the desktop approaches to differences between rivers. Cross-sections are placed at a river site where maintenance of flow is most critical or where instream hydraulic habitat is most responsive to flow reduction, and thus potentially most limiting to the aquatic biota (e.g. riffles). A relationship between habitat and discharge Q, developed by plotting the hydraulic variable against discharge is used to derive the EFR. A breakpoint, interpreted as a threshold below which habitat quality becomes significantly degraded, is identified on the habitat-Q response curve, or a minimum EFR is set as the Q producing a fixed percentage reduction in the particular habitat attribute (IWMI, 2007).

Within the total environmental niche required by an individual animal or plant living in a river, it is the physical aspects that are affected by changes to the flow regime. The most obvious physical dimension that can be changed by altered flow regimes is the wetted perimeter area of submerged river bed of the channel. Hydraulic rating method provides simple indices of available habitat (e.g. wetted perimeter) in a river at a given discharge.

Wetted Perimeter Method: It is a commonly applied hydraulic rating method. Environmental flows are determined from a plot of the hydraulic variable(s) against discharge, commonly by identifying curve breakpoints where significant percentage reductions in habitat quality occur with decrease in discharge. It is assumed that ensuring some threshold value of the selected hydraulic parameter at a particular level of altered flow will maintain aquatic biota and thus, ecosystem integrity. The wetted perimeter or area method has been used in Australia.

7.3.3.3 Habitat Simulation Methodologies

These are widely used and based on hydrological, hydraulic and biological response data. The model links discharge, available habitat conditions (including hydraulics) and their suitability to target biota. Environmental flow is predicted from habitat-discharge curves or habitat time and exceedence series. PHABSIM (Physical Habitat Simulation Model) (Bovee, 1986) recent ref. is a commonly applied habitat simulation methodology. Habitat simulation methodologies also make use of hydraulic habitat- discharge relationships, but provide more detailed, modeled analysis of both the quantity and suitability of the physical river habitat for the target biota. Thus, environmental flow recommendations are based on the integration of hydrological, hydraulic and biological response data. Flow related changes in physical micro habitat are modelled in various hydraulic programs, typically using data on depth, velocity, substratum composition and cover; and more recently complex hydraulic indices, collected at multiple cross sections with each representative river reach. Simulated information on available habitat is linked with seasonal information on the range of habitat conditions used by target fish or invertebrate species, commonly using habitat suitability index curves (Groshens and Orth, 1994) recent ref. The resultant outputs, in the form habitat discharge curves for specific biota, or extended as habitat time and exceedence series, are used to derive optimum environmental flows. The habitat simulation modeling package PHABSIM housed within the instream flow incremental methodology (IFIM) is the pre-eminent modeling platform of this type. The relative strength and limitations of such methodologies are described in King and Tharme (1994); Pusey (1998) and they are compared with the other types of approach in Tharme (2003).

7.3.3.4 Holistic Methodologies

Holistic methodologies are actually frameworks that incorporate hydrological, hydraulic and habitat simulation models. They are the only EFA methodologies that explicitly adopt a holistic ecosystem based approach to environmental flow determination. A wide range of holistic methodologies has been developed and applied in Australia, South Africa and United Kingdom. Ecosystem components that are commonly considered in holistic assessment include geomorphology, hydraulic habitat, water quality, riparian and aquatic vegetation, macroinvertebrates, fish and other vertebrates with some dependency upon the river ecosystem. Each of the components can be evaluated using a range of field and desktop techniques (Tharme, 1996; Tharme 2003.) and the flow requirements are then incorporated into EFA recommendation, using various systematic approaches.

7.3.4 Literature Review

Some important recent studies completed by various researchers/organizations are discussed here.

Realizing the importance of EFR, several countries have made environmental flows mandatory through various guidelines, such as The Mekong River Agreement, 1995; South Africa's National Water Act, 1998; Swiss Water Protection Act, UNEP Act, etc. The South African Water Act of 1998 stipulates that future water resource developments should be environmentally sustainable and that a component of the natural flow of rivers should be reserved to ensure some level of ecological functioning. Detailed methods for quantifying the environmental instream flow requirements of rivers have been available internationally and in South Africa for some time, but the implementation of the new act introduced a degree of urgency and pointed towards the need for rapid, low-confidence assessments that could be used for initial planning. The desktop reserve model was developed to fulfill this requirement, but since its development in 1999 there have been many more detailed IFR determinations. Initially, the practice of EFR's began as a commitment to ensuring a 'minimum flow' in the river, often arbitrarily fixed at 10% of the mean annual runoff (World Commission on Dams, 2000). However, this 'minimum flow' approach may not be appropriate for safeguarding essential downstream environmental conditions of the river system. Tharme (2003) reviewed the present status of environmental flow methodologies worldwide. It revealed the existence of some 207 individual methodologies, recorded for 44 countries within six world regions. These could be differentiated into hydrological, hydraulic rating, habitat simulation and holistic methodologies, with a further two categories representing combination-type and other approaches. Although historically, the United States has been at the forefront of the development and application of methodologies for prescribing environmental flows, using 37% of the global pool of techniques, parallel initiatives in other parts of the world have increasingly provided the impetus for significant advances in the field.

Application of methodologies is typically at two or more levels. (1) Reconnaissance-level initiatives relying on hydrological methodologies are the largest group (30% of the global total), applied in all world regions. Commonly, a modified Tennant method or arbitrary low flow indices is adopted, but efforts to enhance the ecological relevance and transferability of techniques across different regions and river types are underway. (2) At more comprehensive scales of assessment, two avenues of application of methodologies exist. In developed countries of the northern hemisphere, particularly, the instream flow incremental methodology (IFIM) or other similarly structured approaches are used. As a group, these methodologies are the second most widely applied worldwide, with emphasis on complex, hydrodynamic habitat modelling. The establishment of holistic methodologies as 8% of the global total within a decade, marks an alternative route by which environmental flow assessment has advanced. Such methodologies, several of which are scenario-based, address the flow requirements of the entire riverine ecosystem, based on explicit links between changes in flow regime and the consequences for the biophysical environment. Recent advancements include the consideration of ecosystem-dependent livelihoods and a benchmarking process suitable for evaluating alternative water resource developments at basin scale, in relatively poorly known systems. Although centered in Australia and South Africa, holistic methodologies have stimulated considerable interest elsewhere. They may be especially appropriate in developing world regions, where environmental flow research is in its infancy and water allocations for ecosystems must, for the time being at least, be based on scant data, best professional judgment and risk assessment.

Iyer (2005) has highlighted the importance of in-stream flows in India for different purposes: "Flows are needed for maintaining the river regime, making it possible for the river to purify itself, sustaining aquatic life and vegetation, recharging groundwater, supporting livelihoods, facilitating navigation, preserving estuarine conditions, preventing the incursion of salinity, and enabling the river to play its role in the cultural and spiritual lives of the people." There are several constraints and factors in which India differs from developed countries such as USA, UK, Australia that have taken a lead in addressing the problem of EFR. The preliminary studies on environmental flow requirements of Indian River Basins have been carried out by IWMI (2006). They have estimated EFR for 13 major river basins_of India using available data for Brahmaputra, Cauvery, Ganga, Godavary, Krishna, Mahanadi, Mahi, Narmada, Pennar, Tapi, Periyar, Sabarmati, and Subarnarekha using EMC-EDC approach. Mazvimavi et al. (2007) assessed the environmental flow requirements for river basin planning in Zimbabwe. They estimate the amount of water that should be reserved for environmental purposes in each of the 151 sub-basins or water management units of Zimbabwe. A desktop hydrological method is used to estimate the environmental flow requirement (EFR). The estimated EFRs decrease with increasing flow variability, and increase with the increasing contribution of base flows to total flows. The study has established that in order to maintain slightly modified to natural habitats along rivers, the EFR should be 30–60% of mean annual runoff (MAR) in regions with perennial rivers, while this is 20–30% in the dry parts of the country with rivers, which only flow during the wet season. The inclusion of EFRs in water resources management plans will not drastically change the proportion of the available water allocated to water permits, since the amount of water allocated to water permit holders is less than 50% of the MAR on 77% of the sub-basins in the country. Ministry of Environment and Forests, Govt. of India (MoEF, 2006) provides guidelines for EIA of development projects including river valley projects. However, the document does not specify EFR nor does it provide guidelines for assessment of environmental flows.

Kashaigili et al. (2007) presented the findings of a hydrological study conducted to estimate environmental flow requirements. The desktop reserve model was used to determine maintenance high and low flows, and drought low flow requirements within the Ruaha National Park. The results indicate that to maintain the basic ecological functioning of the river requires an average allocation of 635.3 Mm^3/a (equivalent to 21.6% of mean annual runoff). This is the average annual maintenance flow; comprising of maintenance low flows (i.e. 15.9% MAR; 465 Mm^3/a) and maintenance high flows (i.e. 5.8% of MAR; 170 Mm^3/a). The absolute minimum water requirement was estimated to be 0.54 m^3/s with the probability of exceedance of 0.99. The study confirms that in the absence of ecological information hydrological indices can be used to provide a first estimate of environmental water requirements. However, before being applied, greater understanding of the relationships between flow and the ecological condition of the riverine ecosystem is required. Yang et al. (2008) computed environmental flow requirements for integrated water resources allocation in the Yellow River Basin. Based on the classification and regionalization of the ecosystem, multiple ecological management objectives and the spatial variability of the environmental flow requirements of the Yellow River Basin were analyzed in this study. The summation rule was used to calculate water consumption requirements and the compatibility rule, i.e., “maximum” principle, was also adopted to estimate the non-consumptive use of water in the river basin. The environmental flow requirements for integrated water resources allocation were determined by identifying the natural and artificial water consumption in the Yellow River Basin. The results indicated that the annual minimum environmental flow requirements amounted to 317.62×10^8 m^3, which represented 54.76% of the natural river flows, while for the environmental flow requirements for the integrated water resources allocation were 262.47×10^8 m^3, which represented 45.25% of the natural river flows. It can be concluded that the primary concerns should be put on the downstream river water requirements to determine the environmental flows for integrated water resources allocation in a river basin.

Central Water Commission (CWC, 2007) carried out studies on minimum flows in various Indian rivers. The studies indicated that in case of Himalayan rivers the virgin flows are very high due to snow melt contributions. However, it may not be possible to maintain this condition in the lower reaches due to large existing utilizations. Therefore CWC recommended different minimum flow criterion for Himalayan rivers in mountainous reaches. CWC recommended that minimum flow to be not less than 2.5% of 75% dependable Annual Flow. One flushing flow during monsoon with a peak not less than 250% of 75% dependable Annual Flow (in cumec). However, the minimum flow for Bhagirathi River should be 13% of Annual Mean Flow or 14.69% of 75% dependable Annual Flow, while it should be 22.60% of Annual Mean Flow or 18.75% of 75% dependable Annual Flow for Alaknanda River.

In order to provide an integrated assessment of the suitability of environmental flows to safeguard downstream ecosystems and services, Shofiul Islam (2008) presented a methodology which deals on human well being, river functions and their relation with river flow based in Asian environment. He describes an analytical framework for assessing the relationship between group of people and the river flow regime, in order to determine flow requirements from people perspectives. The near absence of such methods represents a serious gap in the field of Environmental Flow Requirements. It is clear that environmental flow ensures ecosystem sustainability which provides better services to the human well being. Smakhtin and Erivagama (2008) describe a method and software package for desktop assessment of environmental flows -a hydrological regime designed to maintain a river in some agreed ecological condition. The method uses monthly flow data and is built around a flow duration curve, which ensures that elements of natural flow variability are preserved in the estimated environmental flow time series. The curve is calculated for several categories of aquatic ecosystem protection -from 'largely natural' to 'severely modified' category. The corresponding environmental flows progressively reduce with the decreasing level of ecosystem protection. A non-linear data transformation procedure subsequently converts the calculated environmental flow duration curve into a continuous time series of environmental flows. The software has facilities to zoom on a river basin, calculate a variety of hydrological characteristics, define or select any category of ecosystem protection, calculate the associated environmental flow duration curves and time series and display both. The analyses can be carried out either using default (simulated) global flow data, with a spatial resolution of 0.5 degree, or a user-defined value. The package is seen as a training tool for water practitioners, policymakers and students, and as a tool for rapid preliminary environmental flow assessment.

Assessment of environmental flows of Baitarni and Brahmani River Systems was carried out by Jha (2008) to estimate low-flow and high-flow discharges for ecological river maintenance and to assess suitable methodology for environmental flows assessment. Three approaches; (a) Flow duration curves technique, (b) Indicators of Hydrologic Alterations (IHA) techniques using 32 statistical variables, (c) Holistic approach considering water quality and ecological data sets, were used. Minimum environmental flow to maintain base flow and thus aquatic habitat in dry season were estimated to be 2-5 cumec (Volume 0.17-0.43 MCM/day). Maximum environmental flow to retain flood magnitude, scour channel and vegetation, recharge river banks and flood plain were estimated to be 500-900 cumec (43.3 – 77.8 MCM/day) at Champua (upstream) and 2000-6000 cumec (173-518 MCM/day) at Anandpur (downstream). This is required to be applied at least once. The rate of rise and fall should be maintained to (a) pertain spring flushing flow as cue to fish life cycles and (b) vary base flow in wet season, but with removal of some floods. Stochastic Flow duration curve (SFDC) approach is found to be most suitable technique for estimating environmental flows. 7-day 10 year return period and 7-day-100 year return period SFDC can be used by water resources planners and engineers depending on their objectives. He recommended that environmental flows needs to be considered prior to the construction of any water resources projects as well as for its operation in existing water resources projects. Babu and Harish Kumara (2009) studied environmental flows and its importance. Due to the construction of big dam across the Bhadra River which alters its natural flow, there are gains in terms of more cultivated area and associated economic and social benefits, but farming cost are increasing yearly. River water quality is deteriorating and livelihood support base of river ecosystem is shrinking. They estimated the environmental flow requirement in this river by using Tenant method. They recommended the environmental flow requirement as per Tennant law is given in Table 7.5.

Table 7.5 Recommended Environmental flow as per Tennant Method

Month	Average of 30 years	Poor flow @ 10%	Moderate Flow @ 30%	Excellent flow @ 60%
June	8510	851	2553	5106
July	27352	2735	8206	16411
August	27702	2770	8311	16621
September	9490	949	2847	5694
October	7201	720	2160	4321
November	3234	323	970	1940
December	1834	183	550	1101
January	1024	102	307	614
February	537	54	161	322
March	424	42	127	254
April	513	51	154	308
May	744	74	223	446
Total	88548	8855	26565	53129

Mathew et al. (2009) carried out a study to estimate the environmental flow requirements downstream of the Chara Chara weir. The Desktop Reserve Model (DRM) was used to determine both high and low flow requirements in the reach containing the Falls. The results indicate that to maintain the basic ecological functioning in this reach requires an average annual allocation of 862 Mm3 (i.e. equivalent to 22% of the mean annual flow). Under natural conditions there was a considerable seasonal variation, but the absolute minimum mean monthly allocation, even in dry years, should not be less than approximately 10 Mm^3. These estimates make no allowance for maintaining the aesthetic quality of the Falls, which are popular with tourists. The study demonstrated that, in the absence of ecological information, hydrological indices can be used to provide a preliminary estimate of environmental flow requirements. However, to ensure proper management, much greater understanding of the relationships between flow and the condition of the river ecosystem is needed.

Recently, Kumar et al. (2009) carried out environmental flow assessment for a hydropower project on a Himalayan river. They assessed the environmental flows using look up tables, environmental management class based FDC approach and hydraulic habitat analysis. They recommended hydraulic habitat analysis for environmental flow assessment.

7.3.5 Sites for Environmental Flow Assessment

The focus area for this study consists of the Alaknanda and Bhagirathi Basins up to Devprayag. This area is of immense importance due to its fragile ecosystem and the presence of many shrines including Char Dhams (four religious sites: Badrinath, Kedarnath, Gangotri and Yamunotri). In addition, seven Prayags (confluence of two rivers) are located in this area. Unlike other countries, rivers in India have a great religious cultural significance for a vast population. Indian society attaches great cultural and religious importance to rivers. Rivers are worshipped as mother and many of the customs and festivals are linked with them. Many of the Hindu festivals are associated with bathing in holy ponds and rivers. A large number of pilgrims assemble on the banks of rivers and ponds to take holy dip. For this purpose, river flows and water quality particularly during lean season have to be maintained.

Due to steep slopes and perennial river flows, the region has very high hydropower potential to the tune of 10,000 MW. A line diagram of the entire system is given in Fig. 7.11. Keeping in view the location of major hydropower projects (Commissioned, under construction, and proposed), as shown in Fig. 7.12, the sites have been identified for assessment of environmental flows and are given in Table 7.6. In selecting the sites, it has been ensured that all the large and small projects are covered and all the major rivers shows and tributaries are covered.

Table 7.6 Location of Hydropower sites where EFR were assessed

S. No.	Name of Sites	Catchment Area (sq. km)
	Hydro Projects in Operation	
1.	Maneri Bhali I	4105
2.	Maneri Bhali II	4416
3.	Tehri Stage - I	7511
4.	Bhilangana	696
5.	Agunda Thati	121
6.	Badrinath	1149
7.	Vishnuprayag	1130
8.	Rajwakti	545
	Hydro Projects under Development	
9.	Loharinag Pala	3316
10.	Asiganga III	190
11.	Koteshwar	7691
12.	Kotli Bhel-IA	7887
13.	Bhilangana-III	407
14.	Phata Byung	247
15.	Singoli Bhatwari	963
16.	Bhyunder Ganga	230
17.	Alkananda	1010
18.	Rishiganga II	680
19.	Tapovan Vishnugad	3100
20.	Vishnugad Pipalkoti	4672
21.	Birahi Ganga II	225
22.	Nandaprayag Langrasu	6233
23.	Devsari	1138

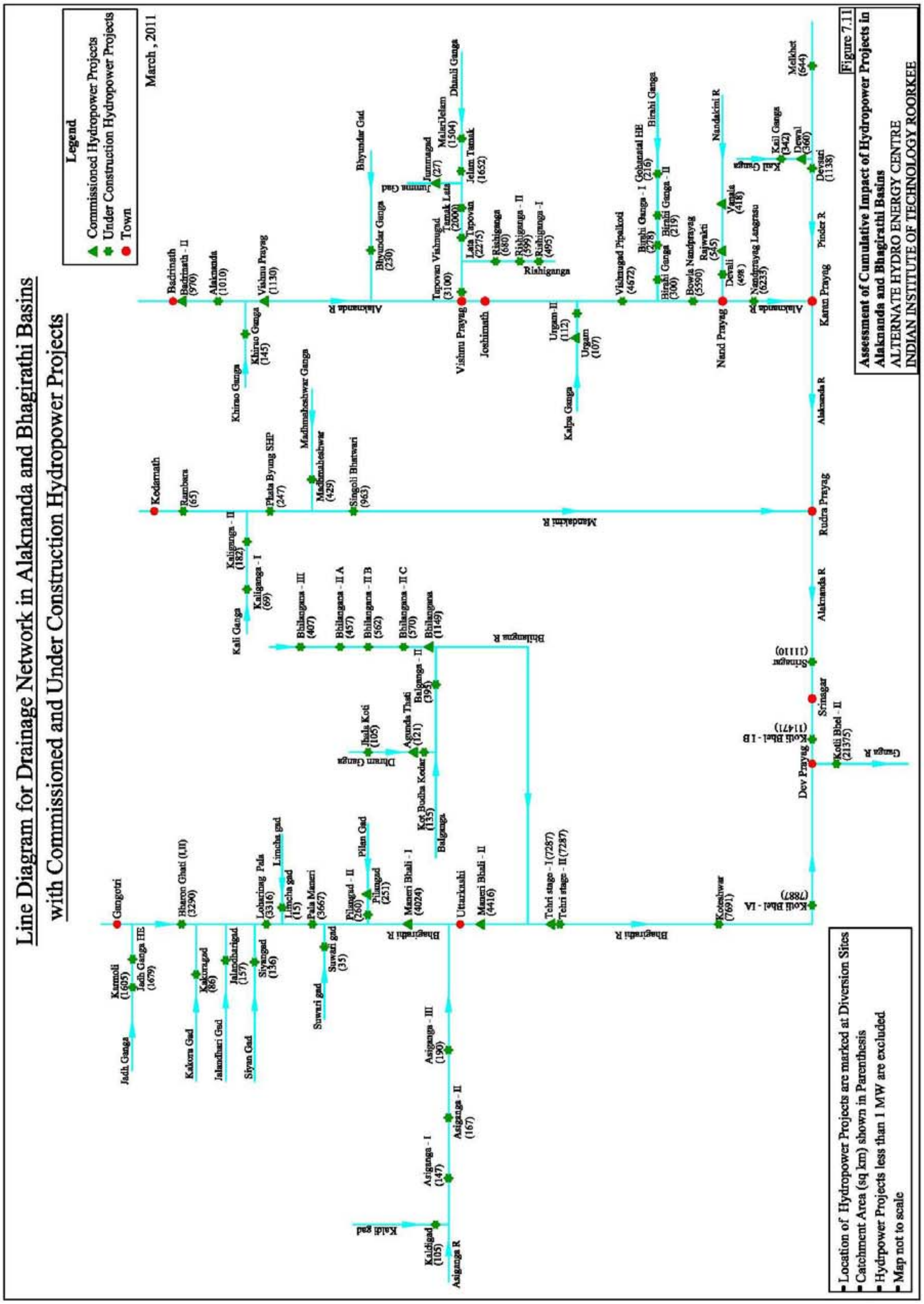


Fig. 7.11: Line diagram for drainage network in Alaknanda and Bhagirathi Basins with existing and under development Hydro Projects

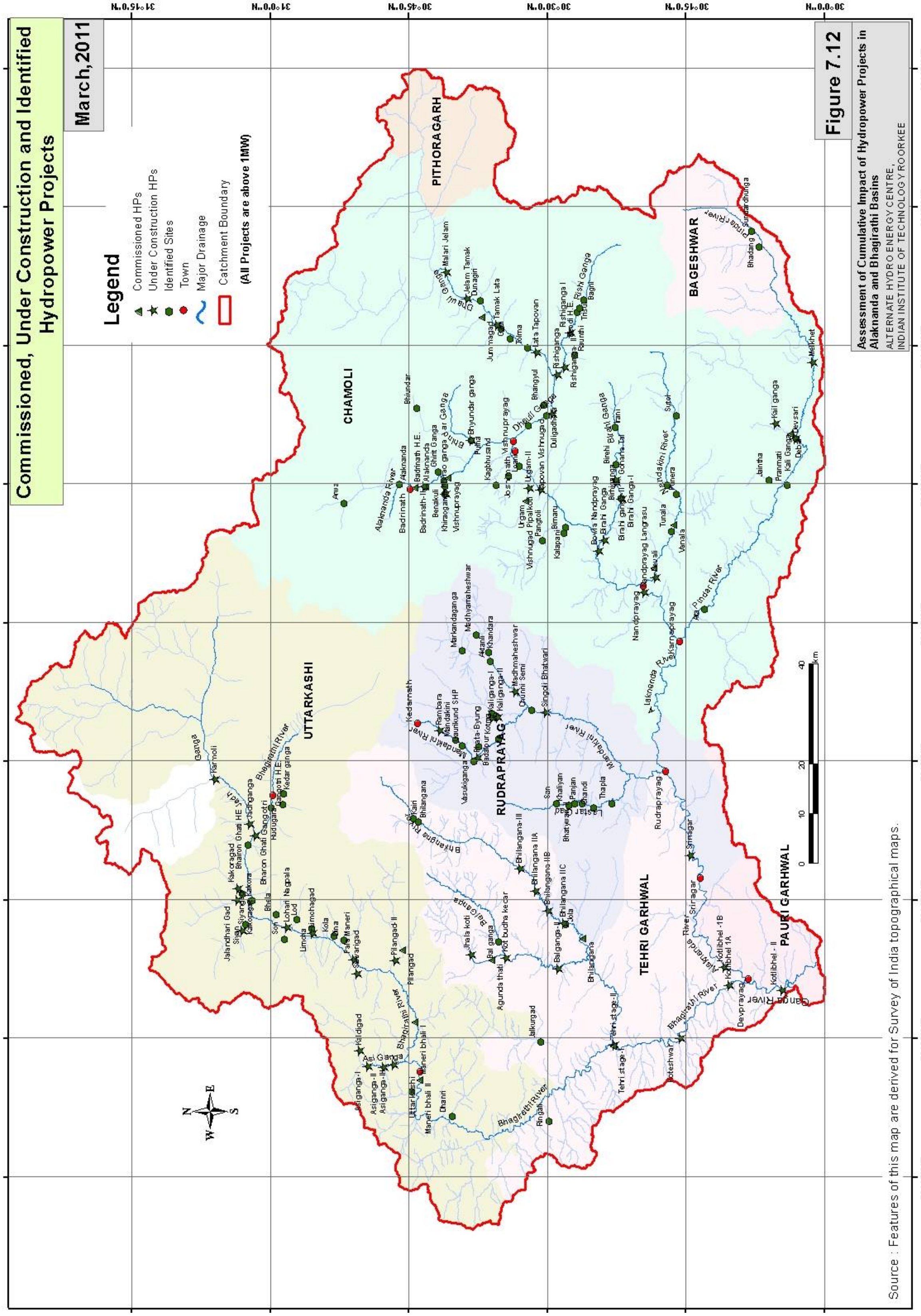


Fig. 7.12: The location of major hydropower projects (Commissioned, under construction, and proposed

Looking the religious cultural importance of the area, the following sites required flows from environmental and religious considerations (mainly in-stream use). Hence, the environmental flow in terms of Religious Flow Requirement (RFR) are assessed at the sites given in Table 7.7.

Table 7.7 Location of religious sites where EFR were estimated

S. No.	Name of Sites	Catchment Area (sq. km)*
24.	Nandprayag	6200
25.	Karanprayag	8460
26.	Rudraprayag	10675
27.	Devprayag	19600
28.	Vishnuprayag	4435
29.	Joshimath	4508
30.	Srinagar	11332
31.	Uttarkashi	4555

* Catchment area may have some minor discrepancy due to methods used by different data providers

7.3.6 Methodology Adopted in this Study

The study was initiated with the aim to determine EFR at various hydropower projects and religious sites in Alaknanda-Bhagirathi basins up to Devprayag. In this study for the assessment of EFR, various methods/approaches are used. The first method is the Hydrological index method in which the environmental flow requirements at various sites are computed by using look-up tables, low flow indices such as Q95, Q90, etc. Q95 (i.e. that flow which is equaled or exceeded 95% of the time) is often used in regulating abstraction in Uttarakhand. Figure of Q95 was chosen purely on hydrological ground. However, implementation of this approach (e.g. how much Q95 can be reduced) often includes ecological information. The Environment Agency of England and Wales is responsible for ensuring that the needs of water users are met whilst safeguarding the environment. It has specified percentages of natural Q_{95} flow that can be abstracted for different environmental weighting bands. For the present study area, the environmental weighing band is considered as D, in which 25% of Q95 can be abstracted and 75% of Q95 will be released as environmental flow. The second hydrological indexing method used for the present analysis is Tessman or Modified Tenant's method. This method is based on the computation of mean annual flow (MAF).

The third is the desktop approach such as Environmental Management Class (EMC) based Flow Duration Curve (FDC) Approach. In this methodology, seventeen fixed percentage points are taken for the computation of dependable flows. The flow duration curve plotted using these fixed points are termed as reference flow duration curve. The Six EMCs (Environmental Management Classes) are used in this study and six corresponding default levels of EWR may be defined. It starts with the unmodified and largely natural conditions (rivers in classes A and B), where no or limited modification is present or should be allowed from the management perspective. In moderately modified river ecosystems (Class C rivers), the modifications are such that they generally have not (or will not – form the management perspective) affected the ecosystem integrity. Largely modified ecosystems (Class D rivers) correspond to considerable modification from the natural state where the sensitive biota is reduced in numbers and extent. Seriously and critically modified ecosystems (Classes E and F) are normally in poor conditions where most of the ecosystem's functions and services are lost. In addition, the habitat simulation method is also used based on the limitation of the study in terms of data availability and time frame. In this method, the available habitat conditions (including hydraulics) and their suitability to target biota is linked with minimum discharge required for their survival. Since, the cross sections in Alaknanda-Bhagirathi basin were available at limited sites; the available data were proportionately used for other projects sites. The results obtained using these various EFA methodologies are described in the subsequent section.

7.3.7 Results and Discussions

The details of location, elevation and catchment area of various stream gauging stations on Alaknanda-Bhagirathi River system are tabulated in the Table 7.8. Table 7.9 shows the site where the river cross section data were available. The various HPs sites selected for the present analysis along with the details about the stream gauging stations, cross section site, catchment area and river stretches are tabulated in the Table 7.10. The long term daily stream flow data for various stream gauging stations (Table 7.8) and cross section at various locations on Alaknanda-Bhagirathi River were collected from Central Water Commission, New Delhi. The 10-daily average stream flow data for these gauging stations were transposed to generate the 10 daily series for the HP sites selected in the present study using the relative proportionality co-efficient between the catchments of gauging stations and HP sites. The long term average 10-daily series thus generated for various HP sites were analyzed using different EFA methodologies as described earlier. The 10-daily mean annual flow (MAF) and mean monthly flow were computed using the generated long term average 10 daily series for various HP and religious sites as given in Table 7.11.

The secondary data of habitat characteristics such as geological, morphological, hydrological and biological characteristics were collected from Department of Environmental Sciences, H. N. B. Garhwal University Srinagar-Garhwal, Uttarakhand. Accordingly the entire basin under study was divided into different stretches/zones on the basis of the habitat characteristics. The primary data on collection of biotic valued ecosystem components (macro invertebrates, fish and fish otter) were made after visiting all the major river zones of study area. The secondary data related with biotic components were also collected from the published literature. Benthic macorinvertebrate data were derived from samples taken following standard protocols. The data on fishes and fish otter were collected through primary and secondary sources. Hydrological requirements (water depth and water velocity) of macro invertebrates, fish and fish otter were also obtained from the analysis of the characteristics of their natural habitat and their life activities in the Alaknanda–Bhagirathi basin. Based on the various approaches as stated earlier for classifying the rivers on the basis of biotic communities or various basin ecological indicators, the entire reach of Alaknanda and Bhagirathi Basins up to Devprayag were classified in to different stretches as given in Table 7.10. Data on important basin ecological indicators were also collected for assessing the environmental management class (EMC) of the rivers (Table 7.10) and the EMC classes are further mapped as shown in

Figure 7.13. On the basis of hydrological requirements (water depth and water velocity) of macro invertebrates, fish and fish otter in the various stretches, and EMC of the various river stretch, the hydraulic mean depth (HMD) and velocity were computed at various HP sites as presented in Table 7.12. This information pertaining to hydrological requirements of macro invertebrates, fish and fish otter at various HP sites were used for computing the environmental flow requirement in the downstream river stretch of HP sites.

The estimated EFR for the selected sites using different methods/approaches are discussed below.

7.3.7.1 Hydrological Index Method

The results obtained for selected sites by using various hydrological index methods are tabulated in Table 7.13.The Tennant method was originally called the “Montana method” by Tennant because it was created using data from Montana region (Tennant 1975). This was developed through field observation and measurement. This “method” indicates, in descriptive terms, the likely status of the habitat form various levels of EFR in two six monthly groups. This method attempts to separate the entire range of the Mean Annual Runoff (MAR) at the site of a river into several ecologically relevant ranges. The recommendations given by Tennant are water availability and requirement in typical Indian basins. Therefore, it was further modified by Tessman called as Modified Tennant Method or Tessman Method. Tessman adopted Tennant seasonal flow recommendation to calibrate the percentage of Mean Annual flow (MAF) to local hydrologic and biological conditions including monthly variability.

7.3.7.2 Desktop Approach

The EMC-FDC desktop approach based on hydrological data was used to estimate the environmental flow at selected HEP sites on Alaknanda and Bhagirathi Rivers Basin. In this methodology, seventeen fixed percentage points are taken for the computation of dependable flows. The reference flows at each point are computed by using the reference-flow duration curve. The EFR values computed considering 17 fixed points of probability of exceedence for the EMC defined at selected sites are given in Table 7.14. Placing a river into a certain EMC is normally accomplished by expert judgment using a scoring system.

7.3.7.3 Habitat Simulation Methodology

As stated earlier, in the previous EFA methodologies, difficulties exist in relating changes in the flow regime directly to the response of species and communities; hence, approach have been developed that use habitat for target species as an intermediate step. Hydraulic Rating Method (HRM) is combined desktop-field methods requiring limited hydrological, hydraulic modeling and ecological data and expertise. Like previous method, HRM also uses the hydrological record and link this data to simple cross-section data in the river of interest. This method uses the relationship between the flow of the river and simple hydraulic characteristics such as hydraulic mean depth (HMD) or water depth, velocity or wetted perimeter to calculate

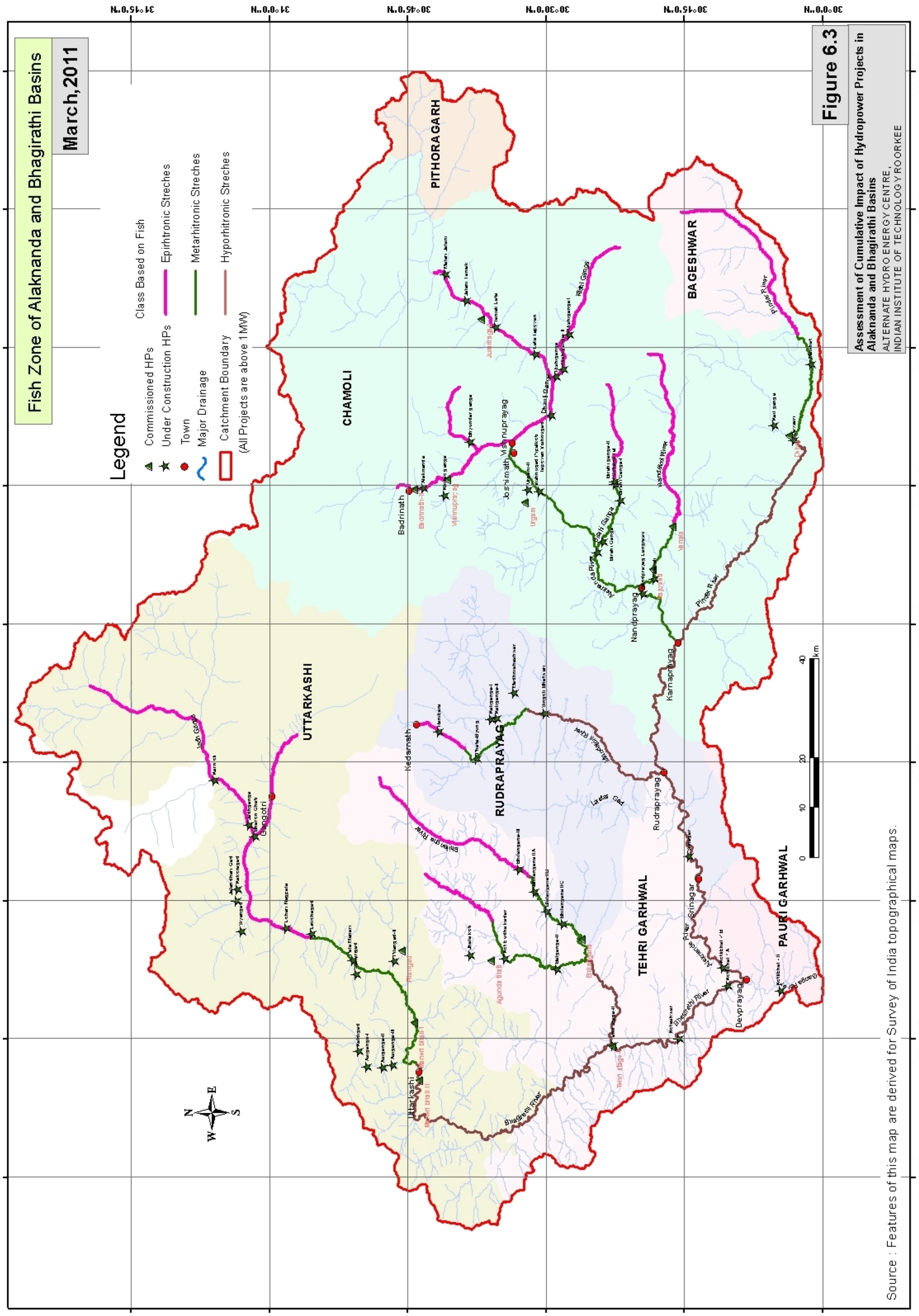


Figure 7.13 Environmental Management Classification (EMC-Biotic) of the study area

Table 7.8 Details of gauging site on Alaknanda-Bhagirathi river basins (CWC)

S. No.	Gauge Site	River	Catchment Area (sq. km)	District	Type	Date of Start	Grid Ref.	By	Latitude			Longitude			Elevation (m)
1	Joshimath	Ganga/Alaknanda	4508	Chamoli	G,GD,GDQ	23.4.71/1.5.71/ 5.8.72	GG200S3	CWC	30	33	30	79	33	40	1375
2	Karanprayag	Ganga/Alaknanda/ Pinder	2294	Chamoli	G,GD	10.6.76/10.6.76	GG260A1	CWC	30	15	15	79	33	40	765
3	Nandkeshi	Ganga/Alaknanda/ Pinder	1296	Chamoli	G,GD	1.6.94/1.6.94	GG260J4	CWC	30	5	0	79	30	0	1260
4	Rudraprayag	Ganga/Alaknanda/	9031	Rudraprayag	G,GD,GDS, GDSQ	9.2.71/9.2.71/ 22.9.87/15.6.76	GG200G5	CWC	30	17	20	78	59	20	614
5	Rudraprayag	Ganga/Alaknanda/ Mandakini	1644	Rudraprayag	G,GD,GDS	9.2.71/9.2.71/ 6.7.92	GG250A5	CWC	30	17	20	78	59	0	610
6	Tehri	Ganga/Bhagirathi/ Bhilangna	7208	Tehri	G,GD	1.10.7./14.1.71	GG100E2	CWC	30	21	24	78	28	40	580
7	Uttarkashi	Ganga/Bhagirathi	4555	Uttarkashi	G,GD,GDS, GDSQ	15.7.71/15.7.71/ 12.6.89/1.6.89	GG100K4	CWC	30	45	0	78	20	0	1096
8	Deoprayag	Ganga	19600	Pauri	G,GD,GDS, GDSQ	6.3.72/ 6.3.72/ 5.11.74/9.11.74	GGOOOZ9	CWC	30	8	0	78	36	0	443
9	Doprayag	Ganga/Bhagirathi	7813	Pauri	G,GD,GDQ	27.1.71	GG100A1	CWC	30	9	0	78	35	0	452
10	Badrinath	Ganga/Alaknanda	1285	Chamoli	G,GD	10.9.76/24.9.76	GG200V5	CWC	30	46	15	79	29	40	3107
11	Chandrapuri	Ganga/Alaknanda/ Mandakini	1297	Rudraprayag	G,GD	29.5.76/29.5.76	GG25015	CWC	30	26	15	79	4	0	847
12	Rishikesh	Ganga/Bhagirathi	7196	Tehri	G,GD,GDS, GDSQ	1.8.70/3.12.70/ 1.12.71/21.8.71	GG100E2	CWC	30	23	0	78	28	0	327
13	Karanprayag	Ganga/Alaknanda	8640	Chamoli	G	1.7.73	GG200K2	CWC	30	15	0	79	13	0	769
14	Rudraprayag	Ganga/Alaknanda	10675	Rudraprayag	G	16.6.72	GG200G5	CWC	30	17	20	78	59	0	800
15	Srinagar	Ganga/Alaknanda	11332	Pauri	G	6.6.73	GG200D5	CWC	30	13	0	78	45	0	560
16	Devprayag	Ganga/Alaknanda	11787	Pauri	G	27.1.71	GG200A2	CWC	30	8	0	78	34	0	400

Note: G = Gauge, GD = Gauge and Discharge, GDS = Gauge, Discharge and silt, GDQ = Gauge, Discharge and water quality, GDSQ = Gauge, Discharge, Silt and water Quality

Table 7.9 Details (salient features) of locations of River Cross Sections sites in Alaknanda-Bhagirathi Basins up to Devprayag

S. No.	Site Name	River/Tributary/Sub-tributary	Year of Survey of C/S	Water Level (HFL) (m)	Maximum Water Depth (d) (m)	Wetted perimeter up to HFL (P) (m)	Total Area of C/S (A) (m^2)
1	Joshimath	Ganga/Alaknanda	2006	1381.85	6.9	64.75	339.50
2	Karanprayag	Ganga/Alaknanda/Pinder	2006	770.55	18.4	73.6	754.9
3	Nandkeshi	Ganga/Alaknanda/Pinder	2004	1266.50	5.0	51.57	175.40
4	Rudraprayag	Ganga/Alaknanda/Mandakini	2006	628.40	15.5	58.6	456.35
5	Tehri (Bhilangana)	Ganga/Bhagirathi/Bhilangana	2001	633.80	5.0	47.0	109.5
6	Uttarkashi	Ganga/Bhagirathi	2001	1120.15	6.0	59.7	195.8
7	Devprayag	Ganga	2004	472.72	29.2	112.30	2174.0
8	Badrinath	Ganga/Alaknanda	2006	3112.50	6.0	48.1	146.15
9	Chandrapuri	Ganga/Alaknanda/Mandakini	2004	855.20	8.2	56.15	327.56
10	Rishikesh	Ganga/Bhagirathi	2002	341.72	14.0	196.7	1425.5
11	Karanprayag	Ganga/Alaknanda	2003	761.35	7.8	83.81	643.70
12	Rudraprayag	Ganga/Alaknanda	2006	629.30	17.0	61.5	456.35

Table 7.10 HEP sites for EFR assessment with corresponding gauging stations, river stretch and EMC (biotic)

S. No.	NAME OF HP SITES/PRAYAG	Catch ment Area	Gauging station	Catch-ment Area	Cross Section at site1/site2/site3	River	River stretch	EMC (Biotic)
1.	Maneri Bhali I	4105	Tehari(0)	7208	Uttarkashi	Bhagirathi	Dabrani-Uttarkashi	C
2.	Maneri Bhali II	4416	Uttarkashi	4071	Uttarkashi	Bhagirathi	Uttarkashi-Deoprayag	D
3.	Tehri stage-I	7511	Tehri(0)	7208	Tehri(0)/Rishikesh/Uttarkashi	Bhagirathi	Uttarkashi-Deoprayag	D
4.	Bhilangana	696	Tehri(Bhilangana)	7208	Tehri(Bhilangana)/	Bhilangana	Ghuttoo-Ghansali	C
5.	Agunda Thati	121	Tehri(Bhilangana)	7208	Tehri(Bhilangana)	Balganga	Jhalakoti-Ghansali	C
6.	Badrinath	970	Badrinath	1285	Badrinath	Alkananda	Mana-Vishnuprayag	B
7.	Vishnuprayag	1130	Joshimath	4508	Joshimath/Badrinath	Alkananda	Mana-Vishnuprayag	B
8.	Rajwakti	545	Karnaprayag	8640	Karnaprayag/Joshimath	Nandakini	Vanala-Nandprayag	C
9.	Lohari Nagpala-UDHP	3316	Tehari(0)	7208	Uttarkashi	Bhagirathi	Gangotri-Dabrani	B
10.	Asiganga III-UDHP	110	Uttarkashi	4555	Uttarkashi	Asiganga	Source-Asiganga	B
11.	Koteshwar-UDHP	7691	Tehri(0)	7208	Tehri(0)/Devprayag(Bhagirathi)	Bhagirathi	Uttarkashi-Deoprayag	D
12.	Kotli Bhel-IA LHP	7887	Doprayag(Bhagira)	7813	Deoprayag(Bhagirathi)/Tehri(0)	Bhagirathi	Uttarkashi-Deoprayag	D
13.	Bhilangana-III-UDHP	587	Tehri(Bhilangana)	7208	Tehri(Bhilangana)	Bhilangana	Ghuttoo-Ghanasali	C
14.	Phata Byung SHP	247	Chandrapuri	1297	Rudraprayag(Mandakini)	Mandakini	Gaurikund-Guptkashi	C
15.	Singoli Bhatwari LHP	963	Chandrapuri	1297	Rudraprayag(Mandakini)	Mandakini	Singoli-Bhatwari	C
16.	Bhyunder Ganga-UDHP	230	Joshimath	4508	Joshimath	Bhyandarganga	Bhyunderganga-Entire stretch	B
17.	Alkananda UDHP	1010	Badrinath	1285	Badrinath/Joshimath	Alkananda	Mana-Vishnuprayag	B
18.	Rishiganga II-	680	Joshimath	4508	Joshimath	Rishiganga	Rishiganga Entire stretch	B
19.	Tapovan Vishnugad	2527	Joshimath	4508	Joshimath/Badrinath	Alkananda	Vishnuprayag-Karnaprayag	C
20.	Vishnugad Pipalkoti	5017	Joshimath	4508	Joshimath/Karnaprayag	Alkananda	Vishnuprayag-Karnaprayag	C
21.	Birahi Ganga II	225	Joshimath	4508	Joshimath/Karnaprayag	Birahiganga	Guhanatal-Pipalkoti	C
22.	Nandaprayag Langrasu	6233	Karnaprayag	8640	Karnaprayag/Joshimath	Alkananda	Vishnuprayag-Karnaprayag	C
23.	Devsari	1180	Karnaprayag	8640	Nandakeshi/Karnaprayaga(Pinder)	Pinder	Debal-Karnaprayag	D
24.	Nandprayag	6200	Karnaprayag	8640	Karnaprayag/Joshimath	Alkananda	Vishnuprayag-Karnaprayag	C
25.	Karanprayag	8460	Karnaprayag	8640	Karnaprayag/Rudraprayag/Joshimath	Alkananda	Karnaprayag-Deoprayag	D
26.	Rudraprayag	10675	Rudraprayag	10675	Rudraprayag/Karnaprayag/Srinagar	Alkananda	Karnaprayag-Deoprayag	D
27.	Devprayag	19600	Devprayag(Ganga)	19600	Deoprayag/Deo(Alkananda)/Deo(Bagirathi)	Ganga	Entire stretch(ganga)	D
28.	Vishnuprayag	4435	Joshimath	4508	Joshimath/Badrinath	Alkananda	Vishnuprayag-Karnaprayag	C
29.	Joshimath	4508	Joshimath	4508	Joshimath/Badrnath/Karnaprayag	Alkananda	Vishnuprayag-Karnaprayag	C
30.	Srinagar	11332	Srinagar	11332	Sringar/Rudraprayga/Deo(Alkana)	Alkananda	Karnaprayag-Deoprayag	D
31.	Uttarkashi	4555	Uttarkashi	4555	Uttarkashi/Rishikesh	Bhagirathi	Uttarkashi-Deoprayag	D

Table 7.11 Mean Monthly Flow (MMF) for various sites in Alaknanda and Bhagirathi Basins

S. No.	HEP Site	MAF (cumec-day)	Mean Monthly Flow (cumec-day)											
			Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
A	**Bhagirathi River**													
1	Asiganga III	5.29	0.3	0.3	0.3	0.7	3.3	8.5	17.1	19.1	10.0	1.9	0.6	0.4
2	Agunda thati	5.48	4.2	4.3	4.2	3.7	4.2	5.4	8.1	10.6	8.1	5.1	3.8	4.3
3	Bhilangana-III	13.74	5.6	5.7	5.7	5.5	9.3	17.8	32.7	38.4	23.0	8.8	5.5	5.9
4	Bhilangana	52.01	39.6	40.6	40.2	35.0	39.4	51.3	77.0	100.8	76.5	48.0	36.5	41.1
5	Lohari Nagpala	92.27	5.9	4.9	5.9	12.2	57.5	148.5	299.0	332.9	174.5	33.5	9.8	7.0
6	Maneri bhali I	114.22	7.3	6.1	7.3	15.1	71.2	183.8	370.1	412.1	216.0	41.5	12.2	8.7
7	Maneri bhali II	122.87	7.9	6.6	7.9	16.3	76.5	197.7	398.2	443.3	232.4	44.6	13.1	9.3
8	Tehri stage-I	243.41	99.7	100.6	101.0	97.6	163.8	315.5	579.2	679.3	408.2	156.0	97.3	104.1
9	Koteshwar	259.73	106.3	107.4	107.7	104.2	174.8	336.6	618.0	724.8	435.5	166.4	103.8	111.1
10	Kotlibhel 1A	266.34	109.0	110.1	110.5	106.8	179.3	345.2	633.8	743.3	446.6	170.7	106.4	113.9
B	**Alkananda River**													
1	Badrinath	39.69	7.6	6.6	8.1	14.2	35.2	70.5	106.0	95.8	64.8	34.7	21.7	14.8
2	Birahi Ganga II	8.18	2.4	2.2	2.5	3.0	4.1	6.8	16.8	23.6	19.3	8.9	4.7	3.5
3	Bhyunder Ganga	9.41	1.8	1.6	1.9	3.4	8.3	16.7	25.1	22.7	15.4	8.2	5.1	3.5
4	Phata Byung	16.82	5.5	6.1	6.6	6.8	9.0	15.8	39.7	53.0	31.8	12.8	7.5	8.0
5	Rajwakti	19.82	5.8	5.4	6.0	7.2	10.0	16.4	40.6	57.2	46.8	21.5	11.3	8.5
6	Rishiganga II-	24.51	4.7	4.1	5.0	8.8	21.7	43.6	65.5	59.1	40.0	21.5	13.4	9.1
7	Singoli Bhatwari	53.57	13.1	13.9	17.1	22.1	29.9	48.0	125.2	176.7	108.8	41.7	23.0	19.2
8	Alkananda	41.33	8.0	6.9	8.4	14.8	36.7	73.4	110.4	99.7	67.5	36.2	22.6	15.4
9	Devsari	19.71	5.8	5.5	6.0	7.2	9.9	17.5	42.2	57.7	45.5	19.7	10.7	7.5
10	Vishnuprayag	46.24	13.2	11.4	14.0	24.6	60.9	122.0	183.4	165.7	112.1	60.1	37.5	25.6
11	Tapovan Vishnugad	126.85	24.4	21.1	25.8	45.4	112.5	225.4	338.9	306.0	207.2	111.0	69.3	47.3
12	Vishnugad Pipalkoti	191.18	36.8	31.8	38.9	68.4	169.5	339.7	510.7	461.2	312.2	167.3	104.4	71.3
13	Nandaprayag Langrasu	255.06	49.1	42.4	52.0	91.3	226.2	453.2	681.3	615.4	416.6	223.3	139.3	95.1
C	**Religious Places**													
1	Vishnuprayag	178.64	36.4	33.9	37.7	66.0	163.8	332.5	486.7	425.3	278.4	151.9	91.8	58.6
2	Joshimath	181.58	37.0	34.4	38.3	67.1	166.5	338.0	494.7	432.3	283.0	154.4	93.3	59.6
3	Uttarkashi	123.93	8.7	6.8	8.2	17.2	78.5	214.2	418.9	445.0	209.8	37.2	12.1	8.4
4	Nandprayag	254.51	48.9	42.2	51.7	90.8	225.0	450.8	677.7	612.1	414.4	222.1	138.6	91.7
5	Karanprayag	303.06	268.3	648.3	887.8	700.2	303.1	164.4	114.9	89.9	83.9	92.1	111.4	152.0
6	Rudraprayag	395.38	97.1	88.6	94.1	130.7	264.5	541.9	1059.5	1188.5	731.6	277.0	161.3	116.0
7	Srinagar	524.19	121.3	113.5	125.6	172.9	326.6	633.3	1345.2	1607.1	1043.9	407.0	222.6	172.9
8	Devprayag	647.1	171.1	161.6	186.4	256.5	422.2	839.1	1676.8	1958.9	1179.5	436.2	246.4	183.9

Table 7.12 Hydrological requirement of biotic life identified at different river stretches of various HP sites

S. No.	Name of HEP Sites/Prayag	River Stretch	EMC (Biotic)	Hydraulic Mean Depth				Velocity Range Used (cm/s) (cm/s)	Cross Section area (m²)	Remarks (Reference cross section site)
				I	II	III	Range			
1.	Maneri Bhali I	Dabrani-Uttarkashi	C	15-20	20-30	-	15-30	>100 (120)	12.84	Uttarkashi
2.	Maneri Bhali II	Uttarkashi-Devprayag	D	-	20-30	30-50	20-50	≤100 (100)	12.84	Uttarkashi
3.	Tehri stage-I	Uttarkashi-Devprayag	D	-	20-30	30-50	20-50	≤100 (100)	36.50	Rishikesh (near Tehri)
4.	Bhilangana	Ghuttoo-Ghansali	C	15-20	20-30	-	15-30	>100 (120)	1.95	Tehri (Bhilangana)
5.	Agunda Thati	Jhalakoti-Ghansali	C	15-20	20-30	-	15-30	>100 (120)	0.98	Tehri (Bhilangana)
6.	Badrinath	Mana-Vishnuprayag	B	<15	-	-	<15	>120 (150)	5.18	Badrinath
7.	Vishnuprayag	Mana-Vishnuprayag	B	<15	-	-	<15	>120 (150)	5.18	Badrinath
8.	Rajwakti	Vanala-Nandprayag	C	15-20	20-30	-	15-30	>100 (120)	3.60	Nandkeshi
9.	Lohari Nagpala-UDHP	Gangotri-Dabrani	B	<15	-	-	<15	>120 (150)	6.42	Uttarkashi
10.	Asiganga III-UDHP	Source-Asiganga	B	<15	-	-	<15	>120 (150)	0.25	Uttarkashi
11.	Koteshwar-UDHP	Uttarkashi-Devprayag	D	-	20-30	30-50	20-50	≤100 (100)	36.50	Rishikesh (near Tehri)
12.	Kotli Bhel-IA LHP	Uttarkashi-Devprayag	D	-	20-30	30-50	20-50	≤100 (100)	36.50	Rishikesh (near Tehri)
13.	Bhilangana-III-UDHP	Ghuttoo-Ghanasali	C	15-20	20-30	-	15-30	>100 (120)	1.95	Tehri (Bhilangana)
14.	Phata Byung SHP	Gaurikund-Guptkashi	C	15-20	20-30	-	15-30	>100 (120)	4.41	Chanderpuri
15.	Singoli Bhatwari LHP	Singoli-Bhatwari	C	15-20	20-30	-	15-30	>100 (120)	4.41	Chanderpuri
16.	Bhyunder Ganga-UDHP	Bhyunderganga-Entire stretch	B	<15	-	-	<15	<120 (150)	1.80	Badrinath
17.	Alkananda UDHP	Mana-Vishnuprayag	B	<15	-	-	<15	<120 (150)	5.18	Badrinath
18.	Rishiganga II-	Rishiganga Entire stretch	B	<15	-	-	<15	<120 (150)	3.60	Joshimath
19.	Tapovan Vishnugad	Vishnuprayag-Karnaprayag	C	15-20	20-30	-	15-30	>100 (120)	10.35	Joshimath
20.	Vishnugad Pipalkoti	Vishnuprayag-Karnaprayag	C	15-20	20-30	-	15-30	>100 (120)	10.35	Joshimath
21.	Birahi Ganga II	Guhanatal-Pipalkoti	C	15-20	20-30	-	15-30	>100 (120)	1.80	Nandkeshi
22.	Nandaprayag Langrasu	Vishnuprayag-Karnaprayag	C	15-20	20-30	-	15-30	>100 (120)	22.03	Karnaprayag(Alaknanda)
23.	Devsari	Dewal-Karnaprayag	D	-	20 - 30	30-50	20-50	≤100 (100)	7.20	Nandkeshi
24.	Nandprayag	Vishnuprayag-Karnaprayag	C	15-20	20-30	-	15-30	>100 (120)	51.20	Karnaprayag (Alaknanda)
25.	Karanprayag	Karnaprayag-Devprayag Karnaprayag-	D	-	20-30	30-50	20-50	≤100 (100)	51.20	Karan Prayag
26.	Rudraprayag	Devprayag	D	-	20-30	30-50	20-50	≤100 (100)	31.02	(Alaknanda)
27.	Devprayag	Entire stretch(ganga)	D	-	20-30	30-50	20-50	≤100 (100)	49.80	Rudraprayag (Alaknanda)
28.	Vishnu Prayag	Vishnuprayag-Karnaprayag	C	15-20	20-30	-	15-30	>100 (120)	33.60	Devprayag
29.	Joshimath	Vishnuprayag-Karnaprayag	C	15-20	20-30	-	15-30	>100 (120)	33.60	Joshimath
30.	Srinagar	Karnaprayag-Devprayag	D	-	20-30	30-50	20-50	≤100 (100)	49.80	Joshimath
31.	Uttarkashi	Uttarkashi-Devprayag	D	-	20-30	30-50	20-50	≤100 (100)	19.04	Deoprayag Uttarkashi

Table 7.13 Environmental Flow Assessment based on Look-Up Tables

S. No.	HP Site	MAF (cumec)	WCD (cumec)	FRANCE (cumec)	UK (cumec)
A	**Bhagirathi River**				
1	Asiganga III-UDHP	5.29	0.53	0.53	0.16
2	Agunda thati	5.48	0.55	0.14	1.17
3	Bhilangana-III-UDHP	13.74	1.37	1.37	2.76
4	Bhilangana	52.01	5.2	1.30	11.07
5	Lohari Nagpala-UDHP	92.27	9.23	9.23	2.77
6	Maneri bhali I	114.22	11.42	2.86	3.43
7	Maneri bhali II	122.87	12.29	3.07	3.68
8	Tehri stage-I	243.41	24.34	6.09	48.96
9	Koteshwar-UDHP	259.73	25.97	25.97	52.24
10	Kotlibhel 1A	266.34	26.63	26.63	53.57
B	**Alkananda River**				
1	Badrinath	39.69	3.97	0.99	4.03
2	Birahi Ganga II	8.18	0.82	0.82	1.77
3	Bhyunder Ganga-UDHP	9.41	0.94	0.94	0.96
4	Phata Byung SHP	16.82	1.68	1.68	2.76
5	Rajwakti	19.82	1.98	0.50	4.43
6	Rishiganga II-	24.51	2.45	2.45	2.49
7	Singoli Bhatwari LHP	53.57	5.36	5.36	7.10
8	Alkananda UDHP	41.33	4.13	4.13	4.20
9	Devsari	19.71	1.97	0.49	4.35
10	Vishnuprayag	46.24	4.62	1.15	6.98
11	Tapovan Vishnugad	126.85	12.69	12.69	19.42
12	Vishnugad Pipalkoti	191.18	19.12	19.12	19.43
13	Nandaprayag Langrasu	255.06	25.51	25.51	25.92
C	**Religious Places**				
1	Vishnu Prayag	178.64	17.86	17.86	19.24
2	Joshimath	181.58	18.16	18.16	19.56
3	Uttarkashi	123.93	12.39	12.39	3.81
4	Nand Prayag	254.51	25.45	25.45	25.69
5	Karan Prayag	303.06	30.31	30.31	66.82
6	Rudra Prayag	395.38	39.54	39.54	71.70
7	Srinagar	524.19	52.42	52.42	93.69
8	Devprayag	647.10	64.71	64.71	127.73

Table 7.14 Environmental Flow Assessment based on EMC-FDC Approach

S. No.	HEP Site	MAF (cumec)	EMC (biotic)	Discharge (cumec)	(%) of MAF
A	**Bhagirathi River**				
1	Asiganga III-UDHP	5.29	B	2.18	41.30

S. No.	HEP Site	MAF (cumec)	EMC (biotic)	Discharge (cumec)	(%) of MAF
2	Agunda thati	5.48	C	2.63	48.00
3	Bhilangana-III-UDHP	13.74	C	5.50	40.00
4	Bhilangana	52.01	C	21.11	47.60
5	Lohari Nagpala-UDHP	92.27	B	29.25	31.70
6	Maneri bhali I	114.22	C	25.47	22.30
7	Maneri bhali II	122.87	D	14.25	11.60
8	Tehri stage-I	243.41	D	70.10	28.80
9	Koteshwar-UDHP	259.73	D	74.31	27.90
10	Kotlibhel 1A	266.34	D	74.80	28.80
A	**Alaknanda River**				
1	Badrinath	39.69	B	20.68	52.10
2	Birahi Ganga II	8.18	C	3.44	42.10
3	Bhyunder Ganga-UDHP	9.41	B	3.02	32.10
4	Phata Byung SHP	16.82	C	6.27	37.30
5	Rajwakti	19.82	C	8.34	42.10
6	Rishiganga II-	24.51	B	8.80	35.90
7	Singoli Bhatwari LHP	53.57	C	18.00	33.60
8	Alkananda UDHP	41.33	B	14.84	35.90
9	Devsari	19.71	D	6.50	33.00
10	Vishnuprayag	46.24	B	19.84	42.90
11	Tapovan Vishnugad	126.85	C	45.54	35.90
12	Vishnugad Pipalkoti	191.18	C	68.63	35.90
13	Nandaprayag Langrasu	255.06	C	91.57	35.90
C	**Religious Places**				
1	Vishnu Prayag	178.64	C	63.42	35.50
2	Joshimath	181.58	C	64.46	35.50
3	Uttarkashi	123.93	D	14.25	11.50
4	Nand Prayag	254.51	C	89.59	35.20
5	Karan Prayag	303.06	D	90.04	32.80
6	Rudra Prayag	395.38	D	113.87	28.80
7	Srinagar	524.19	D	112.70	21.50
8	Devprayag	647.10	D	186.36	28.80

an acceptable flow. The cross section area and top width at various depth or elevation for each site were computed. Based on the cross section area and top width, the hydraulic mean depths were calculated at various elevation or depth. The relationship between cross section area and HMD were developed for various sites on Alaknanda-Bhagirathi River are shown in Figure 7.14 to Figure 7.17. The HMD and velocity requirement for the survival of the various biotic lives such as macro invertebrates, fish and fish otter are given in Table 7.12. Based on the relationship between HMD and cross section area, the cross section area required for biotic life on various river stretches of HEP sites was computed. The environmental flow in term of minimum flow requirement for survival of macro invertebrates, fish and fish otter was estimated and presented in Table 7.14.

7.3.7.4 Recommendation

In the present study, the various EFA methodologies were used to compute the flow that should be released in the river for environmental purpose. Since, the look up table used in the various countries such as France, USA and UK may be area specific, the same may not used for Indian condition. The minimum flow given by World commission of Dam and 75% of low flow based on Q95 along with the actual minimum required based on EMC-HMD approach may be appropriate. Finally, a range of flows between the maximum and the minimum of the values from these methods/approaches are considered as the range of environmental flows. The summary of results obtained for EFR using various EFA methodologies along with the range of environmental flows is presented in Table 7.16 and the results obtained in term of percentage of MAF for EFR using various methodologies is presented in Table 7.17. To ensure the natural flow variation, the environmental flows should be distributed throughout the year to mimic the natural distribution of stream flow as shown graphically in Fig. 7.18 and Fig. 7.19 for selected sites in Alaknanda and Bhagirathi river basin and presented in Table 7.18 for HP sites on Bhagirathi and Table 7.19 for HP sites on Alaknanda River.

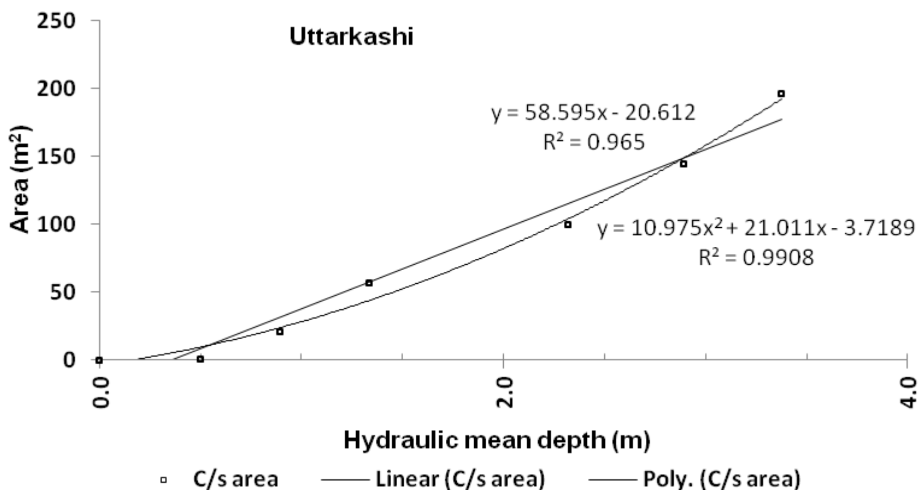


Figure 7.14 Relationship between Cross section area and Hydraulic mean depth at Uttarkashi on Bhagirathi River

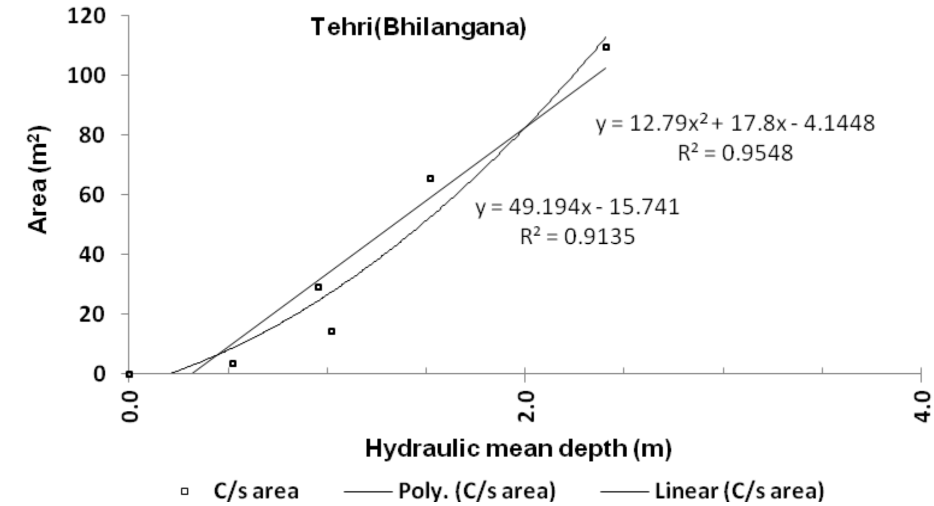


Figure 7.15 Relationship between Cross section area and Hydraulic mean depth at Tehri on Bhilangana River

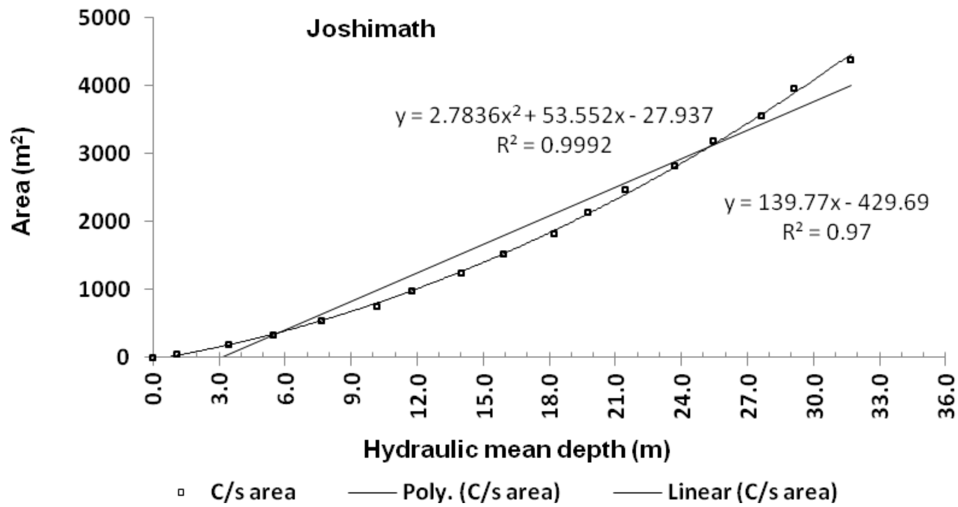


Figure 7.16 Relationship between Cross section area and Hydraulic mean depth at Joshimath on Alkanada River

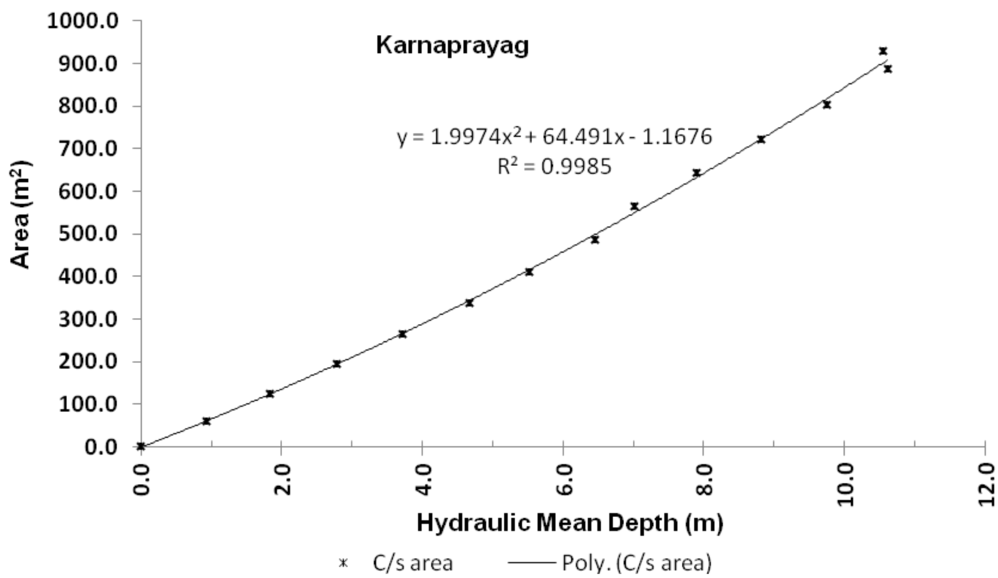


Figure 7.17 Relationship between Cross section area and Hydraulic mean depth at Karnaprayag on AlkanandaRiver

Table 7.15 Environmental flow assessment based on EMC HMD approach

S. No.	HEP Site	HMD (m)	Velocity (m/s)	Cross section area (m^2)	Discharge (cumec)	MAF (cumec)	MAF (%)
A	**Bhagirathi River**						
1	Asiganga III-UDHP	0.15	1.50	0.25	0.38	3.06	12.25
2	Agunda thati	0.15	1.20	0.98	1.18	5.48	21.46
3	Bhilangana-III-UDHP	0.30	1.20	1.95	2.34	19.82	11.81
4	Bhilangana	0.30	1.20	1.95	2.34	31.05	7.54
5	Lohari Nagpala-UDHP	0.15	1.50	3.57	5.36	92.27	5.80
6	Maneri bhali I	0.30	1.20	7.14	8.57	114.22	7.50
7	Maneri bhali II	0.50	1.00	11.09	11.09	122.87	9.03
8	Tehri stage-I	0.50	1.00	36.50	36.50	243.41	15.00
9	Koteshwar-UDHP	0.50	1.00	36.50	36.50	259.73	14.05
10	Kotlibhel 1A	0.50	1.00	36.50	36.50	266.34	13.70
A	**Alaknanda River**						
1	Badrinath	0.15	1.50	5.18	7.77	39.69	19.58
2	Birahi Ganga II	0.15	1.20	1.80	2.16	8.18	26.41
3	Bhyunder Ganga-UDHP	0.15	1.50	1.80	2.70	9.41	28.69
4	Phata Byung SHP	0.30	1.20	3.60	4.32	16.82	25.68
5	Rajwakti	0.30	1.20	3.60	4.32	16.18	26.70
6	Rishiganga II-	0.15	1.50	3.60	5.40	24.51	22.03
7	Singoli Bhatwari LHP	0.30	1.20	4.41	5.29	53.57	9.88
8	Alaknanda UDHP	0.15	1.50	5.18	7.77	41.33	18.80
9	Devsari	0.50	1.00	7.20	7.20	41.89	17.19
10	Vishnuprayag	0.15	1.20	5.48	6.58	68.66	9.58
11	Tapovan Vishnugad	0.30	1.20	10.35	12.42	103.40	12.01
12	Vishnugad Pipalkoti	0.30	1.20	18.34	22.01	205.30	6.05

S. No.	HEP Site	HMD (m)	Velocity (m/s)	Cross section area (m^2)	Discharge (cumec)	MAF (cumec)	MAF (%)
13	Nandaprayag Langrasu	0.30	1.20	22.03	26.44	255.06	10.36
C	**Regional Places**						
1	Vishnu Prayag	0.80	1.20	16.96	20.35	178.64	22.57
2	Joshimath	0.80	1.20	16.96	20.35	181.58	22.21
3	Uttarkashi	0.80	1.00	19.04	19.04	123.93	15.36
4	Nand Prayag	0.80	1.20	22.50	27.00	254.51	24.14
5	Karan Prayag	0.80	1.00	28.40	28.40	303.06	16.89
6	Rudra Prayag	1.20	1.00	31.02	31.02	395.38	7.85
7	Srinagar	1.20	1.00	49.80	49.80	524.19	9.50
8	Devprayag	1.20	1.00	49.80	49.80	647.10	7.70

Table 7.16 Summary of results obtained for EFR using various EFA methodologies

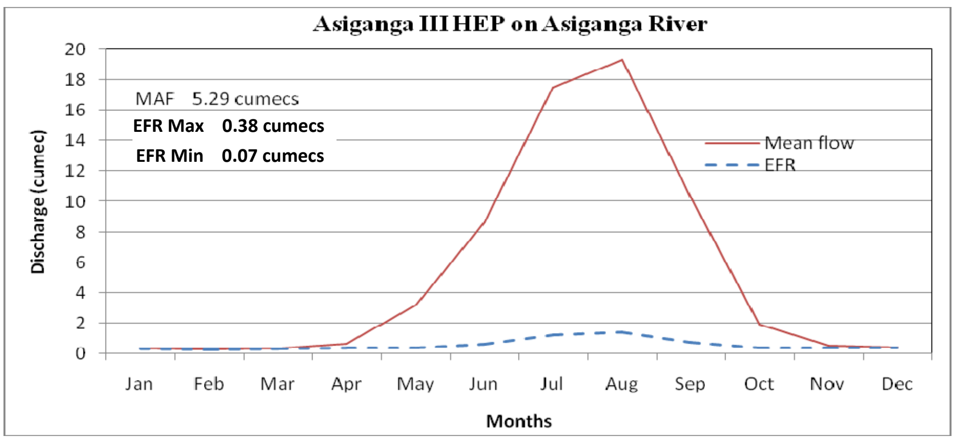
S. No.	HEP Site	Catchment Area(km^2)	MAF (cumec)	WCD (cumec)	FRANCE (cumec)	75% of Q95 (cumec)	EMC-HMD (cumec)	Range of EFR	
								Minimum (cumec)	Maximum (cumec)
Bhagirathi River									
1	Asiganga III-UDHP	110	3.06	0.31	0.31	0.07	0.38	0.07	0.38
2	Agunda thati	121	5.48	0.55	0.14	0.88	1.18	0.14	1.18
3	Bhilangana-III-UDHP	587	19.82	1.98	1.98	2.99	2.34	1.98	2.99
4	Bhilangana	696	31.05	3.11	1.24	5.03	2.34	1.04	5.03
5	Lohari Nagpala-UDHP	3316	92.27	9.23	9.23	2.08	5.36	2.08	5.36
6	Maneri bhali I	4105	114.22	11.42	2.86	2.57	8.57	2.57	8.57
7	Maneri bhali II	4416	122.87	12.29	3.07	2.76	11.09	2.76	11.09
8	Tehri stage-I	7511	243.41	24.34	6.09	36.72	36.50	6.09	36.72
9	Koteshwar-UDHP	7691	259.73	25.97	25.97	39.18	36.50	25.097	39.18
10	Kotlibhel 1A Bhagirathi	7887	266.34	26.63	26.63	40.18	36.50	26.63	40.18
Alaknanda River									
1	Badrinath	970	39.69	3.97	0.99	3.02	7.77	0.99	7.77
2	Birahi Ganga II	225	8.18	0.82	0.82	1.33	2.16	0.82	2.16
3	Bhyunder Ganga-UDHP	230	9.41	0.94	0.94	0.72	2.70	0.72	2.70
4	Phata Byung SHP	247	16.82	1.68	1.68	2.07	4.32	1.68	4.32
5	Rajwakti	545	16.18	1.62	1.62	2.63	4.32	1.62	4.32
6	Rishiganga II-	680	24.51	2.45	2.45	1.87	5.40	1.87	5.40
7	Singoli Bhatwari LHP	963	53.57	5.36	5.36	5.33	5.29	5.33	5.33
8	Alkananda UDHP	1010	41.33	4.13	4.13	3.15	7.77	4.13	7.77
9	Devsari	1138	41.89	4.19	1.05	6.92	7.20	1.05	7.20
10	Vishnuprayag	1130	46.24	4.62	1.16	5.24	6.58	1.16	6.58
11	Tapovan Vishnugad	2527	103.4	10.34	10.34	7.88	12.42	7.88	12.42
12	Vishnugad Pipalkoti	5017	205.3	20.53	20.53	15.65	22.01	15.65	22.01

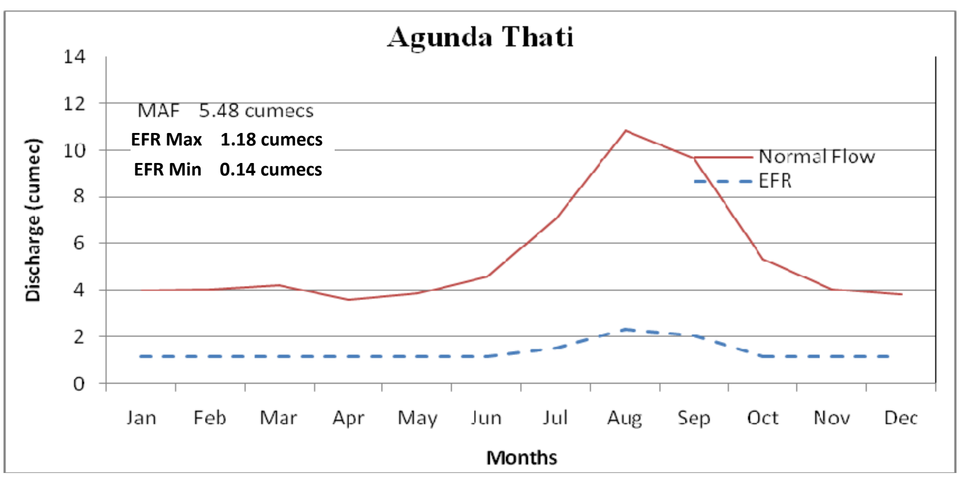
S. No.	HEP Site	Catchment Area(km²)	MAF (cumec)	WCD (cumec)	FRANCE (cumec)	75% of Q95 (cumec)	EMC-HMD (cumec)	Range of EFR	
								Minimum (cumec)	Maximum (cumec)
13	Nandaprayag Langrasu	6233	255.06	25.51	25.51	19.44	26.44	19.44	26.44
	Religious Places								
1	Vishnu Prayag	4435	178.64	17.86	17.86	14.43	20.35	14.43	20.35
2	Joshimath	4508	181.58	18.16	18.16	14.67	20.35	14.67	20.35
3	Uttarkashi	4555	123.93	12.39	12.39	2.86	19.04	2.86	19.04
4	Nand Prayag	6200	254.51	25.45	25.45	19.27	27.00	19.27	27.00
5	Karan Prayag	8460	303.06	30.31	30.31	50.12	28.40	30.31	50.12
6	Rudra Prayag	10675	395.38	39.54	39.54	53.78	31.02	31.02	53.78
7	Srinagar	11332	524.19	52.42	52.42	70.27	49.80	49.80	70.27
8	Devprayag	19600	647.1	64.71	64.71	95.80	49.80	49.80	95.80

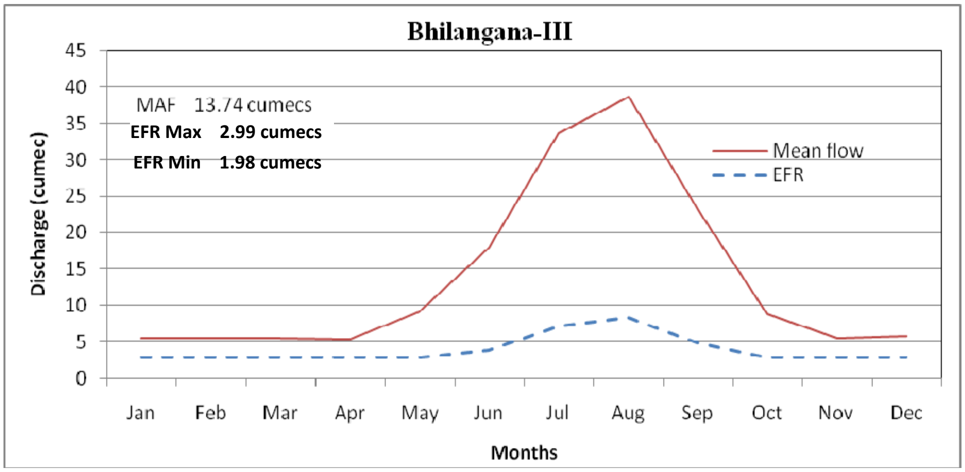
Table 7.17 Summary of results obtained for EFR using various EFA methodologies (as Percentage of MAF)

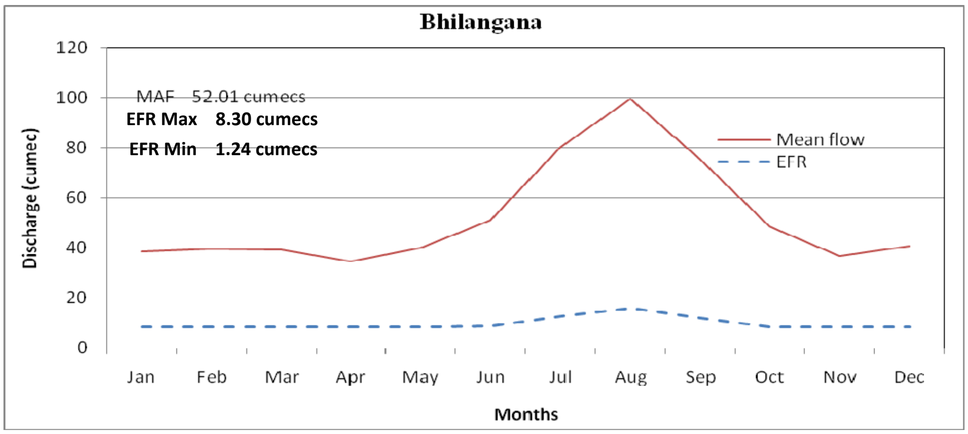
S. No.	HEP Site	Catchment Area(km²)	MAF (cumec)	WCD (%)	FRANCE	75% of Q95 (%)	EMC-HMD (%)	Range of EFR	
								Maximum (%)	Maximum (%)
	Bhagirathi River								
1	Asiganga III-UDHP	110	3.06	10.00	10.00	2.21	12.25	2.21	12.25
2	Agunda thati	121	5.48	10.00	2.5	16.01	21.46	2.5	21.46
3	Bhilangana-III-UDHP	587	19.82	10.00	10.00	15.10	11.81	10.00	15.10
4	Bhilangana	696	31.05	10.00	2.5	16.18	7.54	2.5	16.18
5	Lohari Nagpala-UDHP	3316	92.27	10.00	10.00	2.25	5.80	2.25	5.80
6	Maneri bhali I	4105	114.22	10.00	2.5	2.25	7.50	2.25	7.50
7	Maneri bhali II	4416	122.87	10.00	2.5	2.25	9.03	2.25	9.03
8	Tehri stage-I	7511	243.41	10.00	2.5	15.09	15.00	2.5	15.09
9	Koteshwar-UDHP	7691	259.73	10.00	10.00	15.08	14.05	10.00	15.08
10	Kotlibhel 1A bhagirathi	7887	266.34	10.00	10.00	15.09	13.70	10.00	15.09
Alkananda River									
1	Badrinath	970	39.69	10.00	2.5	7.62	19.58	2.5	19.58
2	Birahi Ganga II	225	8.18	10.00	10.00	16.23	26.41	10.00	26.41
3	Bhyunder Ganga-UDHP	230	9.41	10.00	10.00	7.65	28.69	10.00	28.69
4	Phata Byung	247	16.82	10.00	10.00	12.31	25.68	10.00	25.68
5	Rajwakti	545	16.18	10.00	10.00	16.22	26.70	10.00	26.70
6	Rishiganga II	680	24.51	10.00	10.00	7.62	22.03	10.00	22.03
7	Singoli Bhatwari	963	53.57	10.00	10.00	9.94	9.88	9.88	9.94
8	Alkananda	1010	41.33	10.00	10.00	7.62	18.80	7.62	18.80
9	Devsari	1138	41.89	10.00	2.5	16.53	17.19	2.5	17.19
10	Vishnuprayag	1130	68.66	10.00	2.5	7.62	9.58	2.5	9.58
11	Tapovan Vishnug	2527	103.4	10.00	10.00	7.62	12.01	7.62	12.01

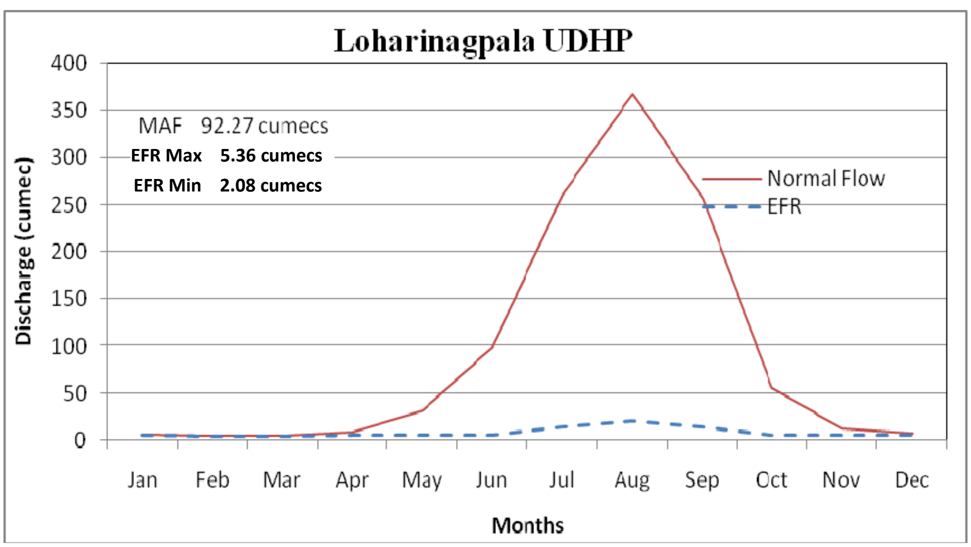
S. No.	HEP Site	Catchment Area(km²)	MAF (cumec)	WCD (%)	FRANCE	75% of Q95 (%)	EMC-HMD (%)	Range of EFR	
								Maximum (%)	Maximum (%)
12	Vishnugad Pipalkoti	5017	205.3	10.00	10.00	7.62	10.72	7.62	10.72
13	Nandaprayag Langrasu	6233	255.06	10.00	10.00	7.62	10.36	7.62	10.36
Religious Places									
1	Vishnu Prayag	4435	178.64	10.00	10.00	8.08	11.39	8.08	11.39
2	Joshimath	4508	181.58	10.00	10.00	8.08	11.21	8.08	11.21
3	Uttarkashi	4555	123.93	10.00	10.00	2.31	15.36	2.31	15.36
4	Nand Prayag	6200	254.51	10.00	10.00	7.57	10.61	7.57	10.61
5	Karan Prayag	8460	303.06	10.00	10.00	16.54	9.37	10.00	16.54
6	Rudra Prayag	10675	395.38	10.00	10.00	13.60	7.85	10.00	13.60
7	Srinagar	11332	524.19	10.00	10.00	13.40	9.50	10.00	13.40
8	Devprayag	19600	647.10	10.00	10.00	14.80	7.70	10.00	14.80

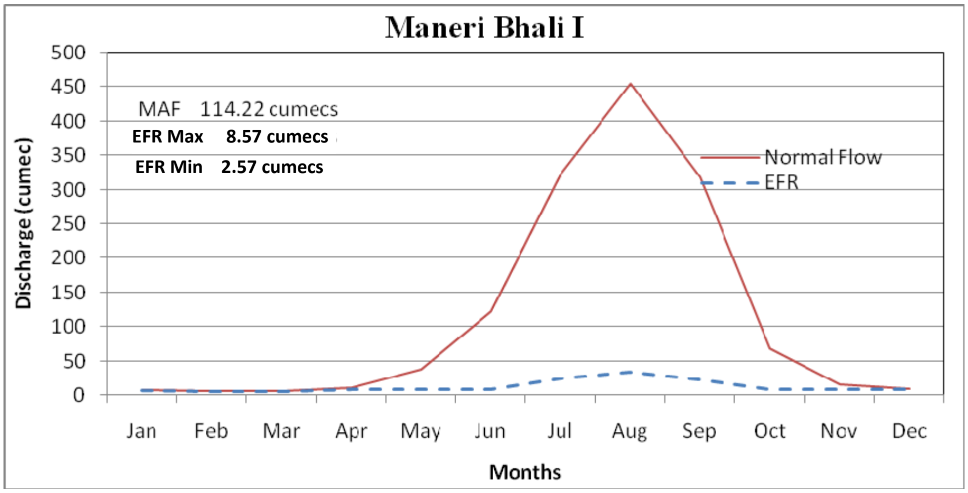


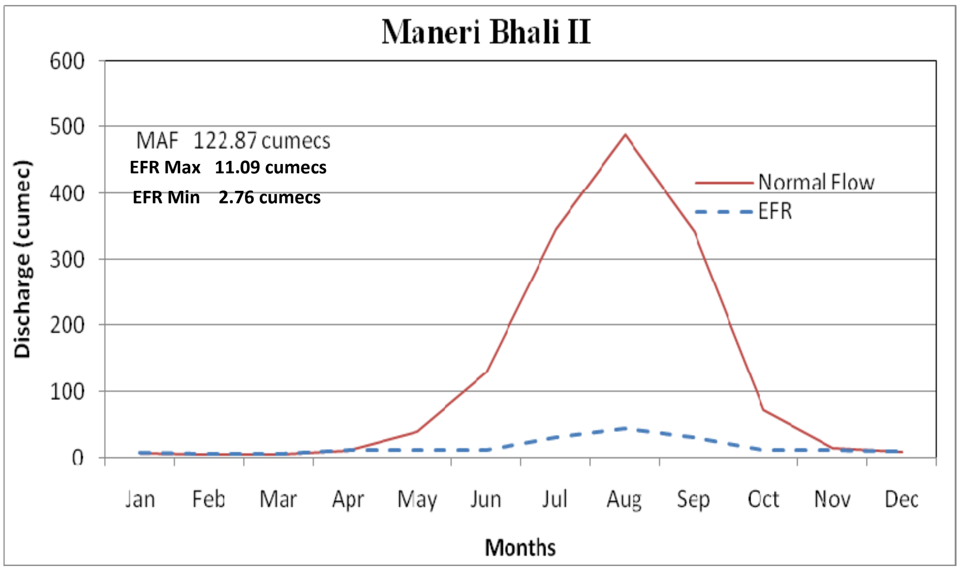


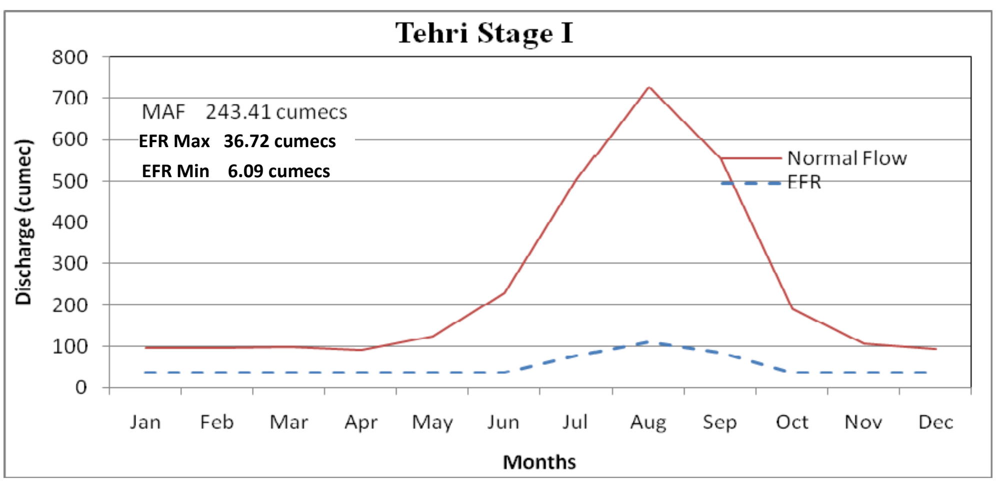

Bhilangana-III
MAF 13.74 cumecs
EFR Max 2.99 cumecs
EFR Min 1.98 cumecs
Mean flow
EFR
Discharge (cumec)
Months
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

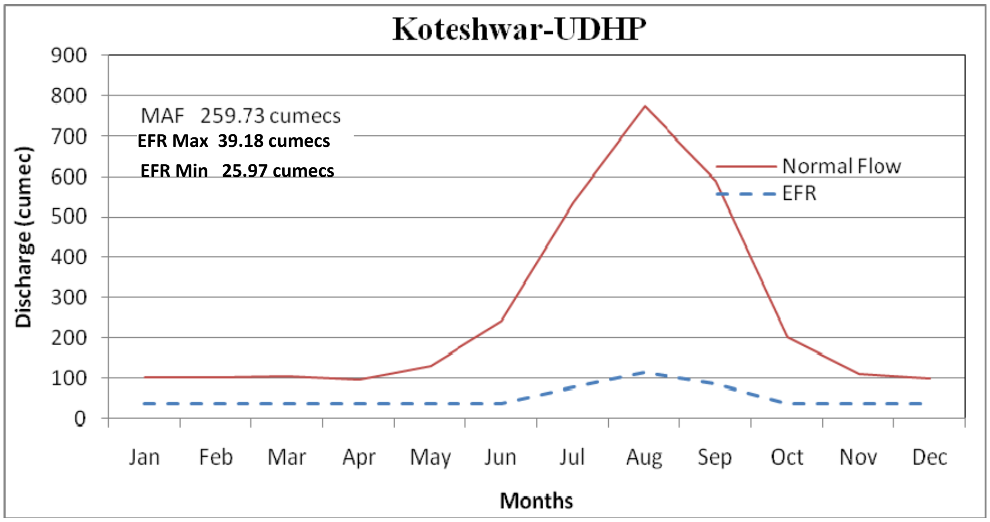

Bhilangana
MAF 52.01 cumecs
EFR Max 8.30 cumecs
EFR Min 1.24 cumecs
Mean flow
EFR
Discharge (cumec)
Months
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec


Loharinagpala UDHP
MAF 92.27 cumecs
EFR Max 5.36 cumecs
EFR Min 2.08 cumecs
Normal Flow
EFR
Discharge (cumec)
Months
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec


Maneri Bhali I
MAF 114.22 cumecs
EFR Max 8.57 cumecs
EFR Min 2.57 cumecs
Normal Flow
EFR
Discharge (cumec)
500
450
400
350
300
250
200
150
100
50
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months


Maneri Bhali II
MAF 122.87 cumecs
EFR Max 11.09 cumecs
EFR Min 2.76 cumecs
Normal Flow
EFR
Discharge (cumec)
600
500
400
300
200
100
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months


Tehri Stage I
MAF 243.41 cumecs
EFR Max 36.72 cumecs
EFR Min 6.09 cumecs
Normal Flow
EFR
Discharge (cumec)
800
700
600
500
400
300
200
100
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months



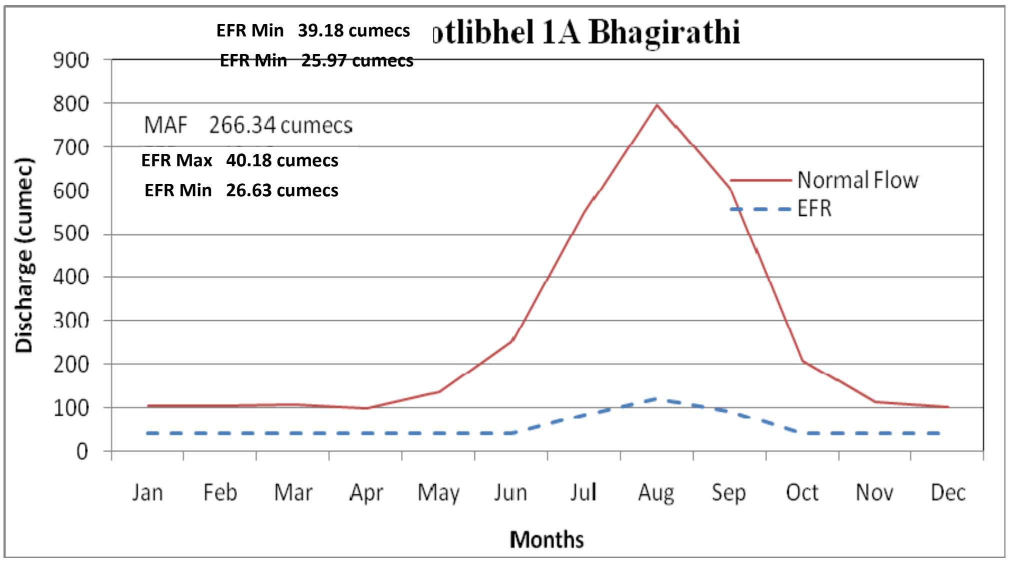
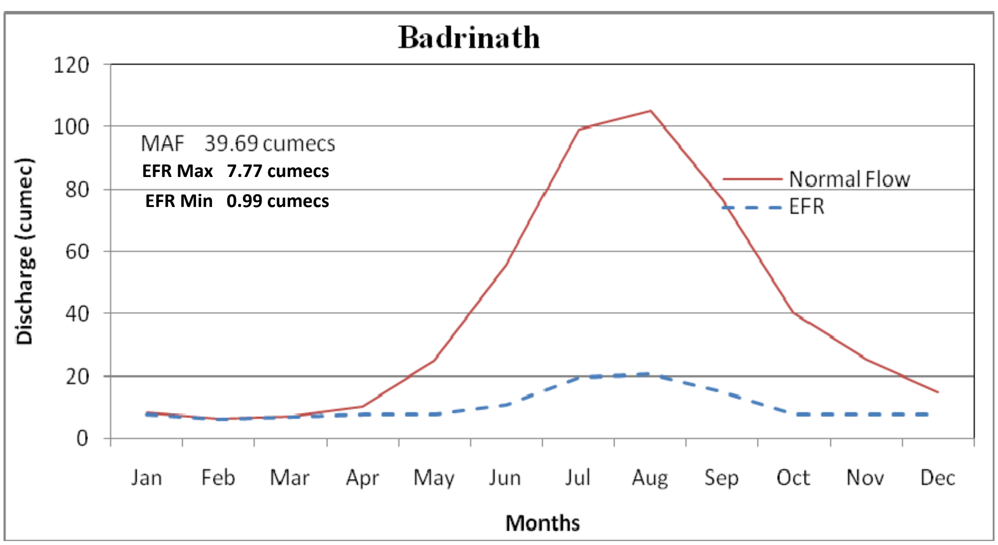
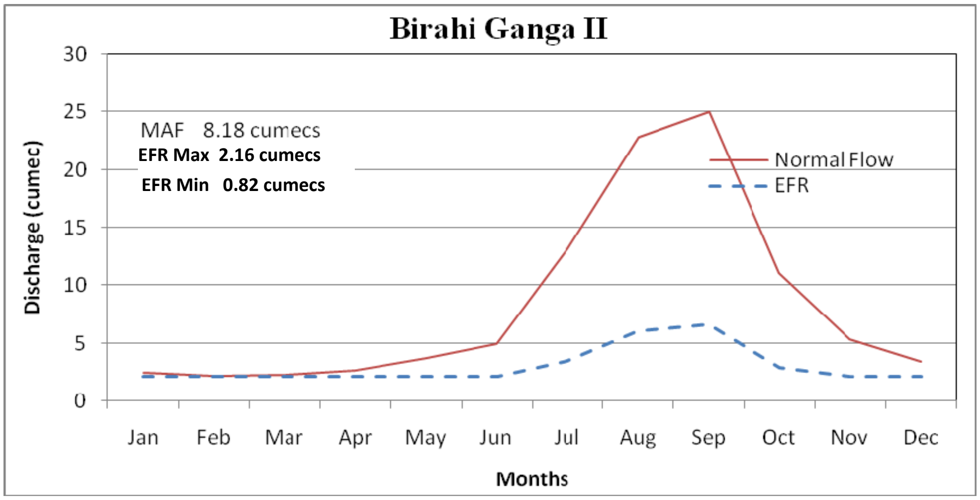
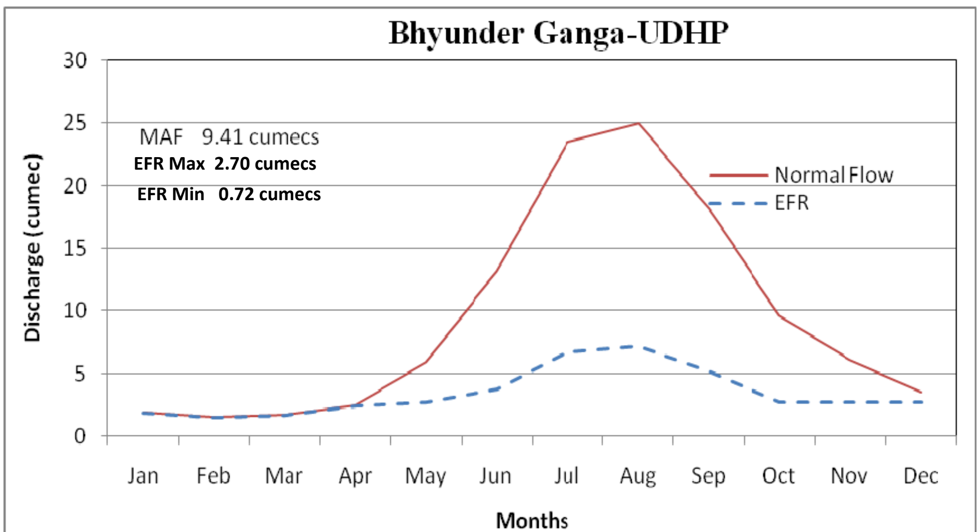
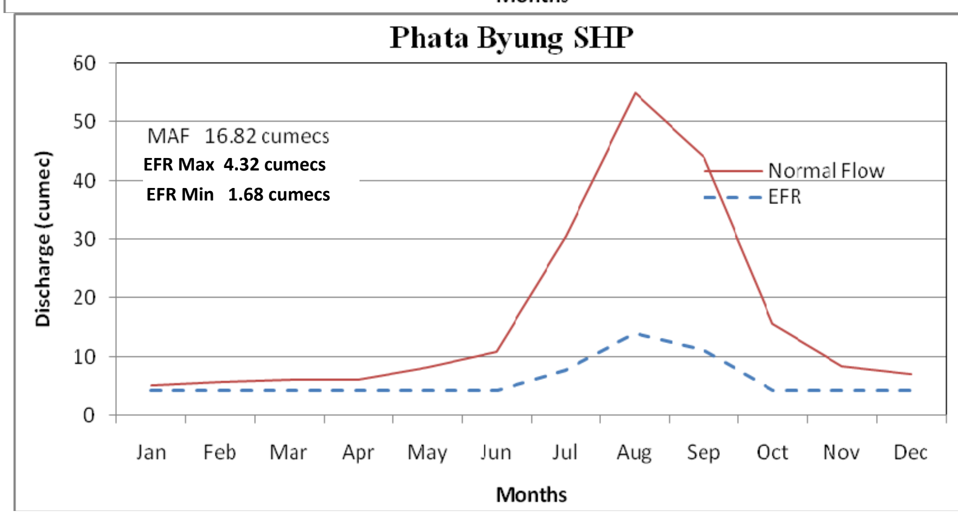


Fig. 7.18 EFR and average 10-daily flow for HEP Sites in Bhagirathi Basin

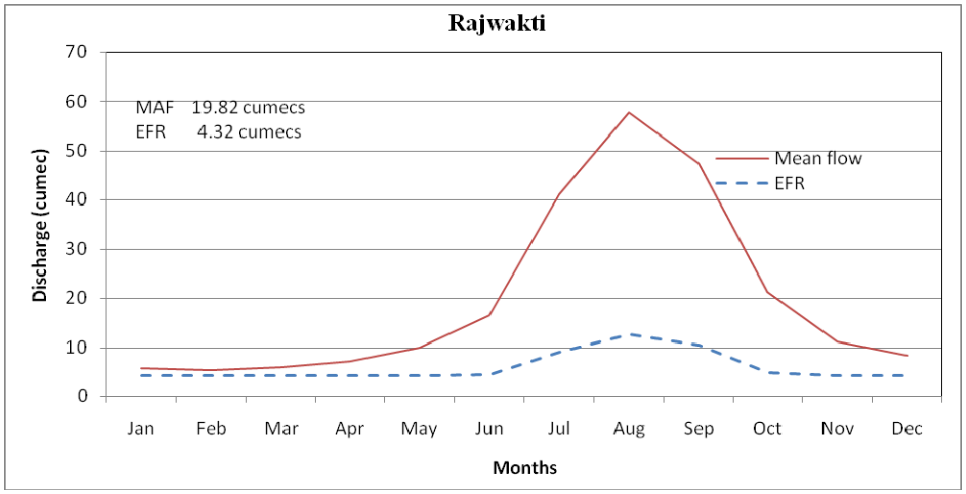


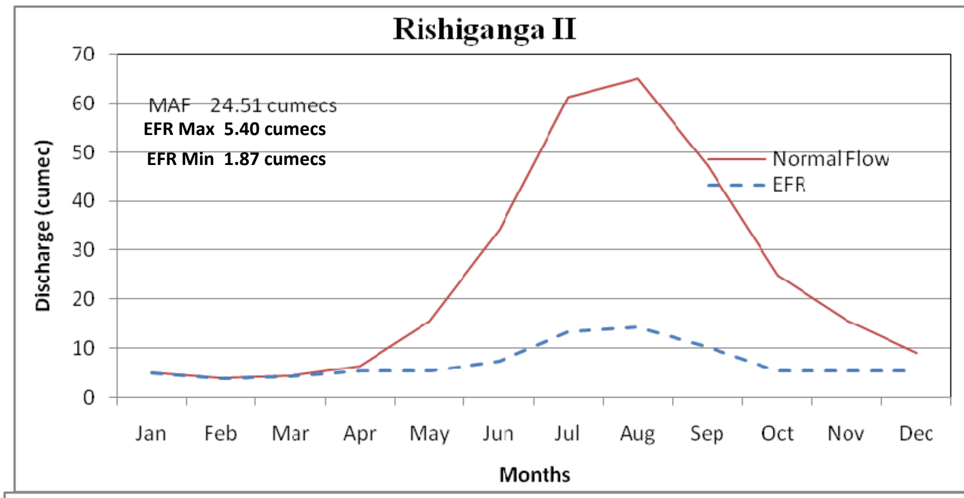


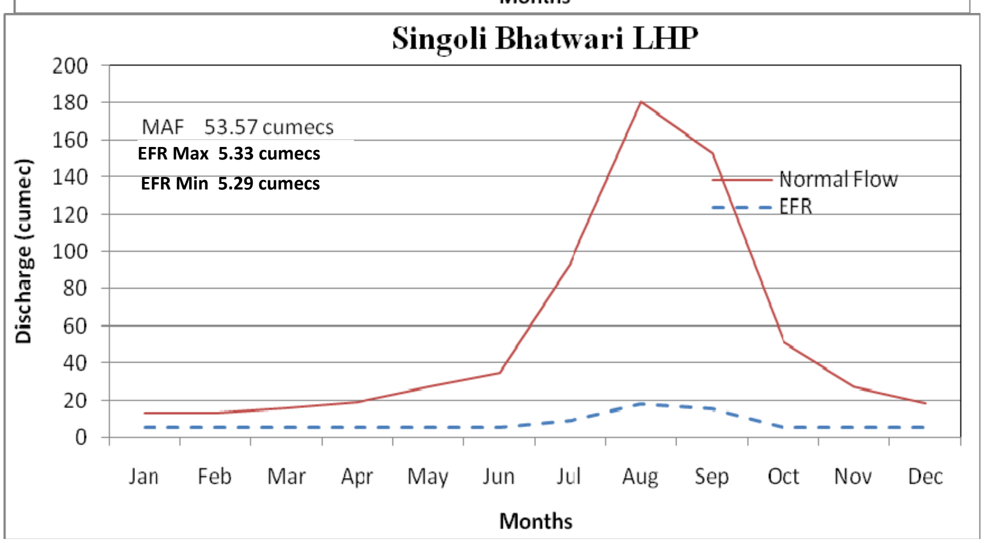


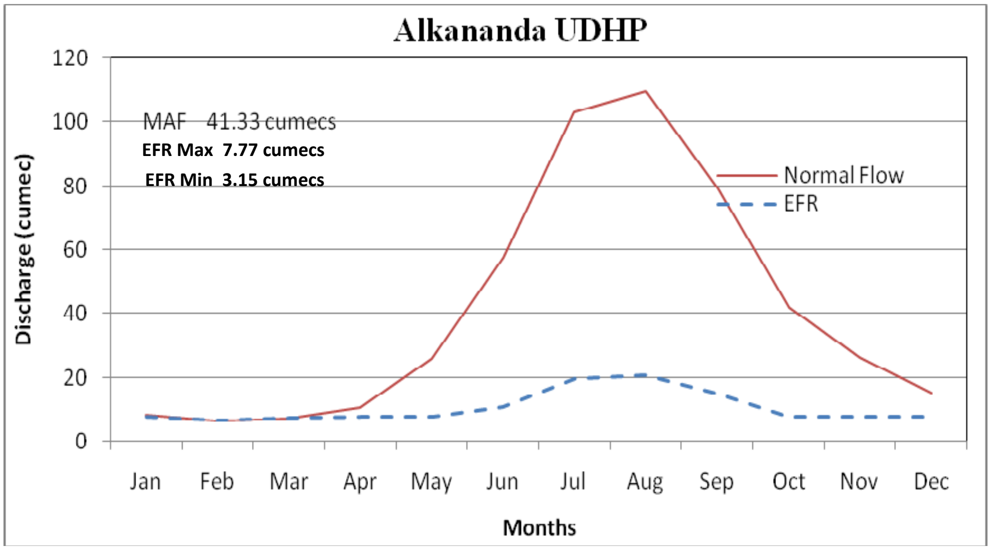


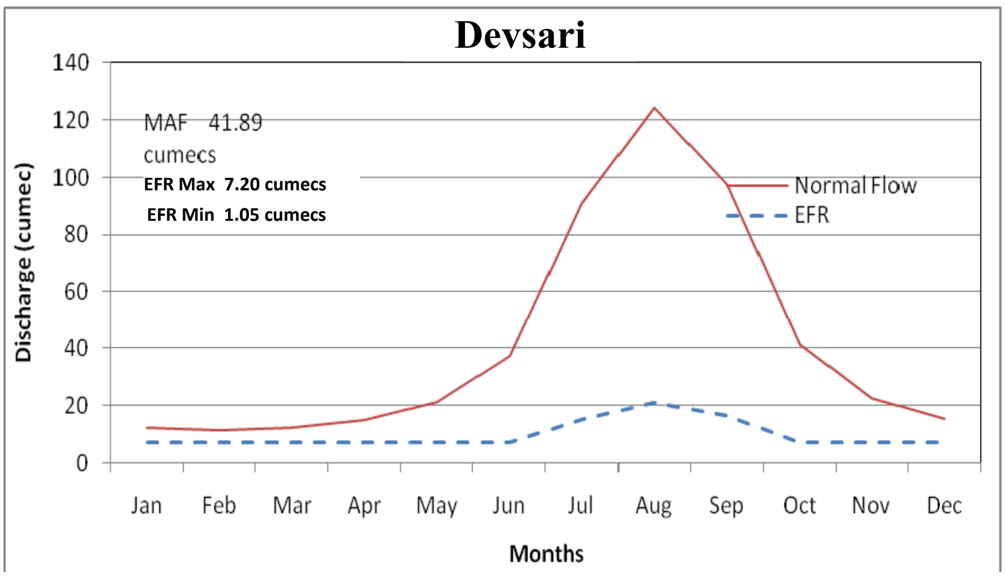
EFR Max 4.32 cumecs
EFR Min 1.62 cumecs

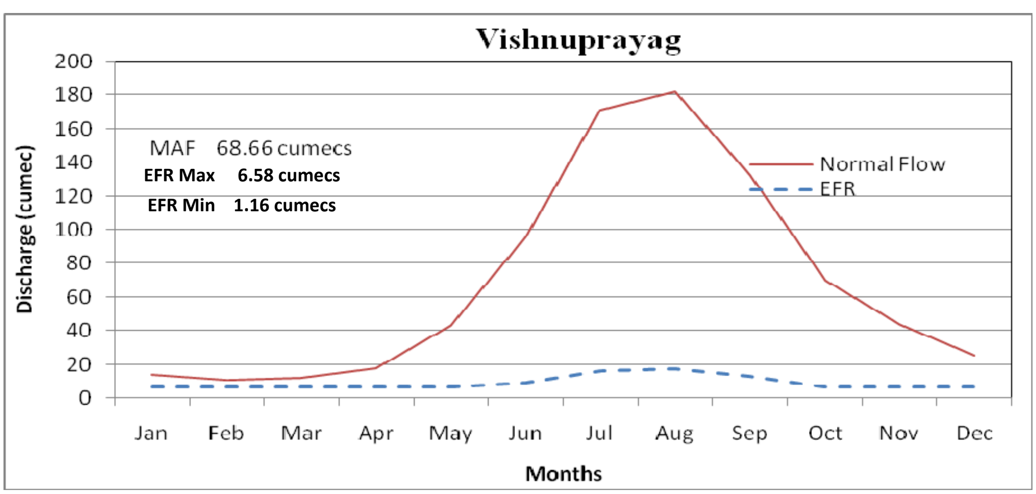

Rajwakti
MAF 19.82 cumecs
EFR 4.32 cumecs
Mean flow
EFR
Discharge (cumec)
70
60
50
40
30
20
10
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months


Rishiganga II
MAF 24.51 cumecs
EFR Max 5.40 cumecs
EFR Min 1.87 cumecs
Normal Flow
EFR
Discharge (cumec)
70
60
50
40
30
20
10
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months


Singoli Bhatwari LHP
MAF 53.57 cumecs
EFR Max 5.33 cumecs
EFR Min 5.29 cumecs
Normal Flow
EFR
Discharge (cumec)
200
180
160
140
120
100
80
60
40
20
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months


Alkananda UDHP
MAF 41.33 cumecs
EFR Max 7.77 cumecs
EFR Min 3.15 cumecs
Normal Flow
EFR
Discharge (cumec)
120
100
80
60
40
20
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Months


Devsari
MAF 41.89 cumecs
EFR Max 7.20 cumecs
EFR Min 1.05 cumecs
Normal Flow
EFR
Discharge (cumec)
140
120
100
80
60
40
20
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Months


Vishnuprayag
MAF 68.66 cumecs
EFR Max 6.58 cumecs
EFR Min 1.16 cumecs
Normal Flow
EFR
Discharge (cumec)
200
180
160
140
120
100
80
60
40
20
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Months

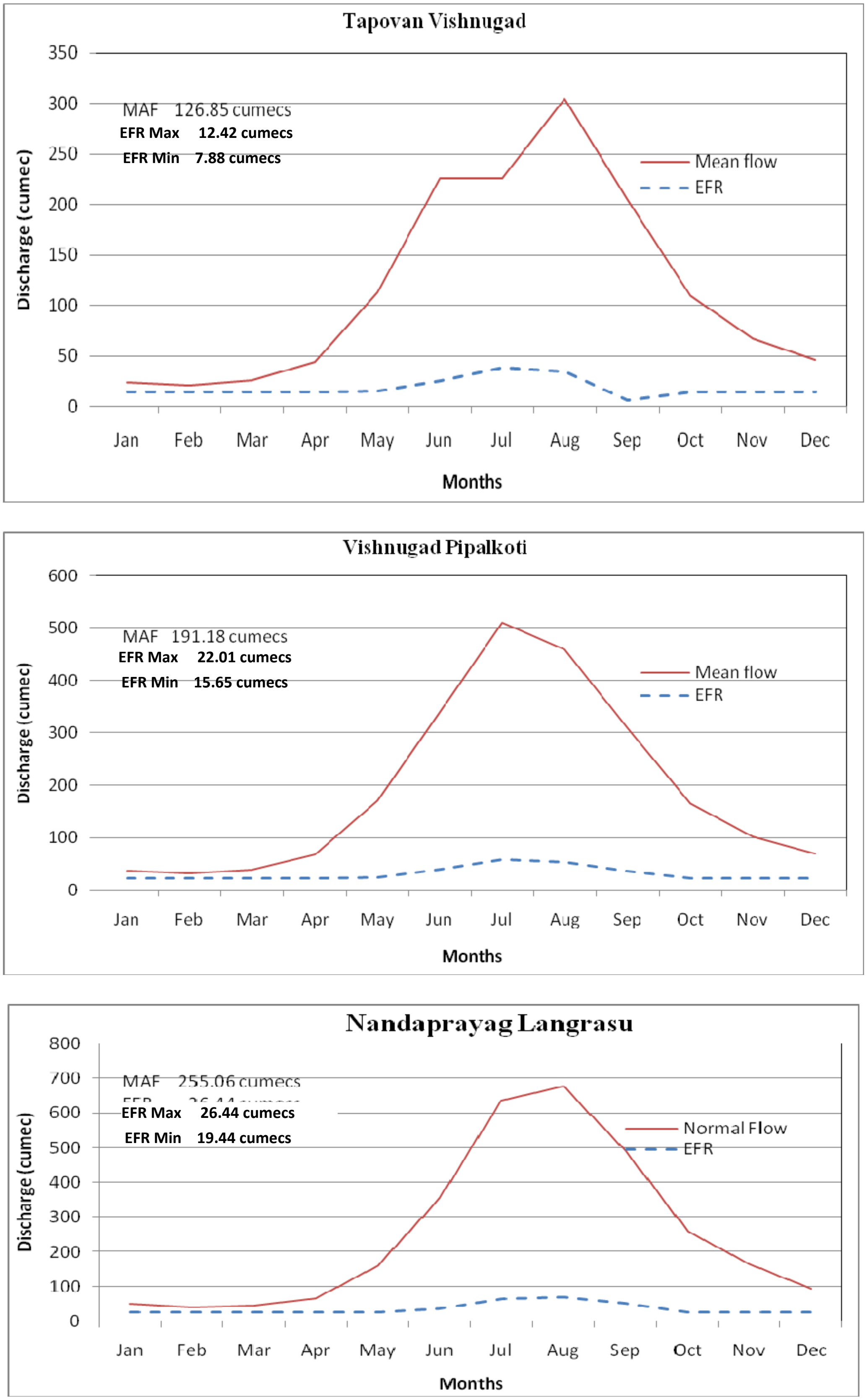


Fig. 7.19 EFR and average 10-daily flow for HEP Sites in Alaknanda basin

Table 7.18 Ten daily variation of Environmental Flows for Bhagirathi River

Months		1 Asiganga III	2 Agunda thati	3 Bhilangana-III	4 Bhilangana	5 Lohari Nagpala	6 Maneri Bhali I	7 Maneri Bhali II	8 Tehri Stage-I	9 Koteshwar	10 Kotlibhel 1A
	MAF-----→	5.29	5.48	13.74	52.01	92.27	114.22	122.87	243.41	259.73	266.34
	EFR-----→	0.38	1.18	2.99	5.03	5.36	8.57	11.09	36.72	39.18	40.18
Jan	I	0.34	1.18	2.99	8.30	5.36	7.28	7.83	36.72	39.18	40.18
	II	0.33	1.18	2.99	8.30	5.36	7.15	7.69	36.72	39.18	40.18
	III	0.33	1.18	2.99	8.30	5.36	7.17	7.72	36.72	39.18	40.18
Feb	I	0.29	1.18	2.99	8.30	5.03	6.23	6.70	36.72	39.18	40.18
	II	0.27	1.18	2.99	8.30	4.79	5.93	6.37	36.72	39.18	40.18
	III	0.27	1.18	2.99	8.30	4.78	5.92	6.37	36.72	39.18	40.18
Mar	I	0.26	1.18	2.99	8.30	4.59	5.69	6.12	36.72	39.18	40.18
	II	0.32	1.18	2.99	8.30	5.36	6.87	7.39	36.72	39.18	40.18
	III	0.38	1.18	2.99	8.30	5.36	8.57	9.91	36.72	39.18	40.18
Apr	I	0.38	1.18	2.99	8.30	5.36	8.57	11.09	36.72	39.18	40.18
	II	0.38	1.18	2.99	8.30	5.36	8.57	11.09	36.72	39.18	40.18
	III	0.38	1.18	2.99	8.30	5.36	8.57	11.09	36.72	39.18	40.18
May	I	0.38	1.18	2.99	8.30	5.36	8.57	11.09	36.72	39.18	40.18
	II	0.38	1.18	2.99	8.30	5.36	8.57	11.09	36.72	39.18	40.18
	III	0.38	1.18	2.99	8.30	5.36	8.57	11.09	36.72	39.18	40.18
Jun	I	0.40	1.18	2.99	8.30	5.71	9.13	11.82	36.72	39.18	40.18
	II	0.62	1.18	3.90	8.30	8.73	13.97	18.08	47.87	51.08	52.38
	III	0.84	1.31	5.02	9.28	11.78	18.85	24.39	61.61	65.74	67.41
Jul	I	1.07	1.52	6.18	10.74	15.10	24.16	31.27	75.90	80.98	83.05
	II	1.27	1.94	7.61	13.70	17.97	28.76	37.23	93.48	99.74	102.28
	III	1.43	1.99	8.20	14.03	20.14	32.22	41.71	100.64	107.38	110.12
Aug	I	1.51	2.32	8.95	16.37	21.31	34.09	44.13	109.83	117.19	120.17
	II	1.40	2.34	8.60	16.56	19.80	31.68	41.01	105.55	112.62	115.49
	III	1.26	2.10	7.68	14.81	17.71	28.34	36.68	94.27	100.58	103.15
Sept	I	1.06	2.07	6.81	14.63	14.88	23.82	30.83	83.60	89.20	91.47
	II	0.70	1.69	4.88	11.94	9.83	15.73	20.36	59.95	63.96	65.59
	III	0.45	1.34	3.48	9.47	6.40	10.24	13.26	42.71	45.57	46.73

		1	2	3	4	5	6	7	8	9	10
Months		**Asiganga III**	**Agunda thati**	**Bhilangana-III**	**Bhilangana**	**Lohari Nagpala**	**Maneri Bhali I**	**Maneri Bhali II**	**Tehri Stage-I**	**Koteshwar**	**Kotlibhel 1A**
Oct	I	0.38	1.18	2.99	8.30	5.36	8.57	11.09	36.72	39.18	40.18
	II	0.38	1.18	2.99	8.30	5.36	8.57	11.09	36.72	39.18	40.18
	III	0.38	1.18	2.99	8.30	5.36	8.57	11.09	36.72	39.18	40.18
Nov	I	0.38	1.18	2.99	8.30	5.36	8.57	11.09	36.72	39.18	40.18
	II	0.38	1.18	2.99	8.30	5.36	8.57	11.09	36.72	39.18	40.18
	III	0.38	1.18	2.99	8.30	5.36	8.57	10.04	36.72	39.18	40.18
Dec	I	0.38	1.18	2.99	8.30	5.36	8.50	9.14	36.72	39.18	40.18
	II	0.35	1.18	2.99	8.30	5.36	7.64	8.21	36.72	39.18	40.18
	III	0.38	1.18	2.99	8.30	5.36	8.57	10.01	36.72	39.18	40.18

Table 7.19 Ten daily variations of Environmental Flows for Selected Sites on Alaknanda River

		1	2	3	4	5	6	7	8	9	10	11	12	13
Months		**Badri nath**	**Birahi Ganga II**	**Bhyunder Ganga**	**Phata Byung**	**Rajwakti**	**Rishiganga II**	**Singoli Bhatwari**	**Alkananda**	**Devsa ri**	**Vishnu prayag**	**Tapovan Vishnugad**	**Vishnugad Pipalkoti**	**Nandaprayag Langrasu**
	MAF------->	39.69	8.18	9.41	16.82	19.82	24.51	53.57	41.33	19.71	68.66	126.85	191.18	255.06
	EFR------→	7.77	2.16	2.70	4.32	4.32	5.40	5.33	7.77	7.20	6.58	14.57	22.01	26.44
Jan	I	7.77	2.16	1.93	4.32	4.32	5.03	5.33	7.77	7.20	6.58	14.57	22.01	26.44
	II	7.53	2.16	1.79	4.32	4.32	4.65	5.33	7.77	7.20	6.58	14.57	22.01	26.44
	III	6.84	2.16	1.62	4.32	4.32	4.22	5.33	7.12	7.20	6.58	14.57	22.01	26.44
Feb	I	6.39	2.16	1.51	4.32	4.32	3.94	5.33	6.65	7.20	6.58	14.57	22.01	26.44
	II	6.39	2.16	1.52	4.32	4.32	3.95	5.33	6.66	15.50	6.58	14.57	22.01	26.44
	III	6.66	2.16	1.58	4.32	4.32	4.11	5.33	6.93	20.89	6.58	14.57	22.01	26.44
Mar	I	7.16	2.16	1.70	4.32	4.32	4.42	5.33	7.45	14.45	6.58	14.57	22.01	26.44
	II	7.77	2.16	1.86	4.32	4.32	4.85	5.33	7.77	7.20	6.58	14.57	22.01	26.44
	III	7.77	2.16	2.08	4.32	4.32	5.40	5.33	7.77	7.20	6.58	14.57	22.01	26.44
Apr	I	7.77	2.16	2.45	4.32	4.32	5.40	5.33	7.77	7.20	6.58	14.57	22.01	26.44
	II	7.77	2.16	2.70	4.32	4.32	5.40	5.33	7.77	7.20	6.58	14.57	22.01	26.44
	III	7.77	2.16	2.70	4.32	4.32	5.40	5.33	7.77	7.20	6.58	14.57	22.01	26.44
May	I	7.77	2.16	2.70	4.32	4.32	5.40	5.33	7.77	7.20	6.58	14.57	22.01	26.44
	II	7.77	2.16	2.70	4.32	4.32	5.40	5.33	7.77	7.20	6.58	14.57	22.01	26.44
	III	9.00	2.16	3.13	4.32	4.32	6.26	5.33	9.00	7.20	7.62	16.88	25.50	30.63
Jun	I	10.87	2.16	3.78	4.32	4.32	7.56	5.33	10.87	7.20	9.20	20.39	30.79	36.99
	II	13.60	2.16	4.73	4.32	4.32	9.45	5.33	13.60	14.31	11.51	25.51	38.53	46.28
	III	16.92	2.35	5.88	5.33	4.70	11.76	6.37	16.92	23.74	14.32	31.73	47.92	57.57
Jul	I	19.40	3.49	6.74	7.84	6.98	13.48	9.29	19.40	16.30	16.42	36.37	54.94	66.00
	II	21.03	4.39	7.31	10.67	8.78	14.61	13.10	21.03	7.59	17.80	39.43	59.56	71.54
	III	21.75	5.54	7.56	12.15	11.08	15.12	15.47	21.75	7.20	18.41	40.79	61.61	74.00

		1	2	3	4	5	6	7	8	9	10	11	12	13
Months		**Badri nath**	**Birahi Ganga II**	**Bhyunder Ganga**	**Phata Byung**	**Rajwakti**	**Rishiganga II**	**Singoli Bhatwari**	**Alkananda**	**Devsa ri**	**Vishnu prayag**	**Tapovan Vishnugad**	**Vishnugad Pipalkoti**	**Nandaprayag Langrasu**
Aug	I	20.62	6.03	7.17	14.10	12.06	14.33	17.98	20.62	7.20	17.45	38.67	58.41	70.16
	II	18.34	6.26	6.37	14.03	12.51	12.74	18.43	18.34	7.20	15.52	34.38	51.94	62.39
	III	16.94	6.59	5.89	12.66	13.18	11.77	16.60	16.94	7.20	14.34	31.77	47.98	57.64
Sept	I	14.98	6.60	5.20	11.28	13.19	10.41	15.16	14.98	7.20	12.68	28.08	42.42	50.95
	II	12.56	4.97	4.36	7.71	9.93	8.73	10.57	12.56	7.20	10.63	23.55	35.57	42.73
	III	10.24	3.93	3.56	5.84	7.85	7.11	7.41	10.23	7.20	8.66	19.19	28.99	34.82
Oct	I	7.92	2.93	2.75	4.32	5.86	5.50	5.33	7.92	7.20	6.70	14.84	22.42	26.93
	II	7.77	2.18	2.70	4.32	4.36	5.40	5.33	7.77	15.12	6.58	14.57	22.01	26.44
	III	7.77	2.16	2.70	4.32	4.32	5.40	5.33	7.77	18.54	6.58	14.57	22.01	26.44
Nov	I	7.77	2.16	2.70	4.32	4.32	5.40	5.33	7.77	19.64	6.58	14.57	22.01	26.44
	II	7.77	2.16	2.70	4.32	4.32	5.40	5.33	7.77	7.45	6.58	14.57	22.01	26.44
	III	7.77	2.16	2.70	4.32	4.32	5.40	5.33	7.77	7.20	6.58	14.57	22.01	26.44
Dec	I	7.77	2.16	2.70	4.32	4.32	5.40	5.33	7.77	7.20	6.58	14.57	22.01	26.44
	II	7.77	2.16	2.70	4.32	4.32	5.40	5.33	7.77	7.20	6.58	14.57	22.01	26.44
	III	7.77	2.16	2.70	4.32	4.32	5.40	5.33	7.77	7.20	6.58	14.57	22.01	26.44

Table 7.20 Religious Flow Requirement (RFR) and Average monthly flows (cumec) for places of religious importance.

	Vishnuprayag		Joshimath		Uttarkashi		Nandprayag		Karanprayag		Rudraprayag		Srinagar		Devprayag	
Months	EFR	Average Flow	EFR	Normal Flow	EFR	Normal Flow	EFR	Normal Flow	EFR	Normal Flow	EFR	Normal Flow	EFR	Normal Flow	EFR	Normal Flow
Jan	20.35	35.35	20.35	35.94	8.48	8.48	27.00	48.0	47.96	90.0	53.78	95.3	70.27	126.32	95.80	171.34
Feb	20.35	32.98	20.35	33.52	6.67	6.67	27.00	41.4	41.42	84.0	53.78	87.0	70.27	113.74	95.80	162.61
Mar	20.35	36.69	20.35	37.29	8.09	8.09	27.00	50.7	50.12	92.0	53.78	92.5	70.27	117.02	95.80	186.53
Apr	20.35	64.40	20.35	65.46	16.69	16.69	27.00	88.8	50.12	111.4	53.78	128.3	70.27	144.66	95.80	255.80
May	20.35	162.89	20.35	165.57	19.04	78.22	27.00	224.4	50.12	153.8	53.78	263.3	70.27	249.94	95.80	427.28
Jun	37.83	332.09	37.83	337.56	33.42	217.51	47.80	450.5	74.51	269.7	73.36	539.4	70.27	439.45	125.54	847.99
Jul	55.33	485.64	55.32	493.63	65.68	427.53	71.79	676.7	111.92	655.7	144.88	1065.1	150.01	1119.03	253.75	1713.98
Aug	48.18	422.93	48.18	429.89	69.47	452.20	64.54	608.4	100.62	898.7	162.30	1193.2	222.29	1658.27	294.97	1992.42
Sep	31.42	275.77	31.41	280.31	32.97	214.62	43.61	411.1	67.98	704.1	100.13	736.1	183.11	1365.97	176.95	1195.23
Oct	20.35	149.06	20.35	151.52	19.04	37.17	27.00	218.2	50.12	299.5	53.78	272.3	70.27	524.04	95.80	437.10
Nov	20.35	89.04	20.35	90.50	11.79	11.79	27.00	134.6	50.12	163.3	53.78	158.2	70.27	248.50	95.80	247.38
Dec	20.35	56.80	20.35	57.73	8.23	8.23	27.00	98.4	50.12	114.6	53.78	113.8	70.27	168.68	95.80	184.32

7.3.7.5 Religious places

The flow required for social and religious rituals (instream use) at selected sites in the study area are depicted in Fig. 7.20 and the values are given in Table 7.20.

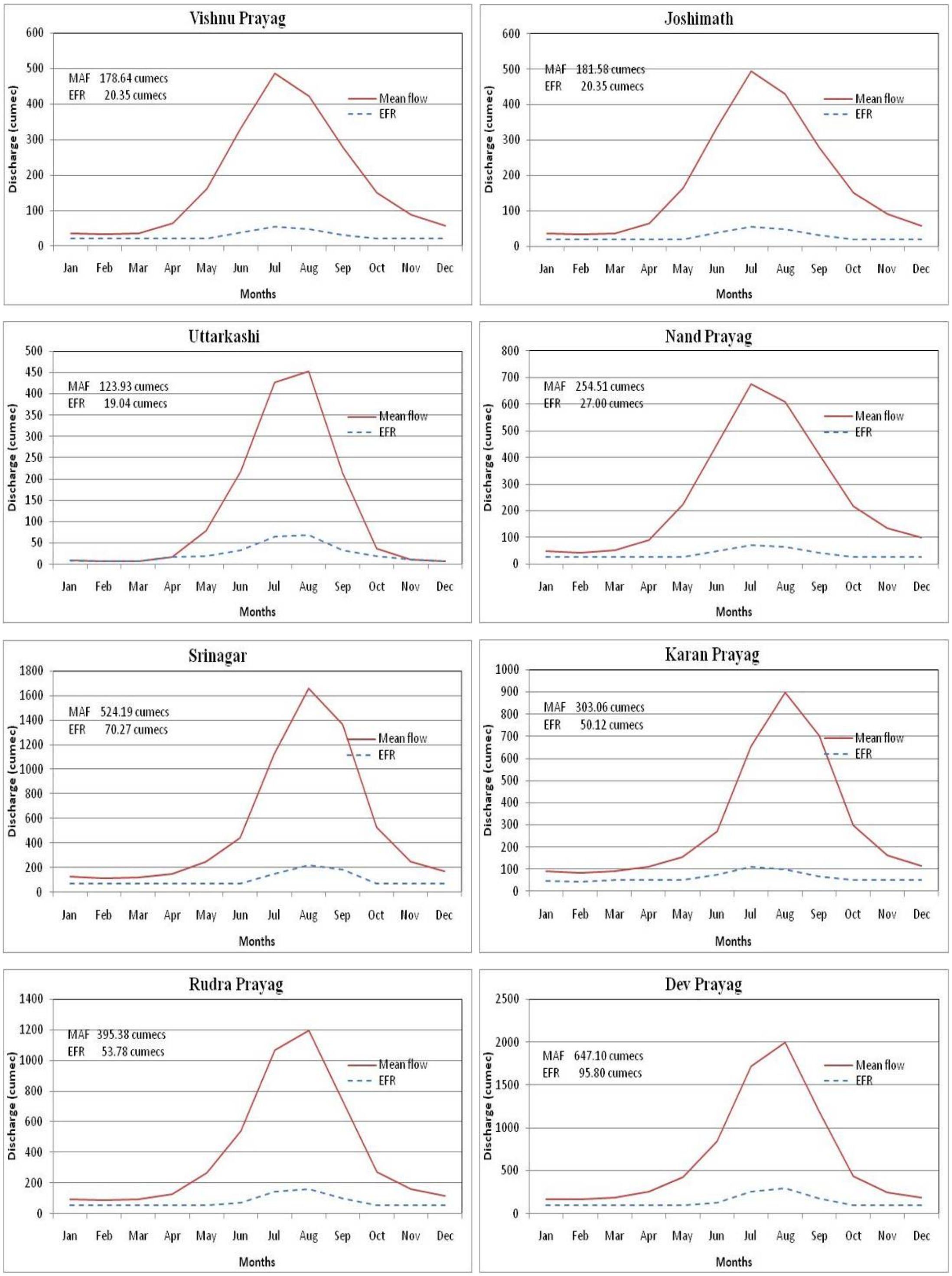


Fig. 7.20 EFR and average 10 daily flow for religious places

To ensure that the river continues to provide the same level of benefits to the society in the post-development situation as it was doing before, the following suggestions may be considered:

a) Project authorities may be directed to ensure that on special occasions such as the Full Moon days (Poornamasi) and auspicious days, the flow at these places is as close to the natural flow as feasible.

b) Bathing ponds (Kunds) may be constructed on the banks of the rivers near the important places. These ponds should be connected with the river in such a manner that a part of river water enters from one end and exits through the other so that the pond always has flowing water.

7.3.4 Summary and Limitations

There are certain limitations of the study due to data availability and time frame.

1. The environmental flows have been assessed using various methods/approaches such as Hydrological index method (e.g. Look-up tables, EMC-FDC approach, Modified Tennant method) and Hydraulic habitat analysis, e.g. EMC HMD approach, etc.
2. The Look-up tables suggest different values of environmental flow for various HP (e.g. river stretches). The look up table used in the various countries such as France, USA and UK are area specific and the same may not be applicable for Indian conditions.
3. The recommendations given by Tennant are not applicable to our country and the study area keeping in view the water availability and water requirements in Indian basins.
4. The hydraulic habitat analysis is based on actual hydrological requirement for survival of available biotic lives in the particular river stretches. Hence, the hydraulic habitat analysis provides appropriate for computing environmental flows.
5. The minimum flow given by World Commission of Dam and 75% of low flow based on Q95 along with the actual minimum required based on EMC-HMD approach appear to be appropriate.
6. Finally, a range of flows has been suggested as environmental flows and the exact value may be arrived at after site specific studies.

A major limitation of this study is that the measured river cross sections and velocity of flows were available at limited locations. These estimated values were used to derive the required parameters such as the hydraulic mean depth at different locations. Similar was the case with river flows. EFRs were estimated using the interpolated values at the places of interest. EFR requirement shall also depend upon the study of the biotec life as it is actually existing at a particular site. In view of the above, the environmental flow values computed in this study may be considered only indicative values.

Actually, EFR critically depends upon the development stage of the region and what the society expects from the river. Methods, such as the Building Block Method, can use detailed data from different sectors and have the provision of consultation among the experts and stakeholders. However, application of BBM for a large number sites requires a lot of time and finances. It is, therefore, recommended that the exact values of EFR for implementation in the field may be arrived at by conducting specific measurements and field campaigns and consultations with all the stakeholders.

7.4 Operation of Hydropower Projects and Streamflow Variability

This section discusses the change in variability of streamflows as induced by the operation of hydropower generation projects. Data of four typical projects has been used to illustrate the impacts.

7.4.1 Classification of hydropower projects

Based on the way the incoming river flows are stored and regulated to generate energy, hydropower projects can be classified in two categories. For details, refer to Section 8.3.

7.4.1.1 Based on Water Storage

a) Storage Based Projects

Natural flow of many rivers varies considerably with time – there are periods of very high flows and there are periods of low flows. But this flow pattern may be quite different than the pattern of demands. In storage based projects, a reservoir of water is created behind a dam and this is used to regulate the incoming flows so that water is supplied to the powerhouse in accordance with the demands to generate energy.

b) Run of River (ROR) Projects

In these projects, energy is generated by utilizing the river flows as available. Some ROR projects have small storage to take care of daily fluctuation of flows. In absence of the ability to regulate the incoming flows, the energy generation from these projects may have large variations over a year.

7.4.1.2 Based on Diversion of Water

Based on diversion of water from the river, hydropower projects can be classified in two categories, as explained below.

a) When the Powerhouse is at a Distance from the Dam/Weir

In this case, water is typically carried to the powerhouse from the dam through a tunnel or penstocks. Water exits from the powerhouse and joins the river at a certain distance downstream of the dam or diversion structure (See Fig. 7.21). Downstream of this junction, the flow in the river will be nearly the same as in the natural condition. The flow in the river reach between the dam or diversion structure and the powerhouse consists of environmental flow let out from the structure and the flow generated by the local catchment. The flow generated by the local catchment gradually increases with distance but it is also likely that a small part of environmental flow infiltrates with distance depending upon the hydrological and geological conditions of the area.

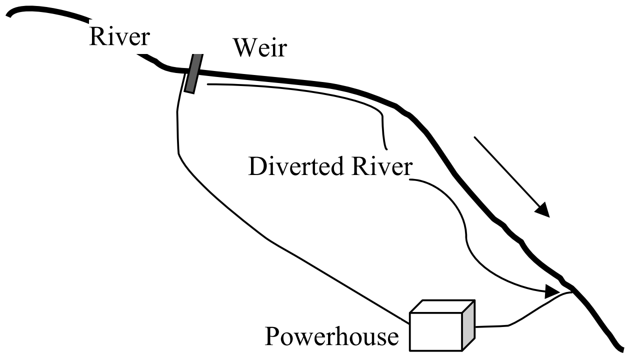


Fig. 7.21 Situation when powerhouse is at a distance from the weir.

b) Powerhouse at the toe of the Dam/Weir

In these commissioned HPs the water that is fed in the powerhouse exits just downstream of the dam or barrage. Thus, when the powerhouse is in operation, there will be flow in the downstream river to the tune of the release from the powerhouse. When the powerhouse is not operational, it will be necessary to ensure that releases at least equal to the environment flow are made to meet the demands of the riverine ecosystem.

7.4.2 Impact of Hydropower Projects on Streamflow Variability

The study area of the Ganga basin up to Devprayag consists of 13 commissioned hydropower projects; 57 projects are under construction. Generation of hydropower does not consume any (significant quantity of) water but may cause significant changes in the streamflow variability. In the following the impact of operation of hydropower projects on the variability of streamflows is discussed.

The inflow to any hydropower project consists of the sum of the (routed) release of water from the immediately upstream project(s) and flow generated by the incremental catchment area. For the most upstream project on any stream, the first component of the flow will be zero. A hydropower project changes streamflow variability by regulating the natural flows and generating electrical energy so that the benefits are maximized. In case a ROR project is operated to generate energy for peaking purpose, typically there will be large energy generation for about 4 to 6 hours and the energy generation will be much less for the remaining time each day. Due to this, there are likely to be additional fluctuations in the flows downstream of the point where the outflow of the power plant of a project meets the river. As one travels down the river, the fluctuations get moderated because of valley storage effect and lateral flow joining the river.

The ideal way to determine the impact of the operation of the project on stream flow variability is to begin computation at the most upstream project on any stream. After simulating the operation of the project, the outflow hydrograph is determined and is compared with the hydrograph in the without-project situation. Statistical indices and visual comparison of the hydrographs can be used to determine the impact of the project on streamflows. Now, the next downstream project is taken up and the same process is repeated to determine the cumulative impact of the two projects on streamflows. In this way, the cumulative impact of a group of the projects on streamflows can be determined.

Modeling of the river flows for a large network of projects that is under consideration in this study will be an extremely complex task due to the following reasons:

a) There are nearly 70 projects spread over an area of 19,600 sq.km of hilly terrain.
b) The projects are of widely different sizes, the pondage or storage varying from nearly zero to 3540 million cubic m.
c) Measured long-term river discharge data at daily interval are available only at 9 sites being operated by CWC. To determine diurnal variation in the stream flows, routing of the flows using (multi)hourly data will be necessary and it will be necessary to have the data of lateral inflows from the various tributaries besides the main rivers.
d) Besides river flows, other data such as river cross-sections at small intervals, channel roughness, bed slopes, etc. which are also crucial for this type of analysis will be required. Currently these data are either not available or are not available at the desired spatial resolution.
e) Although broad operation guidelines are in place for the projects, there are significant deviations in practice due to unforeseen fluctuations in demands (especially in de-regulated energy market and very high tariff for peak power), inflows and their silt contents, beakdowns in machinery and other works, etc. From the analysis of the data of selected projects, no clear pattern of operation for different time periods (months, 10-daily periods) could be ascertained, as described below.

7.4.3 Operation Analysis of Selected Hydropower Projects

Out of 70 commissioned and under development projects, 54 projects are run of river (ROR) type and 16 projects have substantial storage to regulate stream flows. It is clear that the ROR projects will not have any significant impact on the variability of stream flows. Hence, all the projects where the depth of the reservoir (or pondage) behind the dam was less than 20 m or the reservoir storage capacity was less than 10 million cubic meter (MCM) were considered under the category of ROR projects. A closer scrutiny of the Detailed Project Reports of the various projects showed that although some projects (for example Kotli Bhel 1-A and 1-B) have substantial storage, the reservoir was being used to provide head for the generation of power and there was little or no regulation of flows. Hence, for the purpose of determining the impact on streamflow variability, these projects were also taken as ROR projects.

After this screening, it was found that 5 commissioned and under construction projects have substantial storage capacity to regulate incoming streamflows. Thus the operation of these projects has the potential to cause appreciable impact on the variability of streamflows. This could be either beneficial or harmful. The key features of 5 major reservoir based projects and 2 RoR projects are listed in Table 7.21.

Table 7.21 Key features of selected hydropower projects in the study area

S. No.	Project Name	Name of River/ Tributary	Installed capacity (MW)	Reservoir			Gross Storage (M cum)	Live Storage (M cum)	Type of HEP
				FRL (m)	TWL (m)	Depth (m)			
1	Devsari	Pinder, Alaknanda	252	1300	1045.5	32	9.026	3.21	ROR
2	Srinagar	Alaknanda	330	605.5	533.1	66	78	8	Reservoir Based
3	Vishnugad Pipalkoti	Alaknanda	444	1267	1030	42	3.63	2.47	Reservoir Based
4	Koteshwar	Bhagirathi	400	612	535	78.5	86	47	Reservoir Based
5	Maneri Bhali I	Bhagirathi	90	1294.5	1112.5	14.5	0.6	0.6	Reservoir Based
6	Tehri stage-I	Bhagirathi	1000	830	596	230	3540	2615	Reservoir Based
7	Vishnuprayag	Bhagirathi	400	2261	2275	14	Nil	Nil	ROR

For storage-based projects whose inflows are highly cyclic, operation should be planned in such a way that there is enough water in storage to meet the environmental flow requirements over the remaining periods of the dry season.

7.4.4 Running Hours of Project Units

It is well known that the price of peak power is much higher than the base power and due to this, the project operators would like to generate higher amount of peak power to maximize their profits. Due to this, the running hours of the units of the power house vary dramatically. Consequently, the flow in the river just downstream of the project will also show variation.

Operation data of three commissioned projects showing the hours of operation of the various units on daily basis were obtained for a few years and were studied. The results are discussed in the following.

7.4.4.1 Vishnuprayag Project

This is a 400 MW project on the Bhagirathi River having four units of 100 MW each. Daily running hours of the units were available for the period January 2008 to December 2010. Table 7.22 shows the running hours of the units for each month as well as the total running hours of all the units. Total electricity generation for each month is also shown in the table. It can be seen that there is large variation in the running hours of the units from month to month. Average monthly running hours for all the units = 1735 hours 40 min and on an average, each unit ran for about 434 hours each month.

Table 7.22 Monthly running hours of the 4 units of Vishnuprayag Project for January 2008 to Dec. 2010 and total electricity generation.

Month	Running hours Unit 1	Running hours Unit 2	Running hours Unit 3	Running hours Unit 4	Total running hours -all units	Total generation (MU)
Jan-08	426:13	31:04	246:20	46:44	750:21:00	61.213
Feb-08	158:05	412:57	146:20	24:00:00	717:22:00	51.480
Mar-08	358:46	191:46	190:43	24:00:00	741:15:00	63.420
Apr-08	44:24	407:34	288:02	251:54	991:54:00	84.942
May-08	466:22	730:53	666:55	699:30	2563:40:00	250.215
Jun-08	702:05	702:19	702:32	701:25	2808:21:00	306.863
Jul-08	709:22	708:30	717:14	708:46	2843:52:00	312.554
Aug-08	721:31	724:27	712:20	722:44	2881:02:00	316.117
Sep-08	689:08	667:53	684:41	635:39	2677:21:00	276.542
Oct-08	317:41	349:45	599:12	581:51	1848:29:00	164.198
Nov-08	598:30	35:25	199:25	594:00	1427:20:00	97.356
Dec-08	119:35	95:12	50:11	632:01	896:59:00	73.563
Jan-09	216:26	172:59	192:49	170:46	753:00:00	61.784
Feb-09	243:56	41:07	57:28	223:22	565:53:00	39.139
Mar-09	191:44	177:51	192:17	172:07	733:59:00	50.103
Apr-09	232:57	205:42	205:16	190:01	833:56:00	67.584
May-09	643:33	392:19	588:52	537:51	2162:35:00	202.727
Jun-09	692:04	702:41	688:23	681:45	2764:53:00	290.807
Jul-09	731:33	731:33	693:17	731:35	2887:58:00	316.350
Aug-09	712:07	701:15	703:46	702:54	2820:02:00	307.028
Sep-09	705:50	707:20	707:12	711:57	2832:19:00	292.005
Oct-09	602:00	337:32	659:17	303:14	1902:03:00	175.457
Nov-09	117:45	450:54	625:46	24:00:00	1194:25:00	88.879
Dec-09	116:53	340:15	275:27	24:00:00	732:35:00	69.499
Jan-10	354:15	47:57	129:20	211:41	743:13:00	57.674
Feb-10	82:40	144:00	111:51	351:50	690:21:00	46.751
Mar-10	127:37	71:39	307:24	284:30	791:10:00	62.545
Apr-10	202:31	245:35	427:08	361:04	1236:18:00	101.172
May-10	611:08	504:42	617:30	522:11	2255:31:00	219.391
Jun-10	691:20	700:42	706:55	617:08	2716:05:00	285.943
Jul-10	678:17	669:44	677:45	671:55	2697:41:00	294.315
Aug-10	639:38	656:47	656:39	656:02	2609:06:00	284.967
Sep-10	653:46	652:06	649:34	652:53	2608:19:00	286.687
Oct-10	430:17	636:54	654:37	626:55	2348:43:00	228.818
Nov-10	160:52	533:32	481:43	264:50	1440:57:00	117.081
Dec-10	18:17	390:39	352:38	253:28	1015:02:00	78.257

For easy visualization and comprehension of the data, Figure 7.22 shows the total running hours of all the units for different months. As expected, the units run for much longer time during monsoon period than the other months. Average monthly running hours for all the units during May to September for the three years was nearly 2550 hours whereas the same for the other months was in the range of 750 to 800 hours.

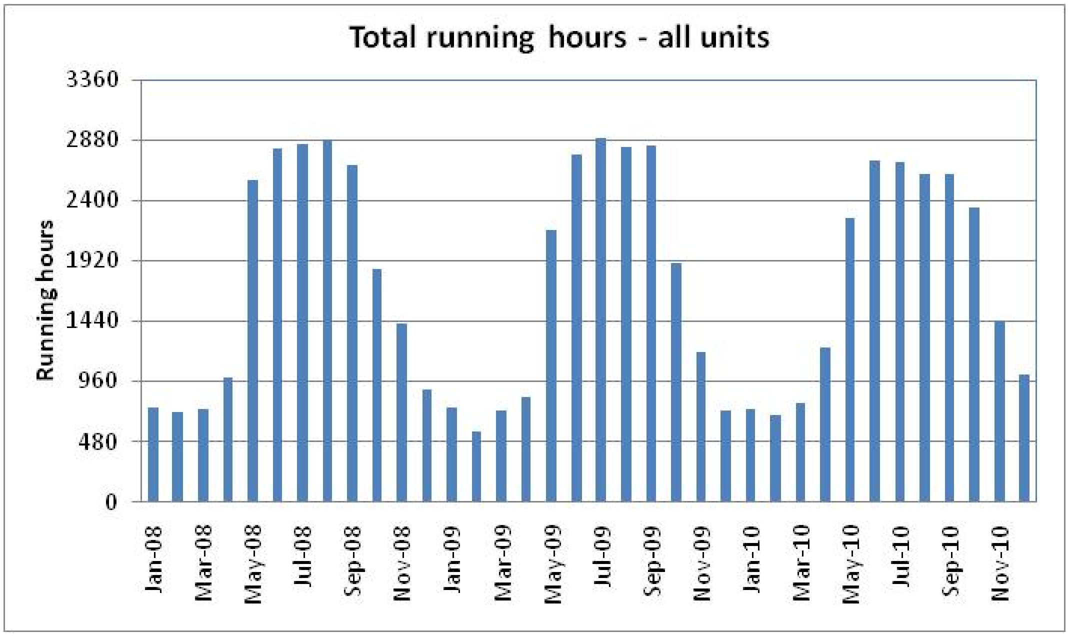


Fig. 7.22 Total running hours for all units of Vishnuprayag project.

7.4.4.2 Maneri-Bhali I Project

This is a 90 MW project on the Bhagirathi River. The reservoir behind the dam has a depth of 69 m and its FRL is at 1294.5 m. Table 7.23 shows the monthly running hours of three units of this project.

Table 7.23 Monthly running hours of the 3 units of Maneri-Bhali I Project for April 2008 to October 2010 and total electricity generation.

Month	Running hours Unit 1	Running hours Unit 2	Running hours Unit 3	Total for all units	Total generation (MU)
Apr-08	249:50:00	380:08:00	634:43:00	1264:41:00	37.812
May-08	720:17:00	714:42:00	550:47:00	1985:46:00	59.780
Jun-08	589:21:00	504:23:00	285:40:00	1379:24:00	41.982
Jul-08	330:02:00	292:14:00	0:00:00	622:16:00	18.824
Aug-08	-	-	-	-	-
Sep-08	540:05:00	352:50:00	232:30:00	1125:25:00	34.320
Oct-08	612:45:00	720:25:00	737:40:00	2070:50:00	60.908
Nov-08	255:25:00	645:15:00	532:05:00	1432:45:00	42.172
Dec-08	0:00:00	729:57:00	421:07:00	1151:04:00	33.844
Jan-09	0:00:00	733:30:00	177:00:00	910:30:00	27.372
Feb-09	381:00:00	247:40:00	110:00:00	738:40:00	22.236
Mar-09	198:30:00	583:40:00	37:55:00	820:05:00	24.480

Apr-09	201:22:00	595:13:00	235:23:00	1031:58:00	30.492
May-09	719:47:00	714:42:00	550:47:00	1985:16:00	55.912
Jun-09	653:31:00	685:21:00	641:31:00	1362:52:00	59.732
Jul-09	655:05:00	674:40:00	539:50:00	1869:35:00	55.608
Aug-09	63:05:00	71:20:00	21:40:00	156:05:00	4.616
Sep-09	436:45:00	526:25:00	679:10:00	1642:20:00	48.160
Oct-09	549:35:00	683:35:00	653:15:00	1886:25:00	54.564
Nov-09	416:20:00	134:50:00	672:35:00	1223:45:00	36.188
Dec-09	338:35:00	0:00:00	627:50:00	966:25:00	28.992
Jan-10	245:00:00	0:00:00	550:05:00	795:05:00	23.672
Feb-10	231:05:00	0:00:00	472:30:00	703:35:00	20.960
Mar-10	407:05:00	45:05:00	565:45:00	1017:55:00	30.180
Apr-10	529:55:00	580:55:00	320:10:00	1431:00:00	41.364
May-10	650:35:00	740:00:00	728:00:00	2118:35:00	61.200
Jun-10	717:25:00	715:15:00	707:00:00	2139:40:00	63.314
Jul-10	510:35:00	446:50:00	506:20:00	1463:45:00	42.928
Aug-10	46:36:00	10:30:00	57:01:00	114:07:00	3.408
Sep-10	447:55:00	620:30:00	608:39:00	1677:04:00	49.424
Oct-10	689:02:00	720:00:00	708:30:00	2117:32:00	66.540
Nov-10	375:50:00	713:15:00	592:45:00	1681:50:00	50.920

Graphical presentation of the data pertaining to the total running hours of all the units for different months Maneri-Bhali I project is given in Figure 7.23.

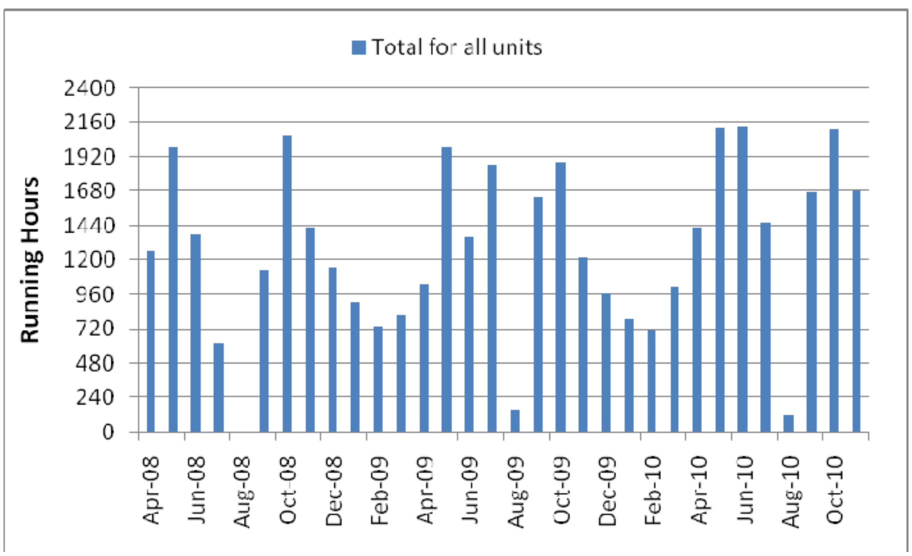


Fig. 7.23 Total running hours for all units of Maneri-Bhali I project.

Average monthly running hours for all the units = 1318 hours. Average monthly running hours for each unit was about 439 hours out of 720 hours which comes to about 61% of time.

7.4.4.3 Maneri-Bhali II Project

This is a 304 MW project on the Bhagirathi River. The power plant has four units. Monthly running hours of the units were available for March 2008 to Dec. 2008 and May 2010 to November 2010. These along with total generation are shown in Table 7.24.

Table 7.24 Monthly running hours of the 4 units of Maneri-Bhali I Project for March to December 2008 and May to Nov. 2010 and total electricity generation

	Running hours Unit 1	Running hours Unit 2	Running hours Unit 3	Running hours Unit 4	Total for all units	Total generation (MU)
Mar-08	433:29:00	177:09:00	354:46:00	70:32:00	1035:56:00	57.633
Apr-08	240:25:00	257:06:00	318:17:00	431:28:00	1247:16:00	75.080
May-08	431:26:00	577:42:00	678:59:00	573:27:00	2261:34:00	144.220
Jun-08	617:22:00	564:00:00	624:29:00	594:05:00	2399:56:00	163.850
Jul-08	211:25:00	622:08:00	625:21:00	486:34:00	1945:28:00	135.250
Aug-08	0:00:00	0:00:00	34:40:00	5:55:00	40:35:00	2.800
Sep-08	3:50:00	607:10:00	568:40:00	681:34:00	1861:14:00	129.000
Oct-08	478:40:00	441:47:00	547:32:00	550:15:00	2018:14:00	125.570
Nov-08	298:05:00	547:25:00	85:25:00	458:55:00	1389:50:00	78.220
Dec-08	186:20:00	625:23:00	0:00:00	289:35:00	1101:18:00	60.020
May-10	623:25:00	636:25:00	319:40:00	561:25:00	2140:55:00	133.580
Jun-10	709:06:00	716:24:00	479:01:00	715:21:00	2619:52:00	175.890
Jul-10	634:57:00	629:04:00	599:34:00	635:05:00	2498:40:00	174.680
Aug-10	578:02:00	555:48:00	542:25:00	581:26:00	2257:41:00	156.490
Sep-10	589:02:00	586:59:00	502:16:00	580:45:00	2259:02:00	155.680
Oct-10	523:37:00	692:41:00	636:52:00	686:50:00	2540:00:00	163.830
Nov-10	329:50:00	652:28:00	147:18:00	403:31:00	1533:07:00	88.290

For easy visualization of the data, Figure 7.24 shows the total running hours of all the units for different months for the Maneri-Bhali II project. Data for the period January 2009 to May 2009 were not available.

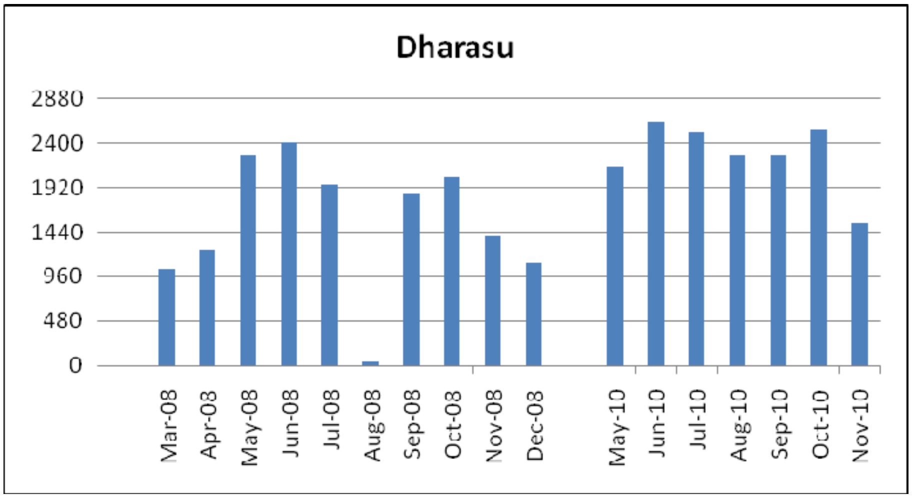


Fig. 7.24 Total running hours for all units of Maneri-Bhali II project.

Average monthly running hours for all the units = 1832 hours. Average monthly running hours for each unit was about 458 hours. It may be noticed that for this project, the variation in the running hours was the least among the three projects studied.

Daily running hours of all the units of Maneri Bhali II proejct for three indicative months, viz., April 2008, Sept. 2008, and Dec. 2008 are given in Fig. 7.25. Again, it can be seen that there is considerable variation in the running hours from day to day and from month to month and this will lead to variation in river flows downstream of the project.

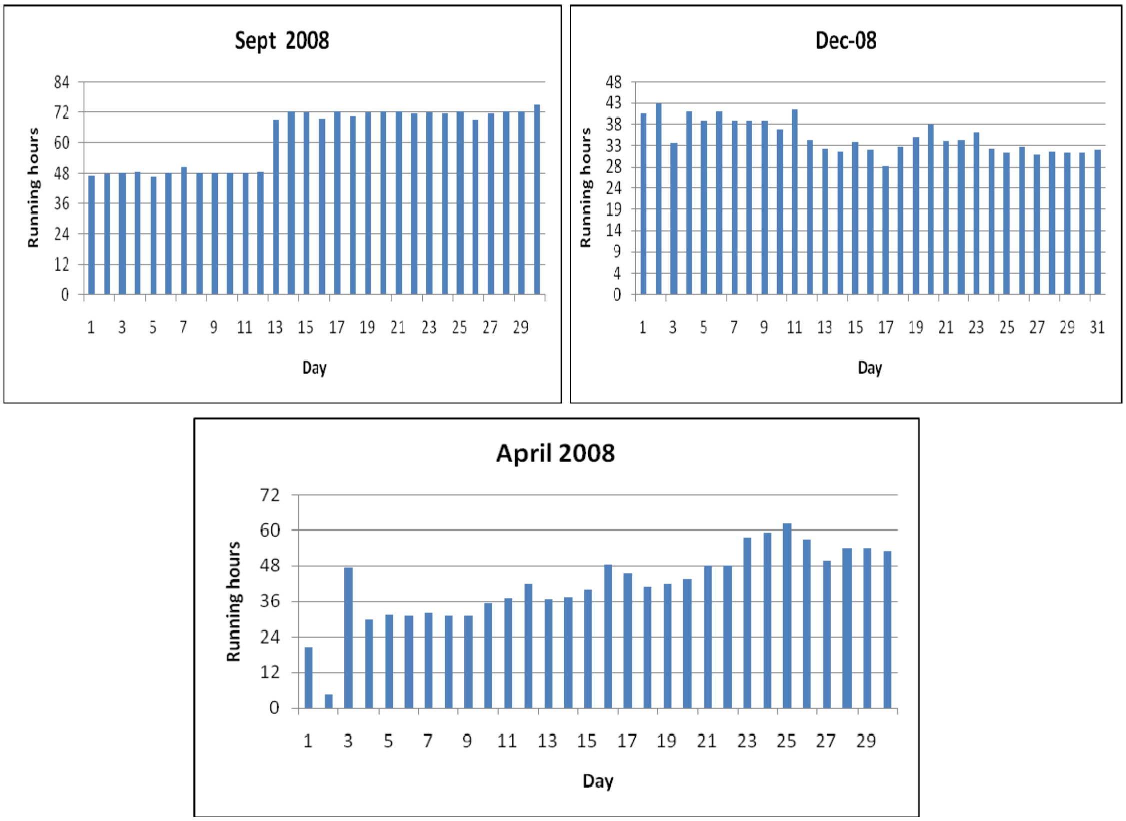


Fig. 7.25 Daily running hours of all the units of Maneri Bahli II proejct for three different months

7.4.5 Analysis of Working Tables

Working table of a project gives complete information about inflow, storage, release of water for various purposes. For a hydropower project, it additionally gives information about energy generation.

7.4.5.1 Tapovan Vishnugad Project

Tapovan Vishnugad hydro electric project is a 520 MW project. Capacity and energy benefits in 90% dependable year as per the DPR are given in Table 7.25. Table 7.26 gives the values of these by considering the EFR computed in this study.

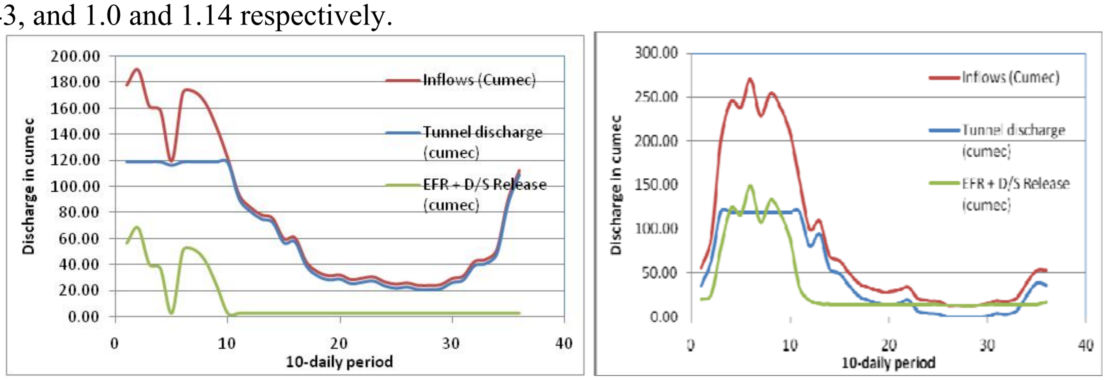
Table 7.25 Tapovan Vishnugad hydro electric project - capacity and energy benefits in 90% dependable year as per the DPR

Month		Days	Inflows (Cumec)	EFR + D/S Release (cumec)	Inflow vol (MCM)	Tunnel discharge (cumec)	Head loss (m)	Net Head (m)	Power Gen (MW)	Energy Gen. (GWHr)	Energy Gen. at 95% IC (GWHr)
June	I	10	178.21	57.00	153.97	119.21	40.08	486.75	520.00	124.80	118.56
	II	10	189.88	68.67	164.06	119.21	40.08	486.75	520.00	124.80	118.56
	III	10	161.96	40.75	139.93	119.21	40.08	486.75	520.00	124.80	118.56
July	I	10	158.54	37.33	136.98	119.21	40.08	486.75	520.00	124.80	118.56
	II	10	119.63	3.00	103.36	116.63	38.36	488.47	513.21	123.17	118.56
	III	11	172.44	51.23	163.89	119.21	40.08	486.75	520.00	137.28	130.42
Aug	I	10	173.16	51.95	149.61	119.21	40.08	486.75	520.00	124.80	118.56
	II	10	164.40	43.19	142.04	119.21	40.08	486.75	520.00	124.80	118.56
	III	11	145.76	24.55	138.53	119.21	40.08	486.75	520.00	137.28	130.42
Sept	I	10	121.78	3.00	105.22	118.78	39.79	487.04	520.00	124.80	118.56
	II	10	93.97	3.00	81.19	90.97	23.34	503.49	412.61	99.03	99.03
	III	10	84.17	3.00	72.72	81.17	18.58	508.25	371.64	89.19	89.19
Oct	I	10	78.22	3.00	67.58	75.22	15.96	510.87	346.18	83.08	83.08
	II	10	75.59	3.00	65.31	72.59	14.86	511.97	334.79	80.35	80.35
	III	11	59.93	3.00	56.96	56.93	9.14	517.69	265.50	70.09	70.09
Nov	I	10	60.54	3.00	52.31	57.54	9.34	517.49	268.24	64.38	64.38
	II	10	41.98	3.00	36.27	38.98	4.29	522.54	183.49	44.04	44.04
	III	10	34.47	3.00	29.78	31.47	2.79	524.04	148.56	35.66	35.66
Dec	I	10	31.28	3.00	27.03	28.28	2.26	524.57	133.64	32.07	32.07
	II	10	31.97	3.00	27.62	28.97	2.37	524.46	136.87	32.85	32.85
	III	11	28.38	3.00	26.97	25.38	1.82	525.01	120.04	31.69	31.69
Jan	I	10	29.49	3.00	25.48	26.49	1.98	524.85	125.25	30.06	30.06
	II	10	30.45	3.00	26.31	27.45	2.13	524.70	129.75	31.14	31.14
	III	11	26.65	3.00	25.33	23.65	1.58	525.25	111.91	29.54	29.54
Feb	I	10	24.90	3.00	21.51	21.90	1.35	525.48	103.67	24.88	24.88
	II	10	25.81	3.00	22.30	22.81	1.47	525.36	107.95	25.91	25.91
	III	8	23.88	3.00	16.51	20.88	1.23	525.60	98.86	18.98	18.98
Mar	I	10	23.89	3.00	20.64	20.89	1.23	525.60	98.91	23.74	23.74
	II	10	24.50	3.00	21.17	21.50	1.30	525.53	101.79	24.43	24.43
	III	11	29.23	3.00	27.78	26.23	1.94	524.89	124.03	32.74	32.74
Apr	I	10	31.17	3.00	26.93	28.17	2.24	524.59	133.13	31.95	31.95
	II	10	42.23	3.00	36.49	39.23	4.34	522.49	184.65	44.32	44.32
	III	10	43.91	3.00	37.94	40.91	4.72	522.11	192.42	46.18	46.18
May	I	10	51.50	3.00	44.50	48.50	6.63	520.20	227.28	54.55	54.55
	II	10	89.98	3.00	77.74	86.98	21.34	505.49	396.08	95.06	95.06
	III	11	112.35	3.00	106.78	109.35	33.72	493.11	485.75	128.24	128.24
TOTAL									10536.21	2575.48	2513.46

Table 7.26 10-daily working table for Tapovan Vishnugad project using 90% dependable inflows and suggested EFR.

Month		Days	Inflows (Cumec)	EFR (Cumec)	EFR + D/S Release (cumec)	Inflow vol (MCM)	Tunnel discharge (cumec)	Head loss (m)	Net Head (m)	Power Gen (MW)	Energy Gen. (GWHr)	Energy Gen. at 95% IC (GWHr)
June	I	10	55.59	20.39	20.39	48.03	35.21	3.50	523.33	165.98	39.84	39.84
	II	10	90.24	25.51	25.51	77.96	64.73	11.82	515.01	300.31	72.08	72.08
	III	10	199.54	31.73	78.33	172.40	119.21	40.08	486.75	520.00	124.80	118.56
July	I	10	244.95	36.37	123.74	211.64	119.21	40.08	486.75	520.00	124.80	118.56
	II	10	238.09	39.43	116.88	205.71	119.21	40.08	486.75	520.00	124.80	118.56
	III	11	270.17	40.79	148.96	256.77	119.21	40.08	486.75	520.00	137.28	130.42
Aug	I	10	228.63	38.67	107.42	197.53	119.21	40.08	486.75	520.00	124.80	118.56
	II	10	254.45	34.38	133.24	219.85	119.21	40.08	486.75	520.00	124.80	118.56
	III	11	239.25	31.77	118.04	227.39	119.21	40.08	486.75	520.00	137.28	130.42
Sept	I	10	209.52	28.08	88.31	181.03	119.21	40.08	486.75	520.00	124.80	118.56
	II	10	154.74	23.55	33.53	133.70	119.21	40.08	486.75	520.00	124.80	118.56
	III	10	100.34	19.19	19.19	86.69	81.15	18.57	508.26	371.54	89.17	89.17
Oct	I	10	108.88	14.84	14.84	94.07	94.04	24.94	501.89	425.16	102.04	102.04
	II	10	70.52	14.57	14.57	60.93	55.95	8.83	518.00	261.09	62.66	62.66
	III	11	64.27	14.57	14.57	61.08	49.70	6.97	519.86	232.76	61.45	61.45
Nov	I	10	50.08	14.57	14.57	43.27	35.51	3.56	523.27	167.40	40.18	40.18
	II	10	37.99	14.57	14.57	32.82	23.42	1.55	525.28	110.83	26.60	26.60
	III	10	33.30	14.57	14.57	28.77	18.73	0.99	525.84	88.73	21.30	21.30
Dec	I	10	29.42	14.57	14.57	25.42	14.85	0.62	526.21	70.39	16.89	16.89
	II	10	28.23	14.57	14.57	24.39	13.66	0.53	526.30	64.75	15.54	15.54
	III	11	30.15	14.57	14.57	28.65	15.58	0.68	526.15	73.83	19.49	19.49
Jan	I	10	33.81	14.57	14.57	29.21	19.24	1.04	525.79	91.13	21.87	21.87
	II	10	21.24	14.57	14.57	18.35	6.67	0.13	526.70	31.63	7.59	7.59
	III	11	18.81	14.57	14.57	17.88	4.24	0.05	526.78	20.12	5.31	5.31
Feb	I	10	18.20	14.57	14.57	15.73	3.63	0.04	526.79	17.25	4.14	4.14
	II	10	13.05	14.57	13.05	11.28	0.00	0.00	526.83	0.00	0.00	0.00
	III	8	13.23	14.57	13.23	9.14	0.00	0.00	526.83	0.00	0.00	0.00
Mar	I	10	12.39	14.57	12.39	10.71	0.00	0.00	526.83	0.00	0.00	0.00
	II	10	13.65	14.57	13.65	11.80	0.00	0.00	526.83	0.00	0.00	0.00
	III	11	15.19	14.57	14.57	14.44	0.62	0.00	526.83	2.96	0.78	0.78
Apr	I	10	18.72	14.57	14.57	16.17	4.15	0.05	526.78	19.68	4.72	4.72
	II	10	18.05	14.57	14.57	15.60	3.48	0.03	526.80	16.52	3.97	3.97
	III	10	22.23	14.57	14.57	19.21	7.66	0.17	526.66	36.34	8.72	8.72
May	I	10	39.49	14.57	14.57	34.12	24.92	1.75	525.08	117.86	28.29	28.29
	II	10	52.99	14.57	14.57	45.78	38.42	4.16	522.67	180.88	43.41	43.41
	III	11	53.67	16.88	16.88	51.00	36.79	3.82	523.01	173.32	45.76	45.76

Fig. 7.26 shows inflows, tunnel discharge and flows in the diverted reach as per the DPR and by using the computed EFR. The mean of the inflows to the project is 86.2 cumec and that in the diverted each is 37.8 cumec. Further the maximum values, the standard deviations and the coefficient of variation of inflows and discharge in the diverted reach are 270 and 49, 87 and 43, and 1.0 and 1.14 respectively.



(a) (b)

Fig. 7.26 Tapovan Vishnugad Project: inflows, tunnel discharge, and downstream discharge as per the DPR (a) and suggested (b).

7.4.5.2 Maneri Bhali II

This is a RoR project of 304 MW installed capacity constructed in Bhagirathi basins. The working table of the project as per the DPR is given in Table 7.27.

Table 7.27 Working Table of Maneri Bhali II Project as per the DPR

Month		Inflows (Cumec)	Net Head (m)	Energy Generation		
				Full (100%) MW cont	Normative (95%) Mw cont	Energy GWh
June	I	114.00	258.70	263.30	240.37	63.18
	II	163.00	245.10	288.80	295.59	69.31
	III	137.00	247.70	288.80	313.50	69.31
July	I	195.00	244.30	326.30	313.50	69.31
	II	167.00	244.30	323.04	313.50	69.31
	III	264.00	244.30	323.04	313.50	76.24
Aug	I	353.00	243.60	323.04	313.50	69.31
	II	460.00	243.60	323.04	313.50	69.31
	III	415.00	243.60	323.04	313.50	76.24
Sept	I	206.00	237.60	323.04	313.50	69.31
	II	314.00	237.60	326.40	313.50	69.31
	III	188.00	237.60	304.72	304.72	69.31
Oct	I	122.00	247.60	238.42	238.42	64.72
	II	72.00	266.10	182.73	182.73	41.04
	III	54.50	270.30	152.52	152.52	34.72
Nov	I	48.00	271.60	124.80	124.80	27.93
	II	46.00	272.00	107.94	107.94	26.80
	III	54.00	270.40	91.54	91.54	31.28
Dec	I	44.00	273.80	82.83	82.83	25.81
	II	40.00	277.00	75.80	75.80	23.73
	III	36.50	281.00	71.80	71.80	24.16
Jan	I	39.00	281.00	68.65	68.65	23.48
	II	34.00	281.70	64.50	64.50	20.52
	III	30.50	282.10	62.25	62.25	20.28
Feb	I	31.00	282.20	60.18	60.18	18.74
	II	27.00	282.60	60.03	60.88	16.35
	III	33.50	281.90	60.88	64.98	16.69
Mar	I	37.00	281.20	64.98	72.24	22.29
	II	44.00	280.10	72.24	80.42	26.40
	III	50.00	279.00	80.42	86.12	32.87
Apr	I	40.50	280.50	86.12	102.75	24.33
	II	83.50	270.30	102.75	126.32	48.35
	III	65.00	275.60	126.32	144.11	38.37
May	I	60.00	276.70	144.11	169.14	35.57
	II	56.50	277.50	169.14	192.59	33.59
	III	75.50	272.70	192.59		48.52
TOTAL (GWHr)						1514.93

The working Table of the project with computed EFR is given in Table 7.28.

Table 7.28 Working Table of Maneri Bhali II with computed EFR

Month		Inflows (Cumec)	EFR (Cumec)	Flow for Power Gen. (cumec)	Net Head (m)	Power (MW)	Energy Gen. (GWHr)
June	I	42.242	11.82	30.42	258.70	97.54	23.41
	II	88.458	18.08	70.38	245.10	193.85	46.52
	III	193.030	24.39	168.64	247.70	288.80	69.31
July	I	258.392	31.27	227.12	244.30	326.30	75.24
	II	348.933	37.23	311.71	244.30	323.04	77.53
	III	473.281	41.71	431.57	244.30	323.04	85.28
Aug	I	478.836	44.13	434.71	243.60	323.04	77.53
	II	374.757	41.01	333.75	243.60	323.04	77.53
	III	296.496	36.68	259.82	243.60	323.04	85.28
Sept	I	206.850	30.83	176.02	237.60	323.04	77.53
	II	199.393	20.36	179.04	237.60	326.40	78.34
	III	93.508	13.26	80.25	237.60	198.64	47.67
Oct	I	33.282	11.09	22.19	247.60	73.68	17.68
	II	16.642	11.09	5.55	266.10	39.59	9.50
	III	12.017	11.09	0.93	270.30	29.04	7.67
Nov	I	10.829	11.09	0.00	271.60	26.30	6.31
	II	9.093	11.09	0.00	272.00	22.11	5.31
	III	7.365	10.04	0.00	270.40	17.81	4.27
Dec	I	8.010	9.14	0.00	273.80	19.61	4.71
	II	6.977	8.21	0.00	277.00	17.28	4.15
	III	8.166	10.01	0.00	281.00	20.52	5.42
Jan	I	4.414	7.83	0.00	281.00	11.09	2.66
	II	5.711	7.69	0.00	281.70	14.38	3.45
	III	3.947	7.72	0.00	282.10	9.95	2.63
Feb	I	3.872	6.70	0.00	282.20	9.77	2.34
	II	4.026	6.37	0.00	282.60	10.17	2.44
	III	4.149	6.37	0.00	281.90	10.46	2.01
Mar	I	5.367	6.12	0.00	281.20	13.49	3.24
	II	11.723	7.39	4.33	280.10	29.36	7.05
	III	31.025	9.91	21.11	279.00	77.39	20.43
Apr	I	17.861	11.09	6.77	280.50	44.79	10.75
	II	18.107	11.09	7.02	270.30	43.76	10.50
	III	44.893	11.09	33.80	275.60	110.62	26.55
May	I	46.031	11.09	34.94	276.70	113.88	27.33
	II	59.830	11.09	48.74	277.50	148.44	35.63
	III	158.727	11.09	147.64	272.70	192.59	50.84
TOTAL							1094.05

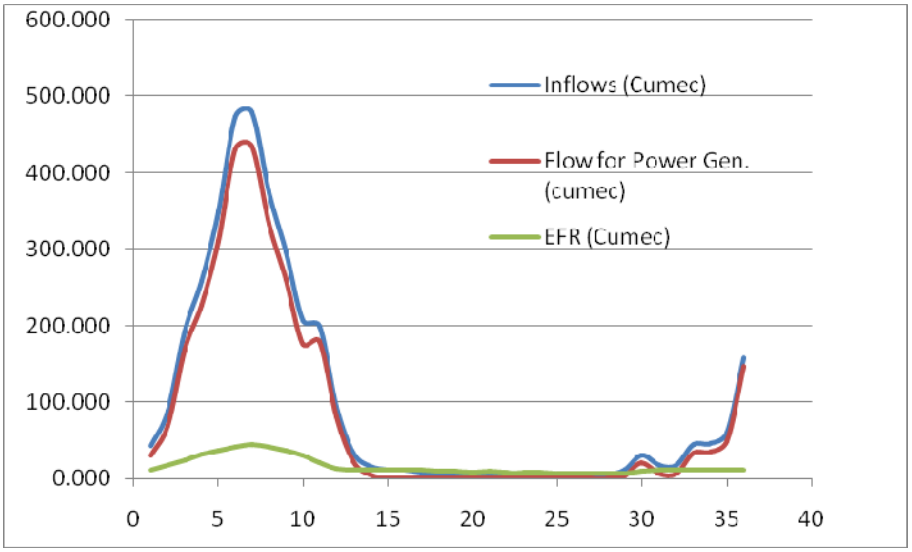


Fig. 7.27 Inflows (90% dependable year), flow for power generation, and EFR for Maneri Bhali II project.

Figure 7.27 shows inflows, flows for power generation and EFR for a 90% dependable year. Statistical properties of the flows are given below.

	Inflows	Flows in the diverted reach
Mean	99.62	16.01
Maximum	478.84	44.13
Minimum	3.87	6.12
Standard Deviation	140	12
Coeft. of ________	1.41	0.72

7.4.5.3 Operation of Tehri Project Complex

Tehri Hydropower Complex (2400 MW) comprises of:

(a)	Tehri Dam & Hydropower Plant	1000 MW
(b)	Koteshwar Hydro Electric Project	400 MW
(c)	Tehri Pumped Storage Plant	1000 MW

a) **Tehri Dam & Hydropower Plant (1000 MW):** Tehri project is a multipurpose project that has been constructed near the old Tehri town. It uses water of Bhagirathi and Bhilangana rivers for irrigation and hydropower generation. In addition, the reservoir space is also used to moderate floods in the downstream areas. Tehri Hydropower Plant includes a 260.5 m high Earth & Rockfill dam, Spillway structures, Power tunnels and an Underground power cavern with an installed capacity of 1000 MW (4 x 250 MW). The project was commissioned in year 2006-2007 and The Tehri Power station is fully operational. Besides providing much needed power to the Northern Grid, the command area is availing irrigation benefits from the Project and drinking water is being supplied to Delhi. The reservoir of the project also helps in moderating floods in the downstream areas.

b) **Koteshwar Hydro Electric Project (400 MW):** The Koteshwar Hydro Electric Project comprises a 97.5 m high Concrete Gravity Dam and Hydropower Plant having four units of conventional Turbine / Generator sets of 100 MW each at Koteshwar, 22 km downstream of Tehri. Koteshwar project is a run of river scheme with minimum diurnal storage. Annual Energy generation from the Project shall be 1234 MU (on 90% dependable year). The Project is scheduled to be commissioned during 11th plan and one unit is expected to be operational by March or April 2011.

c) **Tehri Pumped Storage Plant (PSP) (1000 MW):** Tehri PSP comprising of four reversible pump turbine units of 250 MW each, would involve construction of an Underground Machine Hall on the left bank of Bhagirathi River. The main feature of the Project is the large variation of about 90 m between the maximum and minimum head, under which the reversible units shall operate. The operation of Tehri PSP is based on the concept of recycling of water discharged from upper reservoir to lower reservoir. The Tehri Dam reservoir shall function as the upper reservoir and Koteshwar reservoir as the lower balancing reservoir. On completion, additional generating capacity of 1000 MW, peaking power, will be added to the Northern Region (annual generation of 1377 million units). Project is scheduled to be commissioned during 12th Plan.

The outlets of the Tehri project are located around El. 603 m and the FRL of the Koteshwar project is at 612.5 m. After completion of works in this complex, the river reach between Tehri and Koteshwar will be submerged by the reservoir of the Koteshwar project. Downstream of Koteshwar project, the flow will depend upon the releases from the powerhouse. It is understood from the officers of THDC that at least one unit will be running and the release to the tune of 250 cumec will available in the river.

7.4.5.4 Loharinag Pala Project

Loharinag Pala (LNP) is diversion project on Bhagirathi River located in Bhatwari Tehsil in Uttarkashi District. The project envisages construction of a diversion barrage and an underground powerhouse with 4 units of 150 MW each, yielding a total installed capacity of 600 MW is envisaged. Vertical Francis turbines with maximum head of 481.67 m and rated head of 437.96 m are proposed.

Power generation plan for 90% dependable year has been provided by NTPC. As per the stipulation of the environmental clearance by MOEF, environmental flows are to be released at 0.86 cumec and the generation plan is given in Table 7.29.

Table 7.29 Loharinag Pala: 10-daily working table.

Month	Durartion	Inflow discharge (cumec)	Flow for power generation (cumec)	Power Generated (MU)	Flow in diverted reach	Computed EFR	Flow for power gen (cumec)	Pow gen (MU)	Flow in diverted reach
June	I (1-10)	160.50	158.62	136.80	1.88	5.71	154.79	135.68	5.71
	II (11-20)	124.30	123.30	116.82	1.00	8.73	115.57	101.30	8.73
	III (21-30)	172.30	143.30	132.73	29.00	11.78	158.62	139.04	13.68
July	I (1-10)	190.60	158.62	136.80	31.98	15.10	158.62	139.04	31.98
	II (11-20)	297.70	158.62	136.80	139.08	17.97	158.62	139.04	139.08
	III (21-30)	341.80	158.62	150.48	183.18	20.14	158.62	139.04	183.18
Aug	I (1-10)	319.70	158.62	136.80	161.08	21.31	158.62	139.04	161.08
	II (11-20)	273.00	158.62	136.80	114.38	19.80	158.62	139.04	114.38
	III (21-30)	254.00	158.62	150.48	95.38	17.71	158.62	139.04	95.38
Sept	I (1-10)	217.10	158.62	136.80	58.48	14.88	158.62	139.04	58.48
	II (11-20)	122.40	121.40	115.24	1.00	9.83	112.57	98.67	9.83
	III (21-30)	76.90	75.90	74.76	1.00	6.40	70.50	61.79	6.40
Oct	I (1-10)	58.40	57.40	57.10	1.00	5.36	53.05	46.50	5.36
	II (11-20)	47.80	46.80	46.76	1.00	5.36	42.45	37.20	5.36
	III (21-30)	45.50	44.50	48.95	1.00	5.36	40.15	35.19	5.36
Nov	I (1-10)	43.70	42.70	42.73	1.00	5.36	38.35	33.61	5.36
	II (11-20)	34.90	33.90	34.01	1.00	5.36	29.55	25.90	5.36
	III (21-30)	28.80	27.80	27.93	1.00	5.36	23.45	20.55	5.36
Dec	I (1-10)	27.10	26.10	26.24	1.00	5.36	21.75	19.06	5.36
	II (11-20)	24.80	23.80	23.93	1.00	5.36	19.45	17.04	5.36
	III (21-30)	23.20	22.20	24.57	1.00	5.36	17.85	15.64	5.36
Jan	I (1-10)	21.70	20.70	20.83	1.00	5.36	16.35	14.33	5.36
	II (11-20)	20.00	19.00	19.12	1.00	5.36	14.65	12.84	5.36
	III (21-30)	19.60	18.60	20.59	1.00	5.36	14.25	12.49	5.36
Feb	I (1-10)	19.20	18.20	18.32	1.00	5.03	14.17	12.42	5.03
	II (11-20)	19.30	18.30	18.42	1.00	4.79	14.51	12.72	4.79
	III (21-30)	17.60	16.60	13.37	1.00	4.78	12.82	11.23	4.78
Mar	I (1-10)	17.80	16.80	16.91	1.00	4.59	13.21	11.58	4.59
	II (11-20)	17.80	16.80	16.91	1.00	5.36	12.45	10.91	5.36
	III (21-30)	20.70	19.70	21.81	1.00	5.36	15.35	13.45	5.36
Apr	I (1-10)	23.40	22.40	22.53	1.00	5.36	18.05	15.82	5.36
	II (11-20)	24.00	23.00	23.13	1.00	5.36	18.65	16.34	5.36
	III (21-30)	30.10	29.10	29.23	1.00	5.36	24.75	21.69	5.36
May	I (1-10)	53.80	52.80	52.63	1.00	5.36	48.45	42.46	5.36
	II (11-20)	81.80	80.80	79.34	1.00	5.36	76.45	67.01	5.36
	III (21-30)	81.20	80.20	86.66	1.00	5.36	75.85	66.48	5.36
Total		3352.50	2511.06	**2353.37 Say 2354 Mu**	841.44	295.654	2398.296	2102.21	954.20

Fig. 7.28 shows 10-daily inflows, flow diverted for power generation, and flow in the diverted river for this Project. Except for the monsoon season, most of the flow is diverted for generation of hydropower.

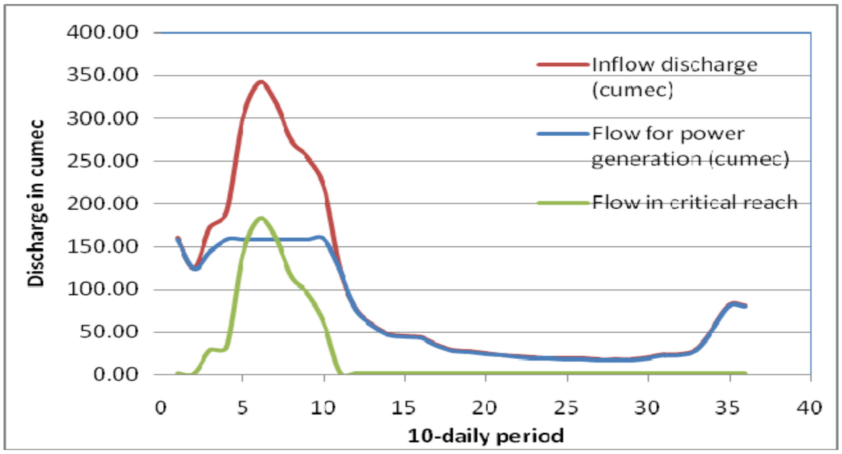


Fig. 7.28 Graph showing 10-daily inflows, flow diverted for power generation, and flow in the diverted reach for the Loharinag Pala Project.

Fig. 7.29 shows the proposed flow in the diverted reach and flow diverted for power generation for the Loharinag Pala Project.

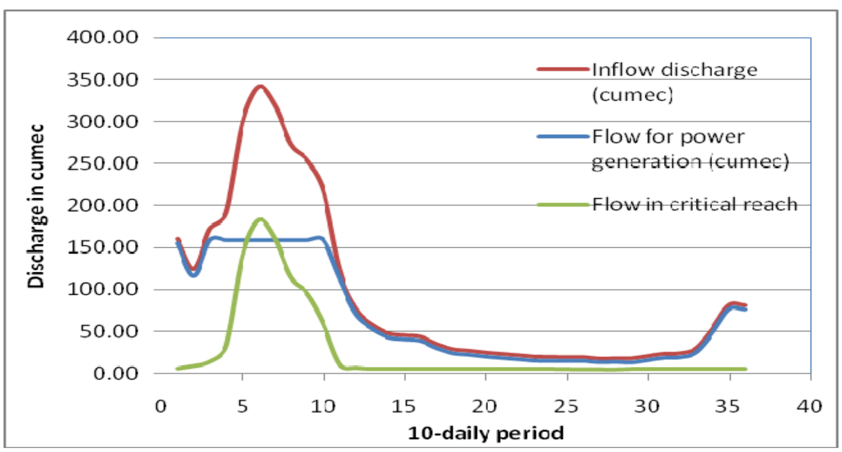


Fig. 7.29 Ten-daily inflows, proposed flow in the diverted reach, and flow diverted for power generation for the Loharinag Pala Project.

Since this project is located in ecologically fragile and sensitive zone, a higher EFR would be desirable so that the river ecosystem is maintained in a very good condition at least, while carrying out limited developmental activities.

To determine the impact of diversion on the statistical properties of river flows, statistical properties of flows have been computed and are shown in Table 7.30 for the following.

a) Inflow to LNP
b) Flow diverted for powerhouse
c) Flow in the critical reach downstream of the barrage

d) Suggested EFR in the critical reach downstream of the barrage
e) Flow for powerhouse in view of Suggested EFR.

With the suggested EFR, the minimum flow in the reach will be 4.59 cumec. The proposed EFR will also reduce the variability of flows in the diverted reach as can be seen from the Coefficient of Variation which has reduced from 2.129 to 1.818 (CV for inflows for the project is 1.066). The proposed diversion pattern will lead to a small reduction in the power generation which will fall from 2354 to 2102 MU in a 90 % dependable year. This will be about 15% reduction in power generation.

Table 7.30 Loharinag Pala Project: statistical properties of river flows.

Statistics	Inflow to LNP	Flow diverted for powerhouse	Flow in Diverted River	Proposed	
				Flow in Diverted River	Flow for power generation
Mean	93.13	69.75	23.37	26.51	66.62
Maximum	341.80	158.62	183.18	183.18	158.62
Minimum	17.60	16.60	1.00	4.59	12.45
Range	324.20	142.02	182.18	178.59	146.18
Std. Dev	99.275	57.564	49.763	48.189	59.477
Coeff. Var	1.066	0.825	2.129	1.818	0.893

7.4.5.5 Devsari Project

It is a project under development on Pinder River. The project has a catchment area of 1138 sq. km and is located downstream of confluence of Pinder River and Kali Ganga. In the energy calculations shown in DPR, ecological flows were considered uniform @ 2.6 cumec. Table 7.31 contains the 10-daily working table for the project for the 90% dependable flows.

Table 7.31: 10-daily working table for the Devsari Project for 90% dependable year.

Month	Period	Days	Initial Level (El m asl	Initial Storage (106 m3)	Inflow (cumec)	Inflow (10^6 m3)	Total Storage (106 m3)	EFR	Net head (m)	Water withdrawal for energy (106 m3)	Q for energy-1	Available Q for sea. gen. & Spillage (106 m3)	Sec power (MW)	Flow for power house (cumec)	Flow in d/s channel (cumec)
June	I	10	1295.0	10.00	24.28	20.979	40.75	9.20	232.078	13.03	15.080	0.00	0.00	15.080	9.20
	II	10	1300.0	10.00	32.99	28.501	46.88	11.51	232.078	15.00	17.366	4.11	8.60	21.474	11.51
	III	10	1300.0	10.00	45.84	39.605	63.98	14.32	232.078	15.00	17.366	14.15	29.64	31.518	14.32
July	I	10	1300.0	10.00	53.78	46.464	78.78	16.42	232.078	15.00	17.366	19.99	41.88	37.360	16.42
	II	10	1300.0	10.00	90.45	78.149	137.60	17.80	232.078	15.00	17.366	55.29	115.80	72.652	17.80
	III	11	1300.0	10.00	128.20	121.837	169.68	18.41	232.078	15.00	15.788	94.00	196.88	109.785	18.41
Aug	I	10	1300.0	10.00	85.27	73.671	153.54	17.45	232.078	15.00	17.366	50.45	105.66	67.813	17.45
	II	10	1300.0	10.00	113.49	98.054	249.61	15.52	232.078	15.00	17.366	80.60	168.83	97.969	15.52
	III	11	1300.0	10.00	92.72	88.124	233.06	14.34	232.078	15.00	15.788	62.60	131.11	78.385	14.34
Sept	I	10	1300.0	10.00	69.83	60.333	155.64	12.68	232.078	15.00	17.366	39.79	83.34	57.155	12.68
	II	10	1300.0	10.00	53.13	45.906	129.81	10.63	232.078	15.00	17.366	25.14	52.65	42.502	10.63
	III	10	1300.0	10.00	41.80	36.117	114.03	8.66	232.078	15.00	17.366	15.77	33.04	33.140	8.66
Oct	I	10	1300.0	10.00	36.94	31.916	83.96	6.70	232.078	15.00	17.366	12.87	26.96	30.240	6.70
	II	10	1300.0	10.00	29.15	25.183	122.27	6.58	232.078	15.00	17.366	5.20	10.90	22.571	6.58
	III	11	1300.0	10.00	25.21	23.956	75.80	6.58	232.078	15.00	15.788	2.84	5.95	18.630	6.58
Nov	I	10	1300.0	10.00	21.63	18.692	50.25	6.58	232.078	13.01	15.058	0.00	0.00	15.058	6.58
	II	10	1300.0	10.00	18.05	15.592	43.32	6.58	232.078	9.91	11.470	0.00	0.00	11.470	6.58
	III	10	1300.0	10.00	19.30	16.679	42.72	6.58	232.078	11.00	12.728	0.00	0.00	12.728	6.58
Dec	I	10	1300.0	10.00	15.47	13.364	35.26	6.58	232.078	7.68	8.892	0.00	0.00	8.892	6.58
	II	10	1300.0	10.00	13.90	12.007	30.77	6.58	232.078	6.33	7.321	0.00	0.00	7.321	6.58
	III	11	1300.0	10.00	15.99	15.198	34.25	6.58	232.078	8.95	9.415	0.00	0.00	9.415	6.58
Jan	I	10	1300.0	10.00	14.86	12.840	26.90	6.58	232.078	7.16	8.285	0.00	0.00	8.285	6.58
	II	10	1300.0	10.00	11.57	9.998	26.57	6.58	232.078	4.32	4.996	0.00	0.00	4.996	6.58
	III	11	1300.0	10.00	11.36	10.800	27.86	6.58	232.078	4.55	4.788	0.00	0.00	4.788	6.58
Feb	I	10	1300.0	10.00	9.88	8.540	24.58	6.58	232.078	2.86	3.308	0.00	0.00	3.308	6.58
	II	10	1300.0	10.00	9.37	8.091	25.39	6.58	232.078	2.41	2.789	0.00	0.00	2.789	6.58
	III	8	1300.0	10.00	8.96	6.193	20.71	6.58	232.078	1.65	2.384	0.00	0.00	2.384	6.58
Mar	I	10	1299.6	10.00	7.27	6.285	21.10	6.58	232.078	0.60	0.698	0.00	0.00	0.698	6.58
	II	10	1295.2	5.95	7.39	6.382	21.50	6.58	232.078	0.70	0.810	0.00	0.00	0.810	6.58
	III	11	1295.8	6.28	9.49	9.017	22.63	6.58	232.078	2.77	2.912	0.00	0.00	2.912	6.58
Apr	I	10	1295.0	5.87	9.54	8.246	22.20	6.58	232.078	2.56	2.968	0.00	0.00	2.968	6.58

Month	Period	Days	Initial Level (El m asl	Initial Storage (106 m3)	Inflow (cumec)	Inflow (10^6 m3)	Total Storage (106 m3)	EFR	Net head (m)	Water withdrawal for energy (106 m3)	Q for energy-1	Available Q for sea. gen. & Spillage (106 m3)	Sec power (MW)	Flow for power house (cumec)	Flow in d/s channel (cumec)
	II	10	1297.0	7.03	10.55	9.116	28.34	6.58	232.078	3.43	3.975	0.00	0.00	3.975	6.58
	III	10	1300.0	9.04	11.26	9.730	35.46	6.58	232.078	4.05	4.685	0.00	0.00	4.685	6.58
May	I	10	1300.0	9.04	17.97	15.530	38.58	6.58	232.078	9.85	11.398	0.00	0.00	11.398	6.58
	II	10	1300.0	9.04	22.03	19.037	40.42	6.58	232.078	13.35	15.457	0.00	0.00	15.457	6.58
	III	11	1300.0	9.04	18.06	17.167	50.26	7.62	232.078	9.93	10.443	0.00	0.00	10.443	7.62
Average			1299.4	8.63		61.49	70.12		232.078	15.20				24.47	9.05

Information pertinent to stream variability was drawn from the working table and is presented in Table 7.32. It can be seen that in the diverted reach, mean flow will be 9.93 cumec after the project begins operation against 41.27 cumec in the pre-project condition. The coefficient of variation which is 0.82 in the pre-project condition will change to 0.484 in post-project situation.

Table 7.32 Devsari Project: statistical properties of river flows for 90% dependable year.

Statistics	Inflow to the project	Proposed	
		Flow in critical reach EFR	Flow for power generation
Mean	33.53	9.05	24.474
Maximum	128.20	18.41	109.79
Minimum	7.27	6.58	0.70
Range	120.92	11.83	109.09
Std. Dev	32.12851	3.911313	28.15921
Coeff. Var	0.958277	0.432016	1.150588

For easy visualization of key discharge components, Fig. 7.30 shows inflow, flow diverted to the power house for energy generation, and the flow in the river channel just downstream of the project.

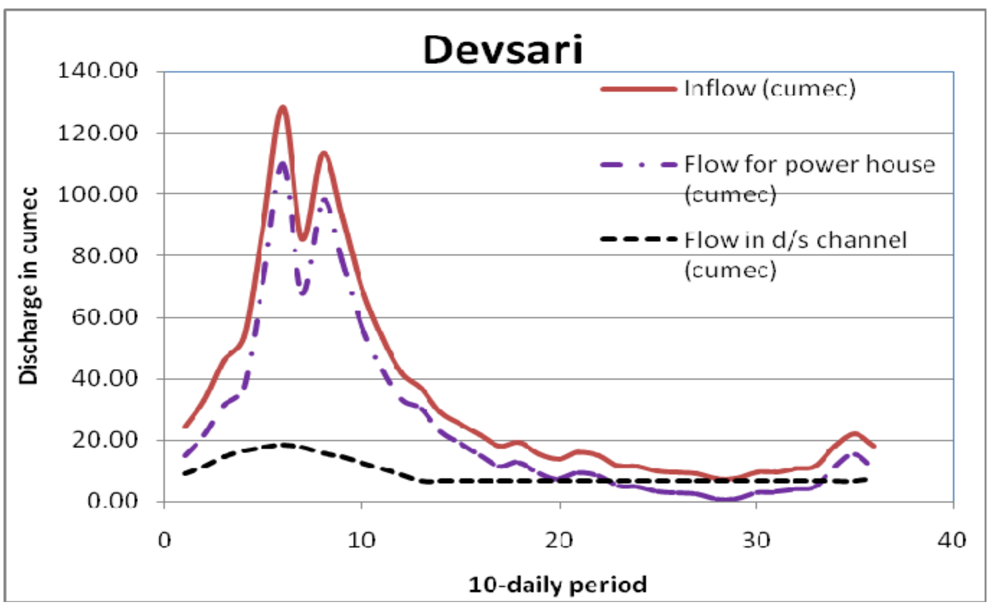


Fig. 7.30 Graph showing inflow, flow diverted to the power house for energy generation, and the flow in the diverted river reach.

7.4.6 Fragmentation of Rivers

Freshwater ecosystems including rivers, lakes and wetlands are extremely rich in species, but unfortunately, are also amongst the most altered and threatened ecosystems in the world. The natural flow regime and the longitudinal and lateral connectivity of rivers, both essential characteristics that sustain the biophysical and ecological processes necessary for life in freshwaters, are disrupted when rivers are fragmented by dams and their reservoirs. This fragmentation and the consequent loss of ecosystem processes do not only affect ecosystems and species, but humans as well. For example, the loss of floodplain inundation patterns affect both native ecosystems and human communities dependent on floodplain fisheries and flood recession agriculture.

The purpose of the river fragmentation and flow regulation indicator is to provide a measure of the degree to which rivers' connectivity and flow regime have been altered by dams and reservoirs. The impacts of dams and reservoirs vary depending on the number and size of the dams, where they are located on the river system, as well as the storage capacity of the associated reservoirs. In total, the indicator partners assessed 292 large river systems with drainage basins representing 54 percent of the world's land area. Fragmentation rankings, i.e., highly affected, moderately affected and unaffected are assigned to each large river system using the number, location, and storage capacity of dams to estimate the proportion of free flowing miles of river length, as well as the annual runoff that is stored behind dams throughout the system.

Unaffected rivers are those without dams in the main channel of the river and, if tributaries have been dammed, the flow of the river has not changed substantially (less than 2% of the natural flow has been affected). Highly fragmented and regulated rivers, on the other hand, include those with less than one quarter of their main channel left without dams, where the largest tributary has at least one dam, and where the reservoirs retain a considerable portion of a year's flow.

An analysis of the fragmentation aspect of the Bhagirathi Alakananda basin has been presented in Chapter 8.

7.5 Soil Erosion Study

Soil erosion is a widespread phenomenon and it is a diffuse process which occurs at widely varying rates over the field/landscape and even along a typical landscape profile within a field. Therefore, direct measurement of soil erosion at many points across a region is impractical. Physically, erosion is difficult to measure, and variation of climate requires at least ten years of data to obtain an accurate measure of average annual erosion. Consequently, researchers commonly use erosion prediction methods to make regional assessments of the impact of erosion on crop productivity, off-site sedimentation or in selecting conservation methods for specific fields.

In the present study, an assessment of soil loss has been done to identify soil erosion prone areas within the Alaknanda and Bhagirathi Basins and suggestions for soil conservation measures, wherever, needed or even priority areas can be identified. The most extensively used empirical soil erosion model, has been used.

Before planning for conservation measures within an area, it is desirable to assess the magnitude of soil erosion. Estimates of the rate of soil loss may then be compared with what is considered acceptable and the effects of different conservation strategies can be determined. What is required, therefore, is a method of predicting soil loss under a wide range of conditions (Morgan, 1984). Modeling soil erosion is the process of mathematically describing soil particle detachment, transport and deposition on land surfaces.

Soil erosion is caused by detachment and removal of soil particles from land surface. It is a natural physical phenomenon which helped in shaping the present form of earth's surface (G. Das 2002).

Excessive erosion from the area may be harmful in the following ways:

(i) It may lead to severe loss of valuable fertile soil which affects the agricultural productivity.

(ii) The loss of the soil cover reduces the water retention capacity of the land and may result in increased runoff.

(iii) The downstream surface water resources are polluted by both dissolved and undisolved substances captured by the eroding water.

(iv) Structure and agricultural field lying downstream are damaged or otherwise devalued by the sediments deposited in or on them.

7.5.1 The Universal Soil Loss Equation

Wischmeier and Smith (1958 and 1978) developed the Universal Soil Loss Equation (USLE) for prediction of gross soil erosion. The equation states that:

$$A = R\ K\ LS\ C\ P \qquad \text{... (7.2)}$$

Where, A = Average annual soil loss in tons per hectare year, R = Rainfall/runoff erosivity factor, K = Soil erodibility, LS = Hill slope length and steepness, C = Cover-management, P = Support practice.

The R factor is an expression of the erosivity of rainfall and runoff at a particular location. The value of "R" increases as the amount and intensity of rainfall increases.

The K factor is an expression of the inherent erodibility of the soil or surface material at a particular site under standard experimental conditions. The value of "K" is a function of the particle-size distribution, organic-matter content, structure, and permeability of the soil or surface material

The LS factor is an expression of the effect of topography, specifically hill slope length and steepness, on rates of soil loss at a particular site. The value of "LS" increases as hill slope length and steepness increase, under the assumption that runoff accumulates and accelerates in the down slope direction. This assumption is usually valid for lands experiencing overland flow but may not be valid for forest and other densely-vegetated lands.

The C factor is an expression of the effects of surface covers and roughness, soil biomass, and soil-disturbing activities on rates of soil loss at a particular site. The value of "C" decreases as surface cover and soil biomass increase, thus protecting the soil from rain splash and runoff

The P factor is an expression of the effects of supporting conservation practices, such as contouring, buffer strips of close-growing vegetation, and terracing, on soil loss at a particular site. The value of "P" decreases with the installation of these practices because they reduce runoff volume and velocity and encourage the deposition of sediment on the hill slope surface. The effectiveness of certain erosion-control practices varies substantially due to local conditions. For example, contouring is far more effective in low-rainfall areas than in high-rainfall areas.

7.5.2 GIS Database Preparation

Soil loss from watershed is assessed by applying universal soil loss empirical equation (USLE) using geographical information system (GIS).

Base map preparation

Different layers were created in vector format for analysis of study area as given in Table 7.33 Most of the analysis and overlay operations are easily and efficiently done in raster model and therefore, all maps in vector model were converted into raster structure using Arc GIS software. Boundary, Soil and land use maps which were already in polygon form were rasterized through polygon to raster mode.

Table 7.33 List of input database

Sl. No.	Name of Layer	Shape file Layer (SHP)	Source	Software used
1.	Boundary	Polygon	Toposheet	Arc GIS 9.3.1
2.	Stream	Polyline	Toposheet	Arc GIS 9.3.1
3.	Soil map	Polygon	Toposheet	Arc GIS 9.3.1
4.	Land use map	Polygon	Satellite Imagery	Arc GIS 9.3.1, ERDAS 9.0

Land use classification

Using IRS (LISS-III DATA) imageries of resolution 23.5m land use/land cover map was prepared. Unsupervised classification was done using ERDAS 9.0 software. Seven different land use classes, built up area, water body, open forest, dense forest, barren land, agriculture land, forest and fallow land were generated for study area. These layers of land use were in raster form and therefore the same were converted into vector. Clean and build operation was done to obtain area and perimeter of the different classes. The land use map of Alaknanda and Bhagirathi Basins for the year 2000 is given in Fig. 3.8.

Digital Elevation Model

Digital elevation model (DEM) is digital representation of a topographic surface. However, most often it is used to refer specifically to a raster or regular grid of spot elevations. The best resolution available is 30m with a vertical resolution of 1m.

DEM was generated using 90 m SRTM data of the Alaknanda Bhagirathi basin. After creation of DEM, slope map of the watershed was prepared and areal coverage of various slope classes is depicted in Table 7.34. Slope map of the study area is presented in Fig. 4 whereas the drainage map is presented in Fig. 5.

Table 7.34 Areal statistics of slope class of Alaknanda and Bhagirathi Basins

S. No.	Class	Area (km^2)	% Total
1	0-20%	1594.17	8.44
2	20-40%	4243.914	22.46
3	40-60%	5415.628	28.67
4	60-80%	4025.141	21.31
5	80-100%	2105.881	11.15
6	100-120%	964.1864	5.10
7	120-140%	479.5885	2.54
8	>140%	60.13018	0.32

Estimation of Soil loss

Rainfall/runoff Erosivity Factor (R)

The erosivity factor of rainfall (R) is a function of the falling raindrop and rainfall intensity,

In this study, the storm wise rainfall data were not available for computation of rainfall erosivity factor (R). So, the relationship between seasonal value of R and average seasonal (June to September) rainfall has been used, as defined by Ram Babu *et al.* (2004). The rainfall erosivity factor has been defined by the following equation:

$$R = 71.9 + 0.36\,X \qquad \ldots (7.3)$$

Where, R = average seasonal erosivity factor (Meter tonnes ha^{-}1. cm. h^{-1} 100 $^{-1}$), X= average seasonal rainfall (mm).

In and around the study area, eight rain gauge stations are available and rainfall data have been used for duration of ten years. Average values of ten years data were used to calculated.

The rainfall erosivity factor (R) by using Eq. 7.34. The generated has been is presented in Fig. 7.31. The values from R-Map have been adopted in this study to calculate soil erosion.

Soil Erodibility Factor (K)

Various soil types are available in the study area. Based upon the depth, texture and location, the severity of the erosion is determined. As per the soil codes and soil types, the soil has been classified in five categories. Fine-textured soils that are high in clay have low K values (about 0.05 to 0.15) because the particles are resistant to detachment. Coarse-textured soils, such as sandy soils, also have low K

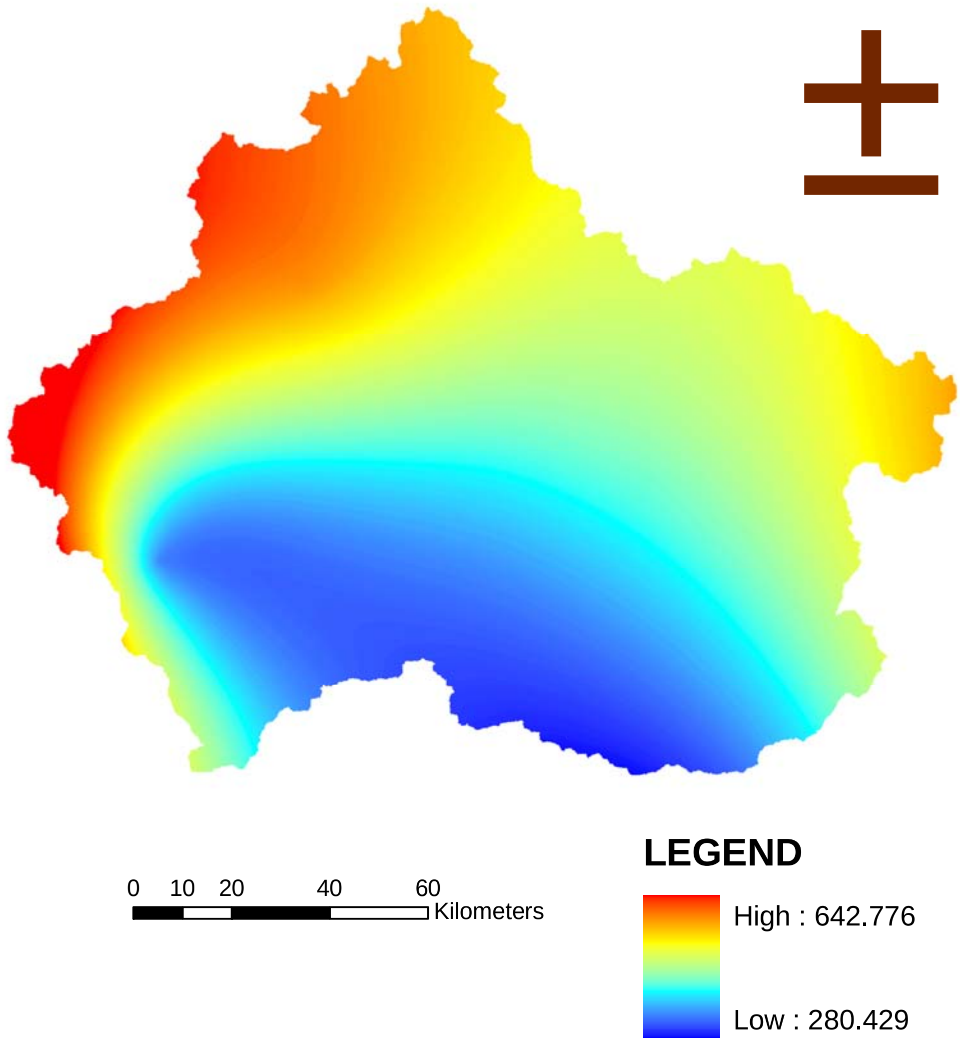


Fig. 7.31 Rainfall Erosivity Factor (R) Map in the study area.

values (about 0.05 to 0.2) because of high infiltration resulting in low runoff even though these particles are easily detached. Medium-textured soils, such as a silt loam, have moderate K values (about 0.25) because they are moderately susceptible to particle detachment and they produce runoff at moderate rates. Soils having high silt content are especially susceptible to erosion and have high K values, which can range between 0.25 to 0.4, thus an average value of 0.325 is assigned. Soil with very very severe soil erosion is considered as 0.4 Silt-size particles are easily detached and tend to crust, producing high rates and large volumes of runoff. The soil map of the study area is presented in Fig.7. The various classes of soil and the values of K are given in Table 7.35.

Table 7.35 Soil erodibility factor for different types of soils of Alaknanda and Bhagirathi Basins.

S. No.	Soil Codes	Soil type	Erosion rate	K Value
1	1,2,38,39, 43,44,47	Moderately -Deep/Soil of Side Sloes/Fluvial	Slight Erosion	00.10
2	8,12,14,15,18,19,20,27,28, 29,30,32,33,35,36,37,40,41 ,42,45,46	Moderately Shallow/ Soil of Side Sloes	Moderate Erosion	00.15
3	7,10,11,13,21,23,24,25,26, 34,	Shallow/ Soil of Side Sloes	Severe Erosion	0.25
4	3,4,5,6,16,17,22,31	Very Shallow/Soil of Side Sloes	Very Severe Erosion	00.325
5	9,48,49	Soil at cliff	Very Very Severe Erosion	00.40

Preparation of K-factor Map

The K-Factor map has been prepared by considering the soil classification map (Fig 7.32). The K value for different types of soils used in this study given in Table 7.35. Depending upon the soil class, suitable K values have been assigned and the map is presented in Fig 8.

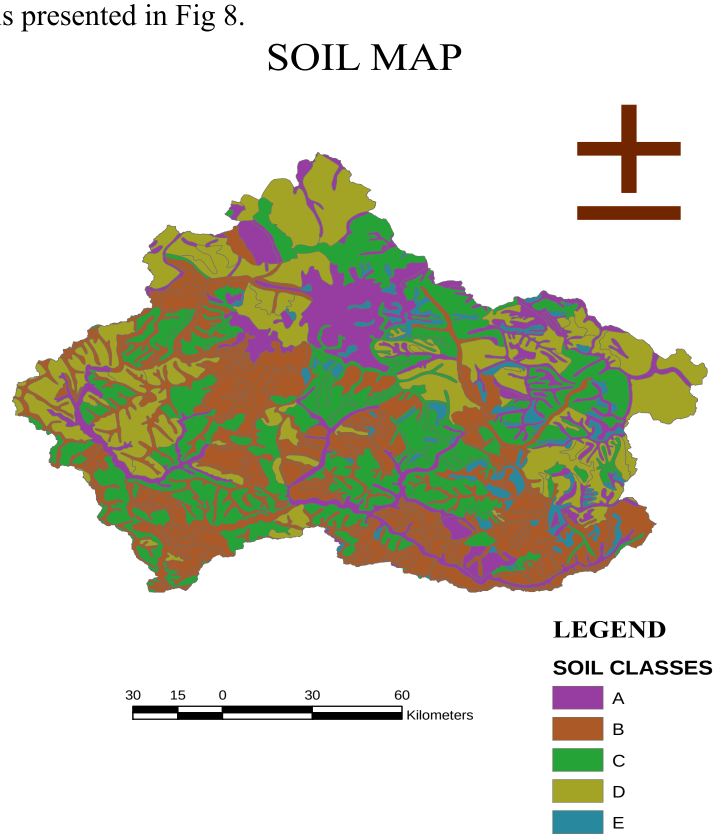


Fig. 7.32 Soil map of Alaknanda and Bhagirathi Basins.

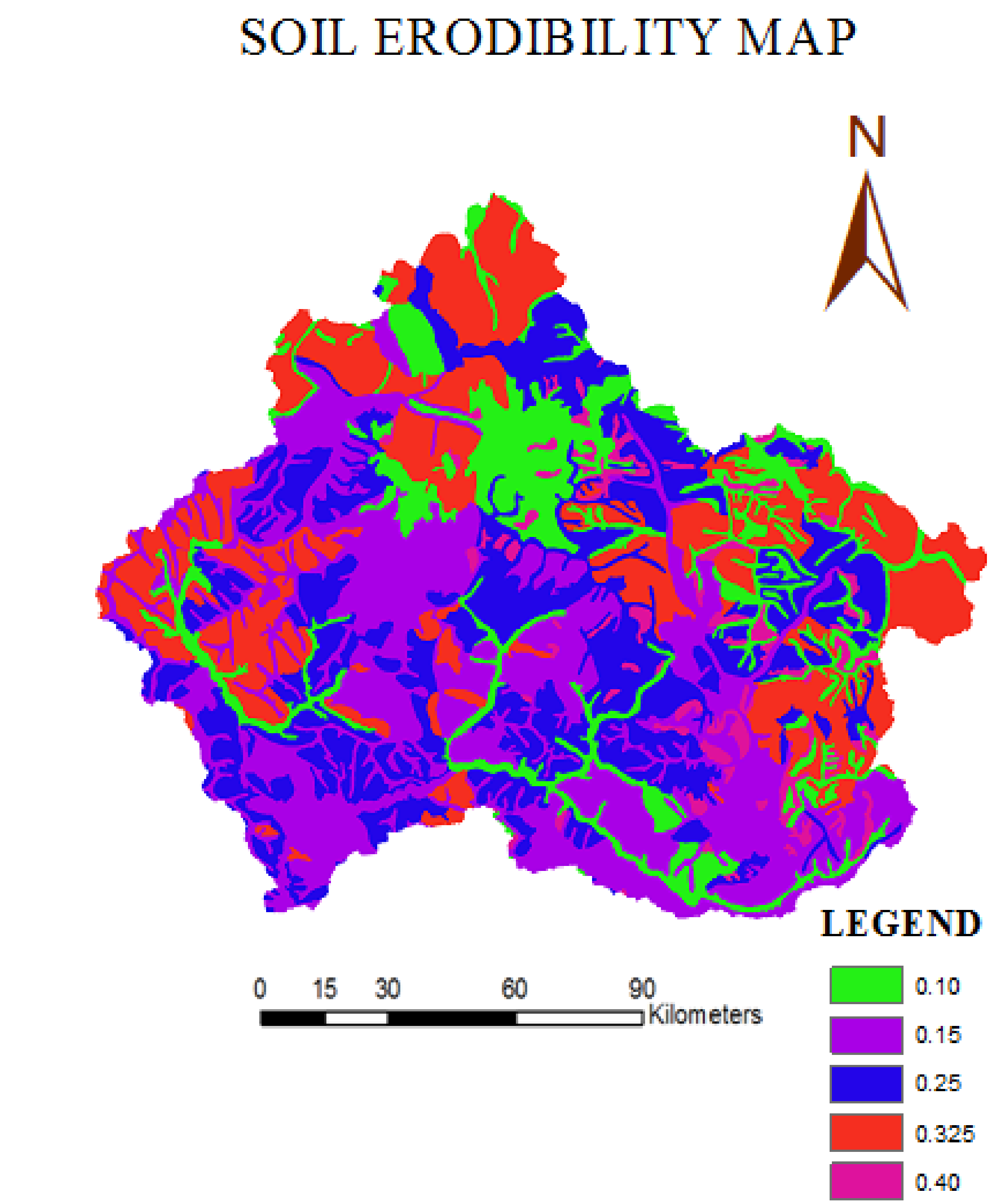


Fig. 7.33 Soil erodibility (K) map of Alaknanda and Bhagirathi Basins.

Slope Length and Gradient Factor (LS)

The effect of topography on erosion is accounted for by the LS factor in USLE, which combines the effects of a hill slope-length factor (L) and a hill slope-gradient factor (S). Generally speaking, as hill slope length and/or hill slope gradient increase, soil loss increases. As hill slope length increases, total soil loss and soil loss per unit area increase due to the progressive accumulation of runoff in the down slope direction. As the hill slope gradient increases, the velocity and erosivity of runoff increases.

Hill slope-Length Factor (L)

If soil loss is entirely generated by inter rill erosion, which is nearly always uniform along a hill slope, the L value will be 1 for all lengths. However, if the soil loss is generated entirely by rill erosion, the L value will increase linearly with length because rill erosion increases in the down slope direction as runoff accumulates. Soil loss is usually combination of both inter rill and rill erosion. L values remain nearly constant as hill slope lengths increase when inter rill erosion predominates along hill slopes, or increase when rill erosion predominates.

Wischmeier and Smith (1965) derived the following expression for the relation between soil loss and slope length after long term observation.

$$L = (\lambda / 22.13)^{m} \qquad \text{… (7.4)}$$

Where,

λ= slope length measured from the water divide of the slope (m)

m = exponent dependent upon slope gradient and may also be influenced by soil properties, type of vegetation etc (taken as 0.4).

Hill Slope-Gradient Factor (S)

The hill slope-gradient factor, S, reflects the effect of hill slope-profile gradient on soil loss. For a unit plot, with a 9 percent gradient as described earlier, the S value is equal to 1. The S values vary from above to below 1, depending on whether the gradient is greater than or less than that of the unit plot. Soil losses increase more rapidly as gradient increases than as length increases. Also, rill erosion is affected more by hill slope gradient than is inter-rill erosion.

The slope gradient factor (S) is the ratio of soil loss from a plot of known values of the factor S. In this study, slope gradient factor (S) is calculated by using following equation (McCool et al., 1987),

$$S=10.8 \sin\theta + 0.03 \qquad \text{for slopes > 4 m, and s < 9\%} \qquad \text{… (7.5)}$$

$$S=16.8 \sin\theta - 0.50 \qquad \text{for slopes > 4 m, and s} \geq 9\% \qquad \text{… (7.6)}$$

Where, θ = field slope in degrees= $\tan^{-1}$(field slope/100).

The final LS map has been prepared by multiplying L & S factor using above equation 6 & 7 and is shown in Fig 7.34**.**

Cover-Management Factor (C)

Several of the USLE model inputs such as crop management factor (C) and conservation factor (P) depend on land use/cover information. Crop management factor is the expected ratio of soil loss from a cropped land under specific condition to soil loss from clean tilled fallow on identical soil and slope under the same rainfall conditions. The land cover and the manner in which it is managed and the changes that have taken place over time form the basic premise for evaluating sediment yield from a watershed. In case of Alaknanda and Bhagirathi Basins, values of C factors are assigned in land use maps and they are given in Table 7.36 for different land use classes (Jha, 2002). The C map is presented in Fig. 7.35 for the year 2000.

Table 7.36 Crop cover management factor (C) for different types of land use of Alaknanda and Bhagirathi Basins

S. No.	Class	C value
1	Water	0.00
2	River bed	0.35
3	Dense forest	0.01
4	Open forest	0.01
5	Scrub	0.10
6	Barren Outcrop	0.35
7	Snow	0.00

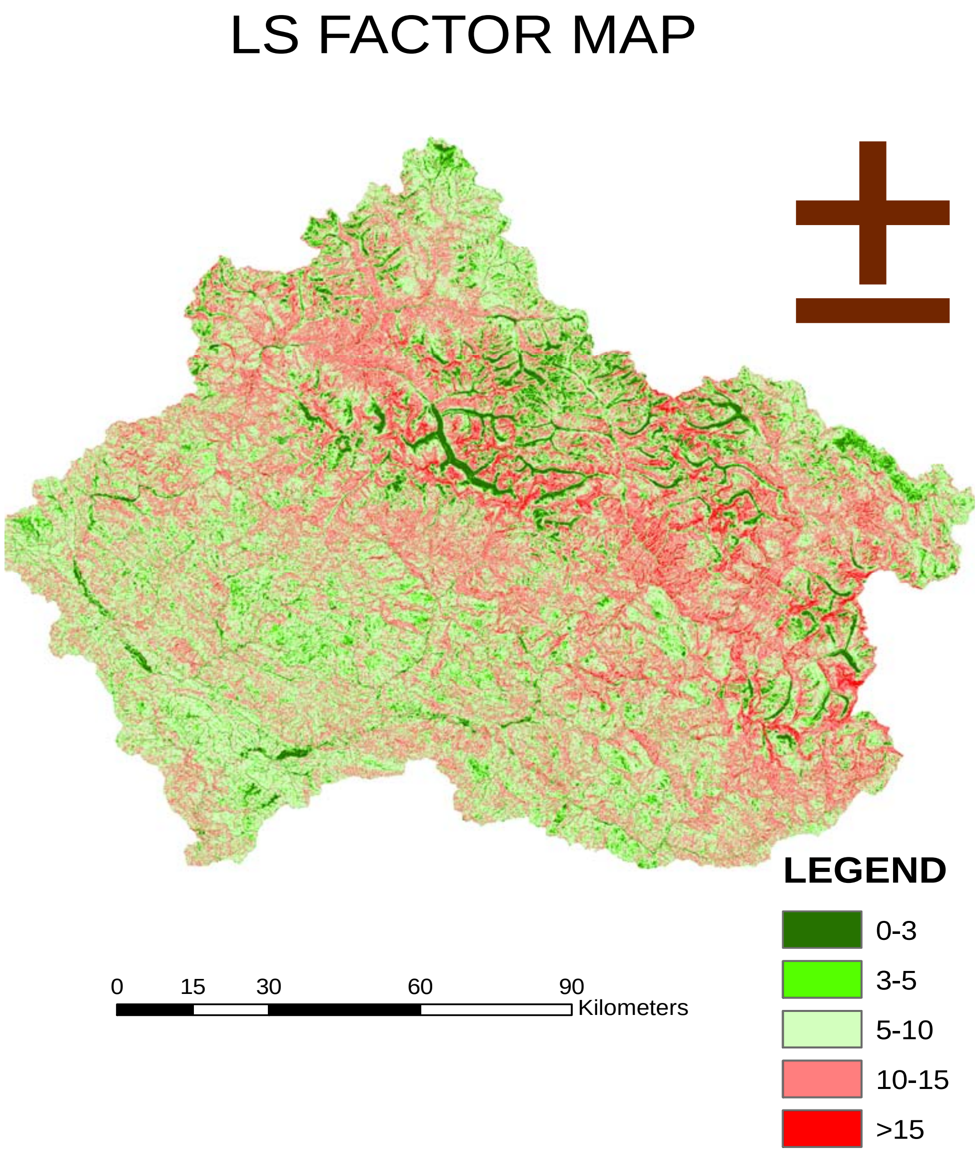


Fig. 7.34: LS factor map of Alaknanda-Bhagirathi catchment.

CROP COVER MANAGEMENT FACTOR (C), 2000

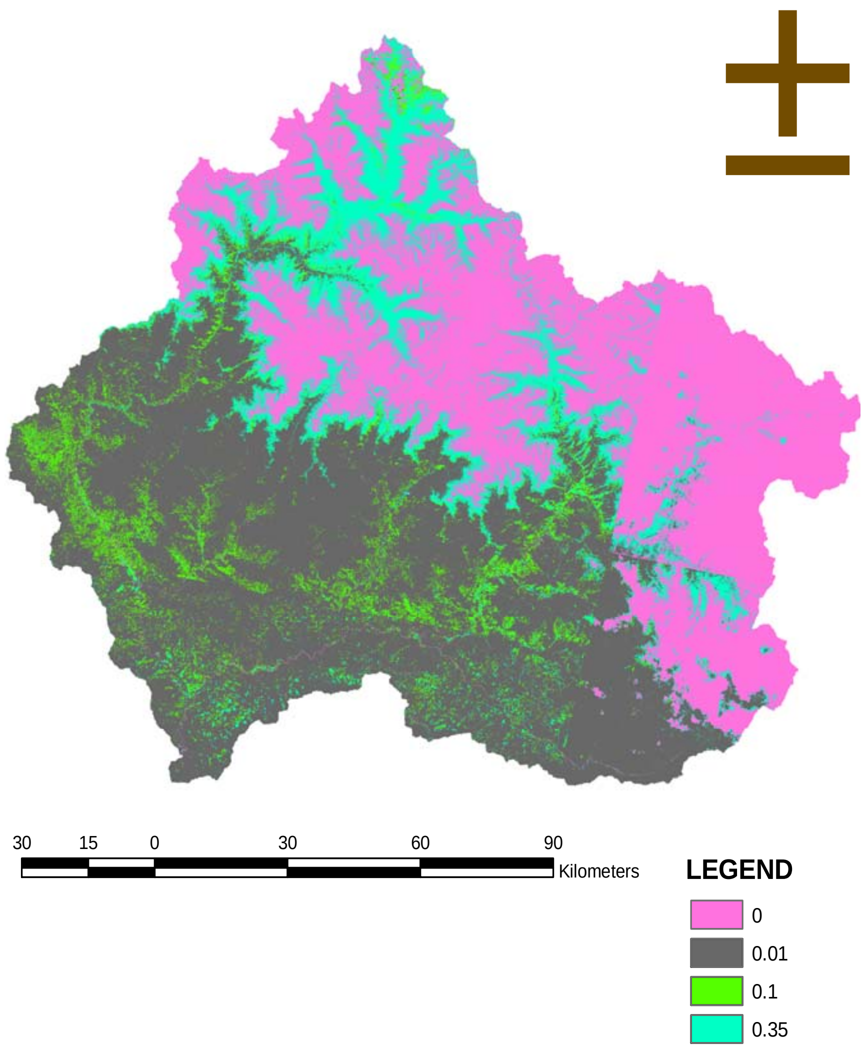


Fig. 7.35: Crop cover management factor (C) map of Alaknanda and Bhagirathi Basins for the year 2000.

Support-Practice Factor (P)

The support-practice (P) and cover-management (C) factors are very important in USLE for mined land and construction-site reclamation planning because these factors represent practices designed to reduce erosion. The P value in USLE is the ratio of soil loss with a specific support practice to the corresponding soil loss with straight-row upslope and down slope tillage. P values for different conservation practices will be different. For the analysis purpose it is assumed that at present water conservation measures are not implemented and therefore, P factor map which has been prepared in ARC GIS environment for P values equal to 1, i.e. no conservation practices. However, when the conservation practices shall be adopted, the soil erosion would reduce accordingly.

7.5.3 Application of USLE in GIS

In this study, an event based spatially distributed model was applied to estimate soil erosion Due to the lack of available data, empirical Universal Soil Loss Equation (USLE) was applied for erosion estimation by discretizing watersheds in to homogeneous cells. GIS based computations of different physical characteristics of these cells, which affect the soil erosion processes in different parts of watershed have been carried out. Using digital elevation models (DEM) with resolution of grid size 30m x 30m, erosion from each grid cell was estimated. The soil loss was estimated using raster calculator tool in Arc GIS. First LS factor was computed depending upon slope steepness and slope length, as follows:

LS factor =

POW ([flowacc] * resolution/22.1,0.4)*(((sin [slope] * 0.0174)*10.8) + 0.03) …(7.7)

Where, flowacc was generated in arc GIS as number of upslope cells contributing the down slope cell, slope was also generated in GIS and converted in radians by multiplying 0.0174 (PI/180); resolution was grid size, i.e. 30m x 30m.

After calculating LS factor, soil loss per pixel was computed using raster calculator by applying the equation:

Soil loss = Rainfall erodibility factor (R) * soil map for K * LS * land use map for C*conservation practice factor P … (7.8)

The computed per pixel soil loss was converted to whole watershed by multiplying number of pixels in the watershed. The event basis computed results are expressed in tonnes/hectare/year. Various classes as per the severity of soil erosion are given in Table 7.37. The soil erosion was categorized into various ranges according to the erosion potential as shown Table 7.38. The soil erosion map of the study area is presented in Fig. 7.36 for the year 2000.

Table 7.37 Soil erosion classes

Erosion Class	Numeric Range (T/ha/year)	Erosion Potential
1	<1	Very Low
3	1-10	Low
4	10-30	Moderate
5	30-100	High
6	>100	Severe

Table 7.38 Status of soil erosion potential in the year 2000

Numeric Range (T/ha/year)	Area (in sq km)	Area (in Percentage)
<1	6939.34	36.73819
1-10	6805.42	36.02919
10-30	1757.172	9.302803
30-100	781.1951	4.135796
>100	2605.503	13.79403

Numeric Range (T/ha/year)	Area (in sq km)	Area (in Percentage)
Total	18888.63	100

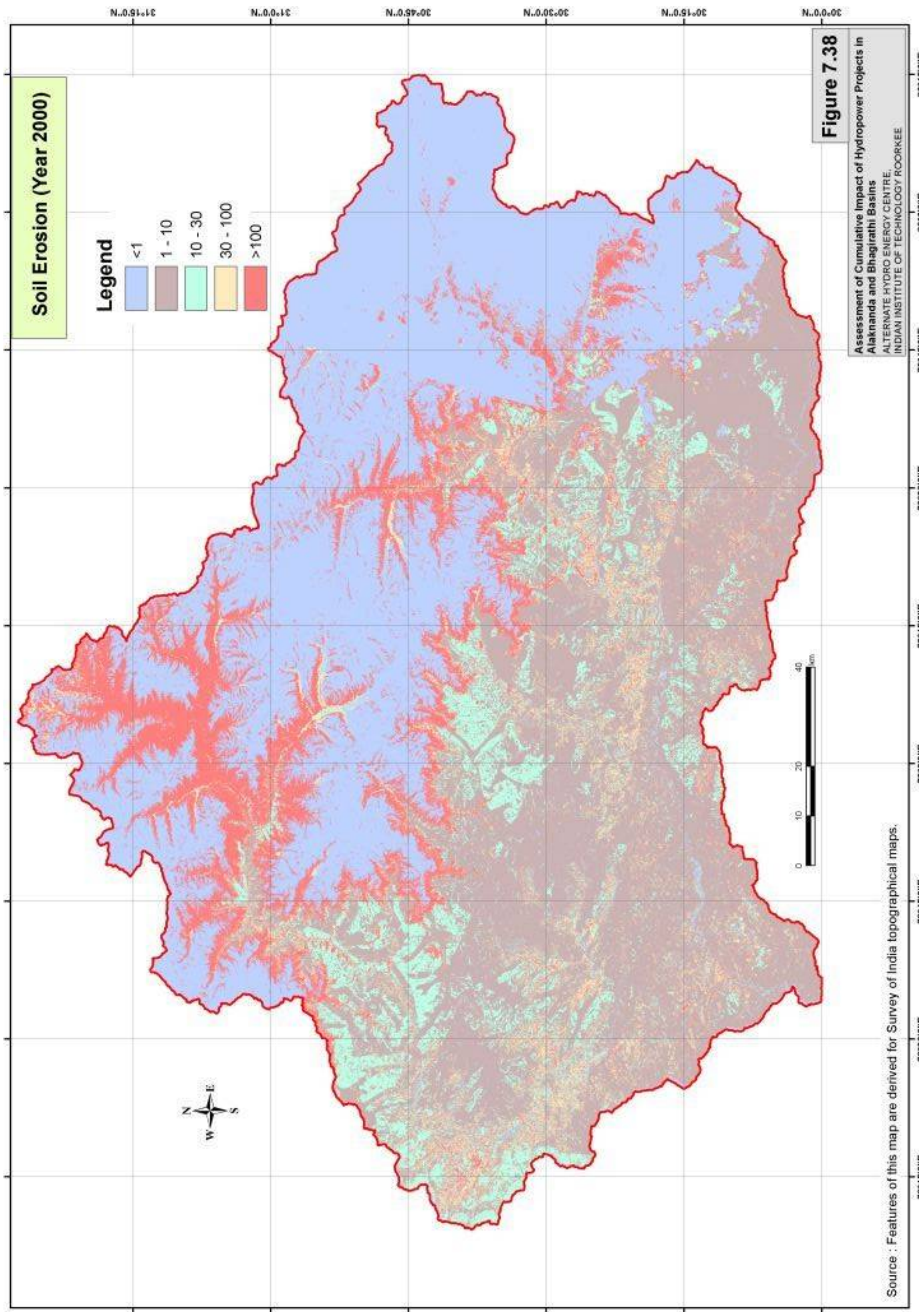


Fig. 7.36 Soil loss map in the Alaknanda and Bhagirathi Basins in the year 2000.

For the soil erosion study, analysis was also made for 2009 year by using the land use of the year 2009. The land use for 2009 and corresponding C-map are presented in Figs. reference 7.36 and 7.37. Similarly, soil loss has been computed as described earlier and the soil erosion has been computed for the year 2009. The soil erosion rates for different categories are given in Table 7.39. With the inputs for the year 2009, the soil erosion map was prepared and is shown in Fig. 7.38.

On the soil erosion map the location of various hydro power projects is marked. Fig. 7.39 shows the location of the commissioned and under development projects with soil erosion map. Basin wise soil erosion map is shown in Fig. 7.40. Table 7.40 shows the overall picture of soil erosion rates in the study area.

Table 7.39 Status of soil erosion potential in the year 2009

Numeric Range (T/ha/year)	Area (in sq. km)	Area (in percentage)
<1	4983	26.38095
1-10	7717.66	40.85876
10-30	1992.413	10.54821
30-100	878.8197	4.652639
>100	3316.738	17.55944
Total	**18888.63**	**100**

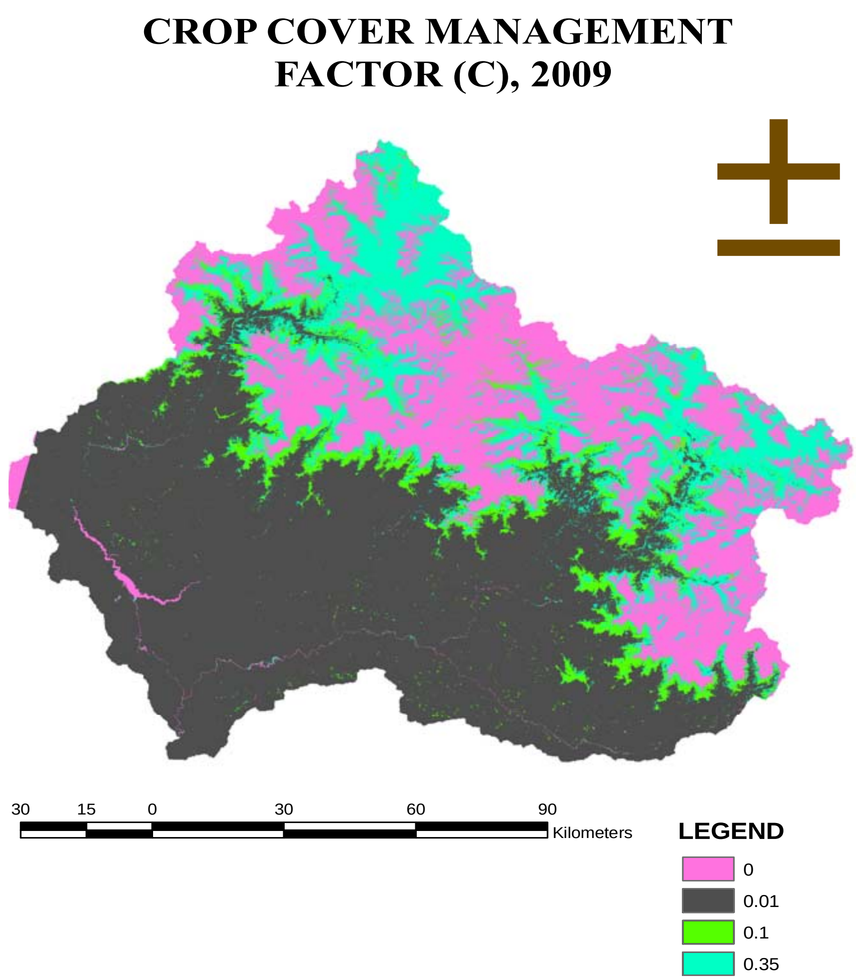


Fig. 7.37 Crop cover management factor (C) map of Alaknanda and Bhagirathi Basins for the year 2009.

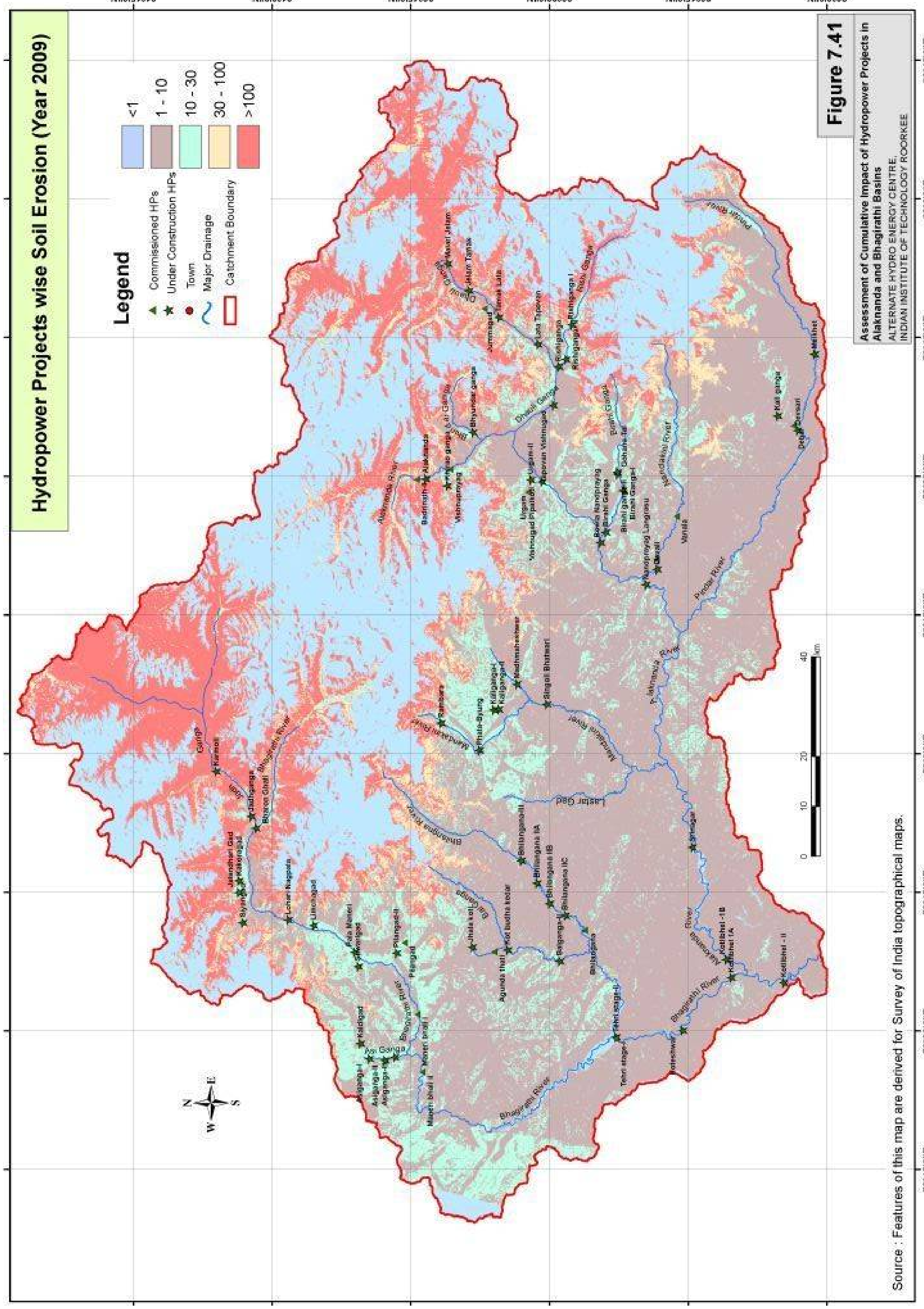


Fig. 7.38 Soil loss map in the Alaknanda and Bhagirathi Basins for the year 2009.

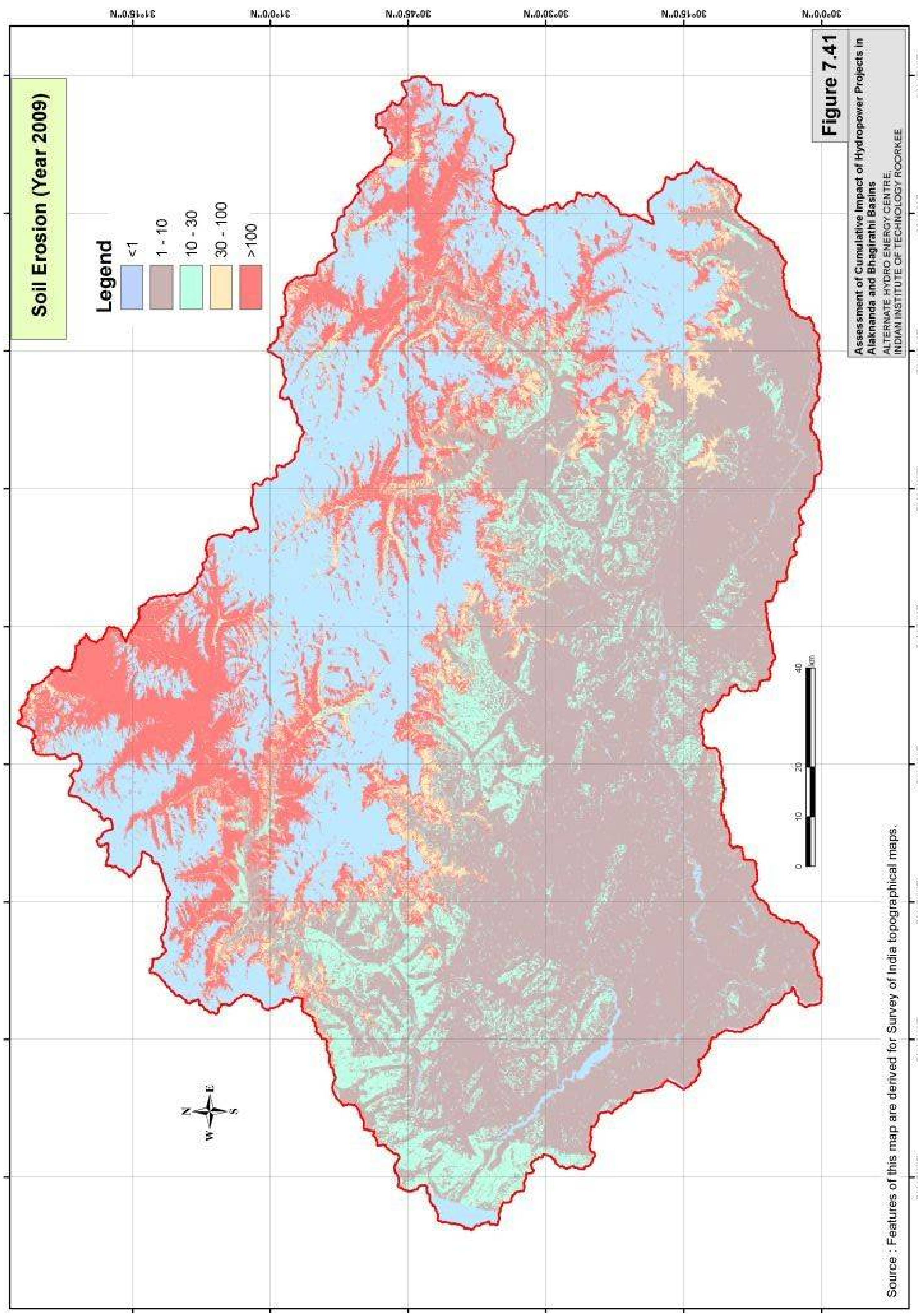


Fig. 7.39 Soil loss map with the location of Hydropower Projects in the Alaknanda and Bhagirathi Basins for the year 2009.

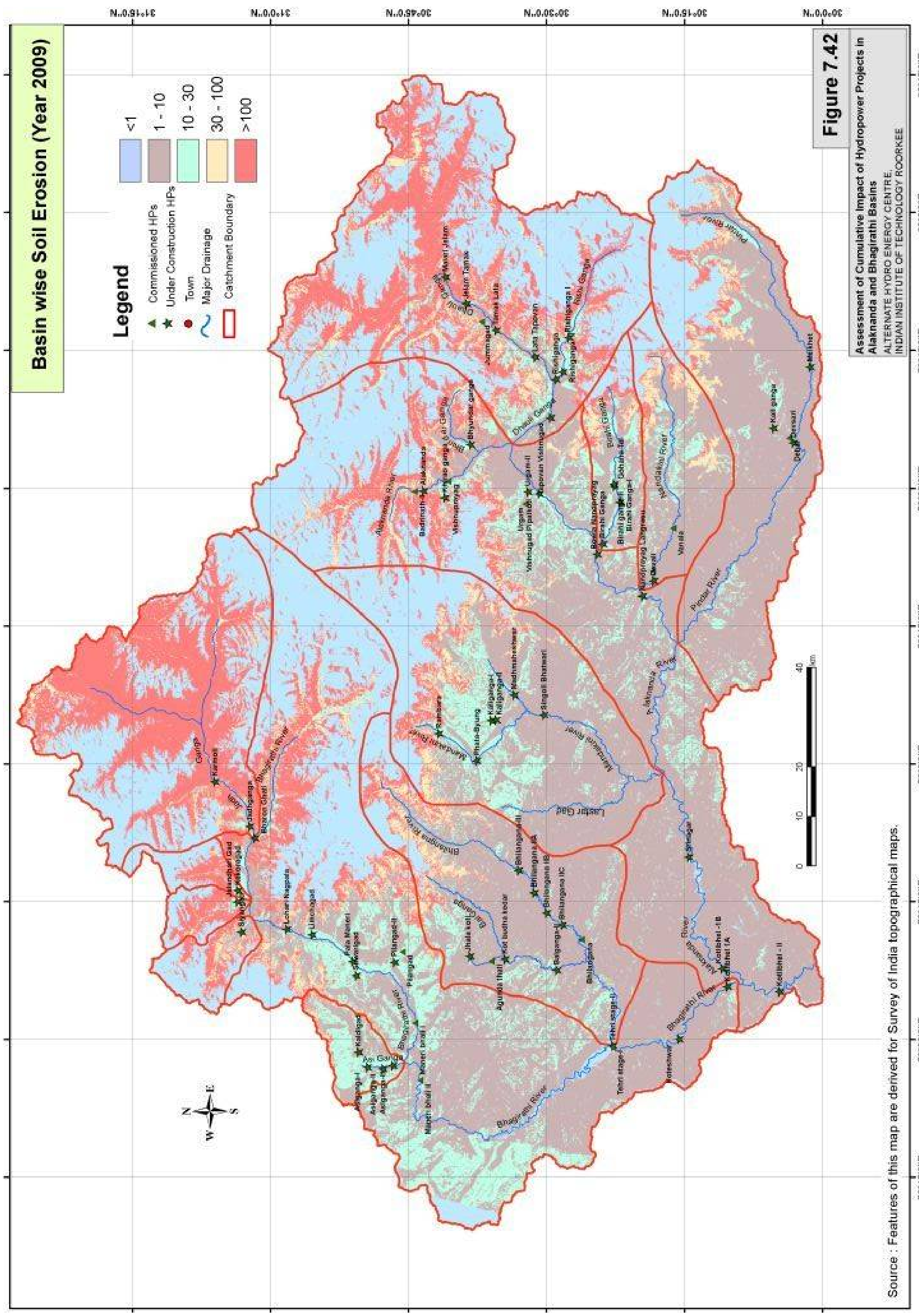


Fig. 7.40 Basin wise soil loss map with the location of hydropower projects in the Alaknanda and Bhagirathi Basins for the year 2009.

Table 7.40 Status of soil erosion rates in various projects in study area

S No	Project Name	Capacity (MW)	Stream Name	Distt Name	Status	Soil Erosion rate (2009)
1	Agunda thati	3	Dharamganga	Tehri Garhwal	Commissioned	Low
2	Badrinath	1.25	Rishiganga	Chamoli	Commissioned	Very High
3	Bhilangana	22.50	Bhilangna	Tehri Garhwal	Commissioned	Low
4	Debal	5	Pinder	Chamoli	Commissioned	Low
5	Jummagad	1.20	Jummagad	Chamoli	Commissioned	Very High
6	Maneri bhali I	90	Bhagirathi	Uttarkashi	Commissioned	Very Low
7	Maneri bhali II	304	Bhagirathi	Uttarkashi	Commissioned	Low
8	Pilangad	2.25	Pilangad	Uttarkashi	Commissioned	Low
9	Rajwakti	3.60	Nandakini	Chamoli	Commissioned	Low
10	Tehri stage-I	1000	Bhagirathi	Tehri Garhwal	Commissioned	Low
11	Urgam	3	Kalpganga	Chamoli	Commissioned	Low
12	Vanala	15	Nandakini	Chamoli	Commissioned	Low
13	Vishnuprayag	400	Alaknanda	Chamoli	Commissioned	Low
14	Alaknanda	300	Alaknanda	Chamoli	Under Development	Moderate
15	Asiganga-I	5	Asiganga	Uttarkashi	Under Development	Moderate
16	Asiganga-II	3	Asiganga	Uttarkashi	Under Development	Low
17	Asiganga-III	3	Asiganga	Uttarkashi	Under Development	Low
18	Balganga-II	7	Balganga	Tehri Garhwal	Under Development	Low
19	Bharon Ghati (I,II)	380	Bhagirathi	Uttarkashi	Under Development	Very High
20	Bhilangana II-A	24	Bhilanganga	Tehri Garhwal	Under Development	Very Low
21	Bhilangana II-B	24	Bhilanganga	Tehri Garhwal	Under Development	Low
22	Bhilangana II-C	21	Bhilanganga	Tehri Garhwal	Under Development	Low
23	Bhilangana-III	24	Bhilangana	Uttarkashi	Under Development	Very High
24	Bhyundar ganga	24.3	Bhyundar ganga	Chamoli	Under Development	Moderate
25	Birahi ganga SHP-II	6	Birahiganga	Chamoli	Under Development	High
26	Birahi Ganga-I	24	Birahiganga	Chamoli	Under Development	Very High
27	Bowla Nandprayag	300	Alaknanda	Chamoli	Under Development	Low
28	Dewali	13	Nandakini	Chamoli	Under Development	Low
29	Devsari	300	Pinder	Chamoli	Under Development	Very Low
30	Gohana Tal	60	Birahiganga	Chamoli	Under Development	Moderate
31	Jadhganga	50	Jadh ganga	Uttarkashi	Under Development	Low
32	Jalandhari Gad	24	Jalandharigad	Uttarakashi	Under Development	Moderate
33	Jelam Tamak	126	Dhauliganga	Chamoli	Under Development	Very High
34	Jhala koti	12.5	Dhram Ganga	Tehri Garhwal	Under Development	Low
35	Kail ganga	3	Kail ganga	Chamoli	Under Development	Low
36	Kakoragad	12.5	Kakoragad	Uttarkashi	Under Development	Moderate
37	Kaldigad	9	Kaldigad	Uttarkashi	Under Development	Low
38	Kaliganga-I	4	Kaliganga	Rudraprayag	Under Development	Moderate
39	Kaliganga-II	6	Kaliganga	Rudraprayag	Under Development	Low

S No	Project Name	Capacity (MW)	Stream Name	Distt Name	Status	Soil Erosion rate (2009)
40	Karmoli HE	140	Jadh ganga	Uttarkashi	Under Development	Very High
41	Khirao ganga	4	Khirao ganga	Chamoli	Under Development	Low
42	Kot budha kedar	6	Dharamganga	Tehri Garhwal	Under Development	Very Low
43	Koteshwar	400	Bhagirathi	Tehri Garhwal	Under Development	Low
44	Kotli Bhel-II	530	Ganga	Tehri Garhwal	Under Development	Very Low
45	Kotlibhel -1A	240	Bhagirathi	Tehri Garhwal	Under Development	Very Low
46	Kotlibhel 1B	280	Alaknanda	Tehri Garhwal	Under Development	Low
47	Lata Tapovan	310	Dhauliganga	Chamoli	Under Development	Low
48	Limchagad	3.5	Bhagirathi	Uttarkashi	Under Development	Moderate
49	Lohari Nagpala	600	Bhagirathi	Uttarakashi	Under Development	Low
50	Madhmaheshwar	15	Madhmahesh war	Rudraprayag	Under Development	Moderate
51	Malari Jelam	114	Dhauliganga	Chamoli	Under Development	Very High
52	Melkhet	15	Pinder	Chamoli	Under Development	Low
53	NandPrayag Langasu	100	Alaknanda	Chamoli	Under Development	Very Low
54	Pala Maneri	480	Bhagirathi	Uttarkashi	Under Development	Very High
55	Phata-Byung	76	Mandakini	Rudraprayag	Under Development	Low
56	Pilangad-II	4	Pilangad	Uttarkashi	Under Development	Low
57	Rambara	76	Mandakini	Rudraprayag	Under Development	Moderate
58	Rishi Ganga-II	35	Rishiganga	Chamoli	Under Development	Low
59	Rishiganga	24	Rishiganga	Chamoli	Under Development	Low
60	Rishiganga I	70	Rishiganga	Chamoli	Under Development	Very Low
61	Singoli Bhatwari	99	Mandakini	Rudraprayag	Under Development	Low
62	Siyangad	11.5	Siyangad	Uttarkashi	Under Development	Low
63	Srinagar	330	Alaknanda	Pauri Garhwal	Under Development	Very Low
64	Suwarigad	2	Bhagirathi	Uttarkashi	Under Development	Moderate
65	Tamak Lata	280	Dhauliganga	Chamoli	Under Development	Very High
66	Tapovan Vishnugad	520	Dhauliganga	Chamoli	Under Development	Very High
67	Tehri stage-II	1000	Bhagirathi	Tehri Garhwal	Under Development	Low
68	Urgam-II	3.8	Kalpganga	Chamoli	Under Development	Low
69	Vishnugad Pipalkoti	444	Alaknanda	Chamoli	Under Development	Low
70	Birahi Ganga	7.2	Birahi Ganga	Chamoli	Under Development	Low

7.5.4 Concluding Remarks

The soil erosion study of Alaknanda and Bhagirathi Basins shows that the area is characterized by a wide range of rates of soil erosion. High soil erosion rates are present in the region of high altitude, covered mostly by snow with large tracts of barren rocks. High erosion rates are also determined in the areas above tree line which are mostly covered by loose glacial and glacio-fluvial sediments. The low altitudinal areas mostly show moderate to low soil erosion.

As already pointed out that the remotely sensed data of the years 2000 and 2009 are of different times of the year. Also within the same year, scenes are from different months. This puts constraints for comparing and obtaining data for temporal changes in the area. Nevertheless, the area under severe erosion in the year 2000 is about 13.79%; while such an area in the year 2009 is 17.55%. Thus, there seems to be an increase in the area of severe soil erosion during the last decade. However, this need to be checked in future by more systematic studies, before any final inference can be drawn.

As given in the Table 7.40, many of the HP projects have been constructed in areas of Very High Soil Erosion. In these areas the HP projects shall face problem of siltation. Moreover, the construction activity in such Very High Soil Erosion Zones may further enhance the soil erosion in the catchment areas. In such cases watershed management practices should be adopted. It may be emphasized that such areas are mostly situated in high altitude, where population density is very low and there is little agriculture.

7.6 Sediment Aspects in Upper Ganga Basin up to Devprayag

A large volume of sediment is transported by the rivers in the Upper Ganga Basin up to Devprayag. An assessment of transport of sediment in this area was made by Chakrapani and Saini (2009). They found that the maximum sediment concentration (2381 mg/l) in the Alaknanda River was at Vishanuprayag during monsoon (July-2004). Immediately after this location on the upstream, a sudden decrease in suspended sediment concentration (724 mg/l) was observed at Birahi, which was attributed to the trapping of sediments by Vishnuprayag dam/reservoir.

The Bhagirathi River showed relatively more sediment concentration as compared to the Alaknanda River, may be due to higher gradient. On the Bhagirathi River, the minimum concentration was observed at Maneri during monsoon (1302 mg/l) and non-monsoon (50 mg/l) respectively. Among the tributaries of Bhagirathi River, Jadh Ganga at Bhaironghati showed highest concentration (8132 mg/l). The concentrations of sediments in the upper reaches of the Bhagirathi River were slightly higher compared to the downstream regions, possibly because of the higher gradient (0.03 compared to 0.01). The suspended sediment concentrations along downstream do not show much variation. However, the suspended sediment concentration at Rishikesh was reported to be far less compared to the simple addition of suspended sediments of Alaknanda and Bhagirathi Rivers e.g. the total suspended sediment concentration measured at Rishikesh during July and August (representing monsoon season) was 870 and 890 mg/l respectively, whereas the addition of suspended sediments of both Alaknanda and Bhagirathi rivers amounts to 1800 and 1970 mg/l respectively.

A large variation in suspended sediment concentration is observed in the river course before and after the reservoir site. One such example is the construction of a dam/reservoir at Maneri on the Bhagirathi River. The location Malla, which is situated before the dam shows sediment concentration of 3204 mg/l during July 2004 (monsoon season), which after passing through the reservoir reduces to 1302 mg/l at Uttarkashi (Chakrapani and Saini 2009).

The Alaknanda and Bhagirathi rivers are important pilgrim centers and attract high tourist inflow during the months of March to October. Because of the increased vehicular traffic, new roads get constructed along the mountains, probably increasing frequency of landslides. These landslides and road construction activities add on to the suspension load of the river. The landslides are frequent during the rains and according to Wasson (2003), approximately two-thirds of the landslides which occurred in the year 1999 in an area of 225 km^2 in the upper Ganga River catchment, were caused due to human activities and amounted to between 3.1×10^4 and 45 10^4 tons of loose materials.

Chakrapani and Saini (2009) concluded the following: "The monthly sediment flux of Alaknanda River at Devprayag varies from 0.009×10^6 tons (during December 2004, representing nonmonsoon season) to 4.50×10^6 tons (during August 2004, representing monsoon season). The tributaries of both Alaknanda and Bhagirathi rivers show variable amounts of sediment loads and show significant temporal variations. The monthly sediment load of Bhagirathi river at Maneri varies from 0.002×10^6 tons (during January 2004, representing post-monsoon season) to 1.6×10^6 tons (during July 2004, representing monsoon season). The Alaknanda River contributes more sediment flux in comparison to the Bhagirathi River because of its larger catchment, whereas the Bhagirathi River shows higher physical weathering rates because of predominantly silicate lithology undergoing intense physical break down under high gradient. The sediment load variations are quite significant between upstream and downstream locations and show strong influence of the monsoon. Human influences in the form of construction of dams/reservoirs and road constructions also show their impact on sediment load variations in the Alaknanda and Bhagirathi rivers."

7.6.1 Management of Sedimentation in Reservoirs

Deposition of sediments in Indian reservoirs is inevitable and ways and means have to be found to manage the problem. Management of reservoir sedimentation includes two types of methods: a) manage the behavior of the reservoir or its geometry so as to allow the maximum sediments to pass through or bypass the reservoir, and b) Remove the deposited sediments.

The sediment load transported by stream varies with time; it is the highest during the period of intense precipitation and is very small during low flows. Therefore, to ensure that the least amount of sediment is deposited in the reservoir, it is important to manage sediment-laden flow differently from the flow containing small amounts of sediments. The concepts of sediment routing were developed in China and the guiding principle is: *discharge the muddy water, impound the clear water*. An advantage of sediment routing is that the characteristics of the sediment being transported are not significantly changed. Hence, this is the most environmental friendly approach. Sediment by-pass prohibits sediment laden flow from entering the reservoir. It consists of a diversion structure upstream of the dam by means of which the flows with heavy sediment concentration are diverted to a by-pass channel or conduit which joins the main river downstream of the dam. As a result, the flows entering the reservoir are relatively clean and naturally, the sedimentation problem will be less serious.

Two methods of removal of the deposited sediments in reservoir to recover the storage capacity are followed in practice. Flushing aims at establishing, for a short time, the same flow conditions in the reservoir area as had existed before the impoundment began. Emptying and flushing operations may be used in reservoirs where a balance between deposition and erosion cannot be obtained. This enables the river current to erode some of the deposited sediment and flush it out of the reservoir through low-level outlets. Normally the flushing is carried out once every year. Flushing is not environmentally friendly because a large amount of accumulated sediment is released during a short period when the natural flow may be smaller and this may cause environmental problems in the downstream areas.

Dredging is the process of removing the sediment from a water body (reservoir or channel), transporting, and depositing it at another location far away. Generally, dredging is an expensive means of recovering the storage capacity unless the deposits removed can be used for beneficial purposes. Dredging may be resorted to when other methods of sediment management are not viable or successful. Dredging is usually focussed on small areas in the reservoir, e.g., the intake structure, due to cost considerations. One has to locate suitable sites to place the excavated material. Ideally such sites should be near the reservoir to reduce the cost of transportation. As the availability of dump sites is limited in most cases, dredging is not a preferred or permanent solution to the problem. Dredging can be carried out without affecting the normal operation of the reservoir.

In this connection, the experience of sediment management for the Sanmenxia Dam in China is highly relevant. This dam was constructed on the Yellow River which is notorious for its very high rates of sediment transport. Through carefully planned changes in the dam and its management, the engineers were able to largely control sediment problems in the Sanmenxia Dam. While the approach followed by them may not be directly applied to the problems in the Alaknanda and Bhagirathi basins, the experience will definitely be useful. With this view, a summary of the problem and the solution approach based on a paper by Wang et al. (2005) is given below.

7.6.2 Reservoir Sediment Management: Case Study of Sanmenxia Dam in China

The Yellow River, with a drainage area of 752,000 km^2 and a length of 5464 km, is the second largest river in China. With a long-term average annual runoff depth of 77 mm, the river basin is mostly arid and semiarid. Soil loss, sedimentation, and flooding in the basin have been a concern for thousands of years. The Sanmenxia Dam is located on the lower part of the middle reach of the Yellow River in China. It is a large-scale multipurpose hydro-project constructed during 1957–1960 on the main stem of the Yellow River. The drainage area above the dam is to 688,400 km^2, which is 92% of the total drainage area of the Yellow River. It controls 89% of the runoff and 98% of the sediment coming into the lower Yellow River. The dam was built at an elevation of 353 m a.s.l. with a maximum dam height of 106 m and a maximum pool level of 340 m a.s.l. The reservoir area extends upstream a distance of 246 km (Wang et.al. 2005).

Sedimentation in the reservoir depends on the incoming water and sediment, the discharge capacity, and the operational level. Following completion of the Sanmenxia dam, reservoir filling began and severe sedimentation problems became evident immediately. During the first 18 months, 93% of the incoming sediment was trapped in the reservoir. The reservoir lost 17% of its storage capacity due to sedimentation. By October 1964, the accumulated sediment deposition below the elevation of 335 m reached a volume of 4.05×10^9 m^3, which was a 41.5% loss of the corresponding storage capacity; and the accumulated sediment deposition below the elevation of 330 m reached a volume of 3.75×10^9 m^3, which was a 62.9% loss of the corresponding storage capacity.

To alleviate the serious reservoir sedimentation problem and to achieve a balance between sediment inflow and outflow, it was decided to reconstruct the dam. The work of the first stage was completed in August 1968. The discharge capacity was nearly doubled at the pool level of 315 m and this played a definite role in reducing sediment deposition in the reservoir area. To mitigate the sedimentation problems, the operation scheme of the dam was changed to detain only floodwater in flood seasons. Further, eight bottom outlets at a lower elevation were reopened to sluice sediment at the lower elevation and to generate stronger erosion.

In the period from the beginning of summer in 1970 to the end of the flood season in 1973, about 4.1×10^6 m^3 of sediment was scoured away from the dam and a part of the reservoir capacity was restored. The reservoir storage capacity below the elevation of 330 m was recovered from a volume of 2.21×10^9 m^3 to a volume of 3.26×10^9 m^3.

Reconstruction of outlet structures has significantly increased the discharge capacity, providing the dam with the necessary facility for avoiding significant detention of floodwater, which is important for maintaining sediment balance across the impounded reach in the reservoir. The dam operation was substantially changed to achieve a sediment balance, and it can be divided into three time periods or three different modes of operation.

The first mode is storage. This mode was employed during the initial period of reservoir impoundment, from September 1960 to March 1962, when the reservoir was operated at high storage level throughout the whole year, according to the original project design. The second mode is flood detention. This mode was applied from March 1962 to October 1973, during which the reservoir was used for flood detention and sediment sluicing, water being released without restrictions. The reservoir was operated at a low storage level throughout the year, detaining floods only during flood seasons and sluicing sediment with the largest possible discharges. The third mode is controlled release. This mode has been used ever since November 1973, to store relatively clear water in nonflood seasons (November–June) and discharge turbid water in flood seasons (July–October). In this period, the reservoir has been operated at a high operational level, with the maximum level not exceeding a value between 322 m and 326 m, to store water for irrigation and hydropower generation in nonflood seasons; and at a low storage level of 305 m during flood seasons, allowing low-head hydropower generation, but in times of flood discharge greater than 2500 m3 s 1 all the outlets were to be opened to sluice the sediment as much as possible.

Experience gained from the reconstruction and operation of Sanmenxia Dam could be gainfully employed in the Indian reservoirs. But the following three aspects are crucial: 1) Correct estimation of the long-term trend of sediment inflow to the reservoir is essential. 2) Enough outlet capacity at various levels, particularly at low levels, on the dam is a necessary to facilitate the release of flood flows and sediment removal. 3) It is necessary to regulate both water and sediment by using the concept of controlled release to maintain a balance between sediment inflow and outflow and to conserve the useful storage capacity of the reservoir.

It needs to be highlighted that sediment particles entering the Sanmenxia Reservoir mainly consist of silt. Hence the experience gained at Sanmenxia is typically applicable to large reservoirs in the middle and lower reaches of large rivers. Vorosmarty et al. (1997) estimated that 30% of the global sediment flux gets trapped behind large reservoirs. In case of Alaknanda and Bhagirathi basins, the rivers carry huge amount of bed load in the form of boulders, cabbles, pebbles and sand. Significant quantities of coarse material will be entering in the reservoirs in the upstream areas due to which sedimentation problem will be more aggravated and of different nature.

7.6.3 Ganga Delta Processes

It is sometimes argued that Ganga delta is experiencing rapid changes in response to the anthropogenic activity in the Himalayas. One group argues that due to dam building activities the supply of sediment to the Ganga delta area is highly reduced causing erosion in Sagar Island. Another group argues that deforestation has caused increased soil erosion in the Himalaya causing siltation in the Ganga Plain.

The delta building is a complex process essentially controlled by sediment supply, tectonic activity and eustasy. Studies in Ganga delta region show that delta building started around 10,000 years BP. Initially delta building was in the western part (area of Hugli estuary) and then it shifted eastward. Present situation of delta building in eastern most part is in existence for last 3000 year (Allison et al., 2003; Goodbred ad Kuehl, 2000). Area of Namkhana Island and Sagar Island are witnessing slight retreat in shoreline and erosion for the last 2000 years. It is a natural phenomenon starting much before the anthropogenic activity. Thus, it cannot be related to the present-day anthropogenic activity in Alaknanda and Bhagirathi basins.

The sediment discharge of Ganga at Rishikesh is 33×10^{6} t/year and at Hardwar the sediment discharge is 14×10^{6} t/year. The estimated total sediment discharge of Ganga River is at Farakka, near the Head of the delta is 729×10^{6} t/year. Thus the contribution of Alaknanda and Bhagirathi basins to the total sediment discharge of Ganga River in delta region is only 4%. The sediment measured during the year 2008-09 by CWC at Rishikesh during monsoon month in 18 m ton which is only 2.5% of total load at Farakka.

As discussed above Ganga delta shows changes on millennium and century scale in response to the internal delta processes, some of which are causing erosion in coastal areas. The contribution of Alaknanda and Bhagirathi basins to the sediment budget of Ganga River in delta region is too small to initiate or enhance any geomorphic changes in the delta region.

7.6.4 Deforestation and Sediment Yield

Many investigators have attempted to examine the impact of forests on soil erosion. Particularly for this area, Wassan et al. (2008) evaluated the role of deforestation on the sediment yield of the Alaknanda basin. Using the geochemical tracers it was demonstrated that main source of sediment in the area are Tethyn zone and Central Crystalline zone and both these areas are located mostly above the tree line. Contribution from topsoil is minimal. Effect of deforestation is probably more or landslides. Deforestation may have effect on exceptional large erosional, catastrophic events.

It was reported that deforestation increased during the last 200 years and particularly since 1962 in the lesser Himalayas (LH). The sediment that is currently being transported by the Ganga River at the mountain front is derived from Higher Crystalline Himalayan (HCH) and LH in nearly equal amount. Hence, Wasson et al. (2008) concluded that the high relief HCH is not the major source of modern sediment. Deforestation occurs in concert with cutting of slopes on account of road construction and saturating rainfall that can trigger landslides even in well-forested land on steep slopes. An important conclusion was that reforestation will help to moderate the effect of some extreme rainfall events, but cannot be expected to stop erosion and destructive sediment transport.

7.7 Studies on Groundwater and Springs

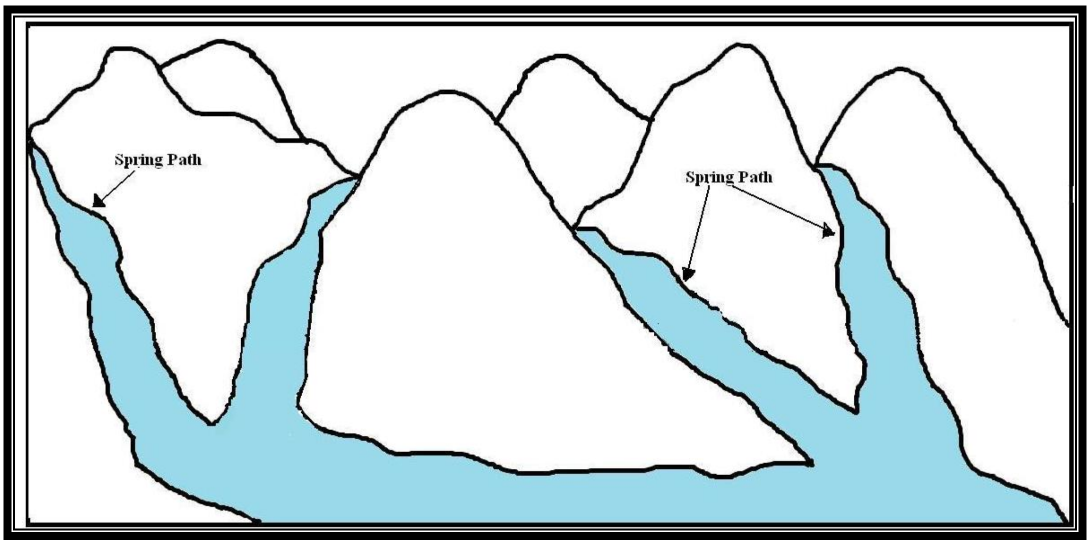
Groundwater in the higher Himalayan region is available only in shallow aquifers. The rocks in these areas have low primary porosity. The groundwater in this region is generally present in fractured and weathered zones which may be localized. Extensive aquifers in Himalayan region are not present due to rugged topography and steep slopes. Moreover, residence time in these shallow aquifers is small (not more than few years). Thus, measurement of groundwater levels and fluctuations in mountain areas through observation wells and piezometers are not practical.

In the hilly areas, springs or the streams emanating due to seepage of water fulfill the drinking water needs of the local population. In the recent years, Uttarakhand State departments like Jal Nigam / Jan Sansthan / Swajal have installed a number of hand pumps, to meet the water requirements of villages of Uttarakhand.

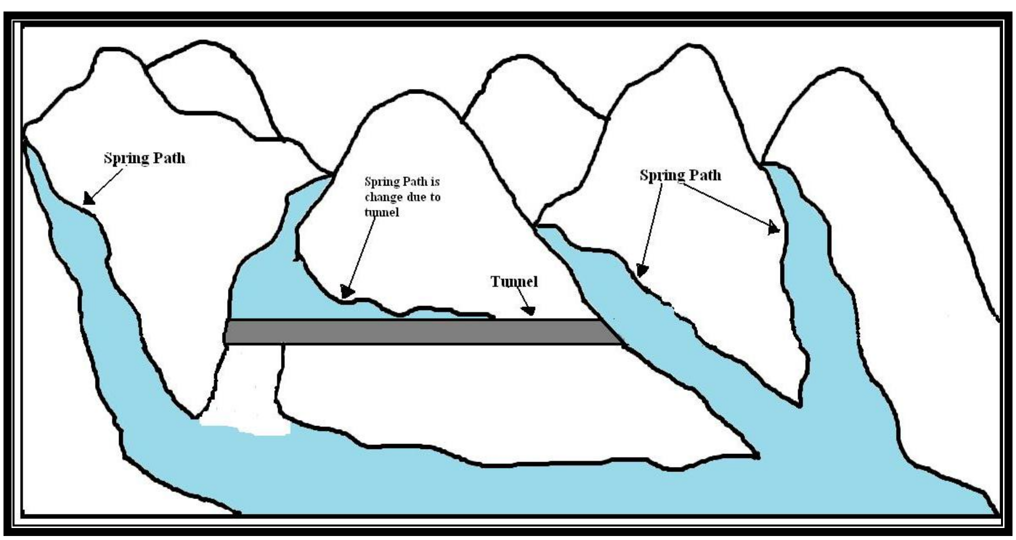
Attempts have been made to collect groundwater level and fluctuation data (based on water table in hand pumps), strata charts etc. from Central Ground Water Board (CGWB).

Due to the construction of a dam, the groundwater recharge is likely to increase. In addition to that, in the vicinity of the project, it is expected that there would be a positive impact of project for groundwater recharge and availability. As the impact of the project would be localized, the cumulative impact may not be applicable for groundwater resources. The springs in the vicinity of the hydropower project may change the path of water due to construction of tunnel. The schematic view of the possible changes on the spring pathways is shown in Fig. 7.41. It may be noted that the due to construction of tunnels it is expected that the discharge of few springs may reduce but at the same time discharge of some other spring may increase. It appears that the overall impact may be the redistribution of the flow.

Since the strata in hilly region are not uniform, the impact of any individual project can be assessed if long term data of groundwater levels and hydrogeologic data are available. However, in the absence of relevant groundwater data in the pre-project scenario, it may be difficult (or improper) to conclude with confidence on the impact of construction of hydro projects on the availability of groundwater and drinking water sources to the population in the project area. However, some general inferences may be drawn from the data of hand pumps / springs. Efforts are underway and more data of springs are expected to be received shortly from the concerned organizations which will help in predicting the impacts.



(a)



(b)

Fig. 7.41: Possible impact of construction of tunnel on spring path.

7.7.1 Hydrogeology of Bhagirathi – Alaknanda Basins

The Alaknanda and Bhagirathi Basins are major basins covering parts of Tehri Garhwal, Rudraprayag, Uttarkashi and Chamoli districts of Uttarakhand. The Central Ground Water Board has carried out Ground Water Management Studies in these districts. However, as per the existing policy, all hydrogeological surveys are being conducted district wise and not basin wise. The point wise reply on the hydrogeology/groundwater scenario of the area is given below.

Groundwater, in general, in the study 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 regions and in subterranean caverns of limestone and dolomitic limestone country rocks. The occurrence and movement of groundwater depends 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. Groundwater emerges as springs and seepage (locally called Strots, Dharas, Naulas etc.) under favourable physiographic conditions such as in gently sloping areas, broad valleys of rivers and along the lithological contacts.

In hilly areas, groundwater flows out as springs and seepage where the water table intersects the ground surface. The general hydrogeological scenario of the State reveals that two main types of aquifers are present viz. a) Local or Discontinuous Aquifers and b) Localised Aquifers. Groundwater occurs in fissured formations characterised by secondary porosity. A brief description of the main types of aquifers is given below:

A) **Local or Discontinuous Aquifers:** These aquifers occur within the Lesser Himalayan Zone, which is exposed mainly in the southern part of the vast Alaknanda and Bhagirathi Basins. Groundwater in these areas occurs generally under unconfined to semi-confined conditions in the sedimentary rocks (sandstone, shale and limestone), meta-sedimentary and low-grade metamorphic rocks like dolomite, slate, phyllite, quartzite etc. Calcareous rocks like limestone and dolomite host groundwater in solution cavities and subsurface channels of limited aerial 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 naulas indicates that in general, the yield is low and varies from 1 to 5 litre per second (lps).

B) **Localised Aquifers:** The localised aquifers are mainly restricted to the Central Himalayan Zone north of the Main Central Thrust. Localised aquifers are also seen in some isolated, small parts of the Lesser Himalayan Zone. Occurrence of groundwater 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 groundwater in the secondary porosity of fractures, joints and fissures of limited vertical and aerial extent. Study of a few spring shows that, as expected, yield of localised aquifers are very low, i.e. even less than 1 lps. Accordingly, the scope of development of groundwater resources in the localised aquifer is insignificant.

Study of groundwater levels in Hand pumps

The fluctuations of groundwater level in the hand pumps at village level in Chamoli and Uttarkashi districts are given in Tables 7.41 and 7.42. These are the fluctuations on average basis.

Table 7.41 Depth to water level and fluctuations in hand pumps of Chamoli district

S. No.	Location/Village	Pre-monsoon Depth to Water level (m)	Post-monsoon Depth to Water level (m)	Fluctuation Rise (+) / Fall (-) (m)
1	Ghat (I)	17.70	14.73	**2.97**
2	Kurur	17.90	15.98	**1.98**
3	Senti	12.50	9.40	**3.10**
4	Kuntari	13.88	12.18	**1.70**
5	Ghat (II)	8.08	*	
6	Jakhera	27.29	23.60	**3.69**
7	Adibadri	17.57	17.43	**0.14**
8	Simli Bazar	13.65	8.60	**5.05**
9	Siroli	12.36	22.80	**-10.44**
10	Gairsain	20.16	*	
11	Mehalchauri (I)	20.80	9.06	**11.02**
12	Dhunarghat	1.02	(0.56m bgl), Free flowing	
13	Mehalchauri (II)	14.09	13.73	**0.36**
14	Maithana	13.47	12.55	**0.92**
15	Malukot	14.30	5.20	**9.10**
16	Dayarkot	40.89	36.34	**4.55**
17	Puryani	20.28	18.60	**1.68**
18	Nauti	12.10	12.05	**0.05**
19	Kirsal	30.70	30.55	**0.15**
20	Gwaldam	53.70	57.10	**-3.40**
21	Tal	6.00	3.60	**2.40**
22	Thala	33.00	26.65	**6.35**
23	Kokrai	31.00	30.40	**0.60**
24	Tungeshwar	14.50	10.04	**4.46**
25	Luwari	22.17	18.6	**3.57**
26	Haripur	10.44	9.70	**0.74**
27	Ichholi	14.80	17.91	**-3.11**
28	Dewal	55.90	60.75	**-4.85**
29	Nandikesri	43.60	47.90	**-4.30**
30	Chopran	5.10	6.92	**-1.82**
31	Tharali (Radibagar)	19.10	14.81	**4.29**
32	Tharali (Pranwati)	23.80	21.58	**2.22**
33	Tharali	17.26	17.84	**-0.58**
34	Kulsari	21.17	21.69	**-0.52**

S. No.	Location/Village	Pre-monsoon Depth to Water level	Post-monsoon Depth to Water level	Fluctuation Rise (+) / Fall (-)
		(m)	(m)	(m)
35	Maltura	37.77	30.67	**7.10**
36	Ming	12.63	12.23	**0.40**
37	Panthi	11.07	10.60	**0.47**
38	Narayanbagar	24.53	25.25	**-0.72**
39	Nalgaon	25.00	17.63	**7.37**
40	Bagoli	2.60	3.14	**-0.54**
41	Kaulsau	18.30	15.16	**3.14**
42	Nandisain	20.20	18.24	**1.96**
43	Malethi	44.93	41.96	**2.97**
44	Nagli	21.10	12.30	**8.80**
45	Ratura	17.00	14.30	**2.70**
46	Bangaon	23.50	24.70	**-1.20**
47	Chamtoli	25.95	25.98	**-0.03**
48	Thirpak	5.64	6.15	**-0.51**
49	Nandaprayag	12.84	11.12	**1.72**
50	Karnaprayag (I)	4.80	7.21	**-2.41**
51	Karnaprayag (II)	18.88	18.50	**0.38**
52	Batadhar	25.93	26.35	**-0.42**
53	Banjani	8.04	7.24	**0.80**
54	Dharapani	13.78	13.18	**0.60**
55	Birsakhet	6.12	5.74	**0.38**
56	Sainji	7.32	5.27	**2.05**
57	Tekna	8.36	6.25	**2.11**
58	Kamera	4.86	3.53	**1.33**
59	Waidana	23.18	20.07	**3.11**
60	Karnaprayag	57.26	58.62	**-1.36**
	Average	19.698	18.766	**1.44**

Table7.42 Depth to water level and fluctuations in hand pumps of Uttarkashi district

S. No.	Location/Village	Pre-monsoon Depth to Water level	Post-monsoon Depth to Water level	Fluctuation Rise (+) / Fall (-)
		(m)	(m)	(m)
1	Purola	22.89	10.26	12.63
2	Chandeli	09.56	9.14	0.42
3	Saundari	31.55	29.31	2.24
4	Hudoli-I	24.95	18.01	6.94
5	Hudoli-II	22.51	41.01	-18.50
6	Kuwa	13.19	12.93	0.26
7	Varnigad	13.27	13.09	0.18
8	Damta-I	17.21	12.69	4.52
9	Damta-II	18.86	18.72	0.14
10	Barakot-I	23.00	19.16	3.84
11	Barakot-II	07.99	9.67	-1.68
12	Barakot-III	06.89	6.41	0.48

S. No.	Location/Village	Pre-monsoon Depth to Water level	Post-monsoon Depth to Water level	Fluctuation Rise (+) / Fall (-)
		(m)	(m)	(m)
13	Naugaon	29.95	29.63	0.32
14	Pujeli	08.90	7.47	1.43
15	Pujeli	12.44	10.18	2.26
16	Gadoli	08.45	10.74	-2.29
17	Sarari	07.45	11.92	-4.47
18	Paunti Bridge	15.45	11.67	3.78
19	Kotialgaon	16.88	16.10	0.78
20	Mungra	11.30	10.41	0.89
21	Naugaon-I	08.04	6.86	1.18
22	Naugaon-II	03.76	3.64	0.12
23	Naugaon-III	08.65	6.42	2.23
24	Purola –I (Karara)	11.42	12.22	-0.80
25	Purola –II	05.84	6.50	-0.66
26	Purola –III	06.93	8.44	-1.51
27	Purola -IV	24.23	22.68	1.55
28	Purola –V	04.66	4.63	0.03
29	Purola –VI (Angora)	18.49	27.54	-9.05
30	Ghundara	18.71	10.49	8.22
31	Sunaldi	08.05	7.92	0.13
32	Sukrala	09.16	9.07	0.09
33	Kharsari (Gaddugarh)	19.02	18.26	0.76
34	Keval (Mori)	20.30	19.26	1.04
35	Mori-I	14.65	14.01	0.64
36	Mori-II	21.02	31.03	-10.01
37	Pora-I	0.39	0.11	0.28
38	Samathi Math	06.21	6.73	-0.52
39	Dhampur	30.58	27.78	2.80
40	Purola	12.76	24.06	-11.30
41	Purola	19.62	23.67	-4.05
42	Arakot (Purola)	34.92	37.24	-2.32
43	Khalari Channi	11.37	10.45	0.92
44	Purola	19.27	18.75	0.52
45	Arakot-I	12.76	13.22	-0.46
46	Arakot-II	14.69	14.84	-0.15
47	Arakot-II	07.00	7.34	-0.34
48	Purola	13.04	--	--
49	Purola	07.28	7.21	0.07
50	Purola	08.90	8.84	0.06
51	Bhani	31.79	32.09	-0.3
52	Kaphnol	13.59	13.86	-0.27
53	Dhauna	05.76	11.62	-5.86
54	Purola	14.40	14.28	0.12
55	Gundiayatagaon	15.02	12.12	2.90
56	Kumola	34.29	33.83	0.46

S. No.	Location/Village	Pre-monsoon Depth to Water level	Post-monsoon Depth to Water level	Fluctuation Rise (+) / Fall (-)
		(m)	(m)	(m)
57	Hanuman Chatti	17.12	17.06	0.06
58	Paligaon	17.98	15.64	2.34
59	Kuthnair	08.39	3.86	4.53
60	Purola	01.79	1.06	0.73
	Average	**14.742**	**14.799**	**-0.028**

The depth to groundwater level variation is large within the district, as the formations are not uniform. At a few locations, even the depletion of water level has been observed during post monsoon. Based on the information available, the variation of the groundwater levels are shown in Figs. 7.42 and 7.43 for Chamoli and Uttarkashi districts respectively.

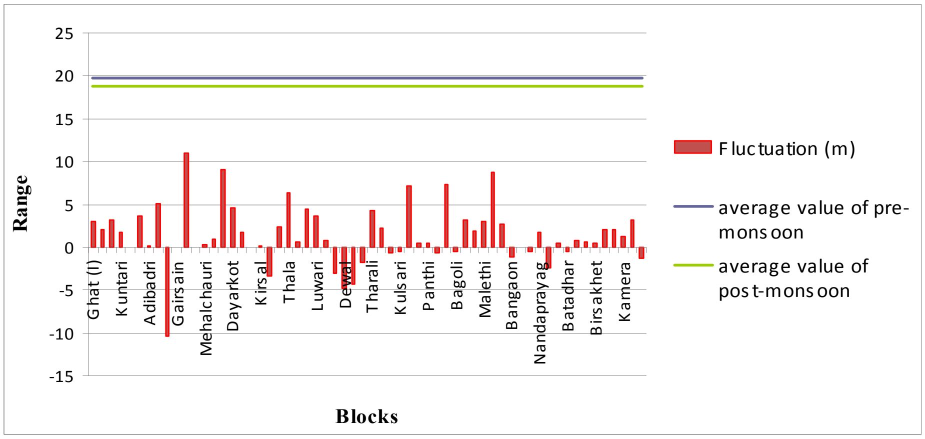


Fig.7.42 Pre-monsoon and post monsoon groundwater levels in hand pumps in Chamoli district

Table 7.41 and Fig.7.42 indicate an average rise of 1.44 m in water table in the Chamoli district in the post-monsoon season. Out of 60 handpumps, 41 show rise ranging from 0.05 m to 11.02 m and 11 handpumps show a decline by 0.03 to 10.44m.

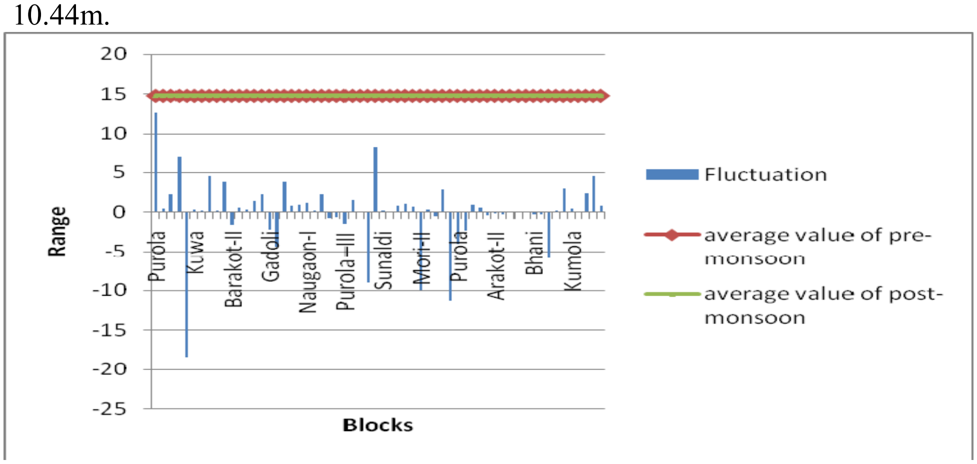


Fig.7.43 Pre-monsoon and post monsoon groundwater levels in Hand Pumps in Uttarkashi district.

In Uttarkashi district, the average change in groundwater level after monsoon season is negligible. Out of 60 handpumps, 39 show rise ranging from 0.03 m to 12.63 m and 20 handpumps show a decline by 0.03 to 18.5 m. Many handpumps in Purola area show declining trend. In Uttarkashi district projects namely Maneri bhali I, Maneri bhali II and Pilangad are commissioned, however many projects (Asiganga (I ,II and III) , Bharon Ghati (I,II), Bhilangana-III, Jadhganga, Jalandhari Gad, Kakoragad, Kaldigad , Karmoli HE, Limchagad, Lohari Nagpala, Pala Maneri Satge I, Pilangad-II, Siyangad and Suwarigad) are under development stage. Similarly Badrinath, Deval, Jummagad, Rajwakti, Urgam, Vanala and Vishnuprayag have been commissioned in Chamoli district. Many projects are in under development stage in Chamoli district viz; Alaknanda, Bhyundar ganga, Birahi Ganga, Birahi ganga SHP-II, Birahi Ganga-I, Bowla Nandprayag, Devali, Devsari, Gohana Tal, Jelam Tamak, Kail ganga, Khirao ganga, Lata Tapovan, Melkhet, NandPrayag Langasu, Rishi Ganga-II, Rishiganga, Rishiganga I, Tamak Lata, Tapovan Vishnugad, Urgam-II and Vishnugad Pipalkoti.

7.7.2 Study of Springs

For the analysis of springs, discharge data along with their location is the major input. The discharge of a spring mainly depends on the lithlogy of the host rock, rainfall, and catchment area characteristic like slope, topography etc. Therefore, long term data on rainfall and spring discharge is required to assess the impact of hydropower projects construction on the discharge of springs. Most of the springs in the Himalayan region are either contact type spring or fracture type springs. The blasting for construction of the tunnels and adits may affect the springs of the fractures through which the water is flowing is disturbed.

Unfortunately, for springs also, long term discharge data is not available. Only average values of the yield/discharge data are available and have been collected from CGWB, Dehradun.

Chamoli District

Block wise minimum and maximum discharges for Chamoli district are given in Table 7.43. Number of water bodies in the Chamoli district are shown in Fig. 7.44. The variation of pre-monsoon and post-monsoon discharges in the Chamoli district is presented in Fig. 7.45 and 7.46.

Table 7.43 Pre and post Monsoon Discharges of Springs for Chamoli district (in LPM)

Block Name	Surface Water Bodies	spring	Pre-monsoon		Pro-monsoon	
			Min	Max	Min	Max
Karanpryag	19	12	15	80	16	150
Dasoli	17	12	18	300	20	400
Ghaat	6	6	45	70	45	72
Naryanbagar	34	21	9	500	12	600
Garsain	50	26	15	65	15	150
Tharali	14	13	0.56	67	0.6	68
Pokhari	10	6	15	35	15	35

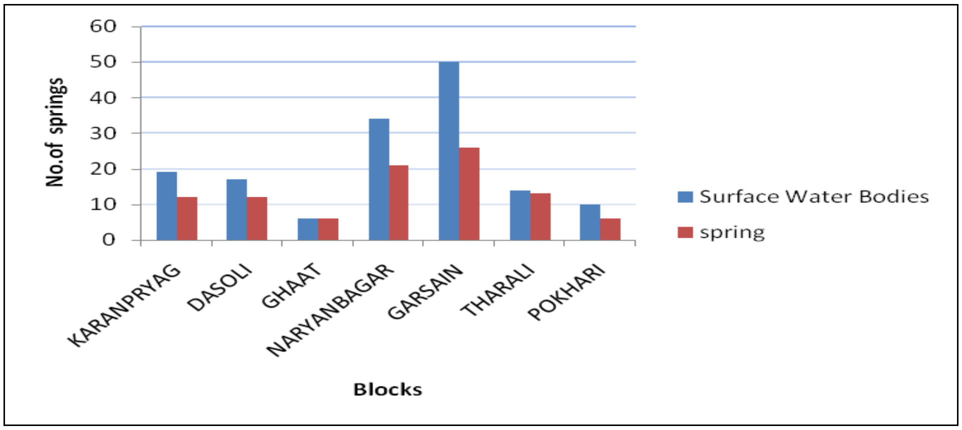


Fig. 7.44 Number of water bodies (streams / gadheras) for different blocks in Chamoli District

Spring discharge data indicates increase in discharge of springs during post monsoon season. Maximum increase in discharge is observed in the Karanparyag block followed by Dasoli and Narayanbagar blocks. Other blocks do not show any appriciable change in discharge in the post monsoon season. Discharge of 32 springs in the Chamoli district are given in Table 7.44. The premonsaon-postmonsoon fluctuation in discharge is presented in Fig.7.47.

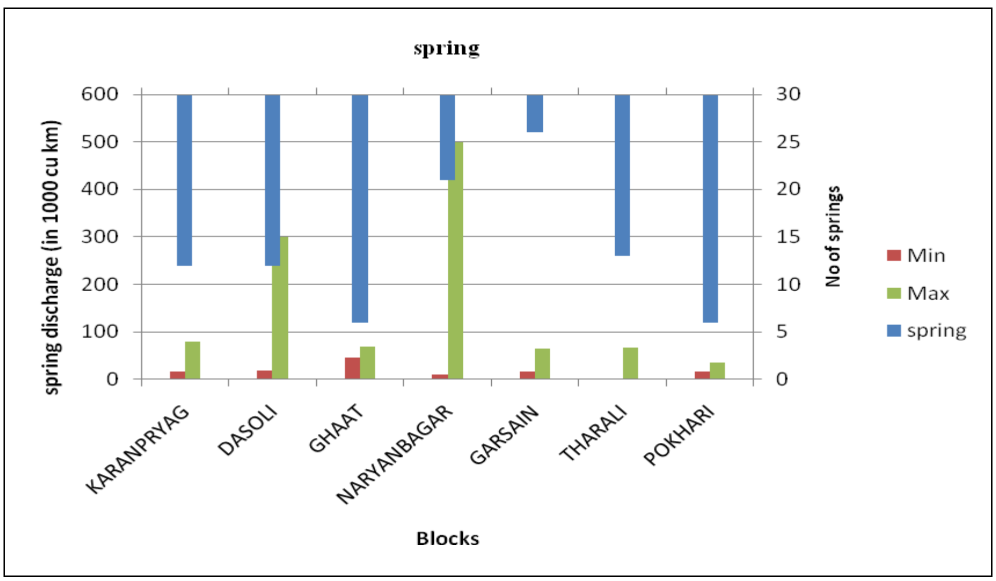


Fig.7.45 Range of discharges of spring in different blocks of Chamoli District for pre-monsoon season

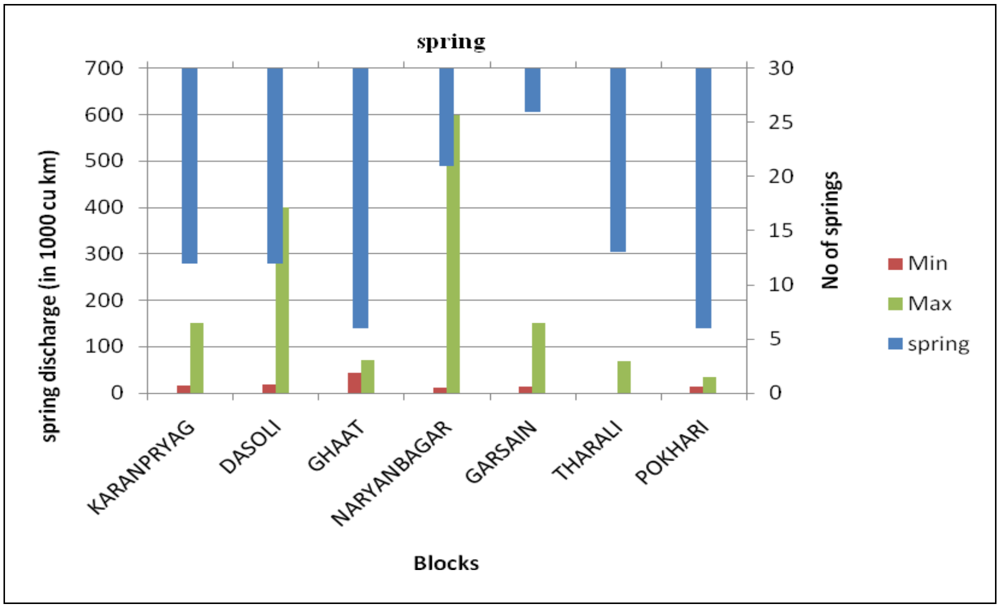


Fig.7.46 Range of discharges of spring in different blocks of Chamoli district for post-monsoon season

Table.7.44 Discharge of Springs inventoried in Chamoli District (CGWB)

Sl. No.	Location/Village	No. of Outlets	Pre-monsoon discharge (lpm)	Post-monsoon discharge (lpm)	Fluctuation (lpm)
1	Tekna	2	16.00	46.15	+30.15
2	Luwani	4	27.66	61.22	+33.65
3	Sunali	1	2.00	6.65	+4.65
4	Shilangi	1	13.00	17.14	+4.14
5	Nagarachukhal	1	3.53	1	-2.53
6	Harsari	1	13.00	13.5	+0.5
7	Nail	1	3.00	13.75	+10.75
8	Malsi	1	12.00	26	+14
9	Ritholi	1	7.5	10	+2.5
10	Kokrai	1	54.55	85.71	+31.16
11	Puryani	1	3.53	4.61	+1.08
12	Lolti	2	20.69	24.20	+3.51
13	Sinei	2	16	18.69	+2.69
14	Luwari	1	4.29	6	+1.71
15	Dheringkera	1	5.45	4.69	-0.76
16	Sunila	2	18	52	+34
17	Talla Harmoni	1	30	50	+20
18	Simli	2	8.33	14.02	+5.69
19	Kaulsau	1	12	10.91	-1.09
20	Nauli	1	11.32	8.57	-2.75
21	Baret	3	27.38	33.39	+6.01
22	Top	1	12	4	-8
23	Matholi	1	7.5	10.91	+3.41

24	Nogra*	1	150	*	
25	Pharkhet	1	16.67	23	+6.33
26	Sunla	1	3.30	6	+2.70
27	Bina	1	40	30	-10
28	Saregwar	1	2	6	+4
29	Khenti	1	2	3.53	+1.53
30	Senti	1	6	4	-2
31	Khadgoli	1	4	12	+8
32	Paduli	1	7	12	+5
Average			**13.21**	**19.99**	**6.77**

Most of the springs in the Chamoli district, except 9 springs, have discharge less than 20 lpm. Only five springs have discharge more than 40 lpm. Only springs which have good discharge during pre monsoon also show appreciable recharge in the post monsoon season.

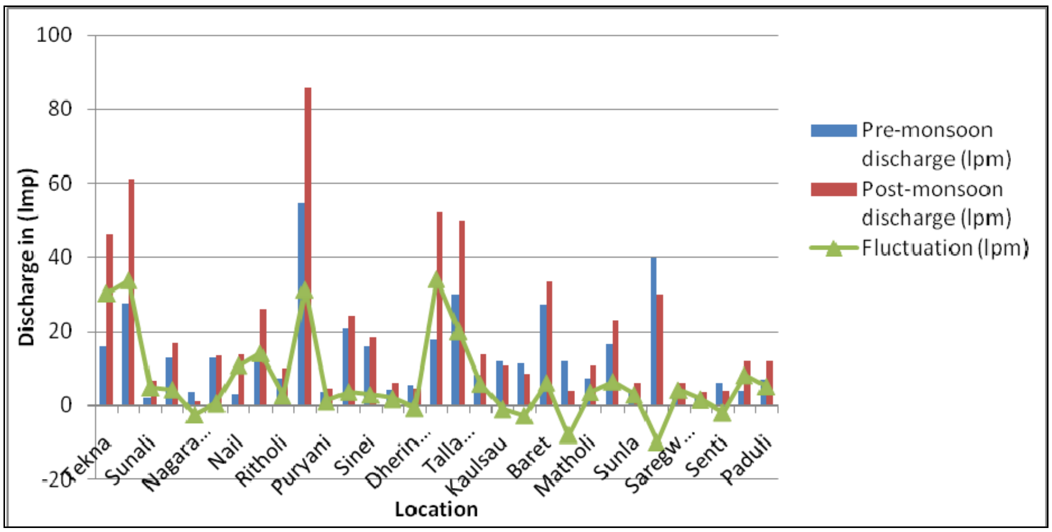


Fig.7.47 Pre-monsoon season and post monsoon discharges at different locations of Chamoli District

Uttarkashi District

Block wise discharges of springs in Uttarkashi district are given in Table 7.45. In this district, average discharge data of springs for three blocks are not available. Number of water bodies in the Uttarkashi district is shown in Fig. 7.48. The variation of pre-monsoon and post-monsoon discharges in the Uttarkashi district is presented in Fig. 7.49 and 7.50. The discharge in only two blocks, i.e., Naugaon and Dunda is moderate, where as it is low in Purola block.

In the Uttarkashi district, discharge data of 38 individual springs have been collected from CGWB, Dehradun and are given in Table 7.46. The variations of the pre-monsoon and post-monsoon discharges are presented in Fig. 7.51.

Table.7.45 Block wise discharges (in lpm) of springs for pre and post monsoon for Uttarkashi district

S.No.	Block Name	Surface Water Bodies	Spring	Pre-monsoon		Pro-monsoon	
				Min	Max	Min	Max
1	Mori	2	0	0	0	0	0
2	Purola	4	2	1.5	1.5	2.5	3
3	Naugaon	13	7	2	35	3.5	40
4	Dunda	4	4	2.5	25	4	35
5	Chinyalisaur	2	0	0	0	0	0
6	Bhatwari	2	0	0	0	0	0
	Total	**27**	**13**				

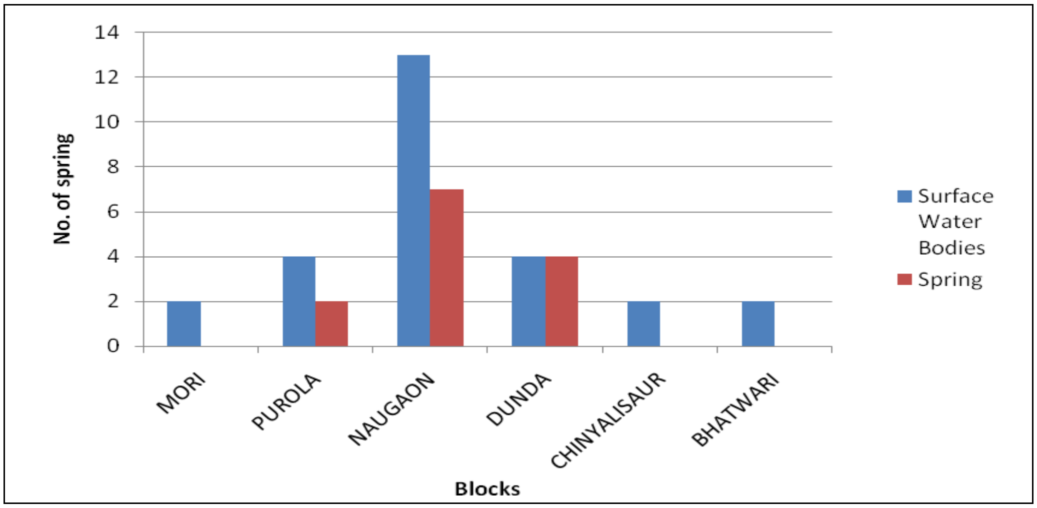


Fig 7.48 Number of water bodies and springs for different blocks in Uttarkashi

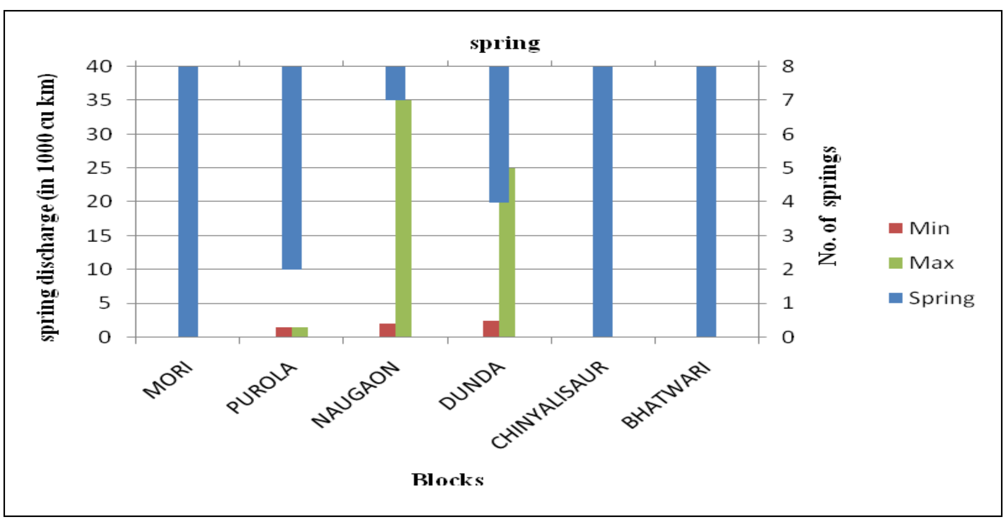


Fig.7.49 Range of discharges of spring in different blocks of Uttarkashi for pre-monsoon season

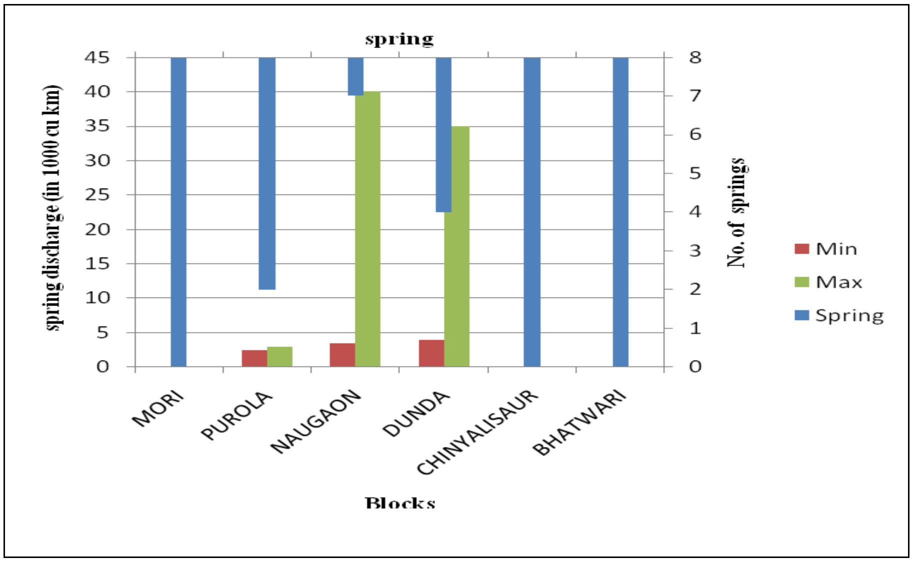


Fig.7.50 Range of discharges of spring in different blocks of Uttarkashi district for post-monsoon season

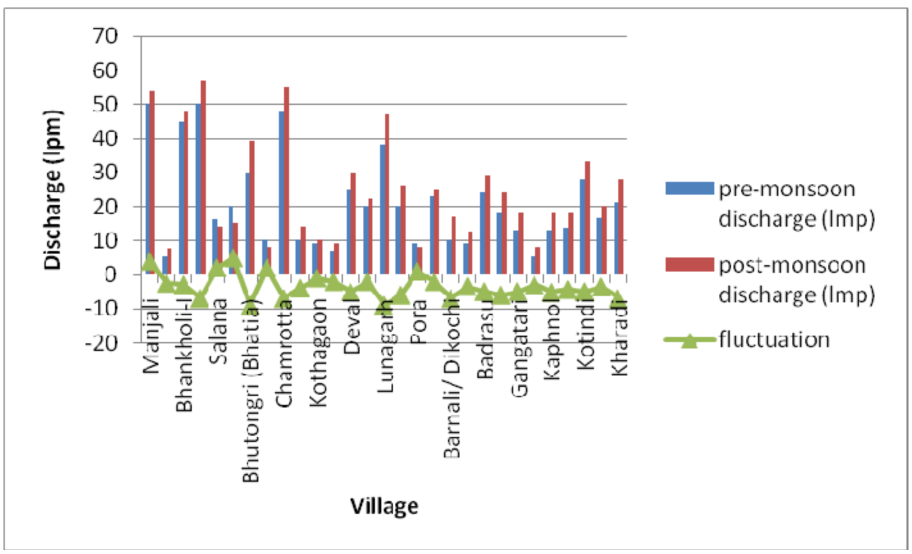


Fig.7.51 Pre-monsoon season and post monsoon discharges at different locations of Uttarkashi District

Table. 7.46 Discharge of Springs inventoried in Uttarkashi district (CGWB)

Sr. No.	Location / Village	Block	Discharge (lpm)	
			Pre	Post
1	Manjali	Naugaon	50	54
2	Matli	Naugaon	5	7.5
3	Bhankholi-I	Naugaon	45	58
4	Bhankholi-II	Naugaon	50	57
5	Salana	Naugaon	16	14
6	Ganganani Dhara	Naugaon	Not measurable	
7	Sari Gad	Naugaon	20	10
8	Bhutongri (Bhatia)	Naugaon	30	39
9	Pujeli	Naugaon	Not measurable	
10	Guna	Naugaon	10	8
11	Chamrotta	Naugaon	48	55
12	Mathodi	Purola	10	14
13	Kothagaon	Naugaon	9	20
14	Dangagaon	Naugaon	7	9
15	Naitwar-Devla	Mori	Not measurable	
16	Deval	Mori	25	30
17	Naitwar	Mori	20	22
18	Lunagarh	Mori	38	47
19	Mora	Mori	20	26
20	Pora	Purola	9	8
21	Khalari Channi	Purola	Not measurable	
22	Chiwan	Mori	23	35
23	Barnali/ Dikochi	Mori	10	30
24	Arakot	Mori	9	12.5
25	Jakhol	Mori	Not measurable	
26	Badrasu	Mori	24	29
27	Dhakiyatgaon	Naugaon	18	24
28	Gangatari	Naugaon	13	18
29	Rajgarhi	Naugaon	5	8
30	Bhani	Naugaon	21	--
31	Kaphnol	Naugaon	12.8	18
32	Dhari	Naugaon	13.6	18
33	Kotindi	Naugaon	28	33
34	Durbali	Naugaon	16.4	20
35	Bangar Gad	Naugaon	Not measurable	
36	Janki Chatti	Naugaon	Not measurable	
37	Yamunotri	Naugaon	Not measurable	
38	Kharadi	Naugaon	21	33

The Table indicates that the springs show about 50% increase in discharge from pre-monsoon to post-monsoon season.

Rudraprayag District

Block-wise data of discharges of springs in Rudraprayag district are given in Table 7.47. Number of water bodies in the Rudraprayag district is shown in Fig. 7.52. The variation of pre-monsoon and post-monsoon discharges in the Rudraprayag district is presented in Figs. 7.53 and 7.54.

Table.7.47 Data of springs for *pre and post Monsoon season* for Rudraprayag

S. No.	Block Name	Surface Water Bodies	Spring	Pre-monsoon		Pro- monsoon	
				min	max	min	max
1	AUGUSTMUNI	53	50	20	1950	6	2900
2	UKHIMATH	36	33	1.8	90	1.8	90
3	JAKHOLI	64	58	3	1500	3	3000
	Total	**153**	**141**				

The table indicates that the springs show about 50% increase in discharge from pre-monsoon to post-monsoon season.

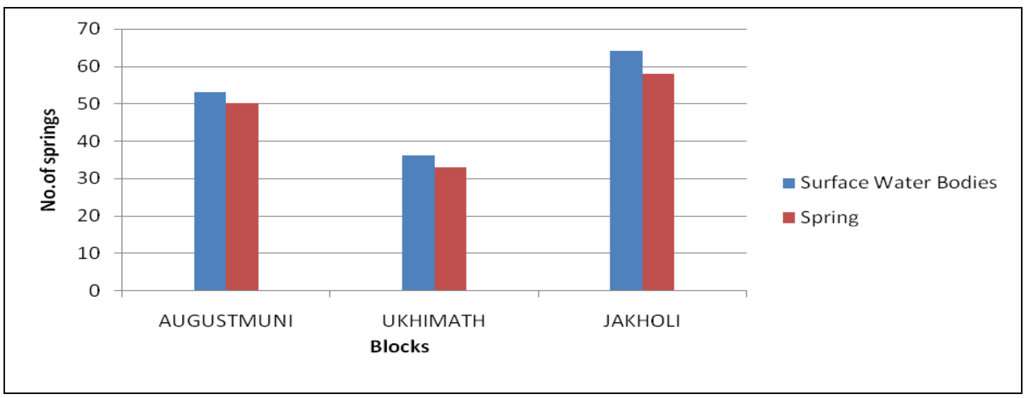


Fig 7.52 Number of water bodies for different blocks in Rudraprayag

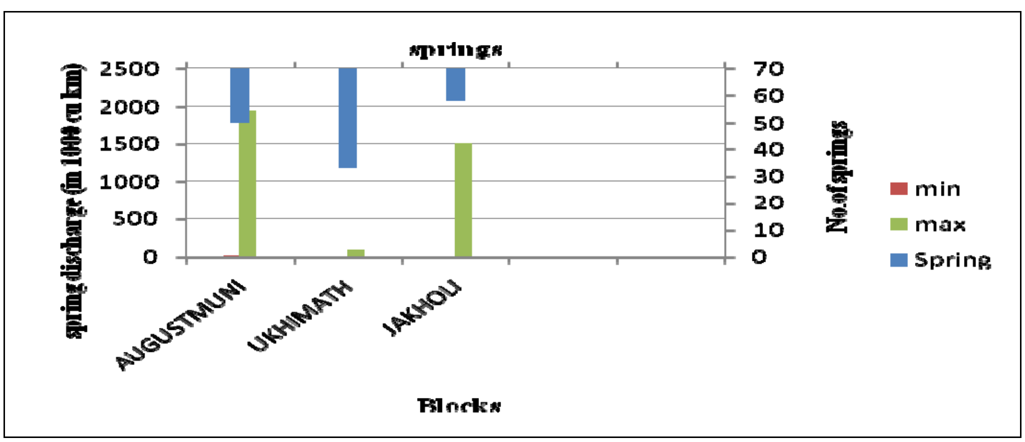


Fig.7.53 Range of discharges of spring in different blocks for Rudraprayag for pre-monsoon season

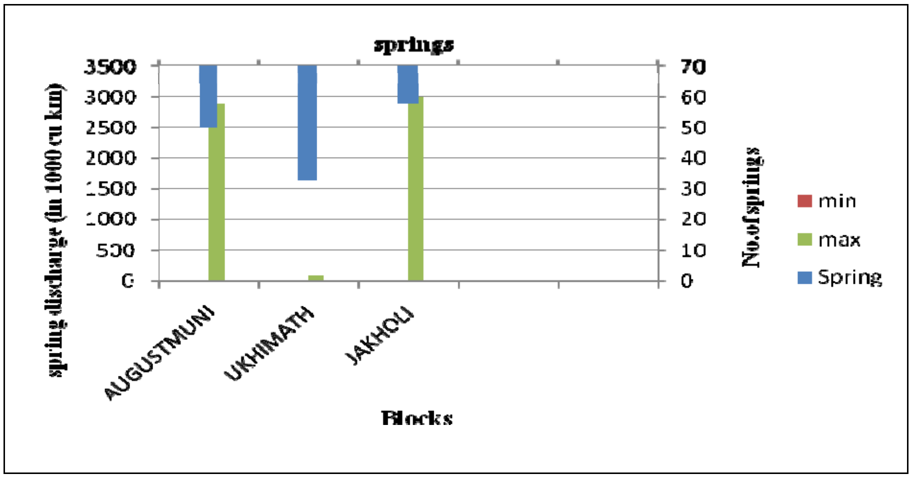


Fig.7.54 Range of discharges of spring in different blocks for Rudraprayag for post-monsoon season

District Tehri Garhwal

Central Ground Water Board has made inventory of springs and has identified 55 springs in the Tehri Garhwal district. The discharge of springs in individual springs is given in Table 7.48. The Table indicates that the discharge in the springs vary from 4 to 1200. Out of 55 springs monitored by CGWB, only 5 springs have discharge more than 100 lpm. Most of the springs have discharge less than 20 lpm.

Table 7.48 Discharge of Springs inventoried in Tehri Garhwal district

Sl. No.	Name	Discharge (lpm)
1	Narendra Nagar- I (Motor Nala)	4
2.	Narendra Nagar	10
3.	Kainchi	14
4.	Dhaudapani	140
5.	Dhaudapani	12
6.	Kunjapuri	14
7.	Fakot	20
8.	Tachala	20
9.	Tachala	10
10.	Bemunda	500 (approx.)
11.	Khadi Tipli	1200 (approx.)
12.	Khadi	60
13.	Budgi Khala	150 (approx.)
14.	Sela Pani	24
15.	Nagani	10 (approx.)
16.	Daral Gaon	16
17.	Daral Gaon	10
18.	New Tehri	24
19.	Chamba	18
20.	Chopriyal	16
21.	Saur jari pan	14

22.	Kaddu Khal	16
23.	Kemu Khala	10
24.	Neergarh	800 (approx.)
25.	Kaudiala – I	4
26.	Kaudiala – II	16
27.	Munnakhal	10
28.	Teen–Dhara	30
29.	Deoprayag	1
30.	Juyalgarh	30
31.	Maletha	20
32.	Mahi Pani	4
33.	Magron	16
34.	Magron	10
35.	Lamphogarhi	8
36.	Badkot	12
37.	Badkot – II	56
38.	Nand Gaon	16
39.	Asena	38
40.	Holta	12
41.	Chakreda	4
42.	Gadera	600 (approx.)
43.	Anand Chowk	16
44.	Manjhgaon	12
45.	Yamuna bridge	20
46.	Sumankyari	4
47.	Syansu	30
48.	Syansu	700 (approx.)
49.	Malidev	3
50.	Digothi khal	10
51.	Gaza	16
52.	U-Band	20
53.	Bairola	16
54.	Thapli- I	16
55.	Thapli- II	16

Data pertaining to the locations springs in the study area was compiled and the same is displayed in Fig. 7.55 along with the location of hydropower projects.

7.7.3 Responses of various organizations

The long term ground water data and spring data was not be available. It was thought appropriate to have the inputs from various projects authorities within the study area. Accordingly, request was made (vide letter No. AHEC/C-567/dated Jan., 08, 2011) to various project authorities to respond and give inputs regarding the impact of the project on ground water and springs in the vicinity of the project.

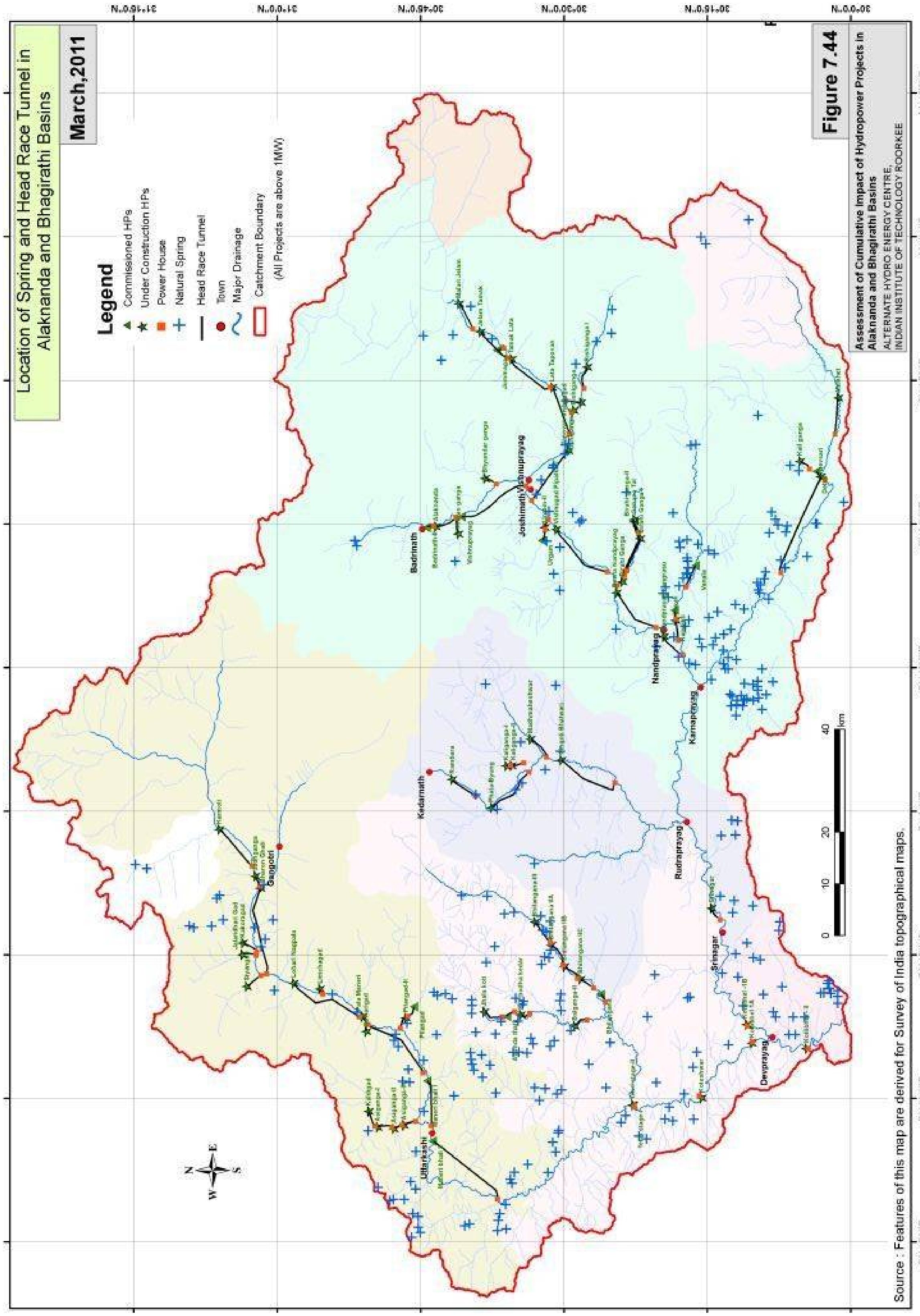


Fig. 7.55: Location of Spring and Head race tunnel in Alaknanda and Bhagirathi Basins

A brief summary of the responses received are presented in the following sections.

(i) Name of the organization: CHAMOLI HYDRO POWER PRIVATE LIMITED

Project Name:
Responses : B.Sadasiva Reddy, Director
Address : Plot No. 813, Raod No. 41, Jubilee Hill, Hyderbad-500 033

Opinion/ Findings

Their project is a small hydro project and therefore, there is no significant impact on the ground water and discharges of springs. As the scheme is run-of-river scheme and has only diversion structure and there is no water storage. But they pointed out that suggested that construction of small diversion structure is beneficial as compare to large dam in Alakananda and Bhagirathi basins. They think that big dams will spoil the ecology and environment and stability of natural slopes and cause land slides in this area. And spring in the vicinity may also get dried up as dam stores water only up to particular point. Hand pump in downstream of dam may also get dried. As such they have not substantiated their opinion with some case study.

(ii) Name of the organization: NTPC LIMITED
Response by : D Gulati, AGM (Hydro Engg.)
Address : Corporate Centre NOIDA

Opinion/ Findings

Tapovan Vishnugad HEP

a) No perceptible change in the spring of the vicinity has been observed during the construction activity.
b) No impact on availability of water in hand pumps in the vicinity of the project area.
c) No major land slide has occured due to under ground and surface construction.

Loharinag Pala HEP

a) During construction of pressure shaft, villagers complained about drying up of spring. However, it has been observed that this spring has recharged after some time.
b) No impact on availability of water in hand pumps in the vicinity of the project area.
c) No major land slide occurs due to under ground and surface construction.

(iii) Name of the organization: BHILANGANA HYDRO POWER LIMITED

Responses : Pramod Kumar Arora
Rank : General Manager (Project Development
Address : B-37 3rd floor, sector-1, Noida-201301 Gautam Budha Nagar

Opinion/ Findings

Hydro Electric Project in Alakanda- Bhagirathi Basin upto Devprayag

S. NO.	Qurey	Submissions
1	Impact on spring in vicinity of the project area like increase or decrease in availability of water or drying up of spring.	No impact is observed/ reported till date.
2	Impact on availability of water in hand pumps.	No impact is observed/ reported till date
3	Any landslides occurring in the project. Area or its vicinity either during construction work or later	No impact is observed/ reported till date

(iv) Name of the organization: Lanco Mandakini Hydro Energy Private Ltd.

Responses : P.V Prasad Babu
Rank : Director (SPV Head)
Address : lanco house plot 397, Udyog vihar, Phase-3, Gurgaon-122016, Haryana, India.

Opinion/ Findings

Phata Byung H.E. Project

The Phata Byung H.E. Project is in excution stage since October, 2008,. Our observations are as follows:

1. We have not experienced any change in the water flow of natural springs in and in the vicinity of the project area except the normal seasonal changes.
2. There is no change reported/ observed in the availability of the water in the hand pumps.
3. During monsoon 2010, there were unprecedented rains in the state causing huge rock falls and heavy landslides in almost all the parts of the state. There were few landslides in the project area. Since, there were no such slides before this monsoon; hence the slides in the last monsoon are not related to any tunneling or underground works.

(v) Name of the organization: GMR Varalakshmi Foundation

Responses : P. Senthupandian
Address : Badrinath, Uttarakhand

Opinion/ Findings

Alaknanda Hydro Power Project (300 MW)

S.NO	Target	Achievements
1	To strengthen 16 self help Groups in the project villages	4 groups of lambagarh participate in plantation drive organized and planted approximately 400 saplings. In months of September 40 more participants in Arudi village participated in the plantation drive.

- In this report the findings are beyond the scope of the work. However, they have indirectly contributed fro the restoration of tress through plantation, which would otherwise have positive impact in terms of ground water and spring flows.

(vi) Name of the organization: Swasti Power Limited

Responses : Priya Darshan
Rank : Administrative Secreatary
Address : Corporate office Plot 111, Road 72, Jubilee Hills, Hyderabad 500033, India.

Opinion/ Findings

Bhilangana Hydro Power Project

- Impacts on springs in vicinity of the project are like increase or decrease in availability of water or drying up of spring. -NIL
- Impact on availability of water in hand pump. – NIL
- Any landslides occurring in the no adverse impact on above issues have been reported in the project area. - NIL

Note: NO adverse impact on above issues has been reported in the project area.

(vii) Name of the organization: L&T Uttaranchal Hydropower Limited.

Responses : Ashutosh pujari
Rank : Advisor
Address : Regd. Office: No 6 Gavni village, next to Jalagam Chandrapuri, Distt: Rudrapryag (U.K) pin- 246425

Opinion/ Findings:

Hydro Electric Project in Alaknanda-Bhagirathi

- Given present status of the execution of work of the project.
- Discharge date of various springs, which are tapped for water supply to villages, as observed during November, 2010 to January, 2011.
- Discharge date of major tributaries of Mandakini River between Barrage and Power House Site of 99M.W. Singoli- Bhatwari Hydro Electric Project, measured at 10 days interval between 11/10/2010 to 01/01/2011.

Note**:** L & T has made efforts in the construction/augmentation of water supply schemes as a CSR. The data of the springs may be useful if recorded on regular basis over a longer period.

(viii) Name of the organization: NIH ROORKEE (as a part of L & T Report)

Responses : Dr.Bhishm kumar
Rank : Scientist F
Address : Jalvigyan bhawan, Roorkee

Opinion/ Findings

Singoli Bhatwari Hydroelectric Project

Report of NIH on hydroelectric Project being constructed by L&T Uttaranchal Limited, based on the site visit for the Singoli Bhatwari Hydroelectric Project.

- Leakage in the tunnal may affect discharge of available springs or streams located in the vicinity of the tunnel. Therefore the reduction in the discharge of spring, if any, needs to be verified based on the data which may be observed during different months especially during lean season.
- The present data and observation indicate that the change in the water source regimes is unlikely. However there is a need to monitor the discharge of springs/water sources at least twice a month till the tunnel construction work is completed.
- Rock mass may also not get affected by the blasting of tunnel. Thus the diversion of water from the current flow path is unlikely. However this requires further investigations.

As per the responses of limited hydro power project authorities regarding the impact of the projects on ground water and spring discharges, presently no adverse impact has been noticed. With regard to the impact of reservoir based hydro power projects, it is expected that storage of water may increase the recharge and the spring flow may increase. However, to make quantitative assessment, it is necessary to analyse long term discharge data of springs.

7.7.4 Concluding Remarks

Groundwater in the Bhagirathi-Alaknanda Basin 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 regions.

Groundwater table data (through water level in hand pumps) are available at few locations for one year only. Due to the large variation in the elevation of measurement points, water table maps cannot be prepared even on local scales. Unfortunately no observation wells/piezometers have been installed by State or Central agencies to monitor the water table fluctuations. Therefore, quantitative analysis in terms of groundwater availability is not possible with the available data.

Spring discharge in the pre project and post project scenarios are required to evaluate the impact of project. But one has to be very careful, because the variation in spring discharge may not solely be due to the project activities, it may also vary due to rainfall recharge during this period. Therefore, long term data of spring discharge and rainfall in the vicinity of the hydropower projects are also needed to improve the evaluation and conclusions drawn. The springs in similar geological formations may behave identically. Therefore, detailed geological information of the completed projects is required to be analyzed. The findings of these studies can be extended to the projects planned to be constructed in the similar geological conditions.

In the present case, to evaluate the pre-and post-impact of hydropower projects on the springs discharge and availability groundwater in the concerned areas, specifically in five districts of Uttarakhand State (Chamoli, Tehri Garhwal, Pauri Garhwal, Rudraprayag and Uttarkashi), efforts were made to get the long term data of groundwater fluctuations and spring discharge. But as the long term data are not available with State and Central Ground Water Organizations, therefore efforts are being made to get the required data from other state govt. organizations for the existing water supply schemes which may take some more time. Therefore, the variations of discharge of springs and water table fluctuations during a year have been shown in this chapter and more specific details along with post project impacts on the water availability in the areas where projects have already been completed and possible impacts in areas where power projects are planned will be provided in due course of time.

In general, the construction of tunnels and reservoirs may have positive as well as negative impacts on the groundwater conditions. Construction of Dam/Reservoir may increase the recharge and groundwater availability may increase for the down stream users. In the negative sense, the springs may get diverted away from the existing route, disrupting the existing supply.

As the impact of the project would be localized, the cumulative impact may not be applicable for groundwater resources. As the groundwater moves through fractures, faults and weathered zones and the soil cover remains limited and non-uniform in mountainous regions therefore, the geology of the area plays a vital role on the possible impact of any individual power project on the availability of groundwater.

Recommendations

(i) Observation wells/piezometers be installed In the vicinity of the hydropower projects, and monitoring of water level should be done right from the beginning of the project work.

(ii) A few observations wells need to be constructed and regular monitoring of groundwater levels should be done by the project authorities up to a distance of at least 2 kms on either sides of the tunnel (planned or under construction).

(iii) A few major existing springs should be selected in the project areas for regular monitoring and records should be maintained and analyzed to asses the impact during the construction as well as post construction time.

(iv) Project authorities should sign a legal document with the authorities of the concerned villages and district administration that if the present water supply or water source will be affected during the construction or after 2 years of the completion of project, the concerned agency will provide water supply free of cost to the affected villages. A copy of the commitment (legal document) should be provided to the District Administration and concerned village Pradhans etc and should be published through the newspaper to make the villagers aware about the commitment of the agency.

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Report-CGWB Report/inputs supplied by Regional Director, CGWB, Uttaranchal Region, Dehradun vide letter No.No. 4(43)/CGWB/UR/Tech-08

Reports from Jal Sansthan……………………….

Reports from Jal Nigam……………………….

Response_ Reddy B.sadasiva, CHAMOLI HYDRO POWER PRIVATE LIMITED.

Response_ Gulati D, NTPC LIMITED.

Response_ Arora Kumar Pramod, BHILANGANA HYDRO POWER LIMITED.

Response_ Babu P.V Prasad, LANCO MANDAKINI HYDRO ENERGY PRIVATE LIMITED.

Response_ Senthupandian P, GMR VARALAKSHMI FOUNDATION.

Response_ Darshan Priya, SWASTI POWER LIMITED.

Response_ Pujari Ashutosh, L&T UTTARANCHAL HYDROPOWER LIMITED

Response_ Kumar Bhishm, NIH ROORKEE

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CHAPTER 8

HYDROPOWER DEVELOPMENT

8.1 Power Scenario:

The State of Uttarakhand was created by carving out Kumaun and Garhwal regions out of Uttar Pradesh in November, 2000. The State is currently a net importer of power, but generates a seasonal surplus. Since its creation, the new State of Uttarakhand has been witnessing a sharp increase in energy demand. Power consumption has grown more than five times in the last eight years (2002-10). The position with regard to the sources of energy supply and consumption of energy based on use for the year 2009-10, is depicted in Fig 8.1 and 8.2.

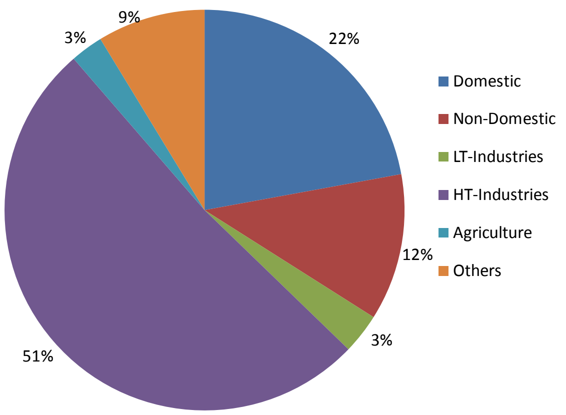


Fig 8.1: Electricity Consumption in Uttarakhand (Total MU 8980) for year 2009-10 (courtesy: UERC)

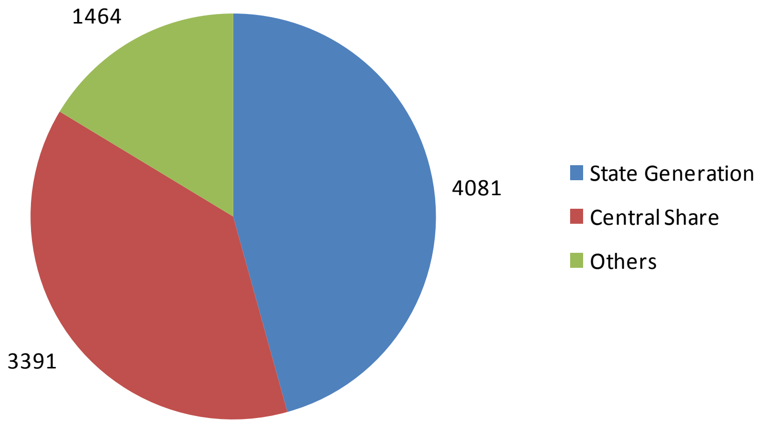


Fig 8.2: Share of Electricity of Uttarakhand (8936 MU for 2009-10) (courtesy: UERC)

As is evident from the charts above, the State is able to meet only 52 percent of its power needs from its own resources. The State, however, plans to become a net exporter of power by expanding its hydro-power generation capacity and by enhancing and improving high voltage transmission systems in the State. The state utility has spent Rs 2063 crores for purchases of 8936 MU. The tariff for purchases of power in the state for the year 2009-10 is shown in figure 8.3

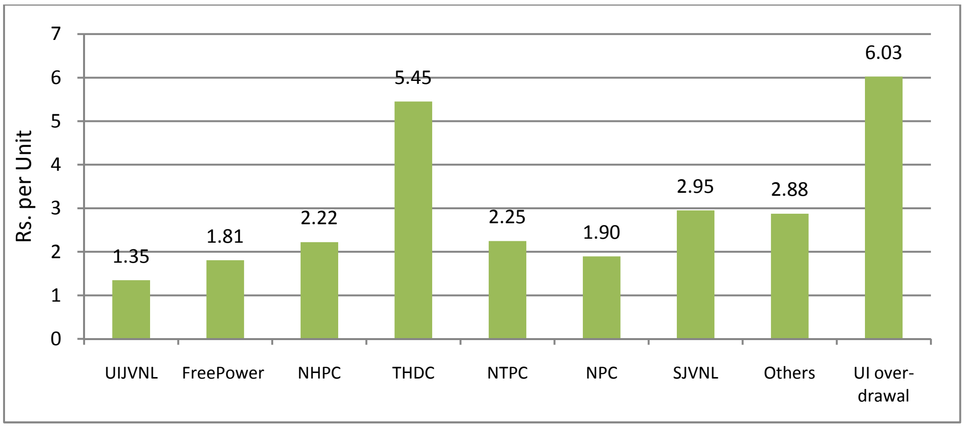


Fig 8.3: Average Cost of Power From Different Sources (Rs./Unit) for 2009-10 (courtesy: UERC)

8.2 Hydropower policy

8.2.1 Hydropower Potential

The principal consumptive use of water in India has traditionally been for irrigation. India uses 83 percent of its water withdrawal for agriculture as compared to the global average of 69 percent. About 5% water is used for drinking and balance for industrial and ecological purposes. Uttarakhand has a hydropower potential of the order of 20,000 MW against which only about 3,164 MW has been harnessed (in operation) so far through 45 hydropower projects of different capacities in central and private sector.

8.2.2 Legal Framework for Water Resources Development

India is a Union of States. The Constitution provides for the distribution of legislative powers. The matters of National interest are included in List-I (Union List) where the Parliament can enact laws. The matters of States' interest are included in List-II (State List) where the States have full legislative powers. The matters of common interest are included in List-III (concurrent List) where both the legislatures can act.

Water is in the State List. However, an entry in the Union List allows the Union Government to regulate and develop inter-State rivers to the extent it is declared by the Parliament by law to be expedient in the public interest. Most of the country is covered by the inter-State river basins. Article 262 of the Constitution deals with the adjudication of disputes related to waters of inter-State rivers or river valleys. However, in practice, the Parliament has allowed the States to deal with waters of inter-State rivers by mutual agreement and only in a few cases tribunals were entrusted by Central Government for resolving inter-State disputes.

8.2.3 State Hydropower Policy

To encourage generation of hydropower, the Government of Uttarakhand (GoU) has formulated and implemented policies (October 2002) with the following broad objectives:

- Creation of conducive conditions for encouraging private sector participation,
- Harnessing water resources in an environment friendly manner,
- Meeting the energy demand of the State/ Country,
- Promotion of the overall development of the region and
- Generation of revenue from hydro resources.

The key features of the Government of Uttarakhand's policy are (a) potential hydro projects identified by the Government of Uttarakhand are advertised for international competitive bids; (b) bids are invited over a minimum premium, payable upfront to the Government of Uttarakhand (c) projects are allocated to bidders making the highest bid over and above the upfront minimum premium; (d) projects are allocated for an initial period of 45 years on a build-own-operate-and-transfer basis; (e) the developers of the project have the right to sell the power outside the state; no agency of the state will guarantee purchase of power for projects above 25 MW but for small hydro is the first right of refusal and (f) 12% of electricity generated is to be made available free of cost to the state during entire life of the project. A capacity of 12,235 MW is under development (at various stages) in state, central and private sector viz State sector 2815 MW – 32 projects, central sector 7302 MW -25 projects and private sector2118 MW- 38 projects.

GoU came out with three separate policy documents in October 2002 covering the following three categories of hydropower projects:

a. Up to 25 MW
b. Above 25 MW to 100 MW
c. Above 100 MW

The policy for Small Hydro Projects (SHP), up to 25 MW, was later revised in January 2008, to include power projects based on biomass, wind power, solar energy, geothermal power etc. in addition to hydropower.
(http://www.uttarakhandjalvidyut.com/gou_policies.htm)

Techno-economic clearance needs to be obtained from Central Electricity Authority (CEA) only if the estimated cost of the project exceeds Rs. 500 crore (MOU route basis) and 2500 corers (on competitive basis)[1] and / or inter-state issues are involved. The salient features of the policy instruments are summarized in table 8.1.

Policy for harnessing renewable energy resources (January 2008) envisages community participation in power generation through gram panchayats and societies of Uttarakhand by way of self identified projects. Allotment of project sites for developing hydropower projects is based on open competitive bidding which provides for pre-qualification based on technical and financial parameters. Participation in the bidding process is open to private sector entities, Central power utilities, State Governments; their entities and Joint Ventures. The developers to whom the projects get allotted would have the status of Independent Power Producers (IPPs).

[1] Gazette of India, Extraordinary Part II, Section 3, Sub-section (ii), Government of India, Ministry of Power, New Delhi, April 18, 2006

Table 8.1 Terms and conditions of hydropower policy of Uttarakhand State[2]

Category	Upto 25 MW	Above 25 MW to 100 MW	Above 100 MW
Offer period on BOOT basis	40 years from the date of award at the end of which they shall revert to the GoU	45 years from the date of award at the end of which they shall revert to the GoU	Project will be allotted for an initial period of 45 years
Application fee	Rs. 1 lacs	Rs. 5 lacs	Rs. 5 lacs
Threshold premium[3]	Rs. 5 lacs per MW[4]	Rs. 5 lacs per MW	Rs. 5 crore per project
Wheeling charges[5]	Wheeling charges would be 10% of net energy supplied at the interconnection point	Wheeling charges would be 10% of net energy supplied at the interconnection point	No mention
Royalty	Exemption for first 15 years; beyond that 18% of net energy wheeled	First 15 years – 12% of net energy wheeled; beyond that 18%	12% of electricity generated during the entire life of the project
Incentives	No entry tax on power generation / transmission equipment and building material	No entry tax on power generation / transmission equipment and building material	No entry tax on power generation / transmission equipment and building material
Banking of power[6]	Banking of energy within fixed period spans of 2 months	Not permissible	No mention
R&R Policy	No mention	No mention	As per R&R policy of GoU
Environment impact assessment (EIA)	No mention	No mention	No mention

Source: State Power Policy documents

[2] Comptroller and Auditor General of India Report "Performance Audit Of Hydropower Development Through Private Sector Participation for the year 2008-09", 2010 http://saiindia.gov.in/cag/report/performance-audit-report-hydropower-development-through-private-sector-participation-uttarakh

[3] The minimum premium/ amount prescribed by GoU for a project.

[4] Revised in Jan 2008; for projects ranging between 2 MW to 5 MW – Rs. 1 lacs per MW whereas the projects ranging above 5 MW to 25 MW – Rs. 5 lacs per MW.

[5] Charges raised by UPCL in lieu of transmission of electricity generated by IPPs for sale of generated energy outside the State and to captive users within the State.

[6] Inter grid arrangement for surplus power generated in different states for lean season use by deficient states.

Forty six (46) projects with a total installed capacity of 2617 MW have been allotted to private sector as Independent Power Producers (IPPs) in the state. Out of these, allotment for 34 projects was done under the erstwhile combined state of Uttar Pradesh in the year 1993. However, after the creation of the state of Uttarakhand and the announcement of the state's own power policy in October 2002, the developers of these projects entered into a fresh Implementation Agreement (IA) with the GoU.

8.3 HYDROPOWER BASICS

8.3.1 Classification

Hydropower projects can be classified by a number of ways which are not mutually exclusive:

- By size (large, medium, small, mini, micro, pico)
- By head (high or low)
- By purpose (single or multipurpose)
- By storage capacity (run-of-river, pond, seasonal, multi-year)
- By function (generation, pumping, reversible)
- By service type (base load, peaking, intermittent)
- By system design (Stand-alone or cascading)

The classification according to size (installed capacity) is the most frequent form of classification used. Small scale hydropower plants have the same components as large ones. Compared to large scale hydropower, it takes less time and efforts to construct a small hydropower project. These power systems can be installed on small rivers or streams. Impacts on ecosystems will vary, however, not so much according to installed capacity or whether or not there is a reservoir, but by the design, where intakes, dams and waterways are situated and how much water flow is used for power generation compared to how much that is left as instream flow. The concept of small versus large hydro gives an impression of small or large negative impacts. This generalization will not hold as it is possible to construct rather large power plants with moderate impacts while the cumulative effects of several small power plants may be more adverse than one larger plant in the same area. It is more fruitful to evaluate hydropower based on its sustainability performance and based on the type of service provided as opposed to a classification based on technical units with little or no relevance for nature or society.

A brief description of various types of hydropower projects follows.

8.3.2 Run of River (RoR) Projects

A run of river hydropower plant draws the energy for electricity production mainly from the available flow of the river. Such a hydropower plant may also have some short-term storage (hourly, daily, or weekly), allowing for some adaptations to the demand profile. This has become more important and economically attractive in the electricity regulated era. Run-of-river hydropower plants are normally operated as base-load power plants. A portion of river water might be diverted to a channel or tunnel, pipe line (penstock) to convey the water to hydraulic turbine installed in a powerhouse building which is connected to an electricity generator. Figure 8.4 shows such type of scheme. Their generation depends on the precipitation of the watershed area and may have substantial daily, monthly, or seasonal variations. Transmission line from the powerhouse is connected to the to the nearest transmission system/substation .The section of river between the diversion point and the tailrace channel/tunnel coming out from powerhouse is called the *'diversion reach'* as significant quantities of water are diverted from this section of river. With due care given to addressing environmental impacts, these types projects can create sustainable green energy with minimal bearing on the surrounding environment and nearby communities. Due to variation in the power generation these projects from the grid point of view are variable/intermittent.

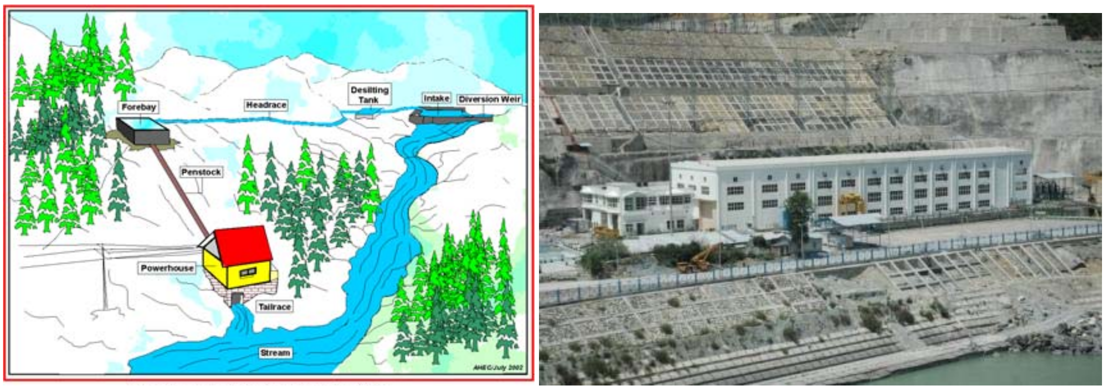


Figure 8.4: Run of river hydropower plant.
(Maneri Bhali II 300 MW District Uttarkashi)

8.3.3 Storage (Reservoir) Projects

In order to reduce the dependence on the variability of inflow, many hydropower plants comprise of reservoirs and the generating stations are located at the dam toe or further downstream. Water is fed to the power house through tunnel or pipelines as per the electricity demand (Figure 8.5). Such reservoirs are often situated in river valleys. High altitude lakes make up another kind of natural reservoirs. In these types of settings, the generating station is often connected to the lake serving as reservoir via tunnels constructed beneath the lake (lake tapping). The design of the HPP and type of reservoir that can be built is very much dependent on opportunities offered by the topography.

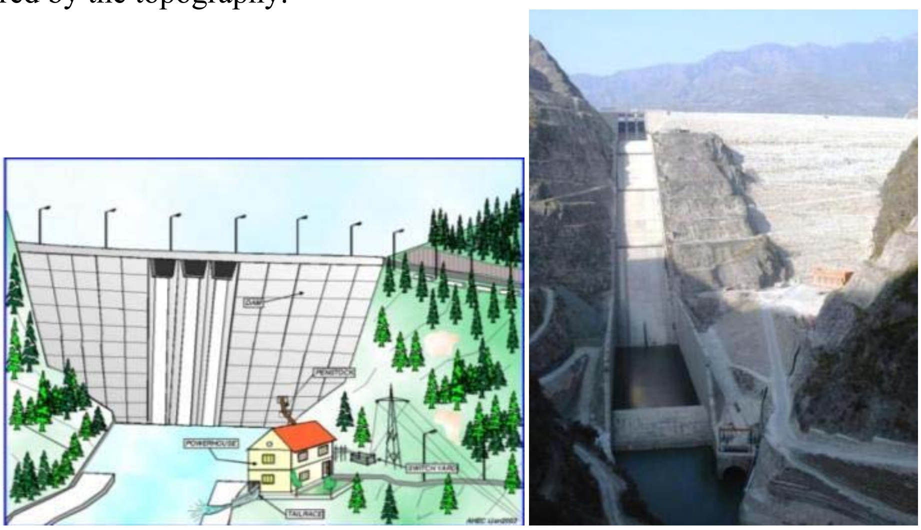
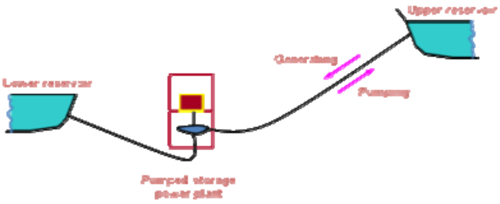


Figure 8.5: Hydropower plants with reservoir
(Tehri stage-I 1000 MW district Tehri Garhwal)

8.3.4 Pumped-storage Projects

Pumped-storage plants pump water into an upper storage basin during off-peak hours using surplus electricity from base load power plants and reverse flow to generate electricity during the daily peak load period. It is considered to be one of the most efficient technologies available for energy storage. Figure 8.6 shows such type of development. In Uttarakhand such a project is at present being developed at Tehri project stage II and others may be planned in future at appropriate locations.



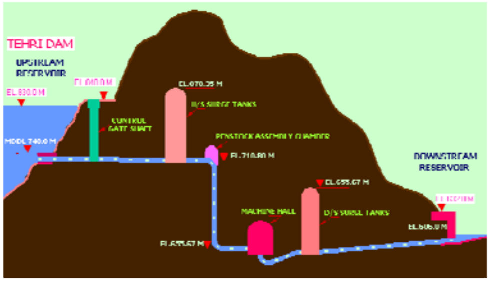


Figure 8.6: Pumped storage project (Source: IEA) **(Tehri Stage II 1000 MW)**

8.4 Operational water use for hydropower generation

Electricity generation technologies vary in terms of both water withdrawal and consumption. Water withdrawal is the amount of water diverted from a water source (river), while consumption is the amount of water that is lost through evaporation, transpiration, human consumption, and incorporation into products. Both values have impact on water availability.

While water is used throughout the life cycle of most technologies, operational cooling needs for thermal power plants withdraw and consume more water than any other life cycle phase, with the exception of biomass feedstock production (Fthenakis and Kim, 2010). Figure 8.7 and Fig 8.8 depict the variability in operational water withdrawal and water consumption rates associated with different electricity generation sources and technologies in USA. Though data used in both figures are from studies of U.S. systems only, but represent a wide range of electricity generation options and climatic conditions, , and thus their results may be applicable and comparable to water use rates in other countries. Water withdrawal and water consumption varies widely. As up- and downstream stages require little water, life cycle water use is close to zero for run-of-river hydropower plants (Fthenakis and Kim, 2010). Hydropower relies upon water in large quantities, but the majority of this is passed simply through the turbines with negligible losses. However evaporation occurs from reservoirs, yet reservoirs often provide other beneficial services besides power production (e.g., flood control, freshwater supply, irrigation water and recreation), and allocation schemes for determining water consumption from various reservoir uses can significantly influence reported water consumption values.

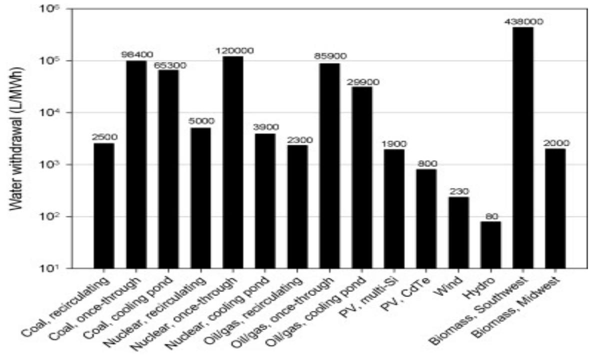


Figure 8.7 Comparison of water withdrawal across fuel cycles (Source: Fthenakis et al., 2010)

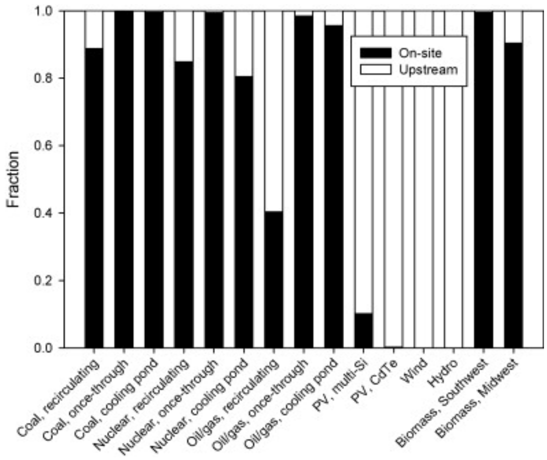


Fig 8.8 Breakdown of water withdrawals based on the water-use stage (Source: Fthenakis et al., 2010)

8.5 Energy Payback ratio and Life Cycle Assessment

Life-Cycle-Assessments **(**LCA) studies provide a well-established and comprehensive framework to compare all energy technologies. LCA methodologies have been evolving for a few decades and are now supported by international initiatives (UNEP and SETAC, 2010) and governed by standards (ISO, 2006). The energy payback ratio (EPR) is the ratio of total energy produced during a system's normal lifespan to the energy required to build, maintain and fuel that system. Other metrics that refer to the same basic calculation include the Energy returned on energy invested (EROI or energy payback time (EPT) or the energy ratio (ER). A high energy payback ratio indicates good performance. Life-cycle energy payback ratios for well performing hydropower plants reach the highest values of all energy technologies, ranging from 170 to 267 for run-of-river, and from 205 to 280 for reservoirs (Gagnon, 2008).(refer to fig 8.9)

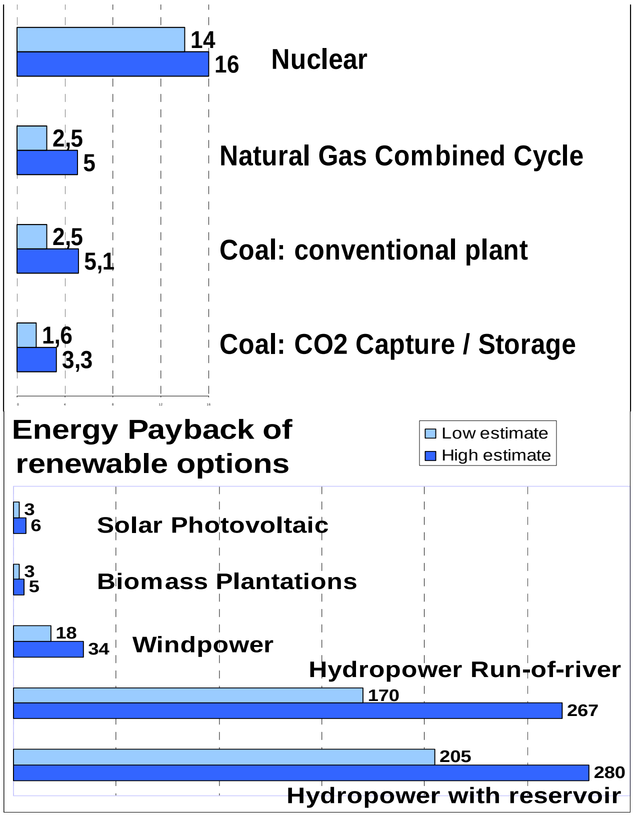


Fig. 8.9 : Energy Payback Ratio for Different Energy Technologies

8.6 GHG emission from Hydropower

Research and field surveys on freshwater systems involving 14 universities and 24 countries (Tremblay *et al.*, 2005) have led to the following conclusions:

- All freshwater systems, whether they are natural or manmade, emit greenhouse gases (GHG) due to decomposing organic material. This means that lakes, rivers, estuaries, wetlands, seasonal flooded zones and reservoirs emit GHG. They also bury some carbon in the sediments (Cole *et al.*, 2007).
- Within a given region that shares similar ecological conditions, reservoirs and natural water systems produce similar levels of CO_2 emissions per unit area. In some cases, natural water bodies and freshwater reservoirs absorb more CO_2 than they emit.

According to the IAEA (1996) and Tremblay 2005 (Table 8.2), hydropower is one of the cleanest ways to generate electricity in terms of GHG emissions. A full scale environmental comparison between the energy options should also include other pollutants (SO_X, NO_X, PM, etc.).

Table 8.2 Full Energy Chain Greenhouse Gas Emission Factors in gCO_2equiv./kWh(e) h^{-1} (Source: Tremblay et al. 2005).

Energy source	Emission Factor* gCO_2equiv./kWh(e).h
Coal (lignite and hard coal)	940- 1340
Oil	690 – 890
Gas (natural and LNG)	650-770
Nuclear Power	8-27
Solar (photovoltaic)	81-260
Wind Power	16-120
Hydro Power	4- 18
Boreal reservoirs (La Grande Complex)[1]	≈ 33
Average boreal reservoirs[2]	≈ 15
Tropical reservoirs (Petit-Saut)[3]	≈ 455 (gross)/ ≈ 327 (net)
Tropical reservoirs (Brazil)[4]	≈ 6 to 2100 (average: ≈ 160)

*: Rounded to the next unit or the next tenth respectively for values < or > 100g-CO_2equiv./kWh(e)h^{-1}.

1: La Grande Complex, Quebec. 9 reservoirs, 15784 MW, ≈ 174 km^2/TWh, (Hydro-Quebec 2000).

2: According to average reservoir characteristics of 63 km^2/TWh, (Hydro-Quebec 2000).

3: Petit-Saut, French Guiana, 115 MW, 0.315 MW/km^2.

4: 9 Brazilian reservoirs from 216 to 12 600 MW, total power = 23518 MW, total surface = 7867 km^2.

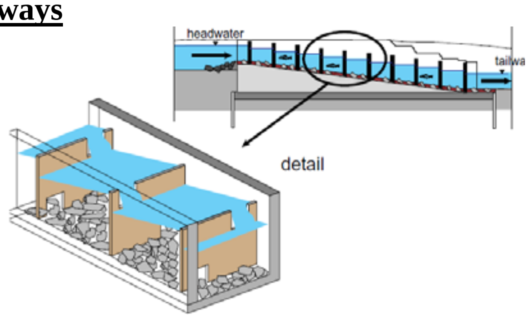
8.7 Barriers for Fish Migration

The building of a dams/ weirs/barrages impact fish populations: migrations and other fish movements can be stopped or delayed, the quality, quantity and accessibility of their habitat, which plays an important role in population sustainability, can be affected. Fish can suffer major damage during their transit through hydraulic turbines or over spillways. Changes in discharge regime or water quality can also have indirect effects upon fish species. Dams/ weirs/barrages may reduce access to spawning grounds and rearing zones. However, natural waterfalls also constitute obstacles to upstream fish migration and river navigation. Solutions for upstream fish migrations tested during the last 30 years have shown acceptable to high efficiency. Fish ladders can partly restore the upstream migration, but they must be carefully designed, and well suited to the site and species considered (Larinier *et al.*, 2004)). High head schemes are usually off limits for fish ladders. Conversely, downstream fish migration remains more difficult to address. In low-head HPPs, improvement in turbine design has resulted in development of as Fish Friendly Turbines which have proven to successfully reduce fish injury or mortality rates (Amaral et al., 2009). The design of the main components (plant, spillway, overflow) if done for fish passage, some avoidance systems may be installed (screens, strobe and laser lights, acoustic cannons, bubbles, electric fields, etc.). However their efficiency is highly site and species dependant, especially in large rivers. In some cases, it may be more useful to capture fish in the headrace or upstream and release the individuals downstream. Other common devices include by-pass channels, fish elevators with attraction flow or leaders to guide fish to fish ladders and the installation of avoidance systems upstream of the power plant. Some of fish passage devices are given in the box 8.1. A comparison of different upstream fishways are given in table 8.3.

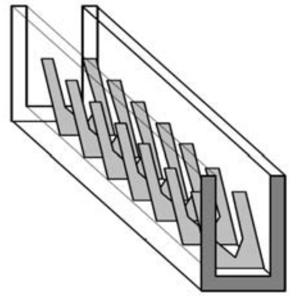
Box 8.1: Fish Passes Devices

Upstream Fish ways

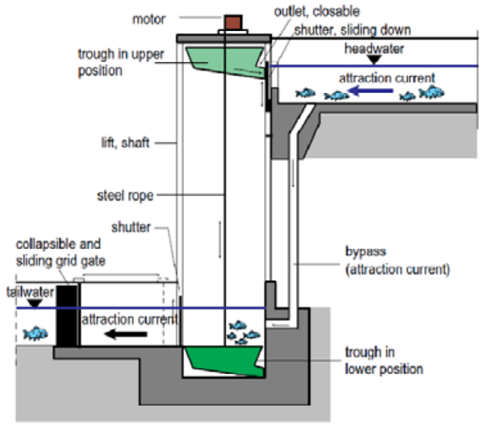
1. **Pool type fish passes:** The principle is the division of the height to be passed into several small drops forming a series of pools. The passage of water from one pool to another is either by surface overflow, through one or more submerged orifices situated in the dividing wall separating two pools, or through one or more notches or slots. Pool passes can accommodate significant variations in water levels and provide passage for most of the species.



2. **Denil fish passes:** It consists of a linear channel, in which baffles are arranged, angled against the direction of flow. The baffles dissipate considerable amounts of energy. These have a steep slope. This is normally selected for larger and stronger swimming species.



Fish Lifts: They are used to carry fish over high head dams. Fish are directly trapped in a trap with a V-shaped entrance at downstream end, lifted and empties its contents into the forebay. The main advantages of fish lifts lie in their cost, which is independent of the height of the dam. They are also considered to be more efficient for some species.



Downstream fish ways

They are required to travel fish downstream. They prevent the entrainment of the fish in turbine intake and ensure timely and safe movement of fish through the reservoir. These facilities are less advanced than upstream fish ways.

Physical Barriers: It involves stopping the fish physically at water intakes using screens and guide fish towards a bypass. The velocity of the flow towards the screen is adapted to suit the swimming capacities of the species and stages concerned. The common screens used are- deflecting screens, high flow screens and drum screens.

Behavioural Barriers: They influence behaviour of fish to prevent it from entering into turbine. Visual, auditory, electrical, and hydrodynamic stimuli have resulted in a large number of experimental barriers: bubble screens, sound screens, fixed and movable chain screens, attractive or repellent light screens, electrical screens and hydrodynamic ("louver") screens. They are less expensive.

Table 8.3: Comparison of different upstream fish ways:

Pool Passes	Denil Passes	Fish lifts
Suitable for migration at dams	Used in existing dams by prefabricating the elements	Suitable for high head dams
Good for strongly swimming & bottom oriented small fish	Good for strong & large fish	Good for weak swimmers
High maintenance	Regular maintenance	Expensive maintenance

8.8 General description of hydropower sites

Hydropower sites have been shown as follows:

(a) Hydropower Projects Commissioned – Fig 8.10
(b) Hydropower Under construction/Development – Fig 8.11
(c) Hydropower Projects Identified for future and are not allotted. Since there are not much details are available and hence excluded. These are mostly small scale hydropower– Fig 8.12

13 hydropower sites have been commissioned in the study area till date. Hydropower projects above 1 MW have only been considered in this study. Projects of 1 MW and below have not been covered under this study. There are 69 projects in the study area at different stages of development. One site is downstream of the confluence of Bhagirathi and Alaknanda at Devprayag. All allotted sites i.e. commissioned and under development hydro projects in the area of study have been considered under the study.

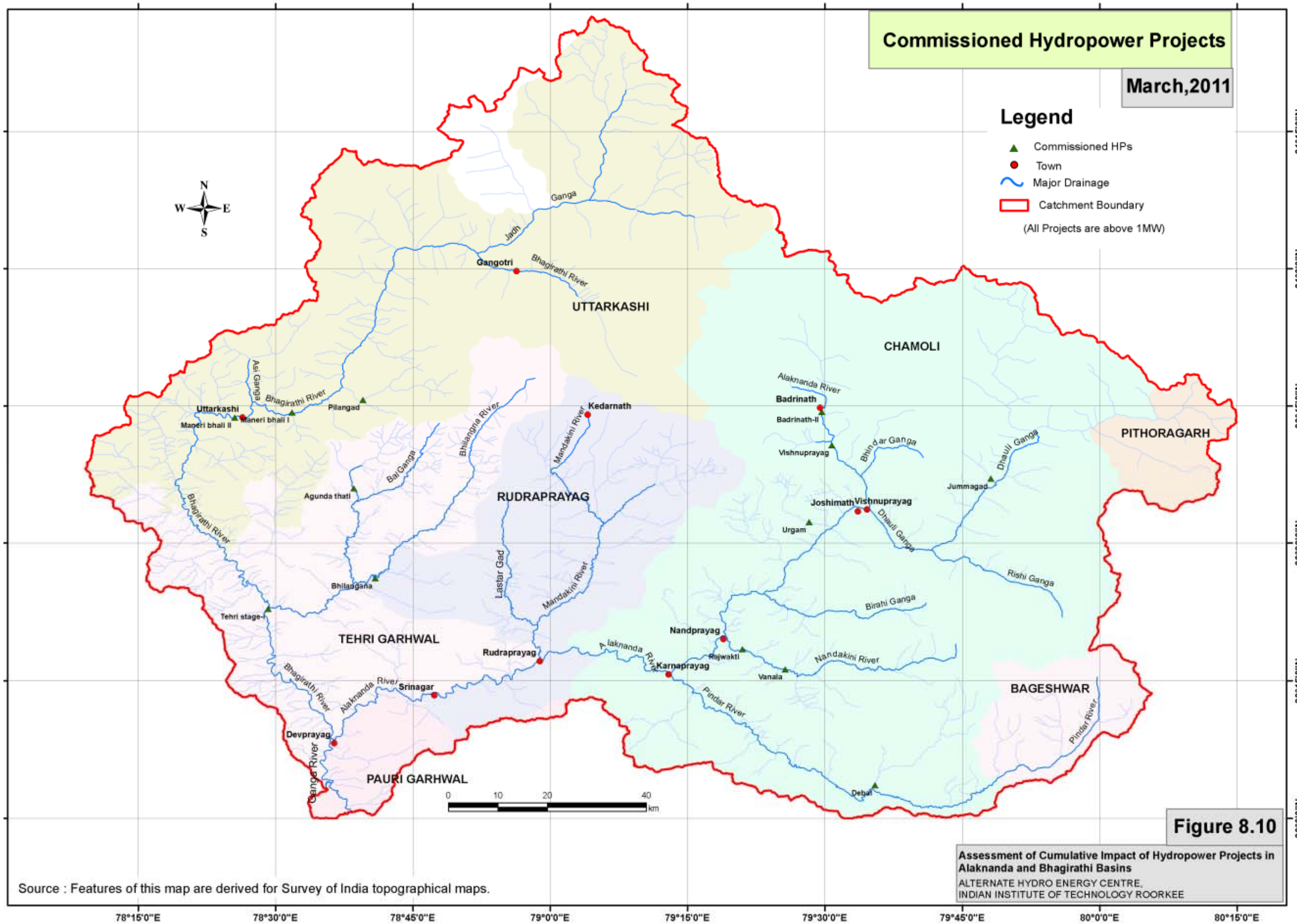
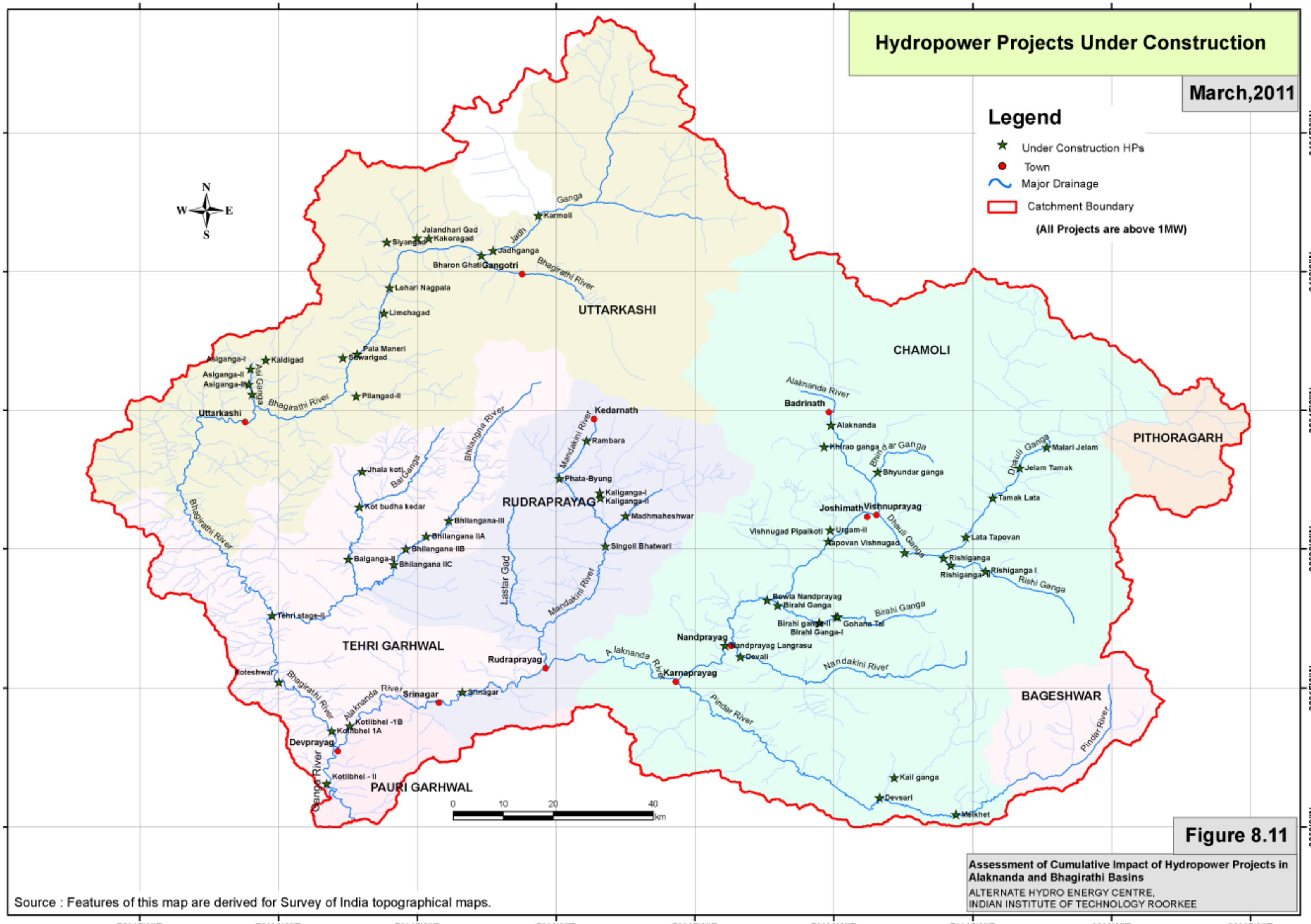


Figure 8.10

Assessment of Cumulative Impact of Hydropower Projects in Alaknanda and Bhagirathi Basins
ALTERNATE HYDRO ENERGY CENTRE,
INDIAN INSTITUTE OF TECHNOLOGY ROORKEE


Hydropower Projects Under Construction
March,2011
Legend
Under Construction HPs
Town
Major Drainage
Catchment Boundary
(All Projects are above 1MW)
UTTARKASHI
CHAMOLI
RUDRAPRAYAG
TEHRI GARHWAL
PAURI GARHWAL
PITHORAGARH
BAGESHWAR
Figure 8.11
Assessment of Cumulative Impact of Hydropower Projects in Alaknanda and Bhagirathi Basins
ALTERNATE HYDRO ENERGY CENTRE,
INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
Source : Features of this map are derived for Survey of India topographical maps.

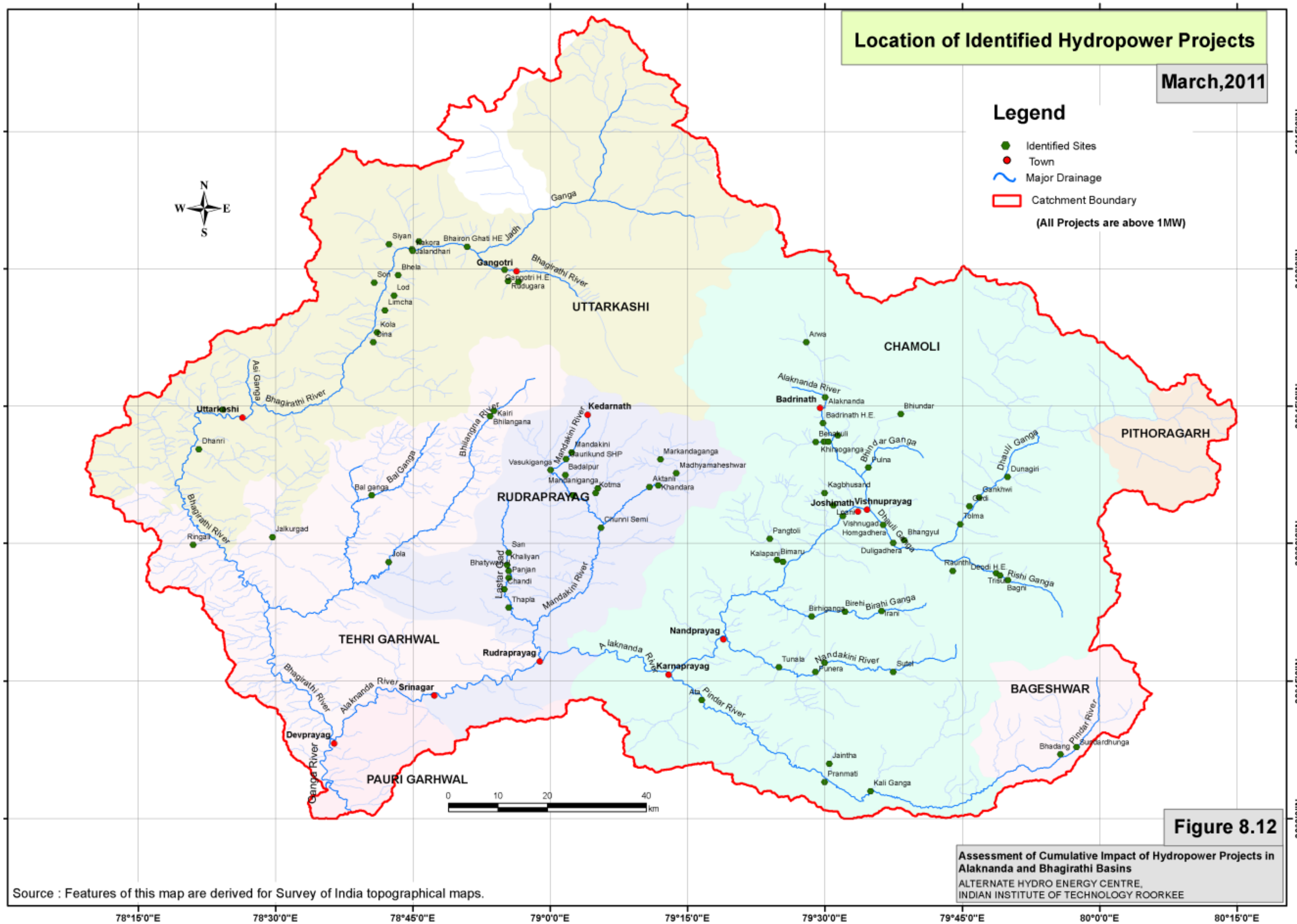

Location of Identified Hydropower Projects
March,2011
Legend
Identified Sites
Town
Major Drainage
Catchment Boundary
(All Projects are above 1MW)
UTTARKASHI
CHAMOLI
RUDRAPRAYAG
TEHRI GARHWAL
PAURI GARHWAL
PITHORAGARH
BAGESHWAR
Source : Features of this map are derived for Survey of India topographical maps.
Assessment of Cumulative Impact of Hydropower Projects in Alaknanda and Bhagirathi Basins
ALTERNATE HYDRO ENERGY CENTRE,
INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

Figure 8.12

8.8.1 HP Projects in Bhagirathi Basin

Originating from the Gangotri glacier at Gaumukh, Bhagirathi flows past the Gangotri town and downstream of it, it is joined by Jadh Ganga. Two HP projects, namely Karmoli (140 MW) and Jadh Ganga (50 MW) are under development on this tributary. Bharon Ghati project (38 MW) is located some distance downstream of junction of Bhagirathi and Jadh Ganga. Further downstream, three small tributaries join the Bhagirathi River and one project each, namely Kakora Gad (12.5 MW), Jalandhari Gad (24 MW) and Siyangad (11.5 MW) are under development.

Downstream of the confluence of Bhagirathi with Siyan Gad is the Loharinag Pala (600 MW) RoR project. Currently, the work on this project is under suspension. A small stream namely, Limcha gad joints from left and a small RoR project of 4 MW capacity with same name is under development on this river. Flowing further downstream is the site of Pala Maneri, a RoR project with 480 MW installed capacity.

Further down, two more small streams Suwari gad and Pilangad join Bhagirathi. On Pilan Gad, a project by the name Pilangad (4 MW) is operational and Pilangad-II (4 MW) is under development. Maneri Bhali I HP, which is a RoR of 90 MW capacity is located some distance upstream of the confluence of Bhagirathi and Asiganga.

In the Asiganga sub-basin, four RoR projects, namely Kaldigad (9 MW), Asiganga-1 (4.5 MW), Asiganga-II (4.5 MW) and Asiganga-III (9 MW) are under development. The town of Uttarkashi is located downstream of confluence of Asiganga and Bhagirathi. Downstream of the confluence is another RoR project Maneri Bhali-II whose installed capacity is 304 MW commissioned in 2008.

Bhilangana is the biggest tributary of Bhagirathi which joints it close to the erstwhile old Tehri town. A cascade of HEPs are under development on Bhilangana. From upstream to downstream, these are Bhilangana III (24 MW), Bhilangana II A (24 MW), Bhilangana II B (24 MW), and Bhilanga II C (21 MW) and (23 MW, in operation). Agunda Thati (3 MW) is in operation on a tributary of Bhilangana and Jhala Koti (13 MW) and Balganga II are under development.

Tehri dam is the largest multipurpose project in the study area. Its reservoir has a gross storage capacity of 7400 million m^3 and 2615 million m^3 as live storage. It's a power house has four untis of 250 MW each. The project was completed in the year 2006. Downstream of Tehri Dam is the Tehri Stage II project of 1000 MW capacity.

Another project in the close vicinity downstream is the Koteshwar HP of 400 MW capacity. The reservoir of the Koteshwar project will act as a pump back lake for Tehri pump storage project. Kotli Bhel 1A is the last project on Bhagirathi before its meets Alaknanda at Dev Prayag.

Installed capacity of 1422 MW has been developed and 3449 MW (13,620 MU) is under development in Bhagirathi Basin as on March 2011.

8.8.2 HP Projects in Alaknanda River

Alaknanda River originates from Satopanth Glacier. It flows past the holy town of Badrinath and a few km downstream is the commissioned Badrinath small scale HP of 1.2 MW capacity with discharge from a small tributaory Rishiganga. The first project under development on this river is Alaknanda HP (300 MW). A small tributary by the name Khirao Ganga joins the Alaknanda River in the course of this project and a small HP of 4 MW by the same name is under development on this tributary.

Vishnuprayag project of 400 MW is the first major RoR project commissioned on Alaknanda. A few kilometer downstream of diversion site of this project, Bhyunder Ganga joins Alaknanda. A small project of 24.5 MW capacity is under development in this stream. Further downstream is the first famous Prayag (confluence) of Alaknanda and Dhauli Ganga, is known as Vishnuprayag. A number of HP projects are under development on Dhauli Ganga, including Malari Jelam (114 MW), Jelam Tamak (126 MW), Tamak Lata (250 MW), Lata Tapovan (170 MW), Tapovan Vishnugad (520 MW), Jummagad (Commissioned 1.2 MW), Rishiganga (13.2 MW), Rishi Ganga I (70 MW), Rishi Ganga II (35 MW). The town of Joshimath is situated downstream of Vishnu Prayag. Urgam is a small scale commissioned project of 4 MW on Kalpa Ganga, a tributary of Alaknanda. Vishnugad Pipalkoti project of 444 MW is under development on Alaknanda between the confluence of Kalpa Ganga and Birahi Ganga. Four RoR projects are under development on Birahi Ganga, These are Birahi Ganga I (24 MW), Birahi Ganga II (24 MW), Gohantal (50 MW) and Birahi Ganga (7.2 MW).

Nandakini River joins Alaknanda at Nandprayag, Bowala Nandprayag project of (300 MW) is under development on main Alaknanda, upstream of Nand Prayag. Two projects namely, Vanala (15 MW) and Rajwakti (4 MW) have been commissioned on Nandakini and Dewali (13 MW) is under development. Nandprayag Langasu project of 100 MW is under development on Alaknanda River downstream of Nand Prayag.

Pindar is a tributary of Alaknanda which has a high water potential. Debal project of 5 MW has been commissioned on Kailganga which is Pindar’s tributary. Three projects which are under development in this sub basin are Melkhet (15 MW), Kali Ganga (5 MW), and Devsari (252 MW).

Mandakini is the last major tributary of Alaknanda which joins it at Rudra Prayag. Originating near the famous Shrine of Kedarnath, Mandakini is joined by tributaries such as Kali Ganga and Madmaheshwar. Projects under development in this sub basin are Kaliganga I & II, Madmaheshwar (15 MW), Rambara (24 MW), Phata Byung (76 MW) and Singoli Bhatwari (99 MW). Kotli Bhel I-B is the last HP on Alaknanda before its confluence with Bhagirathi at Devprayag. Near the town of Srinagar, a project by the same name and with an installed capacity of 330 MW is under construction.

Overall, the commissioned hydropower potential of Alaknanda is 429 MW and 3734 MW (15,513 MU) is under development.

8.9 The details of the hydropower projects in the study area

The hydropower projects with installed capacity of 1 MW or below have not been considered for the following reasons:

1. The impact and cumulative impact of these projects are extremely low
2. These projects are normally on small tributaries and are never on main rivers.
3. As per Ministry of Environment and Forests (MoEF) notification, projects of this size were not subjected to any environmental impact assessment study even before 1994.

As per MOEF, environmental impact assessment is to be carried out as per following gazette notifications

Reference and notification	Applicability
Notification no. S.O. 60(E) dated Jan 27, 1994	Project of upto and below cost ₹ 500 Million
Revised notification no. S.O. 632(E) dated June 13, 2002	Project of upto and below cost ₹ 1000 Million or less than 10,000 Hectare
Notification no. 1533(E) dated Sept 14, 2006 and published as S.O. 195(E) dated Jan 19, 2009	Project of upto and below installed capacity of 25 MW Or less than 10,000 Hectare of cultivatable command area

Thus we may note that the projects of about 10 MW installed capacity (with the assumption that the cost of project may be ₹ 50 Million /MW) and above size were covered under EIA act since 1994 and above 25 MW after 2006. For the projects approved taken up prior to 1994 there were practically no environment impact assessment carried out and after 2002 or 2006, there are no EIA reports for projects of installed capacity of about 25 MW and below.

The data and details of all hydropower projects (1 MW) which have been commissioned and allotted for development has been considered in this study. The majority of large (above 25 MW) hydropower potential has been allotted for development to different project owners (private, state and central PSUs). There may be some more sites and those have been excluded. Small hydropower (below 25 MW) sites which have not been allotted have also not been considered. Further these small hydropower sites will have low impact as they shall be mainly on streams/ tributaries and without any storage.

The data and details of these sites have been collected mainly from the project developers. The data availability of commissioned project few decade back like Maneri Bhali has been low specially on the monitoring of the impacts on environment. The projects which are under construction also are monitored with limited extent. Thus the study has these handicaps.

8. 10. Physiographic Characteristics of Bhagirathi and Alaknanda rivers

Physiographic characteristics of Bhagirathi and Alaknanda rivers and their tributaries have been presented in Table 8.4.

Table 8.4 - Physiographic Characteristics of Bhagirathi and Alaknanda rivers and their Tributaries

Sl. No.	River	Total Length* (m)	Elevation Range		Gradient	Confluence Location
			Highest Point	Confluence Point		
Bhagirathi River						
1.	Bhagirathi	217000	3200	480	1.25%	Confluences with Alaknanda at Devprayag
1(a).	Bhagirathi-Asiganga	83500	3200	1120	2.49%	
1(b).	Bhagirathi-Bhilangana	91000	1120	610	0.56%	
1(c).	Bhagirathi-Devprayag	42500	610	480	0.31%	
2.	Asi Ganga	20500	2440	1120	6.44%	Confluences at Ganganani Uttarkashi
3.	Bhilangana	109000	3000	670	2.14%	Confluences are Tehri
4.	Bal Ganga	37000	1730	814	2.48%	Confluences Bhilangana at Ghansali
Alaknanda River						
5	Alaknanda	224000	4016	480	1.58%	Joins Bhagirathi at Devprayag
5a	Alaknanda - Dhauli Ganga	47000	4016	1446	5.47%	Confluences at Vishnuprayag
5b	Alaknanda-Pindar	60000	1446	795	1.09%	Confluences at Karanprayag
5c	Alaknanda - Devprayag	109000	795	480	0.29%	
6	Dhauli Ganga	50000	2880	1446	2.87%	Confluences at Vishnuprayag
7	Rishi Ganga	38500	4000	1900	5.45%	Confluences Dhauli Ganga at Tapovan
8	Birahi Ganga	29500	2160	994	3.95%	Confluences at Birahi village
9	Nandakini	44500	2200	880	2.97%	Confluences Alaknanda at Nandprayag
10	Pindar	114000	2200	775	1.25%	Confluences at Karnprayag
11	Mandakini	81000	3562	640	3.61%	Confluences at Rudraprayag

*Upper reaches of river have not been accounted

This shows that Bhagirathi with a total length of 217 km up to Devprayag have an average slope of 12.5m per km. Initial reach has average slope of 25 m per km whereas after Tehri Dam has a slope of only 3.1m per km. Its tributaries Asiganga has a rather steep slope of 64.4m per km, Bhilangana has 21.4m per km. Figure 8.13 shows the L section of the river Bhagirathi with three major tributaries.

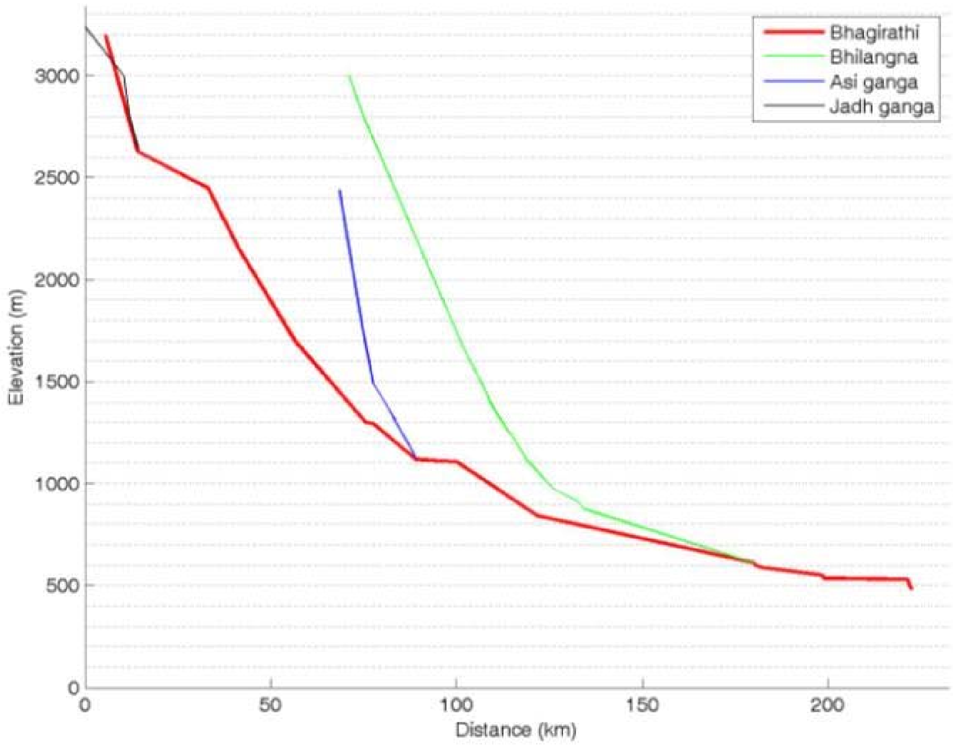


Fig 8.13: L section of the river Bhagirathi with three major tributaries.

On the other hand physiographic characteristics of Alaknanda rivers shows a steeper slope compared to Bhagirathi with an average gradient of 15.8m per km in its 224 km length up to Devprayag. In its initial stretch it has a slope of 54.7m per km indicating a high concentration of hydropower potential. Its tributaries Dhauli Ganga also has a steep slope of 28.7m per km and Rishiganga 54.5m per km. Tributary Mandakini emerging from Kedarnath has a steep slope of 36.1m per km indicating a good hydropower concentration. Figure 8.14 shows the L section of the river Alaknanda and its major tributaries.

8.11. Status of Hydropower Development

An abstract of allotted hydropower projects in both basins indicates (Table 8.5) that against 13 commissioned hydropower projects with total installed capacity of 1851 MW (7,860 MU), 14 projects of 2,538 MW capacity (10,727 MU) or almost 35% of present capacity are in advanced stage of construction whereas 42 projects with installed capacity of 4,644 MW (18,516 MU) are at different stages of development. Thus the present developed hydropower potential is likely to rise by 5 times with the allotted projects (9,033 MW to produce 37,103 MU). This will not be out of place to mention that the small hydropower (below 25 MW) share is about 10% which is a national average.

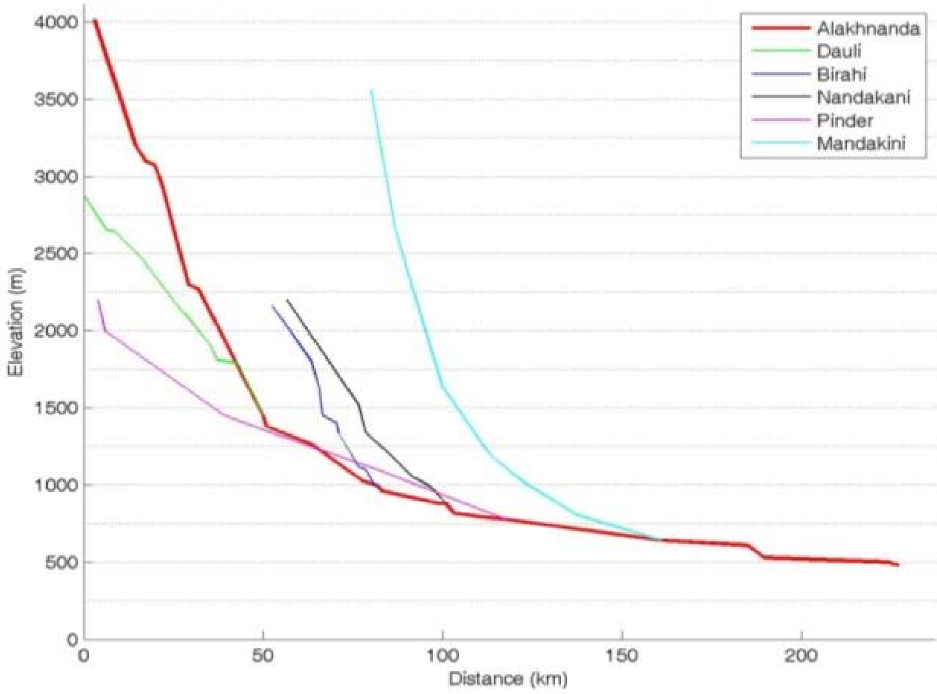


Fig 8.14: L section of the river Alaknanda and five major tributaries.

Table 8.5: Abstract of Alloted hydropower project in Bhagirathi and Alaknanda Basin

HP Type	BHAGIRATHI			ALAKNANDA			TOTAL		
	No. of HP	Installed Capacity (MW)	Generating Units (MU)	No. of HP	Installed Capacity (MW)	Generating Units (MU)	No. of HP	Installed Capacity (MW)	Generating Units (MU)
COMMISSIONED									
Large	3	1,394	5,481	1	400	2,061	4	1,794	7,542
Small	3	28	151	6	29	168	9	57	319
Total	**6**	**1,422**	**5,632**	**7**	**429**	**2,228**	**13**	**1,851**	**7,860**
ONGOING CONSTRUCTION									
Large	2	1,000	3,646	5	1,469	6,627	7	2,469	10,273
Small	1	24	171	6	45	283	7	69	454
Total	**3**	**1,024**	**3,817**	**11**	**1,514**	**6,910**	**14**	**2,538**	**10,727**
UNDER PREPARATION									
Large	6	2,246	8,767	10	1,597	6,543	16	3,843	15,310
Small	16	179	1,036	10	622	2,170	26	801	3,206
Total	**22**	**2,425**	**9,803**	**20**	**2,219**	**8,603**	**42**	**4,644**	**18,516**
TOTAL									
Large	11	4,640	17,894	16	3,466	15,231	27	8,106	33,125
Small	20	231	1,357	22	697	2,621	42	927	3,978
Total	**31**	**4,871**	**19,251**	**38**	**4,163**	**17,742**	**69**	**9,033**	**37,103**

8.12 Location of Hydropower Projects

All hydropower projects have been shown in drainage map of the study area along with diversion as figure 8.15.

Further all the projects have been shown in longitudinal profile for each river and tributaries as figure 8.16(a) to 8.16(l). The diversion site has been shown as W whereas powerhouse has been indicated as PH in parenthesis.

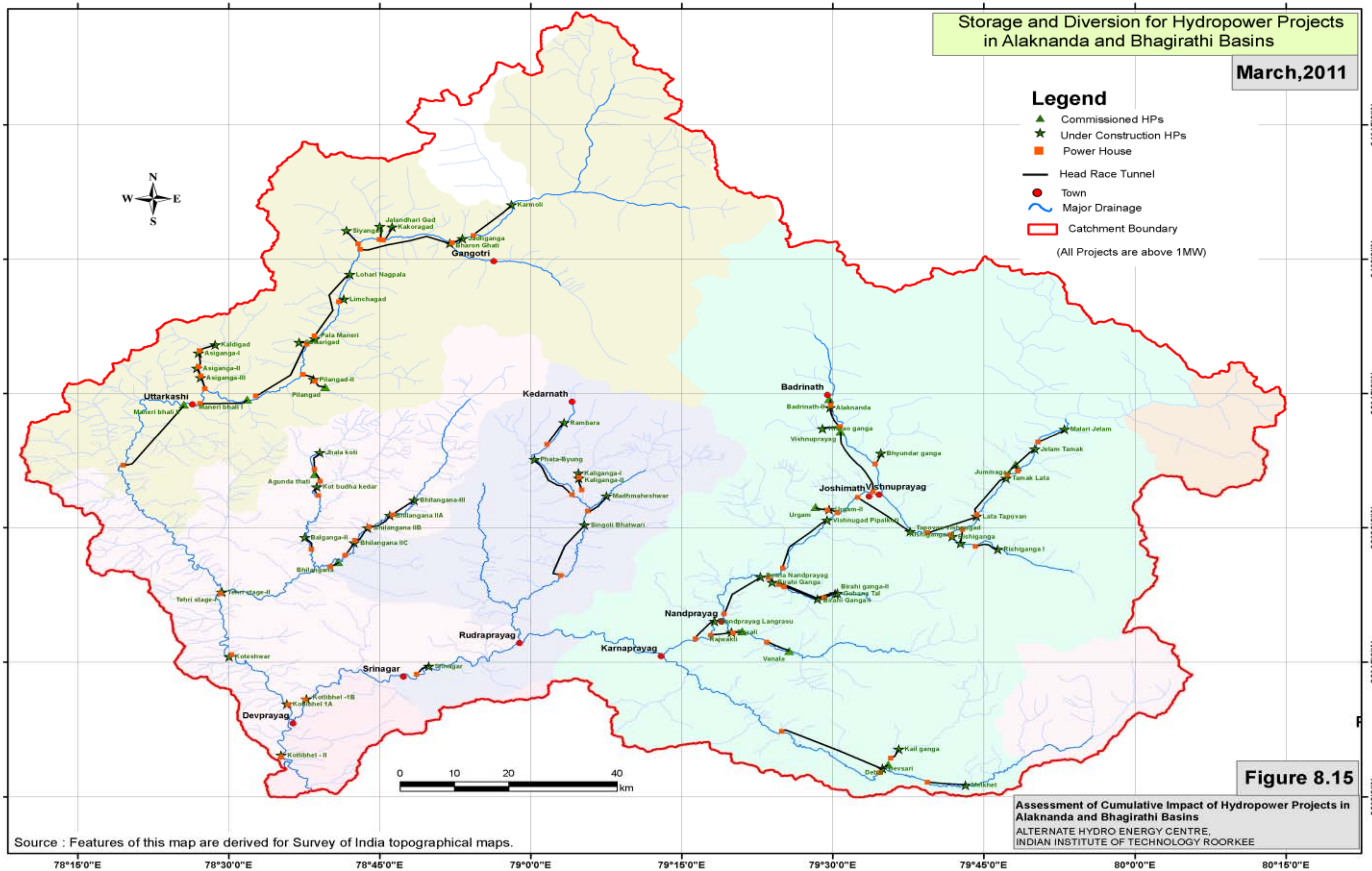


Fig 8.15: Location of hydropower Projects in Bhagirathi and Alaknanda River Basin

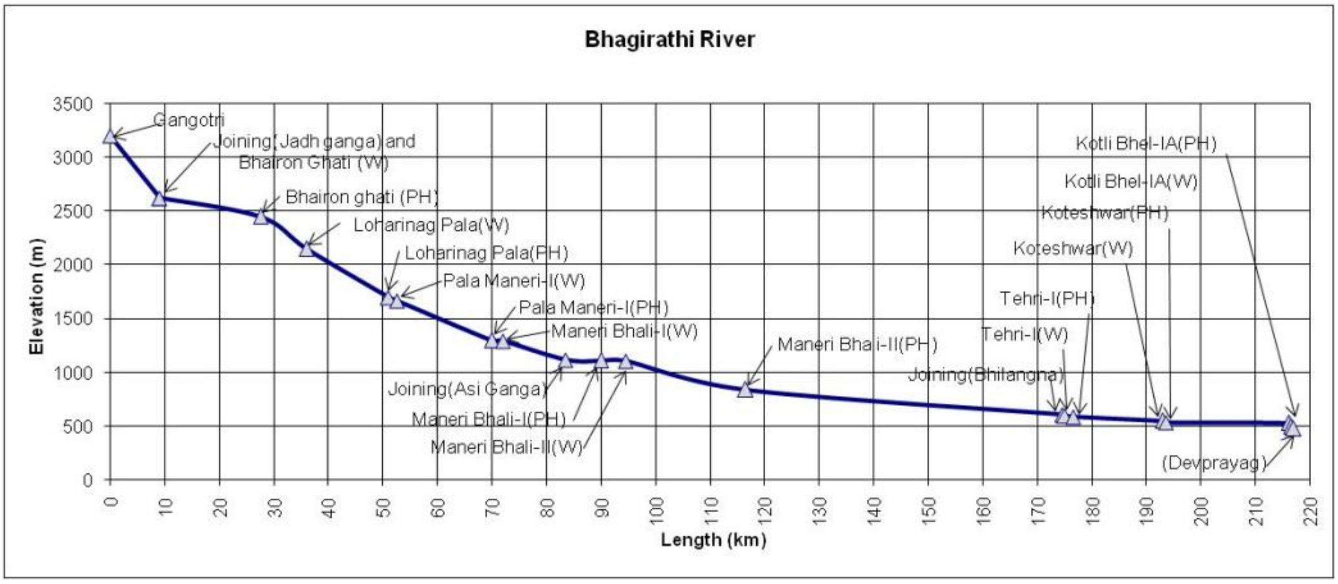


Fig 8.16(a): L-Section of Bhagirathi River with the Hydropower Project Location

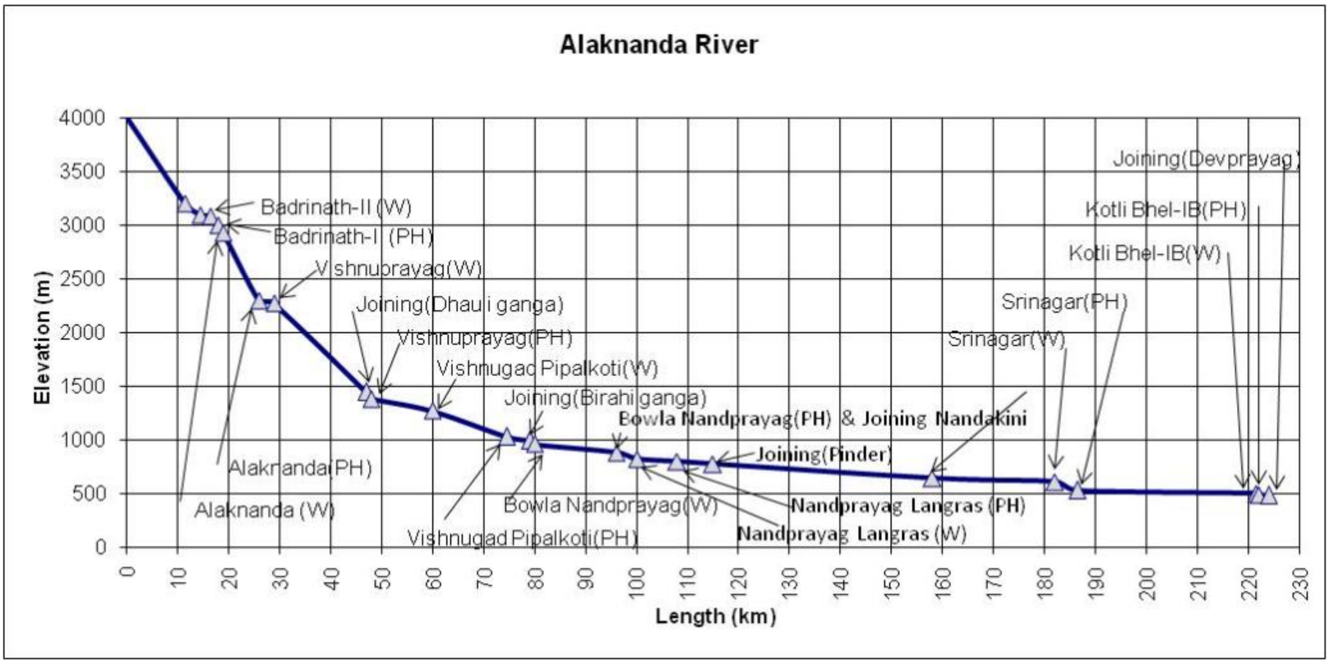


Fig 8.16(b): L-Section of Alaknanda with the Hydropower Project Location

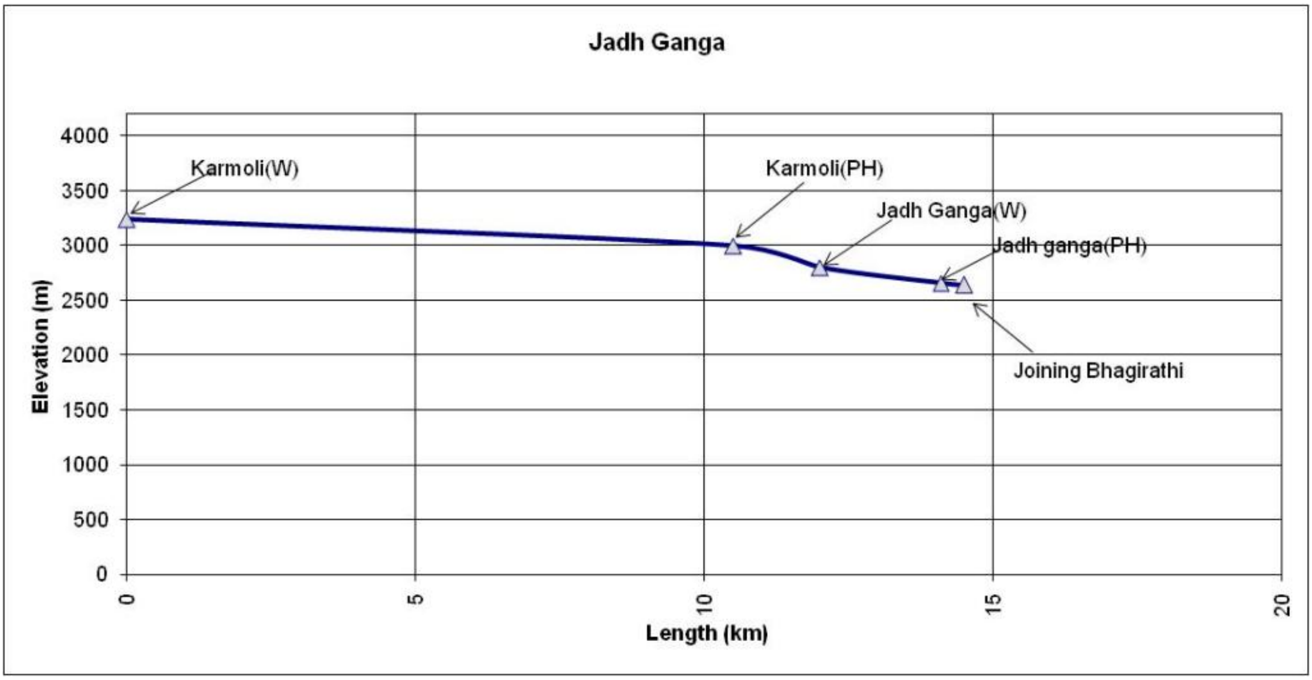


Fig 8.16(c): L-Section of Jadh Ganga with the Hydropower Project Location

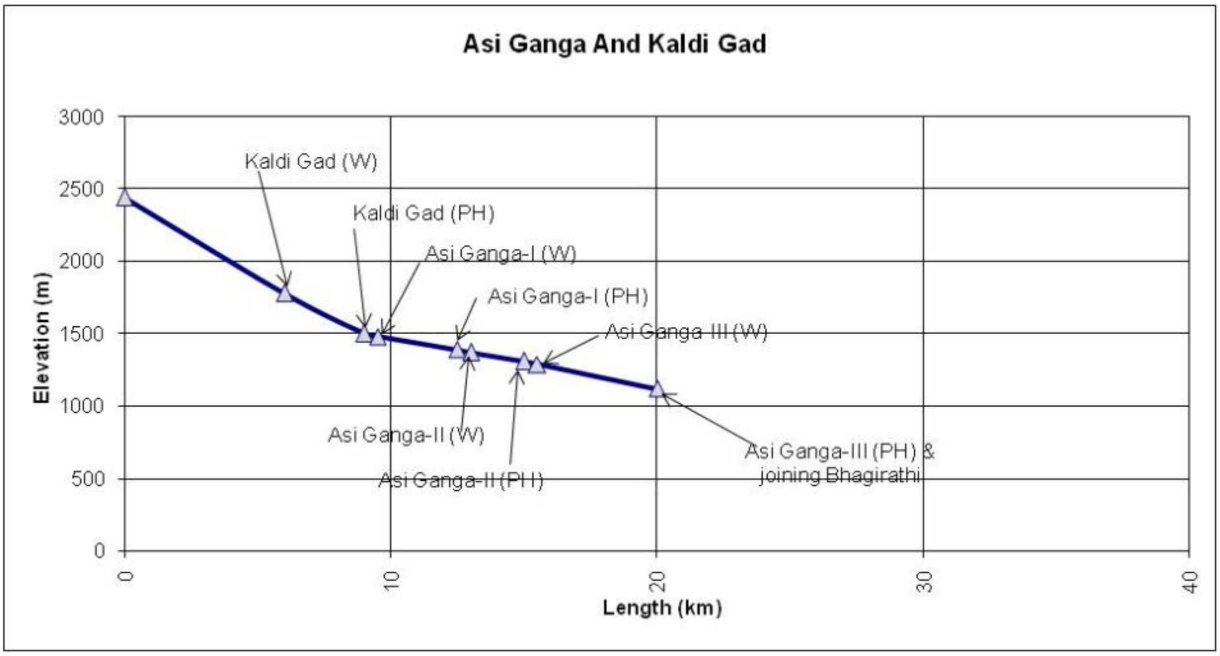


Fig 8.16(d): L-Section of Asi Ganga and Kaldi Gad with the Hydropower Project Location

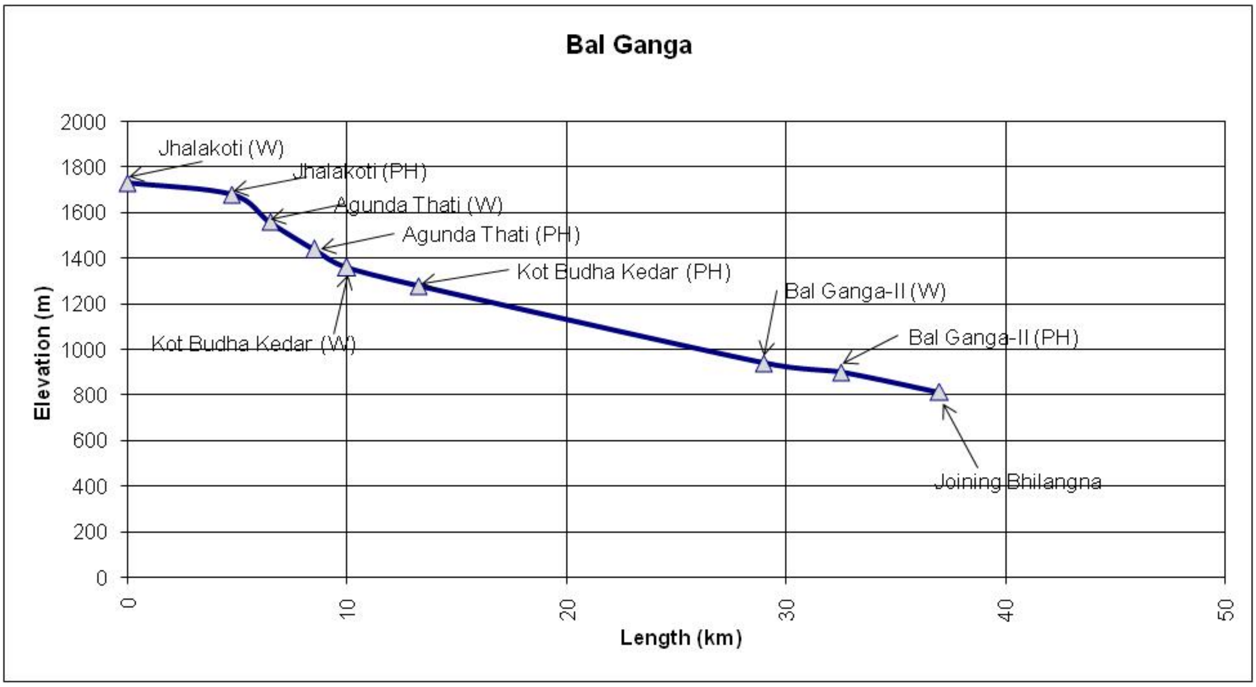


Fig 8.16(e): L-Section of Bal Ganga with the Hydropower Project Location

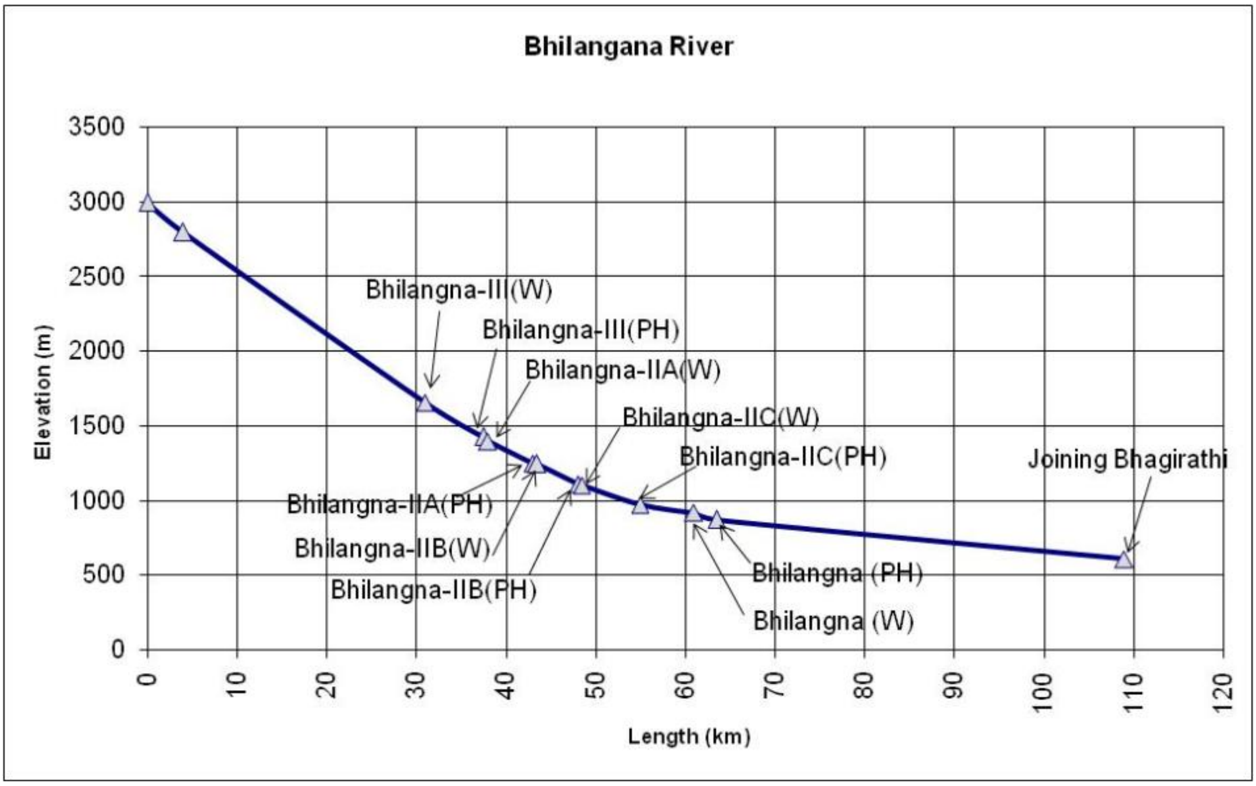


Fig 8.16(f): L-Section of Bhilangana River with the Hydropower Project Location

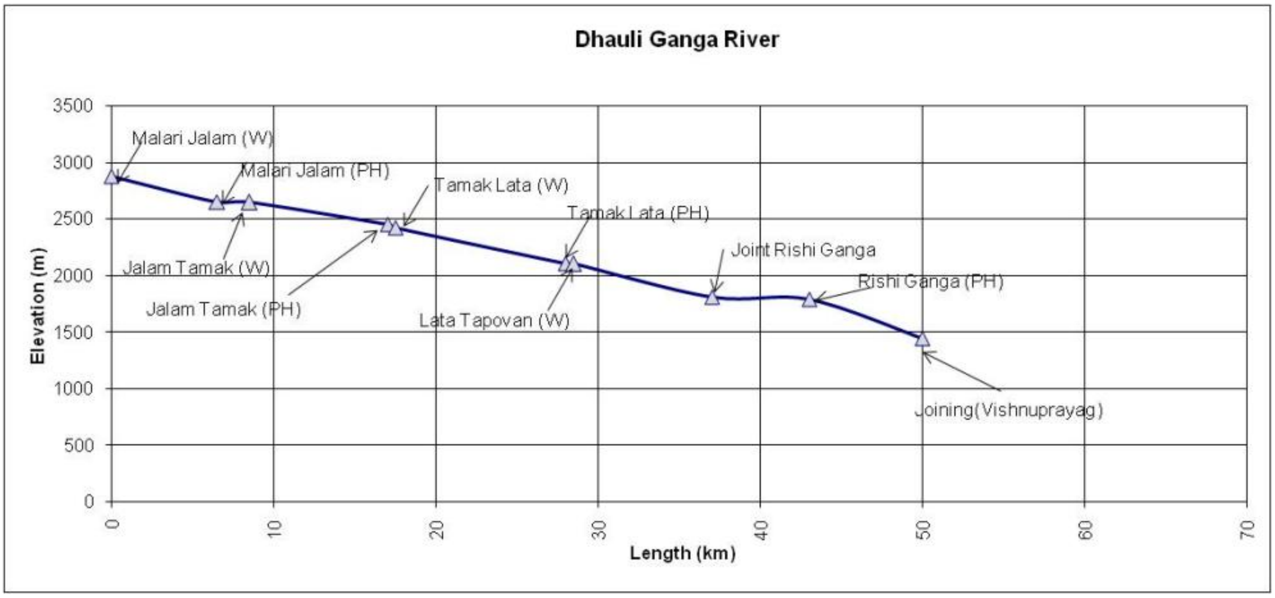


Fig 8.16(g): L-Section of Dhauli Ganga with the Hydropower Project Location

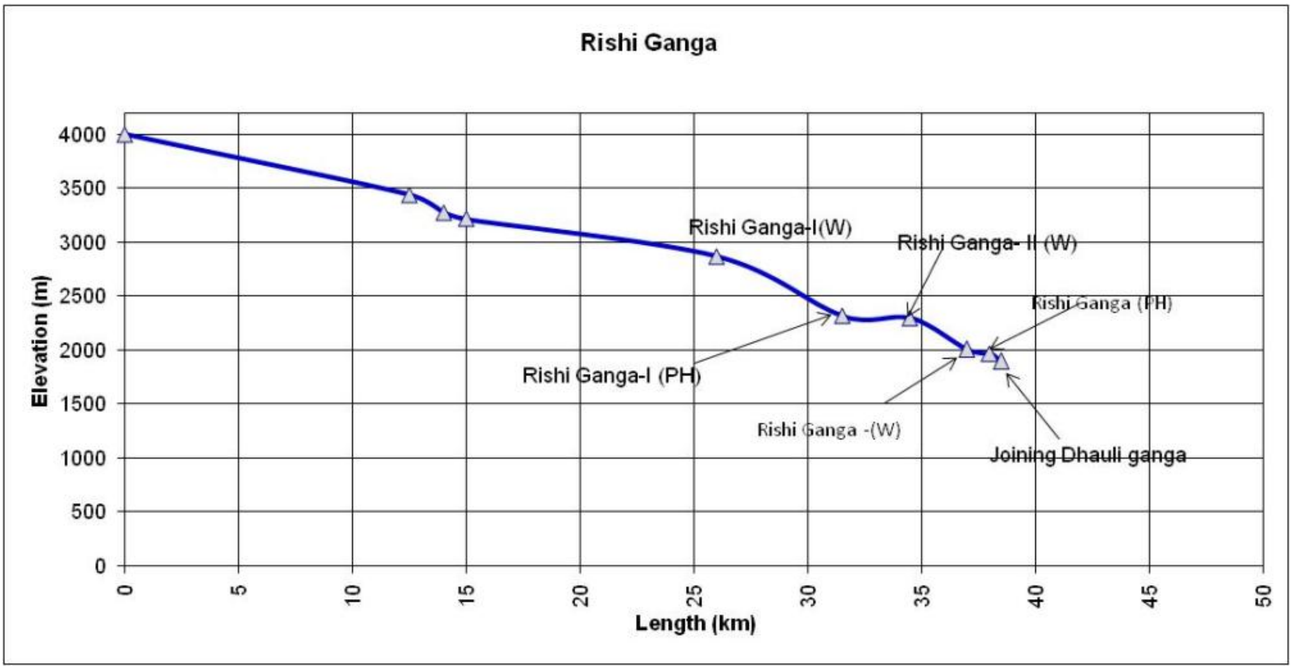


Fig 8.16(h): L-Section of Rishi Ganga River with the Hydropower Project Location

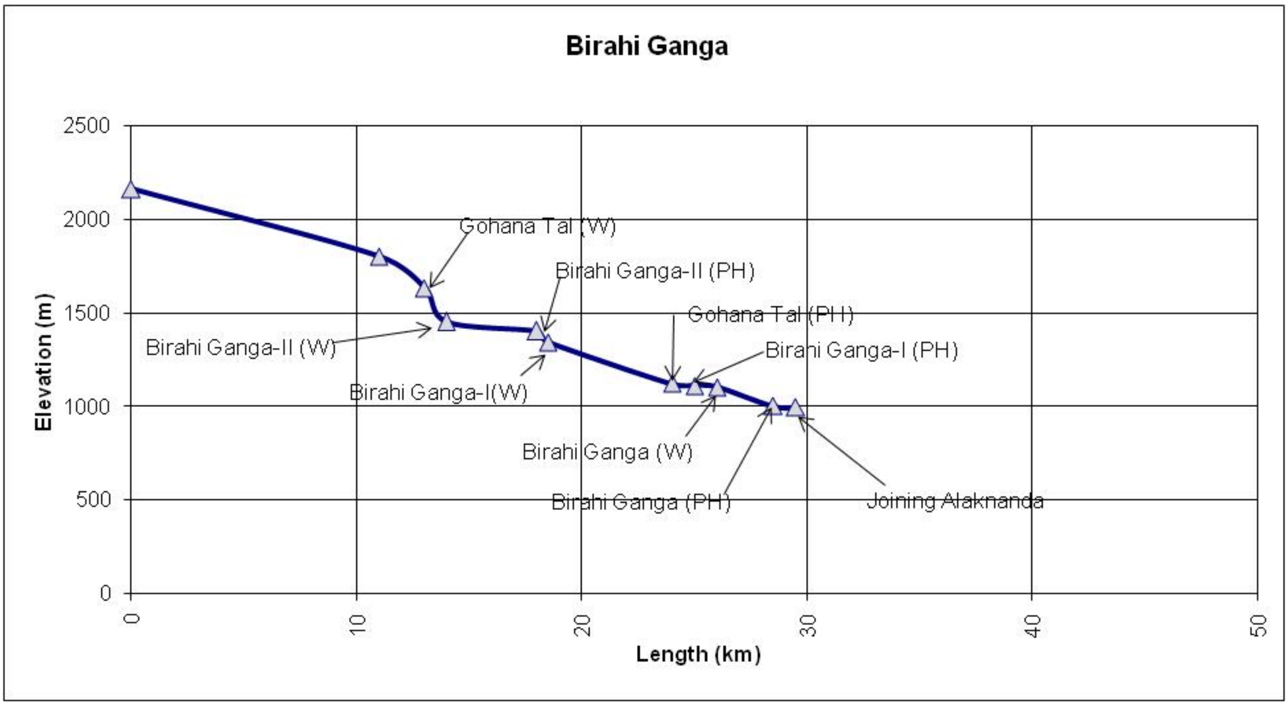


Fig 8.16(i): L-Section of Birahi Ganga with the Hydropower Project Location

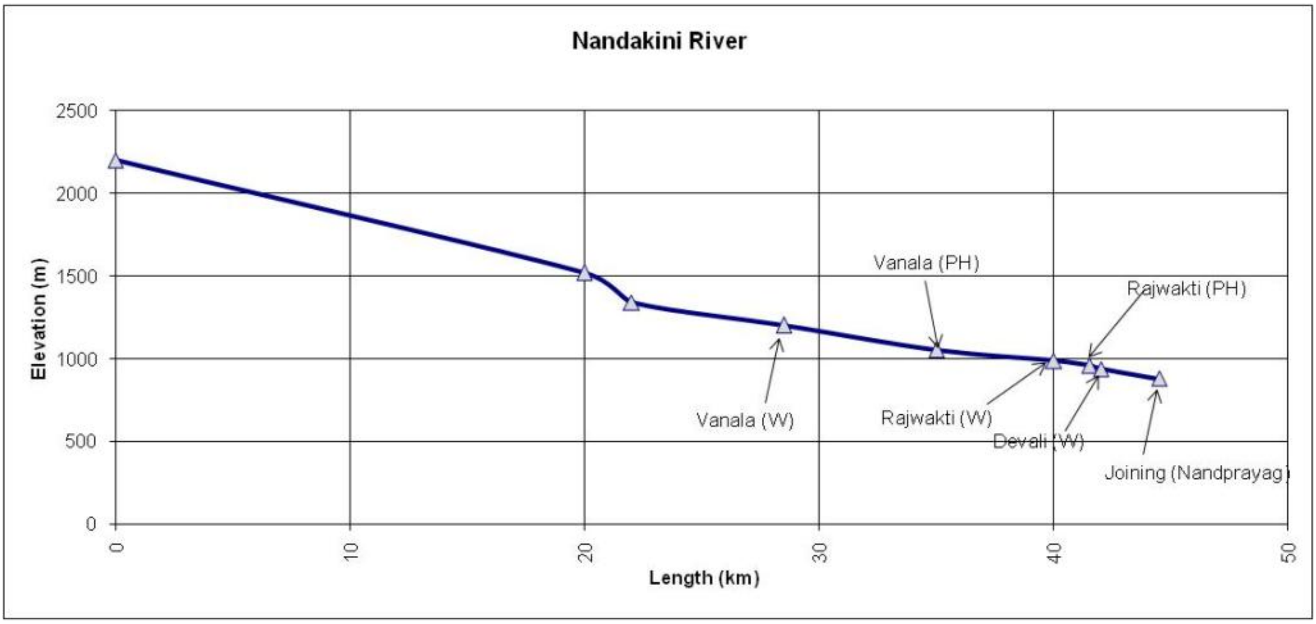


Fig 8.16(j): L-Section of Nandakini River with the Hydropower Project Location

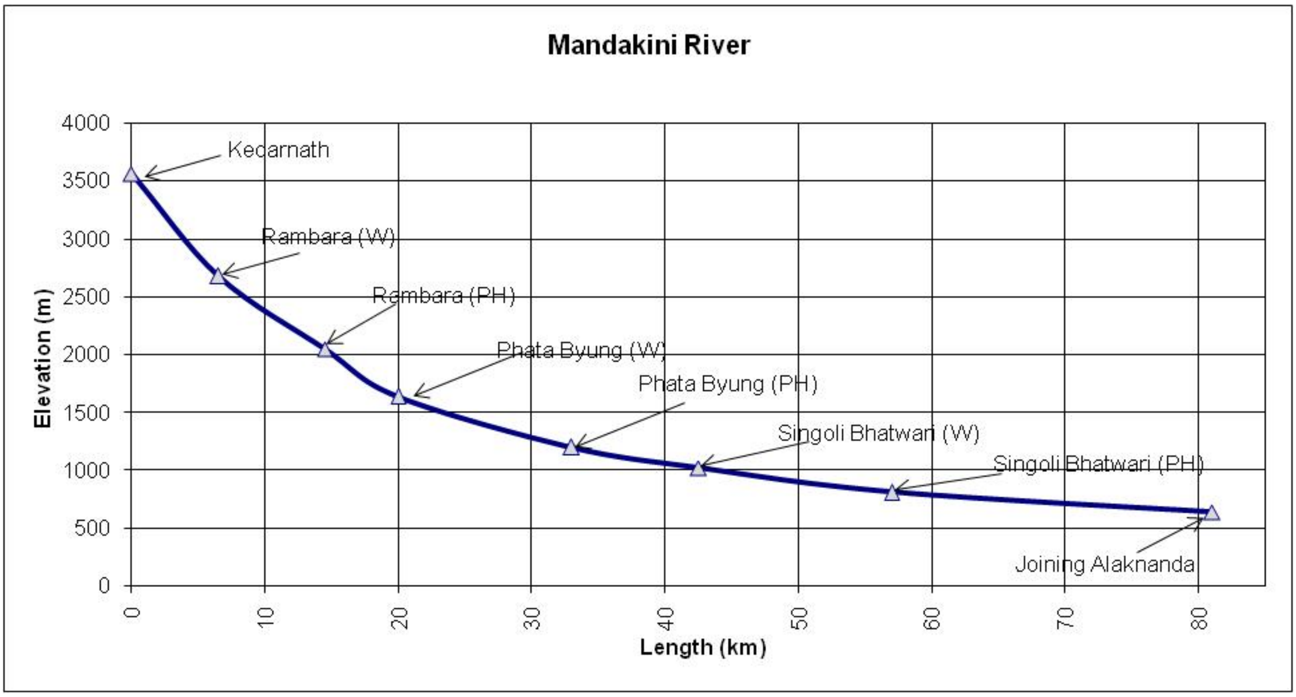


Fig 8.16(k): L-Section of Mandakini River with the Hydropower Project Location

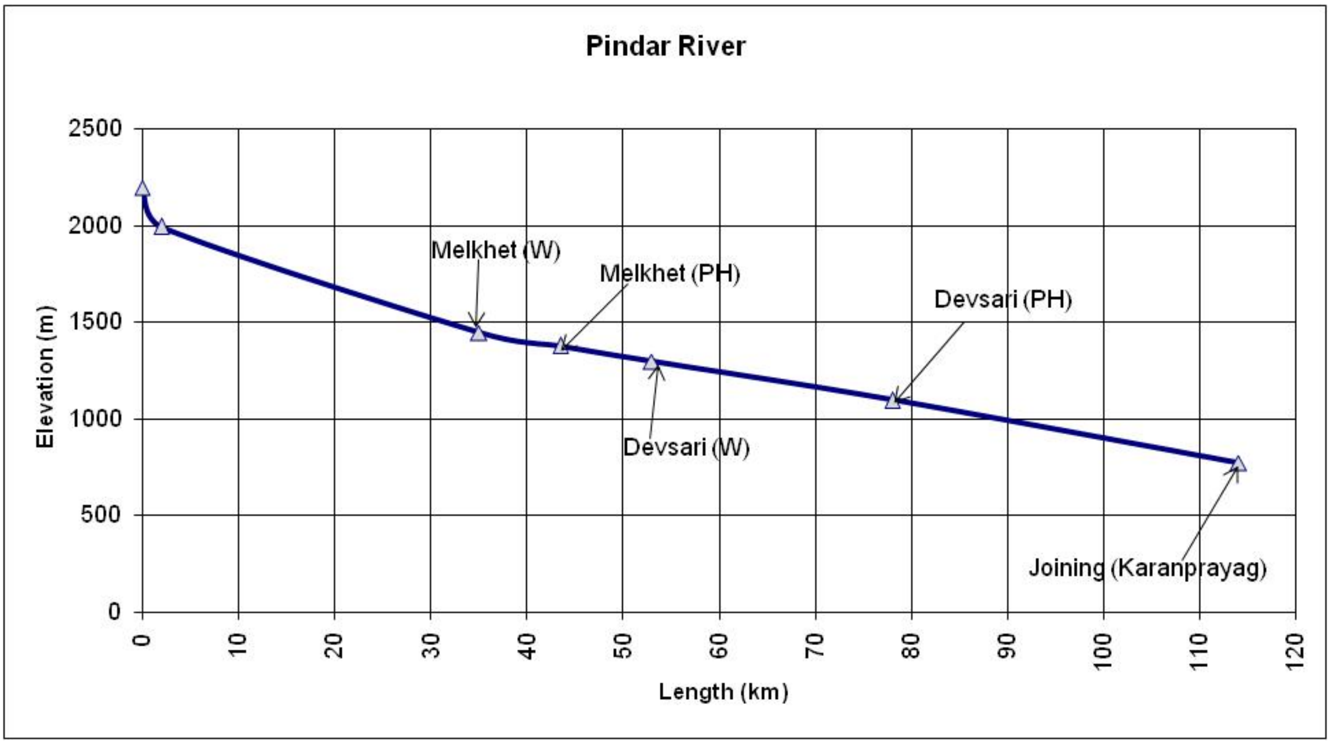


Fig 8.16(l): L-Section of Pindar River with the Hydropower Project Location

8.13 Technical Details

Technical details of all commissioned and under development hydropower projects have been presented in Table 8.6(a) and 8.6(b) for Bhagirathi and Alaknanda rivers respectively. Elevation of different components and storage at intake has been presented in Table 8.6(c) and 8.6(d) for Bhagirathi and Alaknanda rivers respectively. Further the main features of hydropower projects in the category of commissioned, under development (under construction as well as under development) also has been presented for both basins together with their geographical location in table 8.7.

There are 15 projects (2 commissioned, 2 under advance stage of completion, 2 under construction and 9 other stage of development) with storage reservoirs having more than 20 m height (above the river bed level). All of them except Tehri project, basically are Run of River with diurnal storage for operating for peak hours during lean flows.

Table 8.6(a): Technical Details of Allotted Hydropower Projects - Bhagirathi Basin

S. No.	Name of River/ Tributary	Project Name	TYPE	Alignment L/R	Installed capacity (MW)	Catch Area (Sq.Km)	HEAD (m)	Design Discharge (cumec)	Annual Generation (MU)	Project Capital cost (Million Rs.)	Length of Water Conductor System			Diverted River Length (m)
											Open (m)	Closed (m)	Total Length (m)	
1	Bhagirathi	Koteshwar	Storage	Right	400	7691	81	670	1209	2855	78	1030	1108	20700
2		Kotli Bhel-I A	Storage	Right	195	7887	63.33	341.16	973.05	12985	129	340	469	18400
3		Lohari Nagpala	ROR	Right	600	3316	475.67	152.6	2,436.90	24751	194	15010	15204	15000
4		Maneri bhali I	RoR	Left	90	4024	180	70	418	735	127	8871	8998	18000
5		Manaeri bhali-II	ROR	Left	304	4416	285	142	1566	8870	81	17214	17295	22000
6		Tehri stage-I	Storage	Left	1000	7511	228	616	3497	14557	0	2206	2206	44000
7		Tehri stage-II	Storage	Left	1000	7511	222.8	616	3497	14125	0	2206	2206	44000
8		Bharon Ghati	ROR	Left	381	3290	280	152.2	1462	15564	100	5706	5806	18500
9		Pala Maneri	Storage	Right	480	3667	350	156	1993	19228	175	14565	14740	18642
					4450				**17051.95**	**113670**			**68031**	**219242**
10	Jadh Ganga	Jadh Ganga	Storage	Right	50	1679	142.57	39	220.88	2775	110	1920	2030	2100
11		Karmoli	Storage	Right	140	1605	419.67	37	621.31	4656	128	10009	10137	10500
					190				**842.19**	**7431**			**12167**	**231842**
1	Asiganga	Asiganga-I	ROR	Left	4.5	147	100.03	5.63	19.11	325	2057	875	2932	3000
2		Asiganga-II	ROR	Left	4.5	167	61.38	8.56	22.76	340	757	1405	2162	2000
3		Asiganga-III	ROR	Left	9	190.32	142	7.4	48.5	784	246.7	4460	4706.7	4500
4	Kaldigad - Asiganga	Kaldigad	ROR	Left	9	111	264	4.12	63.52	510	553.8	590	1143.8	4000
					27		**567.41**		**153.89**	**1959**		**7330**	**6698**	**13500**

S. No.	Name of River/ Tributary	Project Name	TYPE	Alignment L/R	Installed capacity (MW)	Catch Area (Sq.Km)	HEAD (m)	Design Discharge (cumec)	Annual Generation (MU)	Project Capital cost (Million Rs.)	Length of Water Conductor System			Diverted River Length (m)
											Open (m)	Closed (m)	Total Length (m)	
1	**Balganga**	Balganga-II	ROR	Left	7	395	102	9.05	29.98	258	48	3056	3104	3250
2		Kot Budha kedar	ROR	UA	6	135	180	3.5	51.84	316	40	4948	4988	4750
3		Jhala koti	ROR	Left	12.5	105	250	5.96	59.838	806	220	4430	4650	4750
4		Agunda thati	ROR	Left	3	121	47	3.77	26.23	150	111.5	1867.9	1979.4	2000
					28.5		**579**		**167.888**	**1530**		**804**	**3090**	**37000**
1	**Bhilangana**	Bhilangana	ROR	Left	22.5	1149	168.37	31.91	121.956	90	185	2336	2522	2700
2		Bhilangna-II A	ROR	Left	24	457	146	20.31	149.56	1873	146	4947	5093	5000
3		Bhilangna-II B	ROR	Left	24	562.3	150.8	21.12	163.31	1575	120	3847	3967	4500
4		Bhilangna-II C	ROR	Left	21	570	130.8	19.29	149.42	1566	150	3797	3947	6500
5		Bhilangana-III	ROR	Right	24	407	218	15.5	170.83	1119	95	4746	4841	6500
					115.5		**813.97**		**755.076**	**6222**		**1715**	**11082**	**25200**
Miscellaneous Tributaries to Bhagirathi														
1	**Pilangad**	Pilangad	ROR	Right	2.25	252	102	2.75	2.75	110	1490	140	1630	3000
2	**Kakoragad**	Kakoragad	ROR	Left	12.5	86	393.47	3.75	56.46	773	168	2528	2696	3500
3	**Jalandhari**	Jalandharigad	ROR	Left	24	157	139.57	4.7	117.87	1580	651	2980	3631	3500
4	**Pilangad**	Pilangad- II	ROR	Right	4	140	195.6	2.75	18.68	191	42	2230	2272	2300
5	**Limcha Gad**	Limcha Gad	ROR	Right	3.5	14.75	400	1.1	20.644	257	600	835	1435	1500
6	**Siyangad**	Siyangad	ROR	Right	11.5	136	320	4.21	52.99	660	103	3494	3597	4500
7	**Suwari Gad**	Suwari Gad	ROR	Left	2	35.67	145	2.02	11.06	155	2	1140	1142	2000
					59.75		**1695.64**		**280.454**	**3725.797**		**2082**	**6629**	**20300**
1	**Ganga**	kotli Bhel-II	Storage	Right	530	21375	445	1404.88	1993.46	28806	246	500	747	28000

Table 8.6(b): Technical Details of Allotted Hydropower Projects – Alaknanda Basin

S. No.	Name of River/ Tributary	Project Name	TYPE	Alignment L/R	Installed capacity (MW)	Catch Area (Sq.Km)	HEAD (m)	Design Discharge (cumec)	Annual Generation (MU)	Capital Project cost (Million Rs.)	Length of Water Conductor System			Diverted River Length (m)
											Open (m)	Closed (m)	Total Length (m)	
1	Alaknanda	Alaknanda	ROR	Left	300	1010	603.2	57.3	1199	14521	40	5690	5730	7000
2		Bowla Nandprayag	ROR	Left	300	5590	138.9	239.4	1102	20898	149	10661	10810	16000
3		Kotli Bhel-I B	Storage	Left	320	11471	60.36	587.4	1268.45	19113	342	450	792	27500
4		Nandprayag Langa	ROR	Right	100	6233	45.4	322.16	490.45	130	596	5454	6050	8000
5		Srinagar	Storage	Right	330	11110	65.97	560	1515	12525	248	4627	4875	4500
6		Vishnugad Pipalkoti	Storage	Left	444	4672	212.46	228.86	1813.03	18867	89	16821	16910	17243
7		Vishnuprayag	ROR	Right	400	1678	947.5	65	2060.5	16940	63	15182	15245	19400
					2194		**2074**		**9448.43**	**102995**		**13654**	**60412**	**99643**
1	Dhauliganga	Jelam Tamak	ROR	Right	126	1652	201.33	69.27	534.03	6600	75	7298	7373	8500
2		Lata Tapovan	ROR	Right	170	599	279.26	79	221.61	7920	200	8359	8558	8500
3		Malari Jelam	ROR	Right	114	1504	213.25	73.96	466.7	6238	56	5262	5318	6500
4		Tamak Lata	ROR	Right	250	2000	306	90.22	1041.43	10530	63	12395	12458	10500
5		Tapowan Vishnugad	ROR	Left	520	3100	494	119.2	2486.41	23784	132	12955	13087	15500
					1180		**1493.84**		**4750.18**	**55072**		**6725**	**70651**	**49500**
1	Rishi ganga	Rishi Ganga	ROR	Left	13.2	545	52	21	82.204	824	25	905	930	1000
2		Rishi Ganga-I	Storage	Right	70	599	536.17	18	327.3	2770	118	5016	5134	6025
3		Rishiganga II	Storage	Right	35	680	236.96	20.53	164.64	2130	112	4250	4362	5397
1	Bhyundar ganga	Bhyundar ganga	ROR	Left	24.3	204.54	460.81	6.29	149.48	1142	129	3387	3516	3250
1	Birahi Ganga	Birahi Ganga	ROR	Right	7.2	300	54.5	20.922	42.25	500	251	1786	2037	2500
2		Birahi Ganga-I	ROR	Left	24	278.66	146	13.5	96.83	1170	427	5717	6144	6500
3		Birahi Ganga-II	ROR	Left	24	217.44	146	19.45	96.83	1319	162	3266	3428	4000

S. No.	Name of River/ Tributary	Project Name	TYPE	Alignment L/R	Installed capacity (MW)	Catch Area (Sq.Km)	HEAD (m)	Design Discharge (cumec)	Annual Generation (MU)	Capital Project cost (Million Rs.)	Length of Water Conductor System			Diverted River Length (m)
											Open (m)	Closed (m)	Total Length (m)	
4		Gohana Tal	ROR	Right	50	218	484.68	11.4	180.88	3539	126	12228	12354	12000
					105.2		**831.18**		**416.79**	**6528**		**1343**	**8885**	**25000**
1	**Mandakini**	Madhmaheshwar	ROR	Right	10	429.67	183	10	60.38	672	809	3415	4224	5500
2		Phata Byung	Storage	Right	76	247.44	414.5	12.5	340.5	4840	16	10326	10342	13000
3		Singoli Bhatwari	ROR	Left	99	963.2	188.17	59.6	472.18	7921	92	12272	12364	14500
4		Ram Bara	ROR	Right	24	65	710	4	121.64	1500	30	7915	7945	8000
					209		**1495.67**		**994.7**	**14933**		**2648**	**19286**	**41000**
1	**Nandakini**	Dewali	ROR	Right	13	497.5	101.7	14.5	70	671	50	7020	7070	10500
2		Rajwakti	ROR	Left	3.6	545	46.5	12	27.68	193	1902	780	2682	2500
3		Vanala	ROR	Right	15	418	135.98	12.5	81.104	767	391	5364	5755	6500
					31.6		**284.18**		**179**	**1630**		**515**	**3606**	**19500**
1	**Pinder**	Devsari	Storage	Left	252	1138	250.99	120.76	1036.77	13571	89	18674	18763	26305
2		Melkhet	ROR	Right	15	644	59.63	29.7	110.192	883	50	6162	6212	8500
					267		**310.62**		**1146.962**	**14454**		**1620**	**17856**	**34805**
Miscellaneous Tributaries to Alaknanda														
1	**Jummagad**	Jummagad	ROR	Right	1.2	27	141.9	1.06	10.593	25	145	1016	1160	2000
2	**Kailganga**	Debal	ROR	Right	5	544	45	13	34.3	286	2170	437	2607	3500
3	**Kailganga**	Kail ganga	ROR	Right	5	480	47.75	15	31.9314	293	2943	215	3158	3000
4	**Kaliganga**	Kaliganga-I	ROR	Right	4	69.55	166	3.3	26.37	239	302	760	1062	1500
5	**Kaliganga**	Kaliganga-II	ROR	Right	6	182	140	5.5	40	379	629	1735	2364	3000
6	**Kalpganga**	Urgam	ROR	Right	3	107	196.5	1.86	10.66	110	2141	356	2497	2500
7	**Kalpganga**	Urgam-II	ROR	Right	3.8	89	201	2.31	15.74	128	502	422	924	1750
8	**khiraoganga**	Khirao ganga	ROR	Left	4	145	63	8.32	19.38	207	25	850	875	2750
9	**Rishi ganga**	Badrinath II	ROR	Right	1.25	4024	75.45	2.04	3.611	120	62	585	647	1500
					33.25		**1076.6**		**192.5854**	**1787.672**		**6375**	**15294**	**20000**

Table 8.6(c): Elevations and other details of all hydro Electric Projects in Alaknanda River

S. No.	Project Name	Project Owner	Name of River/Tributary	Installed capacity (MW)	Elevation (m)				River bed diff. (m)	Depth of Reservoir (m)	Gross Storage (M cum)
					River bed at weir / diversion	FRL	TWL	River bed at outlet			
1	Kotli Bhel-I B	Alaknanda	Alaknanda	320	452	521	500	430	22	69	100.7
2	Srinagar	Alaknanda	Alaknanda	330	539.5	605.5	533.1	530.9	62.1	66	78
3	Rishiganga II	Alaknanda	Rishi ganga	35	2280	2306.7	2060	2058	222	26.7	1.52
4	Devsari	Alaknanda	Pinder	252	1268	1300	1045.5	1037	258	32	9.026
5	Gohan tal	Alaknanda	Birahi ganga	50	1617	1619	1121.6	1119	498	2	0.98
6	Rishi Ganga-I	Alaknanda	Rishi ganga	70	2845	2872	2323	2320	525	27	1.1
7	Lata Tapovan	Alaknanda	Dhauliganga	170	2090	2103	1805	1801	289	13	1.4
8	Vishnugad Pipalkoti	Alaknanda	Alaknanda	444	1225	1267	1030	1025	200	42	3.63
9	Singoli Bhatwari	Alaknanda	Bhagirathi	99	998	1017	809.5	802.77	195.23	19	0.701
10	Phata Byung	Alaknanda	Mandakini	76	1611	1635	1192.5	1189	422	24	0.499245
11	Jelam Tamak	Alaknanda	Dhauliganga	126	2632	2648.5	2425	2420	212	16.5	0.713
12	Malari Jelam	Alaknanda	Dhauliganga	114	2854	2879	2648.5	2638	216	15	0.3441
13	Alaknanda	Alaknanda	Alaknanda	300	2905	2922	2285	2280	625	17	0
14	Bhyundar ganga	Alaknanda	Bhyundar ganga	24.3	2202	2204	1736.6	1735	467	2	0
15	Birahi Ganga	Alaknanda	Birahi Ganga	7.2	1101.5	1105	1047.31	1044.097	57.403	3.5	0
16	Birahi Ganga-I	Alaknanda	Birahi ganga	24	1330	1345	1132	1121.8	208.2	15	0
17	Birahi Ganga-II	Alaknanda	Birahi ganga	24	1600	1610	1452	1446.97	153.03	10	0
18	Bowla Nandprayag	Alaknanda	Alaknanda	300	1022	1027	871.4	870	152	5	0

S. No.	Project Name	Project Owner	Name of River/Tributary	Installed capacity (MW)	Elevation (m)				River bed diff. (m)	Depth of Reservoir (m)	Gross Storage (M cum)
					River bed at weir / diversion	FRL	TWL	River bed at outlet			
19	Debal	Alaknanda	Kailganga	5	1382	1383.3	133.65	1334	1.3	48	0
20	Dewali	Alaknanda	Nandakini	13	933	939	817.5	814.5	118.5	6	0
21	Jummagad	Alaknanda	Jummagad	1.2	1147.39	1143.9	981.35	980.46	166.93	3.49	0
22	Kail ganga	Alaknanda	Kailganga	5	1447	1443	1392.6	1392	55	4	0
23	Kaliganga-I	Alaknanda	Kaliganga	4	1668	1670	1490	1485	183	2	0
24	Kaliganga-II	Alaknanda	Kaliganga	6	1480.52	1487	1336	1335	145.52	6.48	0
25	Khirao ganga	Alaknanda	khaiaoganga	4	2447	2451	2385	2382	65	4	0
26	Madhmaheshwar	Alaknanda	Mandakini	10	1236	1241	1039.1	1038	198	5	0
27	Melkhet	Alaknanda	Pinder	15	1448.75	1452.55	1382.78	1380	68	3.8	0
28	Nandprayag Lang	Alaknanda	Alaknanda	100	845	857	800	795	50	12	0
29	Rajwakti	Alaknanda	Nandakini	3.6	984.5	991	UA	UA	UA	6.5	0
30	Ram Bara	Alaknanda	Mandakini	24	2780	2783	2050	2040	740	3	0
31	Rishi Ganga	Alaknanda	Rishi ganga	13.2	2006	2012	1969	1958	48	6	0
32	Tamak Lata	Alaknanda	Dauliganga	250	2412	2422	2103	2099.5	312.5	10	0
33	Tapowan Vishnug	Alaknanda	Dhauliganga	520	1785	1794	1267	1262.6	522.4	9	0
34	Urgam	Alaknanda	Kalpganga	3	0	990	0	0	0	0	0
35	Urgam-II	Alaknanda	Kalpganga	3.8	1780	1785	UA	UA	0	5	0
36	Vanala	Alaknanda	Nandakini	15	1196.48	1202.5	1056	1054	142.48	6.02	0
37	Vishnuprayag	Alaknanda	Alaknanda	400	2261	2275	1365	1305	956	14	0

Table 8.6(d): Elevations and other details of all hydro Electric Projects in Bhagirathi River

S. No.	Project Name	Project Owner	Name of River / Tributary	Installed capacity (MW)	Elevation				River bed diff.	Depth of Reservoir	Gross Storage (M cum)
					River bed at weir / diversion	FRL	TWL	River bed at outlet			
1	Tehri stage-I	Bhagirathi	Bhagirathi	1000	600	830	596	585	15	230	3540
2	Tehri stage-II	Bhagirathi	Bhagirathi	1000	600	830	591.5	545	51	230	3540
3	kotli Bhel-II	Bhagirathi	Ganga	530	401.4	458.5	408	398	57.1	57.1	148.23
4	Kotli Bhel-I A	Bhagirathi	Bhagirathi	195	458.4	532	490	432	26.4	73.6	46.17
5	Koteshwar	Bhagirathi	Bhagirathi	400	533.5	612	535	531	2.5	78.5	86
6	Jadh Ganga	Bhagirathi	jahnavi	50	2760	2802.5	2649	2647	113	42.5	2.28
7	Karmoli	Bhagirathi	Jahnvi	140	3225	3268.5	2820	2818	407	43.5	1.953
8	Pala Maneri	Bhagirathi	Bhagirthi	480	1611	1665	1278.11	1271	340	54	4.7
9	Bharon Ghati	Bhagirathi	Bhagirthi	381	2440	2444	2143.85	2142.5	297.5	4	1.64
10	Agunda thati	Bhagirathi	Dharamganga	3	1283	1286.5	1233	1231.5	51.5	3.5	0
11	Asiganga-I	Bhagirathi	Asiganga	4.5	1489	1491.05	1388	1385	104	2.1	0
12	Asiganga-II	Bhagirathi	Asiganga	4.5	1370	1372.95	1308.2	1305	65	3	0
13	Asiganga-III	Bhagirathi	Asiganga	9	1298	1303.2	1149.4	1146	152	5.2	0
14	Badrinath II	Bhagirathi	Rishi ganga	1.25	3470	3497	UA	UA	UA	27	0
15	Balganga-II	Bhagirathi	Balganga	7	1140	1145	1042	1040	100	5	0
16	Bhilangana	Bhagirathi	Bhilangana	22.5	961.5	973	878	875	86.5	11.5	0
17	Bhilangna-II A	Bhagirathi	Bhilangana	24	1651	1660	1430.8	1427.8	223.2	9	0
18	Bhilangna-II B	Bhagirathi	Bhilangana	24	1405	1410	1252	1250	155	5	0
19	Bhilangna-II C	Bhagirathi	Bhilangana	24	1245	1248.5	1112	1110	135	3.5	0
20	Bhilangana-III	Bhagirathi	Bhilangana	21	1100	1105	977	975	125	5	0
21	Jalandharigad	Bhagirathi	Jalandhari	18.5	3105	3108	2465.5	2463	642	3	0

S. No.	Project Name	Project Owner	Name of River / Tributary	Installed capacity (MW)	Elevation				River bed diff.	Depth of Reservoir	Gross Storage (M cum)
					River bed at weir / diversion	FRL	TWL	River bed at outlet			
22	Jhala koti	Bhagirathi	Bhilangana	12.5	1722	1724.2	1431.7	1430	292	2.2	0
23	Kakoragad	Bhagirathi	Kakoragad	12.5	2450	2442	2147	2145.5	304.5	8	0
24	Kaldigad	Bhagirathi	Kaldigad	9	1781	1782.35	1506	1502	279	1.35	0
25	Kot budha kedar	Bhagirathi	Balganga	6	1576	1577	1375	1374	202	1	0
26	Limcha Gad	Bhagirathi	Limcha Gad	3.5	2378	2377	1960	1958	420	1	0
27	Lohari Nagpala	Bhagirathi	Bhagirathi	600	2139.5	2147	1665	1659	480.5	7.5	0
28	Maneri bhali I	Bhagirathi	Bhagirathi	304	1280	1294.5	1113	1110	170	14.5	0
29	Manaeri bhali-II	Bhagirathi	Bhagirathi	90	1091	1108	832.45	826	265	17	0
30	Pilangad	Bhagirathi	Pilangad	2.25	UA	UA	UA	UA	UA	0	0
31	Pilangad- II	Bhagirathi	Pilangad	4	1980	1985	UA	UA	UA	5	0
32	Siyangad	Bhagirathi	Siyangad	11.5	2763	2765	2435	2420	343	2	0
33	Suwari Gad	Bhagirathi	Suwari Gad	2	1823.6	1827.63	1675	1674	149.6	4.03	0

Table 8.7: Commissioned, Under Development Stage (Construction and other stages) Hydropower Projects of Bhagirathi and Alaknanda River Basin

S. No.	Project Name	Name of River / Tributary	Position L/R	Installed capacity (MW)	Location												Catch (Sq. Km)	HEAD (m)	Design Discharge (cunec)	Annual Generation (MU)	Capital Project cost (Million Rs.)
					Dam/ Barrage/Weir Site						Tail Race Site										
					Lattitude			Longitude			Latitude			Longitude							
					Deg	Min.	Sec	Deg	Min	Sec	Deg	Min	Sec	Deg	Min	Sec					
COMMISSIONED																					
1	Agunda thati	Dharam-ganga	Left	3	30	36	6	78	37	22	29	35	0	78	38	0	121	47	3.77	26.23	150
2	Badrinath II	Rishi ganga	Right	1.25	30	43	9.1	79	29	48.8	30	40	0	79	29	0	4024	75.45	2.04	3.611	120
3	Bhilangana	Bhilangana	Left	22.5	30	26	7	78	39	30	30	25	41	78	34	30	1149	168.37	31.91	121.956	89.58
4	Debal	Kailganga	Right	5	30	3	0	79	33	10	30	2	40	79	33	0	360	45	13	34..3	286.3
5	Jummagad	Jummagad	Right	1.2	30	40	0	79	50	0	30	36	6	79	48	0	27	141.9	1.06	10.593	24.894
6	Maneri bhali I	Bhagirathi	Left	90	30	44	16	78	32	22	30	43	4	78	26	3	4024	180	70	418	735.3
7	Manaeri bhali-II	Bhagirathi	Left	304	30	42	36	78	24	7	30	41	7	78	20	3	4416	285	142	1566	8870.4
8	Pilangad	Pilangad	Right	2.25	30	46	0	78	38	0	30	45	0	78	39	0	252	102	2.75	2.75	110
9	Rajwakti	Nandakini	Left	3.6	30	18	25	79	21	0	30	18	33	79	19	46	545	46.5	12	27.68	192.5
10	Tehri stage-I	Bhagirathi	Left	1000	30	23	20.4	78	28	51.6	30	23	20.4	78	28	51.6	7700	228	616	3497	14557.3
11	Urgam	Kalpganga	Right	3	30	34	30	79	30	7	30	30	42	79	30	0	107	196.5	1.86	10.66	110
12	Vanala	Nandakini	Right	15	30	16	0	79	25	0	30	17	0	79	23	0	418	135.98	12.5	81.104	766.55
13	Vishnuprayag	Alaknanda	Right	400	30	32	0	79	28	0	30	34	0	79	38	0	1678	947.5	65	2060.5	16940
UNDER CONSTRUCTION																					
1	Bhilangana-III	Bhilangana	Right	24	30	33	7	78	48	26	30	31	25	78	46	16	407	218	15.5	170.83	1118.85
2	Birahi Ganga	Birahi Ganga	Right	7.2	30	24	35	79	23	56	30	25	0	79	23	0	300	54.5	20.922	42.25	500
3	Kail ganga	Kailganga	Right	5	30	5	30	79	36	30	30	4	30	79	35	30	342	47.75	15	31.9314	293.3
4	Kaliganga-I	Kaliganga	Right	4	30	36	40	79	5	10	30	35	30	79	4	50	69.55	166	3.3	26.37	239.385
5	Kaliganga-II	Kaliganga	Right	6	30	35	30	79	4	50	30	34	20	79	5	10	182	140	5.5	40	379.093
6	Koteshwar	Bhagirathi	Right	400	30	16	0	78	30	0	30	16	0	78	30	0	7691	81	670	1209	2854.7

S. No.	Project Name	Name of River / Tributary	Position L/R	Installed capacity (MW)	Location												Catch (Sq. Km)	HEAD (m)	Design Discharge (cumec)	Annual Generation (MU)	Capital Project cost (Million Rs.)
					Dam/ Barrage/Weir Site						Tail Race Site										
					Lattitude			Longitude			Latitude			Longitude							
					Deg	Min.	Sec	Deg	Min	Sec	Deg	Min	Sec	Deg	Min	Sec					
7	Lohari Nagpala	Bhagirathi	Right	600	30	58	16	78	42	0	30	51	30	78	38	7	3316	475.67	152.6	2,436.90	24750.8
8	Madhmaheshwar	Mandakini	Right	10	30	32	55	79	6	55	30	31	50	79	5	40	429.67	183	10	60.38	671.9
9	Phata Byung	Mandakini	Right	76	30	37	35	79	0	28	30	33	40	79	4	5	247.44	414.5	12.5	340.5	4840
10	Rishi Ganga	Rishi ganga	Left	13.2	30	28	55	79	41	53	30	29	19	79	41	0	545	52	21	82.204	823.8
11	Singoli Bhatwari	Mandakini	Left	99	30	30	17	79	5	22	30	24	39	79	2	58	963.2	188.17	59.6	472.18	7921.2
12	Srinagar	Alaknanda	Right	330	30	14	0	78	50	0	30	13	11	78	46	47	11110	65.97	560	1515	12524.8
13	Tapowan Vishnugad	Dhauliganga	Left	520	30	29	30	79	37	30	30	33	25	79	18	32	3100	494	119.2	2486.41	23783.5
14	Vishnugad Pipalkoti	Alaknanda	Left	444	30	30	50	79	29	30	30	25	31	79	24	56	5682.6	212.46	228.86	1813.03	18867.3
UNDER OTHER STAGES OF DEVELOPMENT																					
1	Alaknanda	Alaknanda	Left	300	30	43	24	79	29	42	30	41	12	79	30	18	1010	603.2	57.3	1199	14520.8
2	Asiganga-I	Asiganga	Left	4.5	30	48	37	78	27	5	30	47	45	78	26	51	147	100.03	5.63	19.11	324.9
3	Asiganga-II	Asiganga	Left	4.5	30	47	40	78	26	40	30	47	1	78	27	0	167	61.38	8.56	22.76	340.4
4	Asiganga-III	Asiganga	Left	9	30	46	56	78	27	12	30	44	34	78	27	40	190.32	142	7.4	48.5	784.067
5	Balganga-II	Balganga	Left	7	30	29	0	78	37	30	30	27	0	78	37	0	395	102	9.05	29.98	257.855
6	Bharon Ghati	Bhagirthi	Left	381	31	1	2	78	42	52	31	58	35	78	42	6	3290	280	152.2	1462	15563.8
7	Bhilangna-II A	Bhilangana	Left	24	30	31	37	78	44	52	30	28	36	78	44	52	457	146	20.31	149.56	1872.768
8	Bhilangna-II B	Bhilangana	Left	24	30	29	30	78	43	15	30	27	15	78	41	40	562.3	150.8	21.12	163.31	1575.001
9	Bhilangna-II C	Bhilangana	Left	21	30	23	24	78	36	36	30	26	54	78	41	33	570	130.8	19.29	149.42	1566.05
10	Bhyundar ganga	Bhyundar ganga	Left	24.3	30	38	53.2	79	34	50	30	37	5.6	79	33	56.6	204.54	460.81	6.29	149.5	1141.5
11	Birahi Ganga-I	Birahi ganga	Left	24	30	22	30	79	30	0	30	22	30	79	29	0	278.66	146	13.5	96.8	1170
12	Birahi Ganga-II	Birahi ganga	Left	24	30	22	30	79	30	0	30	22	30	79	29	0	217.44	146	19.45	96.8	1319.17
13	Bowla Nandprayag	Alaknanda	Left	300	30	24	24	79	22	48	30	20	24	79	19	12	5590	138.9	239.4	1102.0	20898.4

S. No.	Project Name	Name of River / Tributary	Position L/R	Installed capacity (MW)	Location												Catch (Sq. Km)	HEAD (m)	Design Discharge (cumec)	Annual Generation (MU)	Capital Project cost (Million Rs.)
					Dam/ Barrage/Weir Site						Tail Race Site										
					Lattitude			Longitude			Latitude			Longitude							
					Deg	Min.	Sec	Deg	Min	Sec	Deg	Min	Sec	Deg	Min	Sec					
14	Devsari	Pinder	Left	252	30	2	35	79	34	17	30	35	4	79	30	20	1138	250.99	120.76	1036.8	13570.75
15	Dewali	Nandakini	Right	13	30	18	0	79	20	0	30	18	0	79	18	0	497.5	101.7	14.5	69.9	67109.4
16	Gohana Tal	Birahi ganga	Right	50	30	22	39	79	24	38	30	23	40	79	24	38	218	484.68	11.4	180.9	3538.7
17	Jadh Ganga	Jadhganga	Right	50	31	2	18	78	53	17	31	1	49	78	52	10	1679	142.57	39	220.9	2774.8
18	Jalandharigad	Jalandhari	Left	24	31	2	51	78	45	5	31	3	3	78	44	9	157	139.57	4.7	117.9	1579.7
19	Jelam Tamak	Dhauliganga	Right	126	30	38	45	79	49	57	30	36	45	79	47	15	1652	201.33	69.27	534.0	6600
20	Jhala koti	Balganga	Left	12.5	30	38	53	78	38	10	30	36	30	78	38	30	105	250	5.96	59.8	805.742
21	Kakoragad	Kakoragad	Left	12.5	31	3	32	78	46	20	31	2	32	78	46	20	86	393.47	3.75	56.5	77278.5
22	Kaldigad	Kaldigad	Left	9	30	50	27	78	28	39	30	49	38	78	27	6			4.12	63.5	510
23	Karmoli	Jadhganga	Right	140	31	6	4	78	58	5	31	2	36	78	54	17	1605	419.67	37	621.3	4656
24	Khirao ganga	khaiaoganga	Left	4	30	41	2.4	79	29	27.7	30	41	10.2	79	30	22.4	145	63	8.32	19.4	206.7
25	Kot Budha kedar	Balganga	UA	6	30	35	13	78	38	3	29	35	0	78	39	0	135	180	3.5	51.8	316
26	Kotli Bhel-I A	Bhagirathi	Right	195	30	10	12.58	78	35	40.55	30	10	30	78	35	43	7887	63.33	341.16	973.1	12984.9
27	Kotli Bhel-I B	Alaknanda	Right	320	30	11	1.26	78	37	39.72	30	9	11	78	36	57	11471	60.36	587.4	1268.5	19113.3
28	kotli Bhel-II	Ganga	Left	530	30	3	52.8	78	29	59.71	30	4	24	78	29	59	21375	445	1404.88	1993.5	28805.8
29	Lata Tapovan	Dhauliganga	Right	170	30	31	30	79	43	30	30	55	28	78	42	7	599	279.26	79	221.6	7920
30	Limcha Gad	Limcha Gad	Right	3.5	30	55	31	78	41	28	30	55	13	78	40	55	14.75	400	1.1	20.6	257.1
31	Malari Jelam	Dhauliganga	Right	114	30	40	54.7	79	53	4.5	30	39	45	79	49	45	1504	213.25	73.96	466.7	6238.1
32	Melkhet	Pinder	Right	15	30	1	23	79	2	20	30	1	40	79	39	17	644	59.63\	29.7	110.2	882.89
33	Nand prayag Langasu	Alaknanda	Right	100	30	19	30	79	18	20	30	17	50	79	17	0	6233	45.4	322.16	490.5	130
34	Pala Maneri	Bhagirthi	Right	480	30	54	50	78	40	50	30	44	20	78	32	20	3667	35.47	156	1993.0	19228
35	Pilangad- II	Pilangad	Right	4	30	45	55	78	39	55	30	46	12	78	38	30	140	195.6	2.75	18.7	191.351
36	Ram Bara	Mandakini	Right	24	30	41	42.3	79	3	20.1	30	39	14	79	1	36	65	710	4	121.6	1500

S. No.	Project Name	Name of River / Tributary	Position L/R	Installed capacity (MW)	Location												Catch (Sq. Km)	HEAD (m)	Design Discharge (cunec)	Annual Generation (MU)	Capital Project cost (Million Rs.)
					Dam/ Barrage/Weir Site						Tail Race Site										
					Lattitude			Longitude			Latitude			Longitude							
					Deg	Min.	Sec	Deg	Min	Sec	Deg	Min	Sec	Deg	Min	Sec					
37	Rishi Ganga-I	Rishi ganga	Right	70	30	27	37	79	46	26	30	27	55	79	44	9	599	536.17	18	327.3	2770.1
38	Rishiganga II	Rishi ganga	Right	35	30	28	3	79	43	50.16	30	29	47	79	42	52	680	236.96	20.53	164.6	2129.8
39	Siyangad	Siyangad	Right	11.5	31	30	10	78	41	50	31	1	50	78	43	0	136	320	4.21	53.0	659.861
40	Suwari Gad	Suwari Gad	Left	2	30	51	0	78	37	0	30	2	35	79	25	0	35.67	145	2.02	11.1	155
41	Tamak Lata	Dauliganga	Right	250	30	36	0	79	47	0	30	30	0	79	43	0	2000	306	90.22	1041.4	10529.9
42	Tehri stage-II	Bhagirathi	Left	1000	30	23	20.4	78	28	51.6	30	23	20.4	78	28	51.6	7700	222.8	616	3497.0	14125
43	Urgam-II	Kalpganga	Right	3.8	30	32	56	79	28	40	30	32	30	79	29	0	89	201	2.31	15.7	128

8.14 River Length Affected

All types of hydropower development affect rivers. ROR hydro projects in hilly areas divert the water through open or closed channel/tunnel/pipe and use the steep gradient of river. Thus reducing the natural discharge in the river for the diverted stretch of the river. On the other hand, storage based hydropower involve a submergence of river stretch. The table 8.9 shows the affected length of the rivers. The diverted river stretches and submerged stretches of rivers have been presented in fig 8.18.

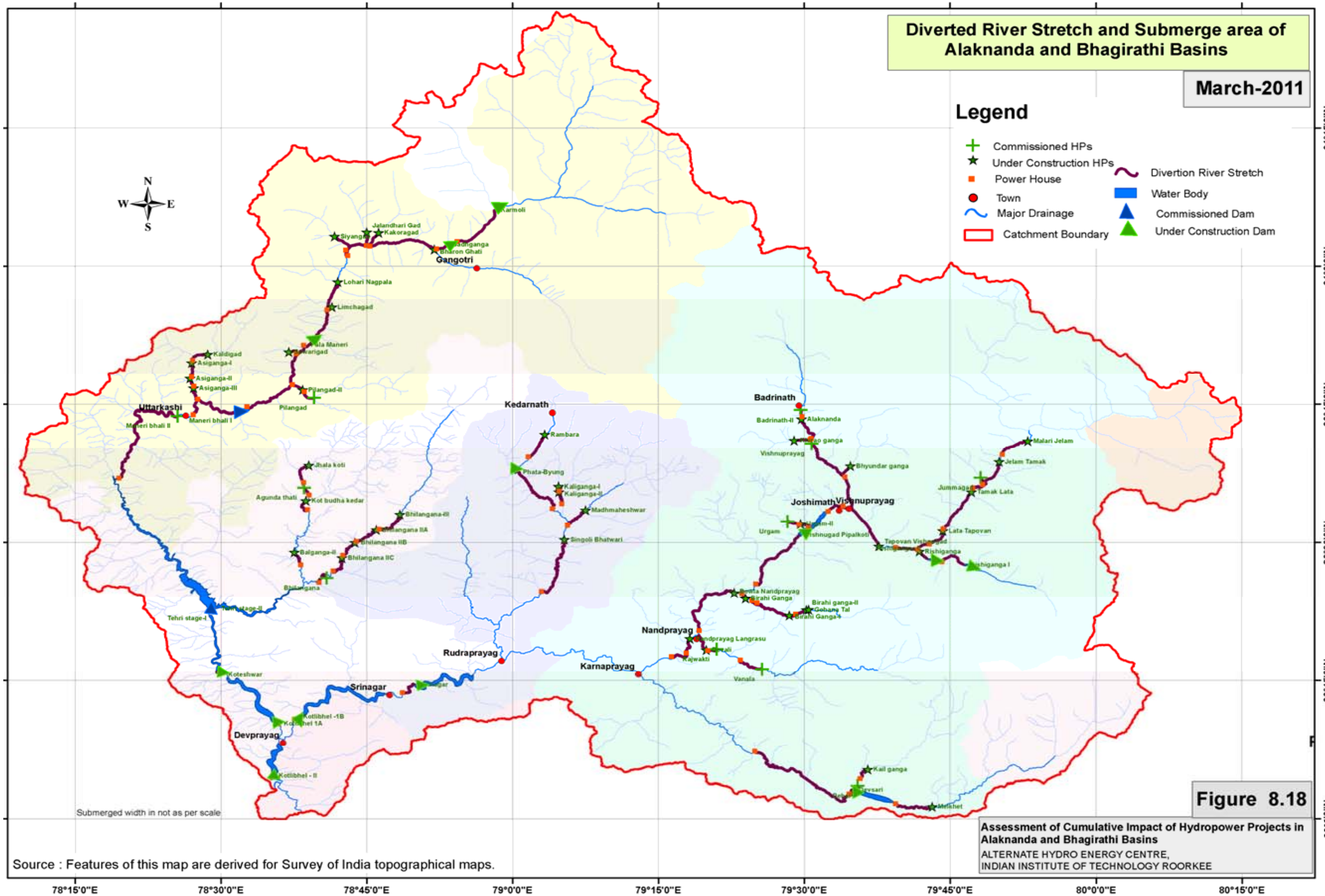
Table 8.9 - Affected Length of Bhagirathi and Alaknanda River and its Tributaries due to Allotted Hydropower Development

Sl. No.	River	Total river stretch (m)	River stretch diverted	River stretch submerged	Affected length	% of River length diverted	% of River length submerged	% of river length affected
Bhagirathi Basin								
1	Bhagirathi	217000	68031	85400	153431	31%	39%	70.71%
2	Asiganga	20500	10945	0	10945	53%	0%	53.39%
3	Bhilangana	109000	20369	19000	39369	19%	17%	36.12%
4	Bal Ganga	37000	14721	0	14721	40%	0%	39.79%
5	Small tributaries	73000	16401	0	16401	22%	0%	22.47%
Alaknanda Basin								
6	Alaknanda	224000	60412	47100	107512	27%	21%	48.00%
7	Dhauliganga	50000	46794	0	46794	94%	0%	93.59%
8	Rishiganga	38500	10426	600	11026	27%	2%	28.64%
9	Birahi Ganga	29500	21926	0	21926	74%	0%	74.32%
10	Nandakini	44500	15507	0	15507	35%	0%	34.85%
11	Mandakini	81000	34875	500	35375	43%	1%	43.67%
12	Pindar	114000	24974	10000	34974	22%	9%	30.68%
13	Small tributaries	83000	18780	0	18780	23%	0%	22.63%

*Upper reaches of river have not been accounted

About 31% of the Bhagirathi river length is diverted whereas 39% of the river is submerged. On the other hand, Alaknanda River may have 27% of river length diverted and only 21% submerged. The tributaries of Bhagirathi except Bhilangana do not have any submergence but there is about 53, 19, 40 percent of diversion of Asiganga, Bhilangana and Balganga tributaries.

The tributaries of Alaknanda basin do not have submergence except about 1% – 2% in Pindar, Mandakini and Rishiganga. But these rivers have diversion in the range 94% - 22%.



Diverted River Stretch and Submerge area of Alaknanda and Bhagirathi Basins
March-2011
Legend
Commissioned HPs
Under Construction HPs
Power House
Town
Major Drainage
Catchment Boundary
Divertion River Stretch
Water Body
Commissioned Dam
Under Construction Dam
Gangotri
Uttarkashi
Kedarnath
Badrinath
Joshimath
Vishnuprayag
Nandprayag
Rudraprayag
Karnaprayag
Srinagar
Devprayag
Submerged width in not as per scale
Source : Features of this map are derived for Survey of India topographical maps.
Figure 8.18
Assessment of Cumulative Impact of Hydropower Projects in Alaknanda and Bhagirathi Basins
ALTERNATE HYDRO ENERGY CENTRE,
INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
78°15'0"E
78°30'0"E
78°45'0"E
79°0'0"E
79°15'0"E
79°30'0"E
79°45'0"E
80°0'0"E
80°15'0"E
31°15'0"N
31°0'0"N
30°45'0"N
30°30'0"N
30°15'0"N
30°0'0"N

8.15 Analysis of Hydropower Projects for Using River

8.15.1 Energy Generation View

An analysis of the data of 70 projects has been carried out and the results have been presented as follows:

1. Annual generation per unit of diverted discharge indicating the energy value for diverted quantity of water from the river. It shows that the Vishnuprayag project has the highest electricity generation as 32 MU for each cubic m of water against the storage based projects like Kotlibhel 1B and Koteshwar which have the low energy generation from diverted unit discharge as 2.5 MU and 1.8 MU respectively. (Fig 8.19(a) & Fig. 8.19(b))

2. Annual generation for per m of head available in the river has been shown in Fig 8.20(a) and Fig 8.20(b) for Alaknanda and Bhagirathi basin respectively. Storage base scheme have high electricity generation for each m head viz. 23 MU for Srinagar and 15 MU Koteshwar respectively. Small scale hydropower projects have low electricity generation for each number of head available in the river gradient as they carry low discharge.

3. Annual generation per MW of installed capacity of the power plants has been shown in Fig 8.21(a) & Fig 8.21(b). This is power plant utilization factor indicating a high value near to 1 for run of river project like Jumagad and low as 0.45 and 0.4 for Kotlibhel 1B and Tehri storage projects respectively with storage base. Storage base project provide base load and are operated.

4. Annual generation for each m length of river diverted has been shown in Fig 8.22(a) & Fig 8.22(b). 336 thousand units per m of diverted stretch of river (excluding submerged stretch) is from Srinagar hydro project whereas Loharinag Pala project may produce about 162 thousand unit for each m of diverted stretch. Small scale hydropower has low values for each m of diversion due to low discharges.

5. Ratio of diversion length (water conductor system for hydropower project with length of river stretch diverted) has been shown in Fig 8.23(a) & Fig 8.23(b). It has been observed that this ratio varies between 1.18 to 0.1 for run of river scheme whereas for storage scheme this is about 0.05 due to the location of power house close to dam.

It may also be seen that water conductor system for a large number of projects are in closed channel/tunnel/pipe. Closed system is useful, beneficial and safe for operation, maintenance, public interaction, loss of land and landscape point of view. It is only disadvantage is that it involves tunneling which may interface with springs and ground water regime.

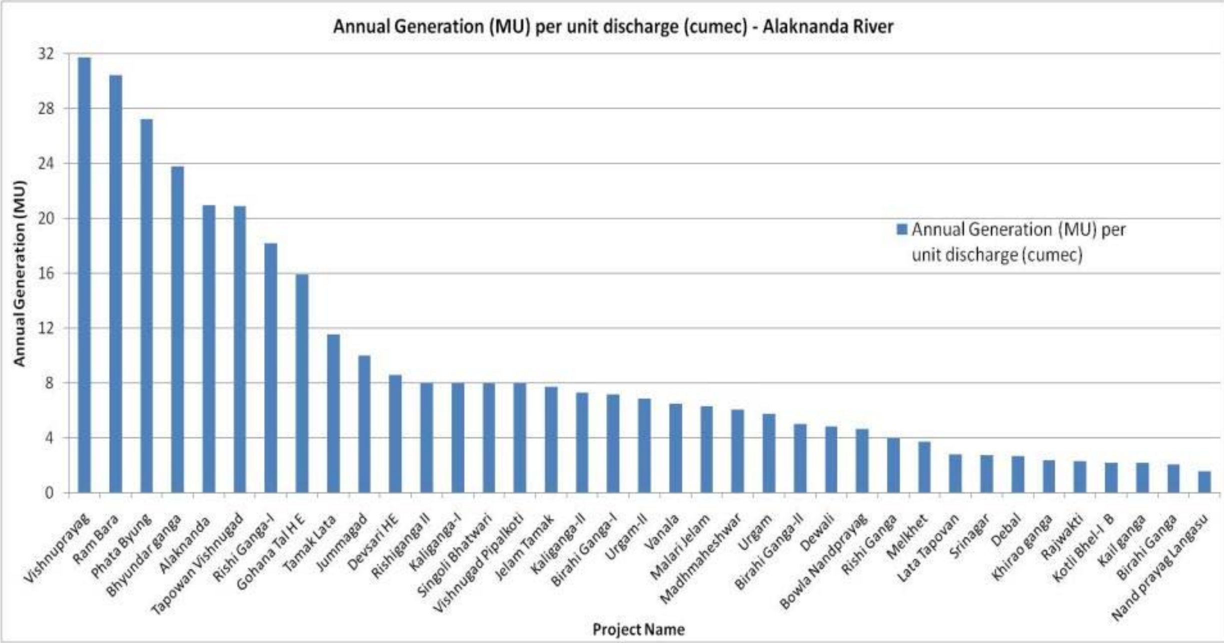


Fig.8.19(a): Annual Generation per unit discharge cumecs for Alaknanda River

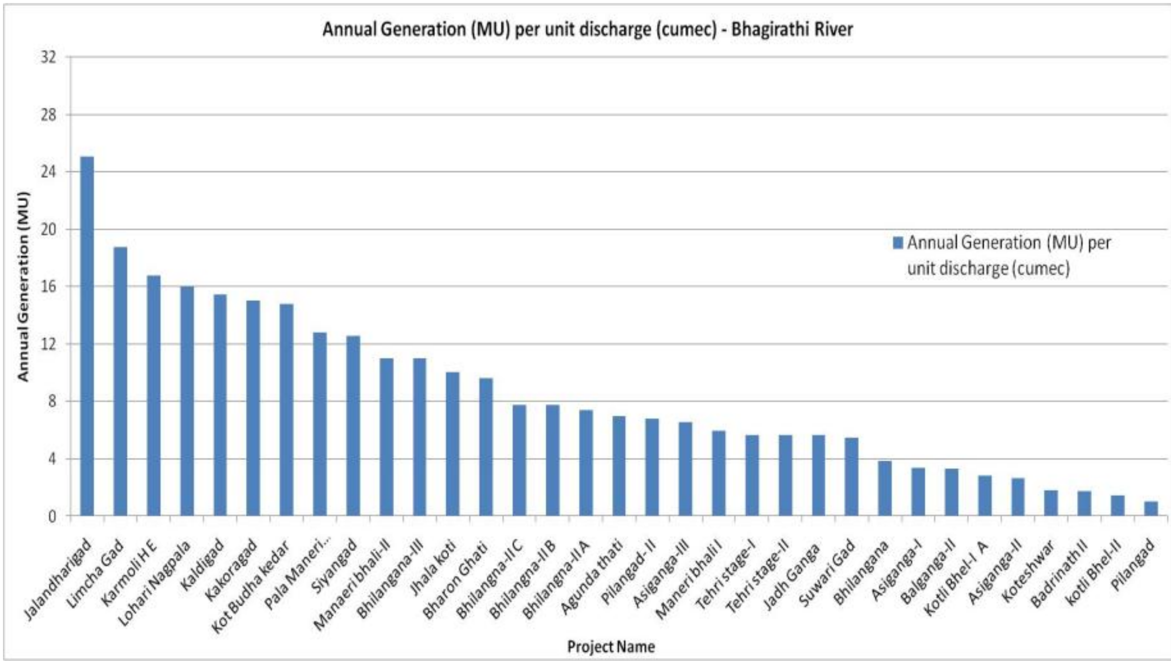


Fig.8.19(b): Annual Generation per unit discharge cumecs for Bhagirathi River

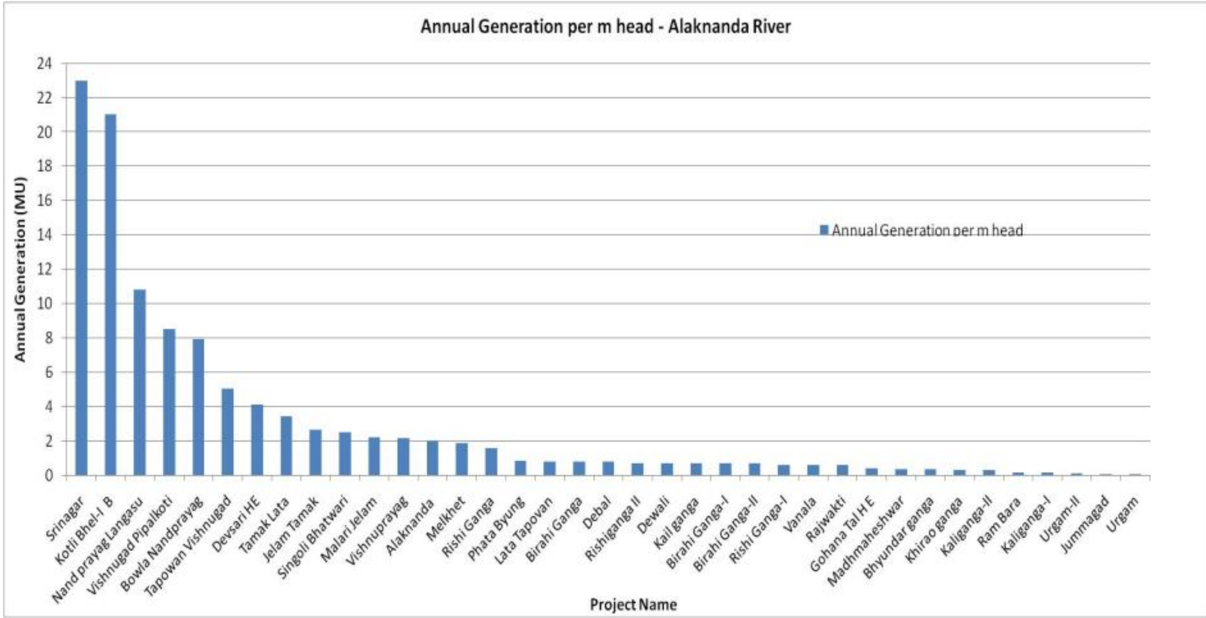


Fig.8.20(a): Annual Generation for per meter of head available in the Alaknanda River

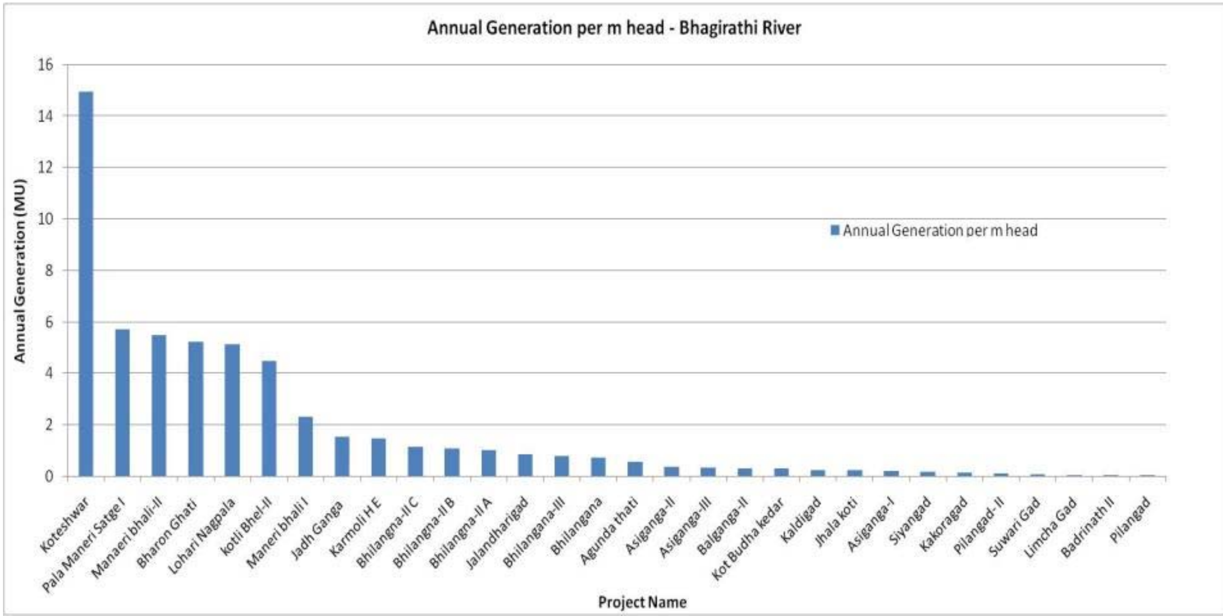


Fig.8.20(b): Annual Generation for per meter of head available in the Bhagirathi River

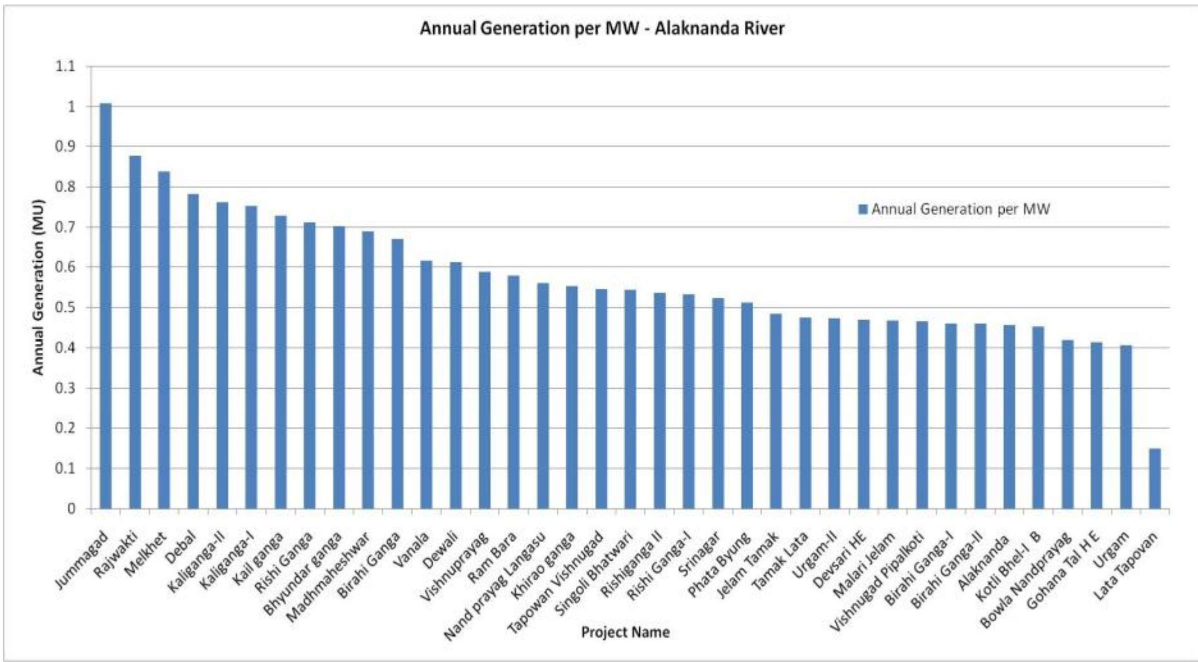


Fig.8.21(a): Annual Generation per MW of installed capacity of the plants in the Alaknanda River

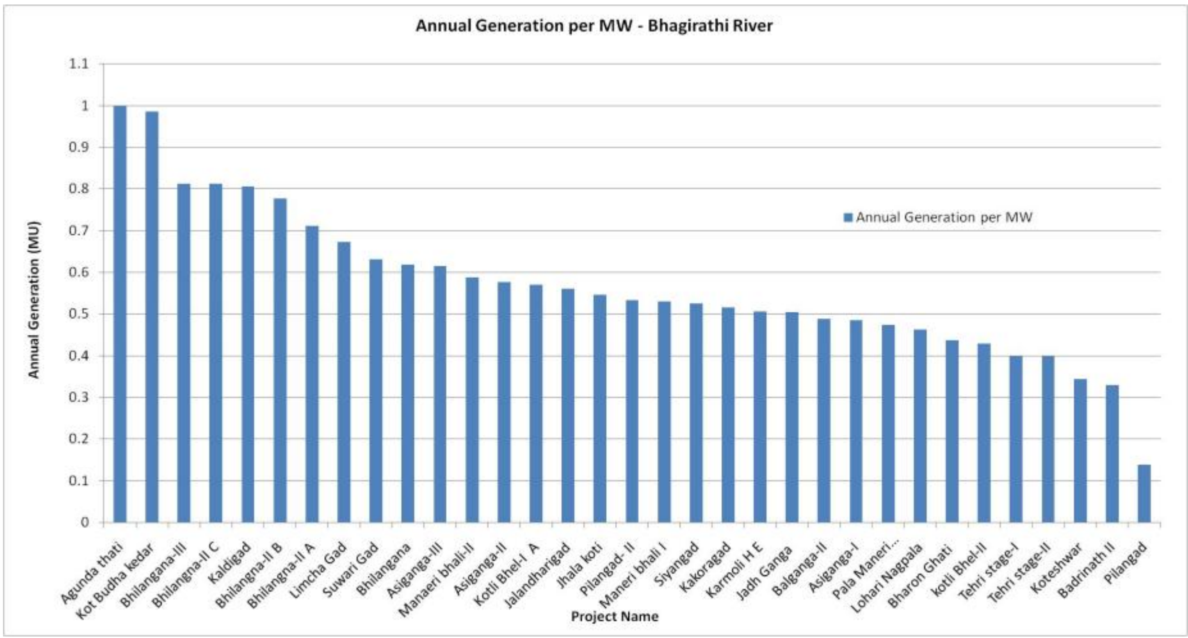


Fig.8.21(b): Annual Generation per MW of installed capacity of the plants in the Bhagirathi River

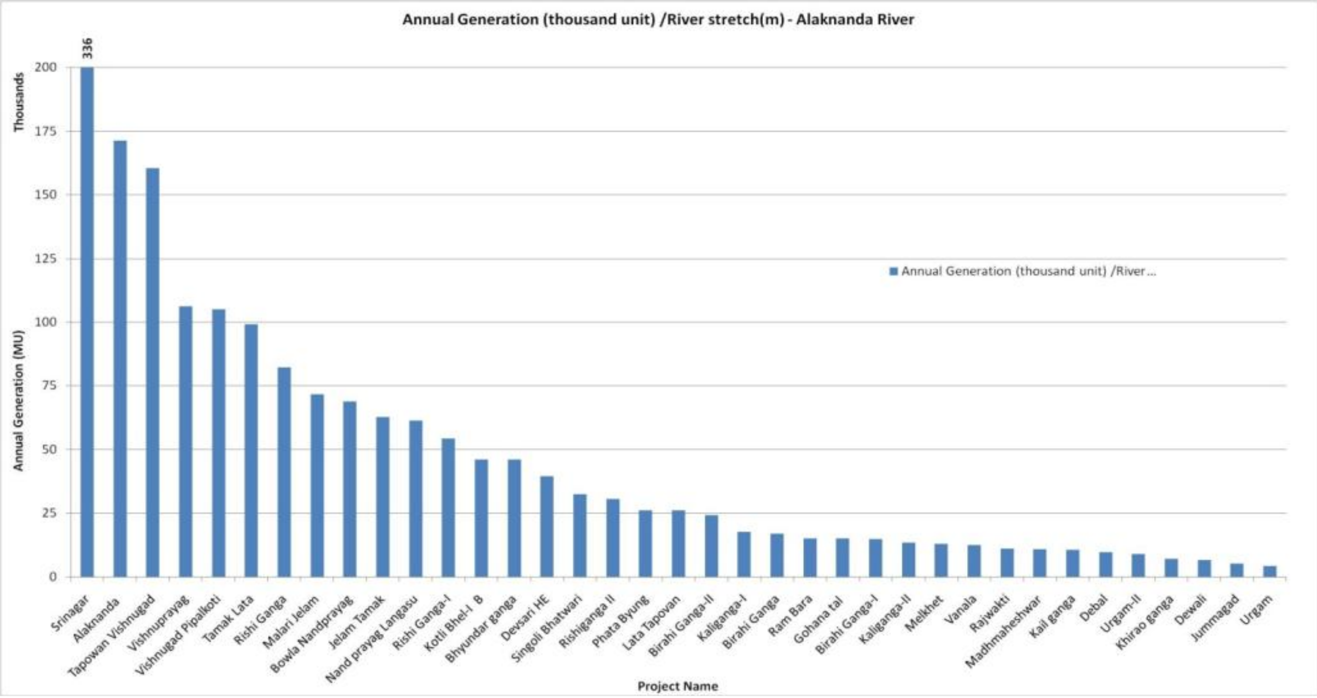


Fig.8.22(a): Annual Generation for each m length of river diverted in the Alaknanda River

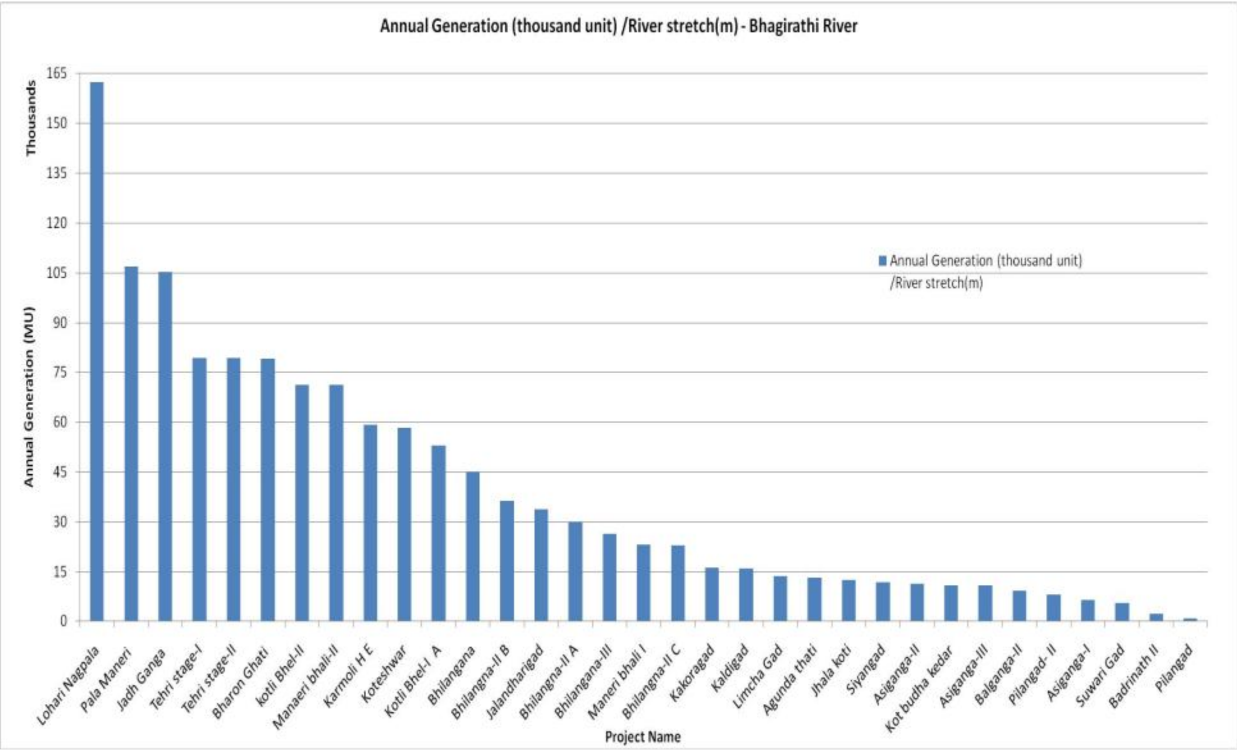


Fig.8.22(b): Annual Generation for each m length of river diverted in the Bhagirathi River

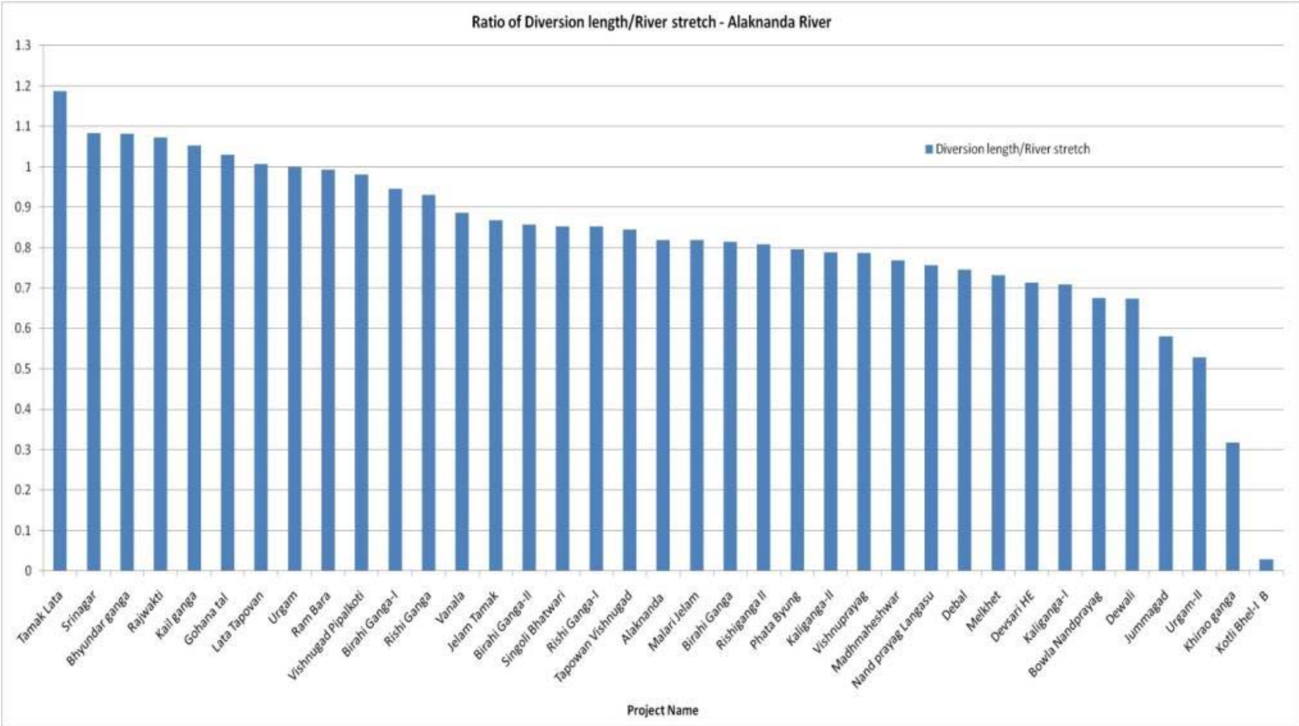


Fig.8.23(a): Ratio of diversion length (water conductor system for hydropower projects with length of river stretch diverted) for Alaknanda River

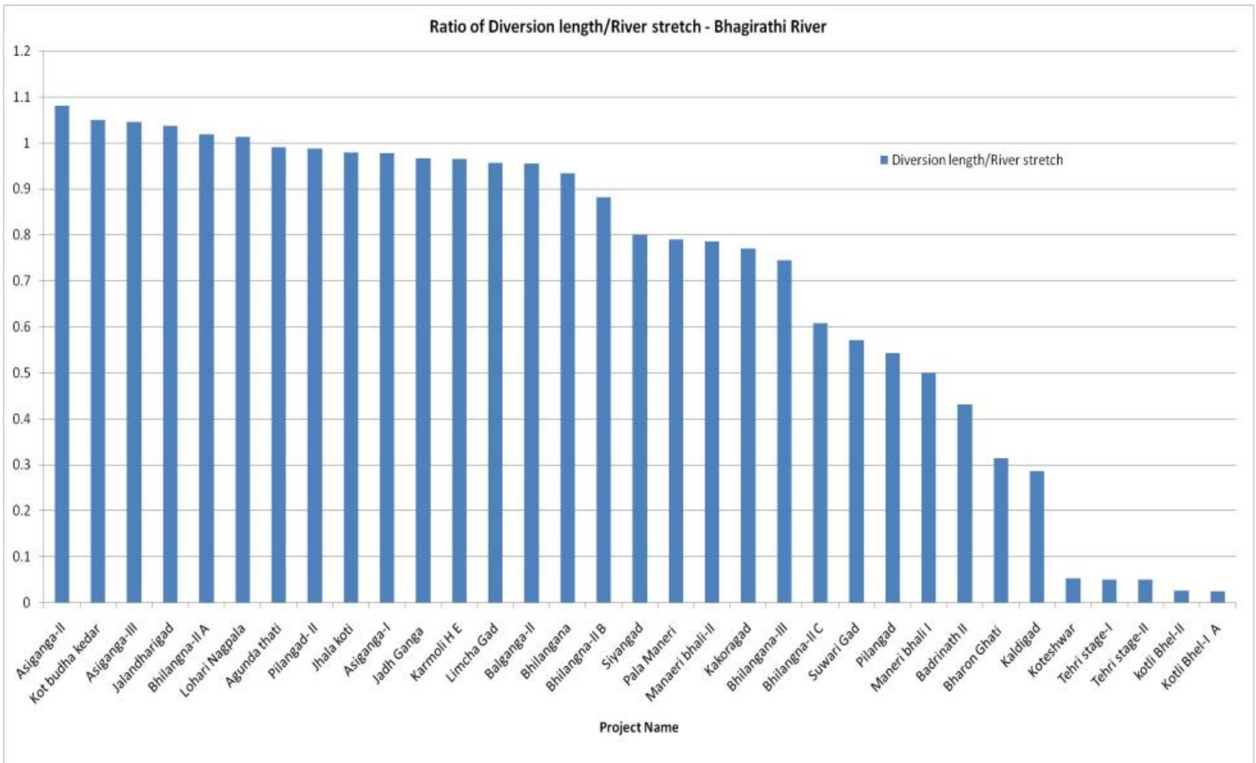


Fig.8.23(b): Ratio of diversion length (water conductor system for hydropower projects with length of river stretch diverted) for Bhagirathi River

8.15.2 Investment on Hydropower

As per Detailed project reports of all hydropower projects, an investment of ₹ 406 Billion is planned on all 70 hydropower projects. It may be noted that additional investment has to be made in creating appropriate transmission network.

An analysis of the data of 70 projects has been carried out for investment point of view and the results have been presented as follows:

1. Investment made on per unit discharge of water used from the river for power generation has been shown in Fig 8.24(a) & Fig 8.24(b)
2. Investment made on per unit head of river stretch used for power generation has been shown in Fig 8.25(a) & Fig 8.25(b)
3. Investment made per MW of installed capacity of the plants for power generation has been shown in Fig 8.26(a) & Fig 8.26(b)

The investment in hydropower projects normally has cost components viz about 60 - 70 % for civil works, about 20-30 % for E&M works and about 10 % on engineering and implementation.

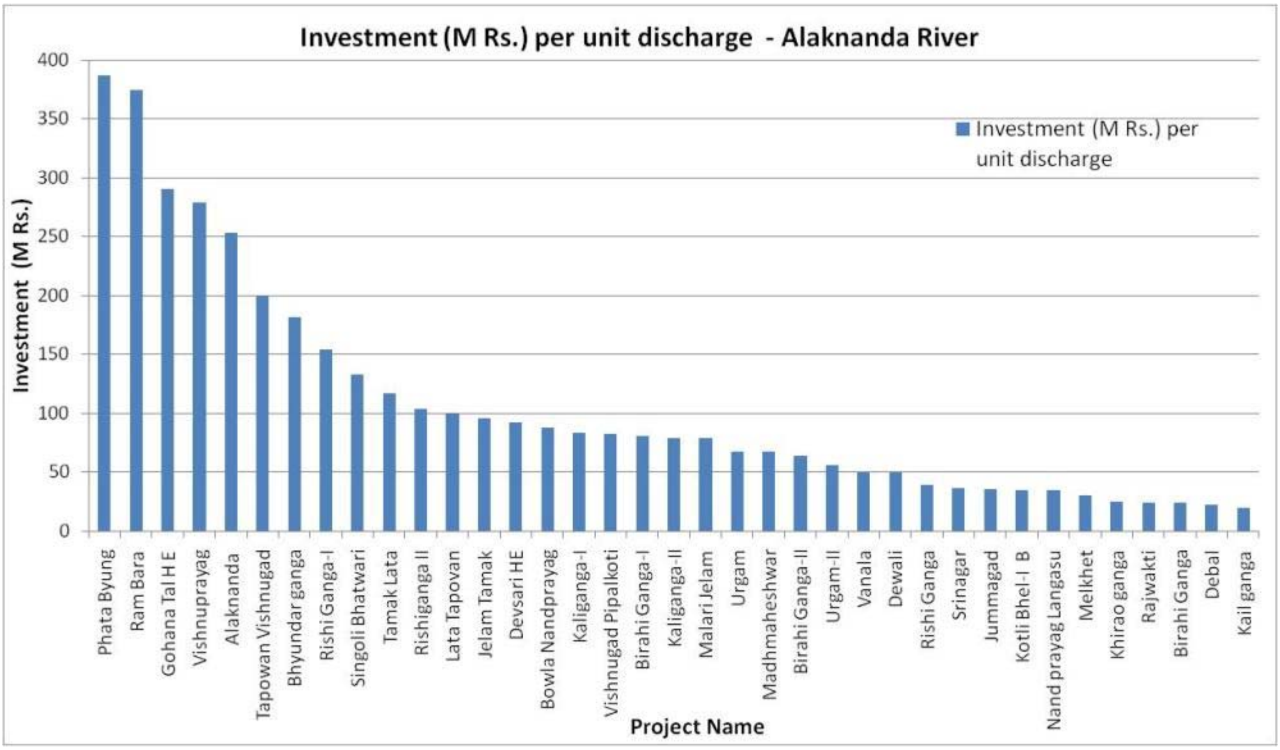


Fig.8.24(a): Investment on per unit discharge of water used from the Alaknanda river for power generation

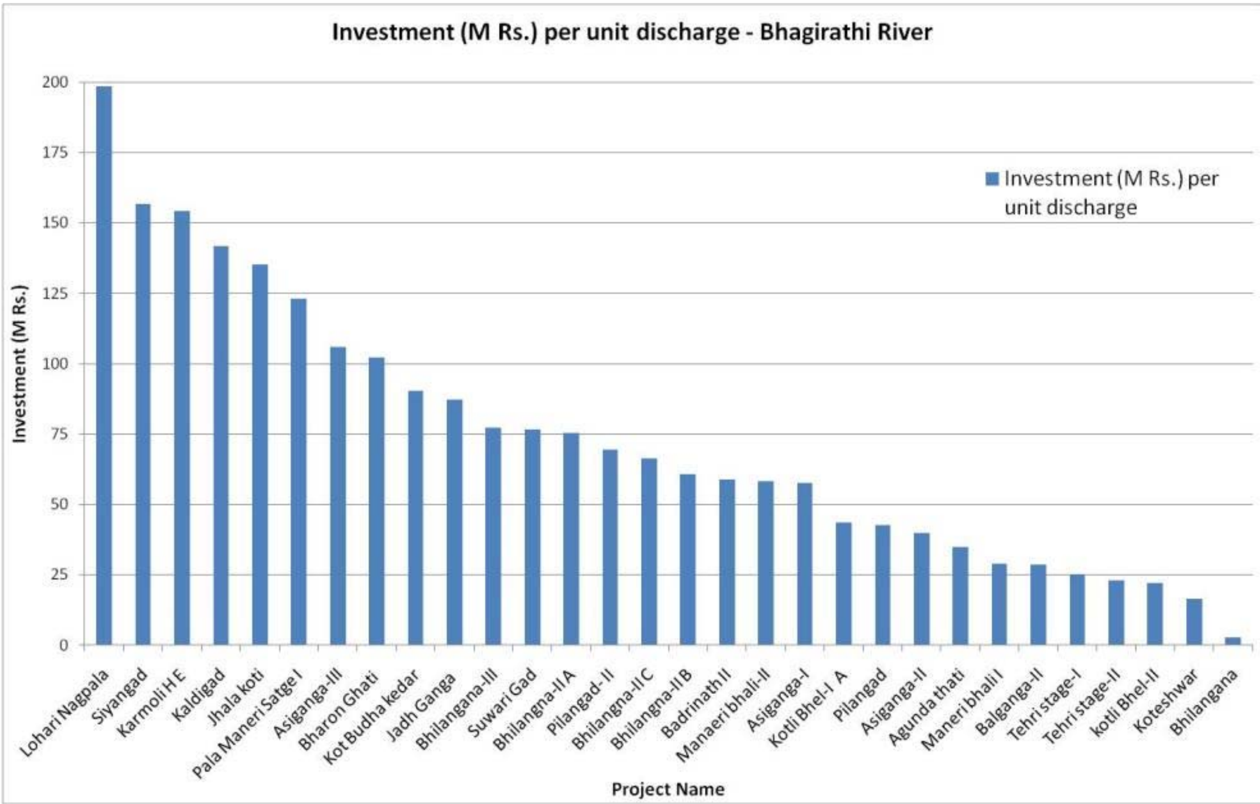


Fig.8.24(b): Investment on per unit discharge of water used from the Bhagirathi river for power generation

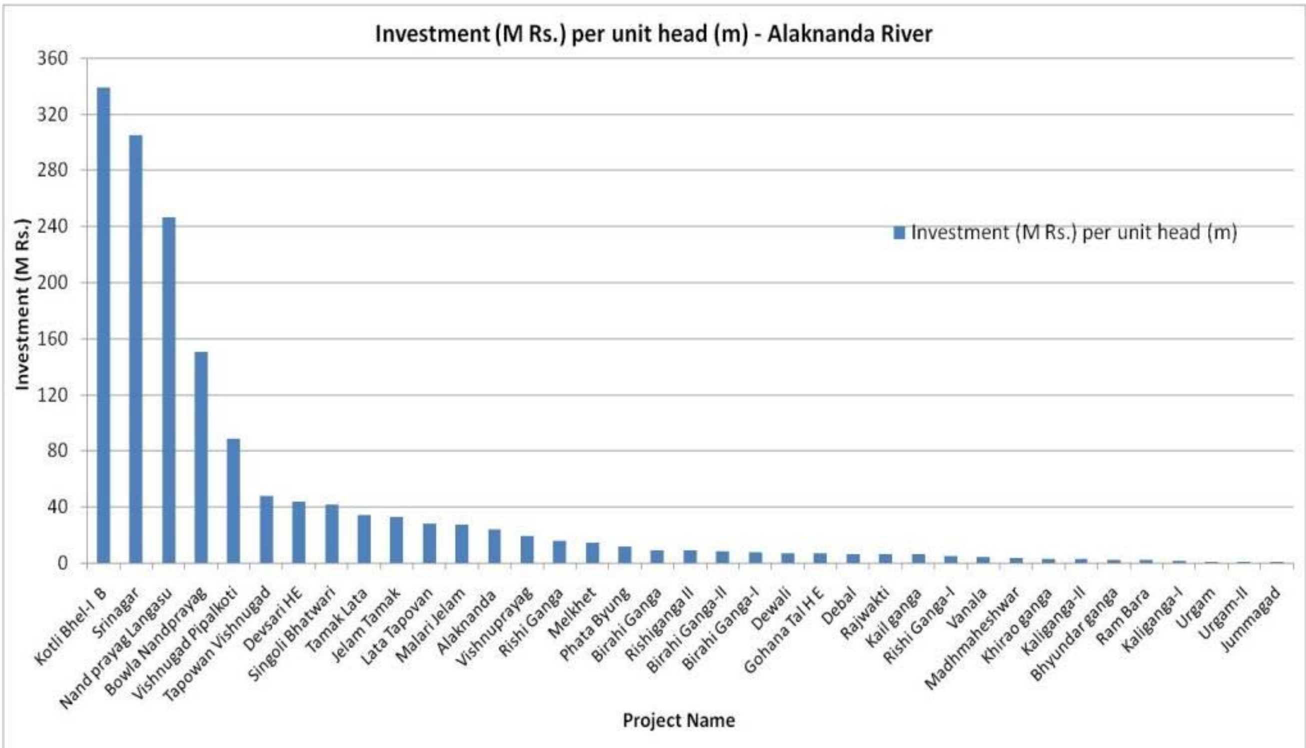


Fig.8.25(a): Investment on per unit head of Alaknanda River stretch used for power generation

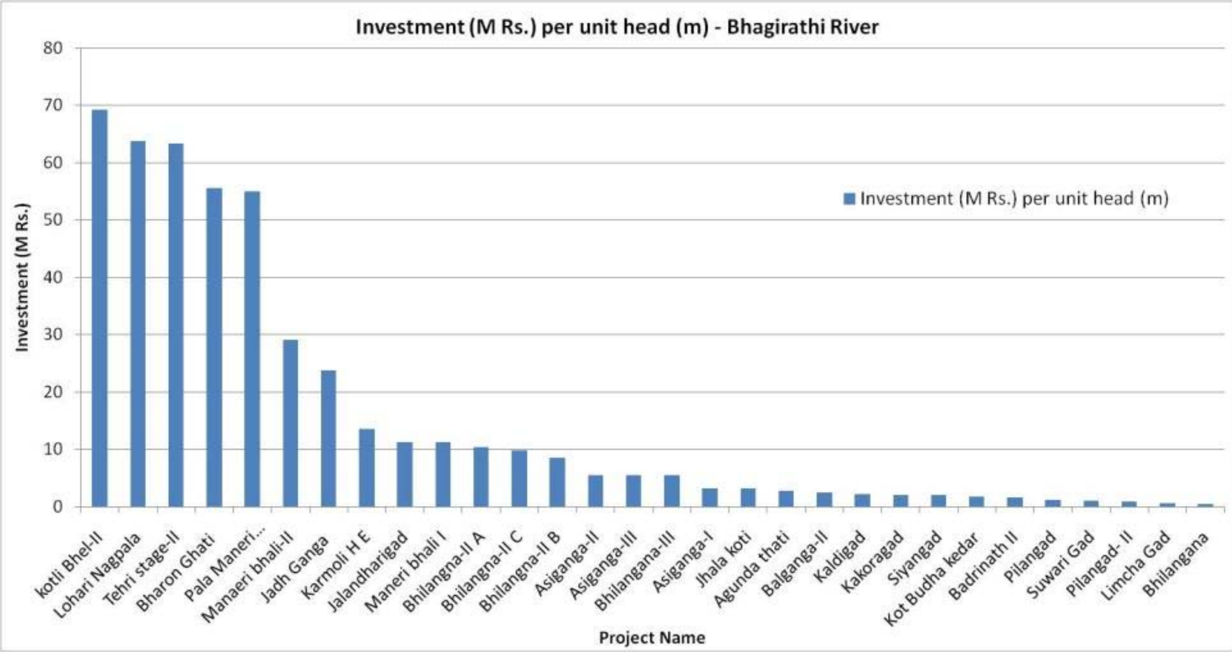


Fig.8.25(b): Investment on per unit head of Bhagirathi River stretch used for power generation

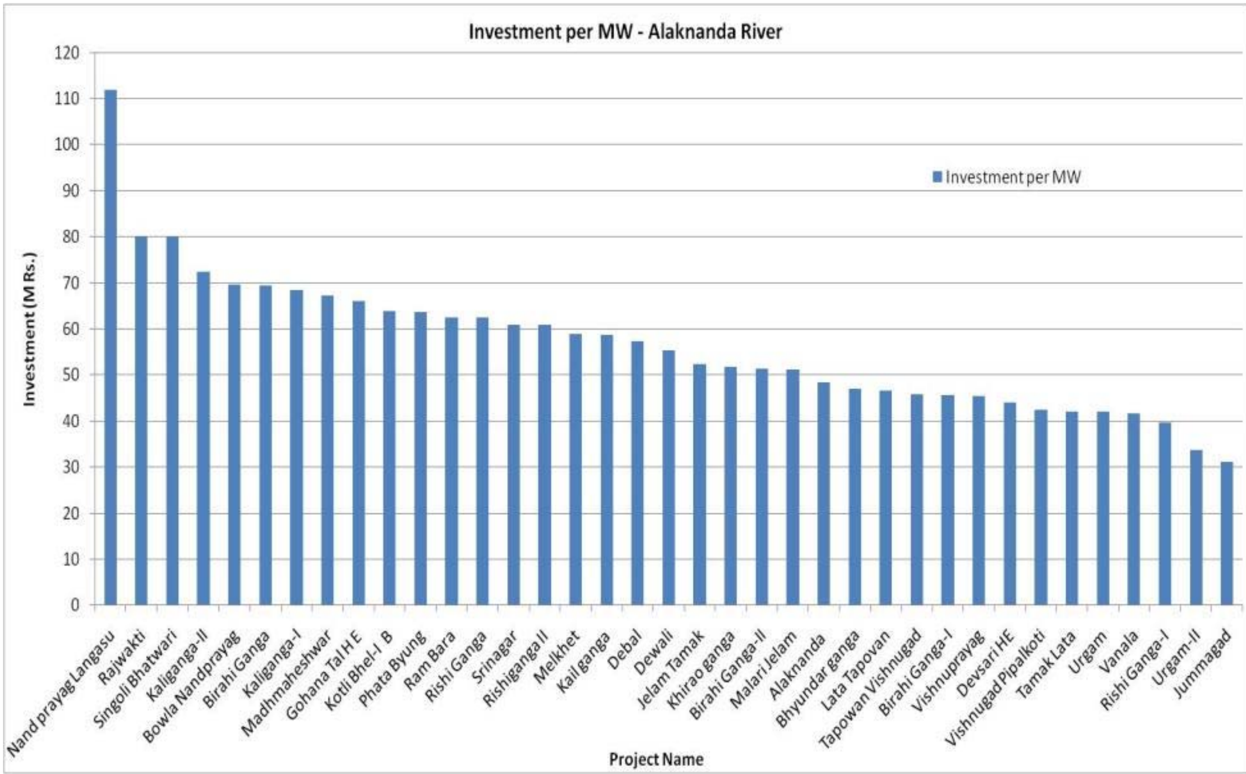


Fig.8.26(a): Investment per MW of installed capacity of the plant for power generation in Alaknanda River

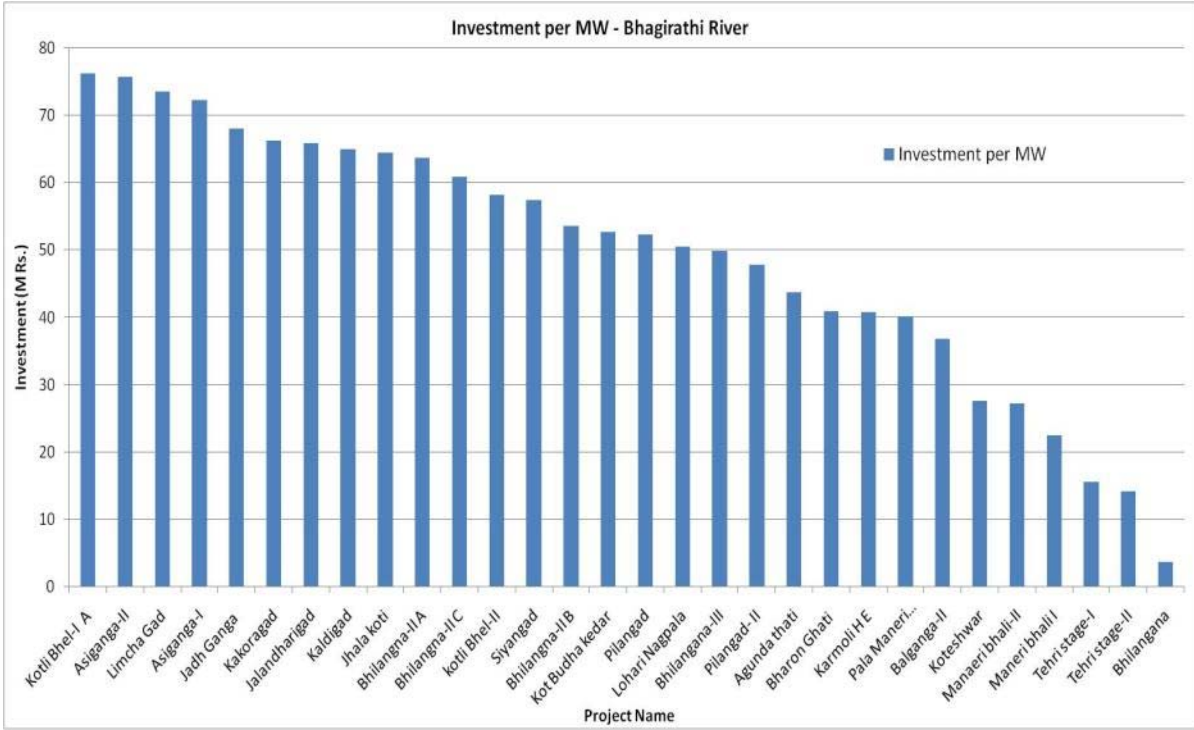


Fig.8.26(b): Investment per MW of installed capacity of the plant for power generation in Bhagirathi River

8.15.3 Storage Point of View

Gross storage proposed/existing per MW of installed capacity for all 70 hydropower project have been analyzed and is given in Fig 8.27(a) & Fig 8.27(b).

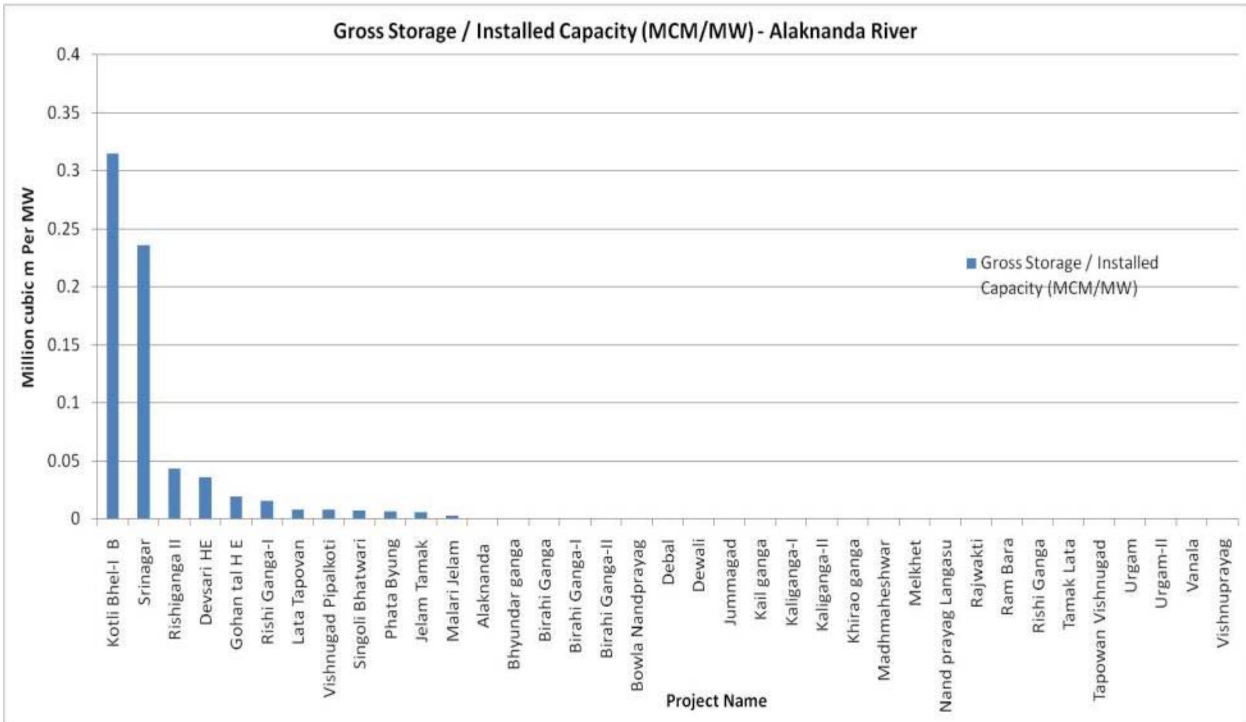


Fig.8.27(a): Gross Storage of hydropower projects in Alaknanda River

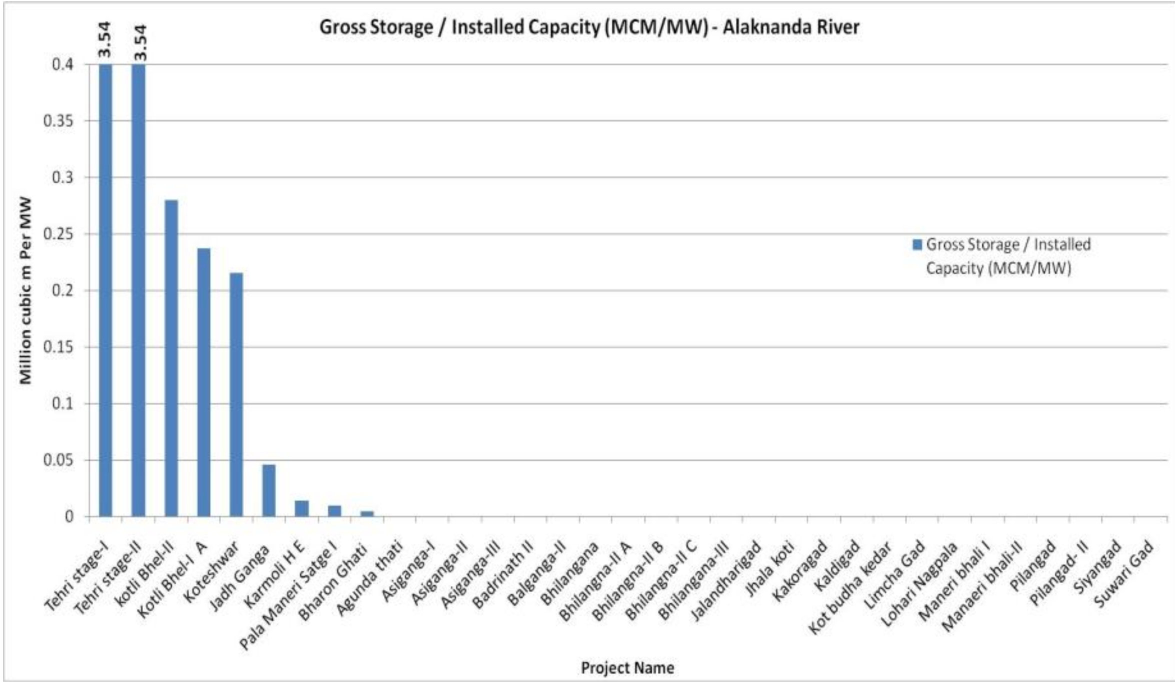
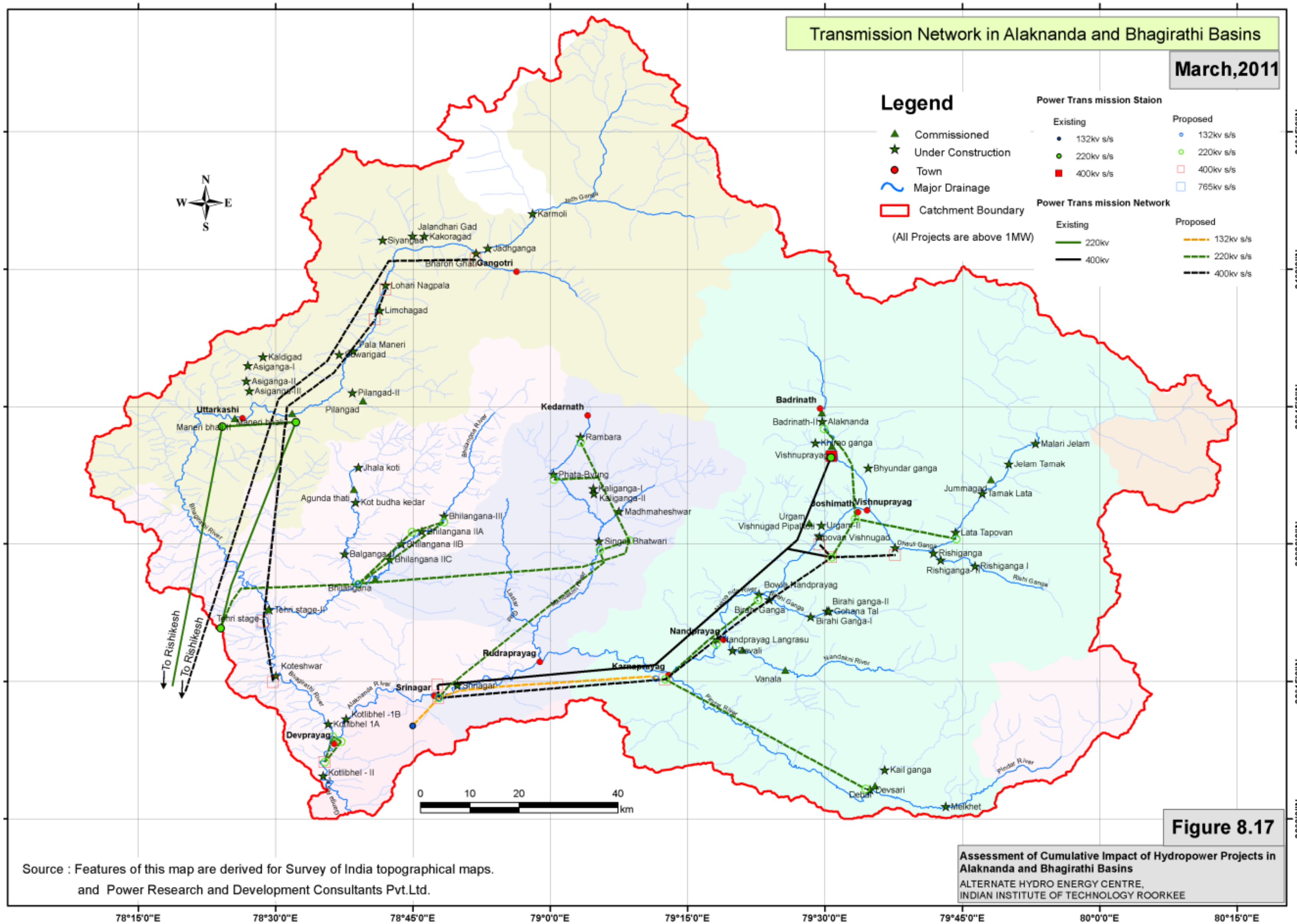


Fig.8.27(b): Gross Storage of hydropower projects in Bhagirathi River

8.16 Transmission Lines

Transmissions lines in the project area are presented in fig 8.17. Uttarakhand Transmission Corporation Limited in consultation with Central Electricity Authority is carrying out the expansion of these lines to evacuate hydropower from these allotted hydropower projects. This leads to additional investments of about ₹10 Billion.


Transmission Network in Alaknanda and Bhagirathi Basins
March,2011
Legend
Commissioned
Under Construction
Town
Major Drainage
Catchment Boundary
(All Projects are above 1MW)
Power Trans mission Staion
Existing
132kv s/s
220kv s/s
400kv s/s
Proposed
132kv s/s
220kv s/s
400kv s/s
765kv s/s
Power Trans mission Network
Existing
220kv
400kv
Proposed
132kv s/s
220kv s/s
400kv s/s
Badrinath
Kedarnath
Uttarkashi
Gangotri
Srinagar
Rudraprayag
Devprayag
Nandprayag
Karnaprayag
Joshimath
Vishnuprayag
To Rishikesh
To Rishikesh
0 10 20 40 km
Figure 8.17
Assessment of Cumulative Impact of Hydropower Projects in Alaknanda and Bhagirathi Basins
ALTERNATE HYDRO ENERGY CENTRE,
INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
Source : Features of this map are derived for Survey of India topographical maps.
and Power Research and Development Consultants Pvt.Ltd.
78°15'0"E
78°30'0"E
78°45'0"E
79°0'0"E
79°15'0"E
79°30'0"E
79°45'0"E
80°0'0"E
80°15'0"E
31°15'0"N
31°0'0"N
30°45'0"N
30°30'0"N
30°15'0"N
30°0'0"N

8.17 Performance

8.17.1 Hydropower Performance

The analyzed performance has been summarized in the table 8.10 with high, medium and low performance indicator for five aspects i.e., Annual Generation per MW of Installed capacity; Annual Generation per unit meter Head, Annual Generation per unit discharge (cumec), Annual Generation /River stretch, Investment per unit discharge and Investment per unit Head. The values for each indicator are given in various figures given at fig 8.19 to fig 8.27. Weightage for each impact for optimized evaluation required an extensive data base and time resource which this study had limitation. This aspect is quite subjective and has not been done in this study.

8.17.2 Economic Aspect of Hydropower Generation

As per state policy the power generation from hydropower projects carries a premium on the investment and free power to the state as royalty. This royalty at the rate of 12% adds to the revenue of the state government for carrying out the development and social welfare activities. The investments in the projects especially by the private sector which are mainly from the outside of the state, further strengthen the economy of the state and its people by way of development. With a very broad estimate @ about 10% of the investment through various activities on the project by the people of the state, it brings a sum of ₹9,764 million for ongoing construction projects and ₹26,949 million for planned projects. Such aspects may be studied in details in due course for building up the database for country which may be used for hydropower development in the country in overall prospective. The details have been summarized and presented in Table no. 8.11.

8.17.3 Reduction in Power Generation due to Environmental Flow

For the sites where environmental flow has been calculated annual energy generation have been computed and are given in table 8.12. The data used in this analysis has been presented in chapter 7. The reduction in potential to generate power in the Bhagirathi Basin is estimated between 4% - 13% (minimum to maximum values of environmental flow) and the Alaknanda Basin between 7% - 15% (minimum to maximum values of environmental flow). The reduction in annual power generation will be less as the calculation for annual generation without environmental flow requirement (EFR) has not discounted any discharge released for environment as practice at present. Here a point of caution is given that the values of environmental flow may change substantially (upward or downward) when the details of various cross sections of the stream are available and a detailed analysis of discharge availability at the intake is carried out. The reduction in annual generation is substantial for several schemes specially the small scale hydro which perhaps cannot sustain the environmental flow requirement based on the comprehensive analysis considering hydrologic, hydraulic, morphological, biotic factors. Environmental flow requirement depends on the development stage of the area and the societal requirement. Exact values of EFR for every single project for implementation can only be established after carrying out the details measurements of discharge, river cross sections, and assessment of impact on biotic life after reduced discharge on commissioned hydropower projects and consultation with the local community. In such situation small streams are to be planned either with low installed capacity or with the high installed capacity to operate only during high flow seasons such

Table 8.10: Performance of Hydropower Projects

River/ Tributary	Project	Capacity	Annual Generation per MW of Installed capacity	Annual Generation per unit meter Head	Annual Generation per unit discharge (cumec)	Annual Generation /River stretch	Investment per unit discharge	Investment per unit Head
Bhagirathi Basin								
Bhagirathi	Pala Maneri	480	Medium	Medium	High	High	Medium	Medium
	Tehri stage-II	1000	Medium	High	Medium	High	Low	Medium
	Koteshwar	400	Medium	High	Low	High	Low	High
	Kotli Bhel-I A	195	High	High	Low	High	Low	High
	Lohari Nagpala	600	Medium	Medium	High	High	High	Medium
	Bharon Ghati	381	Medium	Medium	High	Medium	Medium	Medium
	Tehri stage-I	1000	Medium	High	Medium	High	Low	Medium
	Maneri bhali I	90	High	Medium	Medium	Medium	Low	Low
	Maneri bhali-II	304	High	Medium	High	Medium	Low	Medium
Bhilangana	Bhilangana	23	High	Medium	Low	Medium	Low	Low
	Bhilangna-II A	24	High	Medium	Medium	Medium	Low	Low
	Bhilangna-II B	24	High	Medium	Medium	Medium	Low	Low
	Bhilangna-II C	21	High	Medium	Medium	Medium	Low	Low
	Bhilangana-III	24	High	Medium	High	Medium	Medium	Low
Asiganga	Asiganga-I	4.5	Medium	Low	Low	Low	Low	Low
	Asiganga-II	4.5	High	Low	Low	Low	Low	Low
	Asiganga-III	9	High	Low	Medium	Low	Medium	Low
Balganga	Balganga-II	7	Medium	Low	Low	Low	Low	Low
	Kot Budha kedar	6	High	Low	High	Low	Medium	Low
	Jhala koti	13	High	Low	High	Low	Medium	Medium
Jalandhari Gad	Jalandhari Gad	24	High	Medium	High	Medium	High	Low
Jadh Ganga	Jadh Ganga	50	High	Medium	Medium	High	Medium	Medium
	Karmoli	140	High	Medium	High	Medium	Medium	Low
Kakoragad	Kakoragad	12.5	High	Low	High	Low	High	Low
Pilangad	Pilangad	2.25	Low	Low	Low	Low	Low	Low
	Pilangad-II	4	High	Low	Medium	Low	Low	Low
Siyangad	Siyangad	11.5	High	Low	High	Low	Medium	Low
Kaldigad	Kaldigad	9	High	Low	High	Low	Medium	Low
Dharamganga	Agunda thati	3	High	Medium	Medium	Low	Low	Low
Suwari Gad	Suwari Gad	2	High	Low	Medium	Low	Medium	Low
Limcha Gad	Limcha Gad	4	High	Low	High	Low	High	Low

River/ Tributary	Project	Capacity (MW)	Annual Generation per MW of Installed capacity	Annual Generation per unit meter Head	Annual Generation per unit discharge (cumec)	Annual Generation /River stretch	Investment per unit discharge	Investment per unit Head
Alaknanda Basin								
Alaknanda	Vishnuprayag	400	High	Medium	High	High	High	Low
	Alaknanda	300	Medium	Medium	High	High	High	Medium
	Kotli Bhel-I B	320	Medium	High	Low	High	Low	High
	Srinagar	330	High	High	Low	High	Low	High
	Vishnugad Pipalkoti	444	Medium	High	Medium	High	Medium	High
	Bowla Nandpraya	300	Medium	High	Medium	Medium	Medium	High
	Nand prayag Langasu	100	High	High	Low	Medium	Low	High
	Badrinath II	1.250	Medium	Low	Low	Low	Low	Low
Birahi Ganga	Birahi Ganga	7	High	Medium	Low	Low	Low	Low
	Birahi Ganga-I	24	Medium	Medium	Medium	Low	Medium	Low
	Birahi Ganga-II	24	Medium	Medium	Medium	Medium	Low	Low
	Gohana Tal	50	Medium	Low	High	Low	High	Low
Bhyundar ganga	Bhyundar ganga	24.3	High	Low	High	Medium	High	Low
Pinder	Devsari	252	Medium	Medium	Medium	Low	Medium	Medium
	Melkhet	15	High	Medium	Low	Low	Low	Low
Dhauliganga	Jelam Tamak	126	Medium	Medium	Medium	Medium	Medium	Low
	Malari Jelam	114	Medium	Medium	Medium	Medium	Medium	Medium
	Tamak Lata	250	Medium	Medium	High	Medium	Medium	Medium
	Lata Tapovan	170	Low	Medium	Low	Medium	Medium	Medium
	Tapowan Vishnug	520	High	Medium	High	High	High	Medium
Mandakini	Madhmaheshwar	10	High	Low	Medium	Low	Low	Low
	Ram Bara	24	High	Low	High	Low	High	Low
	Singoli Bhatwari	99	High	Medium	Medium	Medium	Medium	Medium
	Phata Byung	76	High	Medium	High	Medium	High	Low
Rishiganga	Rishi Ganga	13.2	High	Medium	Low	Medium	Low	Low
	Rishi Ganga-I	70	High	Medium	High	Medium	Medium	Low
	Rishiganga II	35	High	Medium	Medium	Medium	Medium	Low
	Debal	5	High	Medium	Low	Medium	Low	Low
Kailganga	Kail ganga	5	High	Medium	Low	Low	Low	Low
Nandakini	Vanala	15	High	Medium	Medium	Low	Low	Low
	Rajwakti	4	High	Medium	Low	Low	Low	Low
	Dewali	13	High	Medium	Medium	Low	Low	Low
Kaliganga	Kaliganga-I	4	High	Low	Medium	Low	Medium	Low
	Kaliganga-II	6	High	Low	Medium	Low	Medium	Low
Kalpganga	Urgam	3	Medium	Low	Medium	Low	Low	Low
	Urgam-II	4	Medium	Low	Medium	Low	Low	Low
Khirao ganga	Khirao ganga	4	High	Low	Low	Low	Low	Low
Jummagad	Jummagad	1.2	High	Low	High	Low	Low	Low

Table 8.11 – Economic aspect of hydropower projects in Bhagirathi and Alaknanda Basins at various stages

		Bhagirathi				Alaknanda				Total			
		Commissioned Project	Ongoing Construction	Under Preparation	Total	Commissioned Project	Ongoing Construction	Under Preparation	Total	Commissioned Project	Ongoing Construction	Under Preparation	Total
Impact due to Annual Energy Generation	Annual Energy Generation (MU)	5,632	1,380	14,237	21,249	2,214	6,910	8,724	17,848	7,846	8,290	22,961	39,097
	Free Electricity to the State @ 12% (MU)	676	166	1,708	2,550	266	829	1,047	2,142	942	995	2,755	4,692
	Annual Revenue (Million Rs.)@ 3.50	**2,365**	**580**	**5,980**	8,925	**930**	**2,902**	**3,664**	7,496	**3,295**	**3,482**	**9,644**	16,421
Capital Investment on Hydro Projects (M Rs.)		26,277	12,244	145,324	183,845	19,452	78,520	124,166	222,138	45,729	90,764	269,490	405,983

In addition the benefits through local area development assistance (LADA) of 1% of project cost, catchment area treatment plant support @2% - 2.5% of project cost, economic growth and social development due to availability of electricity, availability of financial support due to carbon compensation are also there.

Table 8.12: Reduction in Annual Generation due to Environmental Flow Release

Sl. no.	Project Name (Representative Only)	Annual Energy Generation (MU)					
		As per DPR	Without any EFR as per this study	After EFR (min	After EFR (max)	Reduction* (in %)	
						EFR (min)	EFR (max)
BHAGIRATHI							
1	Loharinag Pala	2436	2196	2140	2052	3	7
2	Palamaneri	1993	1861	1821	1757	2	6
3	Asiganga III	48.5	52	51	46	2	11
4	Maneri Bhali I	418	452	434	391	4	14
5	Maneri Bhali II	1566	1220	1188	1086	3	11
6	Agunda Thati	26.23	18	17	13	3	25
7	Bhilangana III	170	141	138	108	2	23
8	Bhilangana	121	118	111	85	6	28
9	Tehri Stage II	3497	3638	3581	2980	2	18
10	Koteshwar	1209	1335	1153	1062	14	20
11	Kotlibhel 1A	937	846	757	713	10	16
	TOTAL	12421	11877	11391	10293	4	13
ALAKNANDA							
12	Badrinath	4	7	6.5	7	0	0
13	Alaknanda	1199	1301	1210	1061	7	18
14	Bhyunder Ganga	150	145	136	104	6	28
15	Rishiganga II	165	210	194	162	7	23
16	Birahi II	96	77	71	53	7	32
17	Vishnuprayag	2060	2155	2053	1826	5	15
17	Tapovan Vishnugarh	2486	2598	2405	2289	7	12
19	Vishnugah Pipalkoti	1813	1958	1795	1729	8	12
20	Phata Byung	340	319	299	223	6	30
21	Singroli Bhatwari	472	438	388	388	11	12
22	Rajwakti	28	28	15	19	20	33
23	Nandprayag Langrasu	490	573	531	515	7	10
24	Devsari	1036	937	914	805	2	14
25	Srinagar	1515	1448	1375	1207	5	17
	TOTAL	11888	12234	11392	10420	7	15

* Actual reduction in annual power generation projected in DPR will be lesser than these values as the discharge adopted in this study for annual generation without environmental flow requirement (EFR) has been discounted for discharge being released for environment as practiced at present, as fact CWC guidelines.

rainy/snow melting seasons. Since the sites selected for calculating environment flow have been representative by choosing most of the large hydropower projects and downstream most hydropower station on different tributaries, the reduction in annual power generation may follow more or less the similar trend for remaining projects in the region.

The values of hydropower have its capability to provide valuable peaking power which cannot be provided by source other than diesel. The state and country is having about 13% peak deficit. Adoption of a large EFRR will substantially erode such capability and peaking shortage would increase.

8.18 Conclusions

New State of Uttarakhand since its creation is able to meet only 52 percent of its power needs from its own resources and these are from hydropower. To encourage generation of hydropower, the Government of Uttarakhand (GoU) has formulated and implemented policies. Development of hydropower projects in the state has just started and has been in full swing for last few years.

Hydropower projects according to size (installed capacity) are the most frequent form of classification used. Water withdrawal and water consumption varies widely for different energy sources. Hydropower plant has the highest energy pay band ratio. Diversion/storage structure impact fish populations and migrations but solutions are available.

All types of hydropower development affect rivers. ROR hydro projects reduces the natural discharge in the river in the diverted stretch of the river during lean season. Storage based hydropower involve a submergence of river stretch. About 31% of the Bhagirathi river length is diverted whereas 39% of the river is submerged. On the other hand, Alaknanda River may have 27% of river length diverted and only 21% submerged.

Water conductor system for a large number of projects is in closed channel/tunnel/ pipe. Closed system is useful, beneficial and safe for operation, maintenance, public, loss of land and landscape point of view. Common perception about the impact on water quality through tunnel is not valid as has been shown in chapter 6.

The performance for all projects has been analyzed and presented with high, medium and low performance indicator for five aspects i.e., Annual Generation per MW of Installed capacity; Annual Generation per unit meter Head, Annual Generation per unit discharge (cumec), Annual Generation /River stretch, Investment per unit discharge and Investment per unit Head.

Water withdrawal from the rivers especially during lean season, economic and human development activities due to hydro projects and religious and cultural activities have recently received a focused attention. The efficiencies and their mitigation for water availability in the diverted river stretch availability of electricity to the state and others and economic impacts have been analyzed and presented.

Based on the analysis of the potential sites, the conclusion emerges that hydropower at identified sites can be harnessed consistent with environmental sustainability provided certain measures are taken.

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CHAPTER – 9

IMPACT ON PLACES OF CULTURAL & RELIGIOUS IMPORTANCE

9.1 OBJECTIVE

This chapter, as per the Terms of Reference (ToR), is restricted to a study of the cumulative impact of hydropower projects in the Bhagirathi and Alaknanda valleys i.e., till the confluence of the two rivers at Dev Prayag. Beyond Dev Prayag the river is known as the Ganga. Thus some major places of religious and cultural importance on the Ganga viz., Rishikesh, Hardwar, Allahabad (Prayag) and Varanasi are beyond the scope of the study. Secondly, though the ToR refers only to the impact on "places of religious and cultural importance", we have widened the scope somewhat to include a discussion of the religious faith and beliefs, especially with reference to the Ganga and its main tributaries, of the people in general and more specifically of those living in and around places of religious and cultural importance and in the vicinity of hydropower projects.

In many cases in India, religion and culture are highly inter-twined and it is difficult to state whether a particular activity falls in the religious or cultural domain. The activities in which the river and/or its water plays a central role include taking a dip in the river (bathing) on auspicious days, shaving the head of an infant (*mundan*), cremation, *shraddha* ceremony etc. Flowing water, which is considered pure, is a pre-requisite for these rituals; some minimum depth of water (say about 3 ft) is required for bathing.

A hydropower project may impact the places of religious and culture importance in two ways: it may submerge a place considered auspicious for various rituals, or diversion of water upstream of such a place may render the available quantity inadequate to perform the rituals. However, it is possible to mitigate most of the undesirable impacts on the places of religious and culture importance through appropriate interventions.

There is little doubt that the river Ganga has a special place in the Hindu psyche. The popular myth about the descent of the river underlines the central role of a venerated sage (Bhagirath) and an important God worshipped by millions of Hindus throughout the length and breadth of the country (Shiva). Ganga is also considered a consort, along with Parvati, of Shiva. While the entire river is considered sacred by the Hindus, its upper reaches lying in the Uttarakhand Himalayas have a special significance. This area is also known as "*Dev Bhoomi*" or "abode of the Gods".

While there is a long history of religious pilgrimage in these basins, in the last decade or so these areas have also acquired a name for non-religious tourism based around water and other adventure sports, trekking, and nature tourism or eco- tourism as well. Fuelled by increasing prosperity and car ownership, improving infrastructure, and a taste for adventure, the new form of tourism has increased the pace of change in these river basins. Accordingly, though this study will inevitably be concerned mainly with the historical cultural and religious practices in the area, it will also briefly consider the impact on other activities such as tourism.

9.2 METHODOLOGY ADOPTED

9.2.1 Approach

Unlike a scientific analysis, which is more amenable to a 'cause and effect' analysis, evaluating the sources of cultural and social change is much more complex since a number of factors are involved. Some may be empirical and objective, and others may be rooted in beliefs, myths and inherited value-systems and therefore highly subjective, but are no less real or important for those who live their lives by them. Therefore, the impact of any activity on cultural and social landscape cannot be stated in 'black and white' as an objective or verifiable phenomenon. The approach of this study, therefore, is not to present a particular point of view, but rather to capture the various perspectives of those who are the religious and other stakeholders and whose life, practices and beliefs are impacted by the existing and proposed hydropower projects. This perspective is necessary to capture the overarching impact of these projects on "things that are of religious and cultural importance".

In order to evaluate the impact of hydropower projects on places of religious and cultural importance, it is necessary to understand the significance of the Ganga to Hindus in terms of the "lived religion" as distinguished from the philosophical and spiritual realm of religion. This would include the place/role of the Ganga in daily rituals and practices, life cycle rituals, and the importance attached to particular places as pilgrimage centres. For the purposes of this chapter we are concerned with pilgrimage centres in the Alaknanda and Bhagirathi till Devprayag.

As Hinduism is not a monolithic or purely text-based religion, it is inappropriate to attempt to reduce it to certain 'core' principles and practices that enable easy interpretation and analysis. As such this chapter will not seek to 'test' the impact of hydropower projects against an agreed single version of Hinduism. Rather, it will seek to represent the various perspectives of groups of Hindus, and for each perspective it will evaluate the impact of the hydropower projects against their own viewpoint. Moreover it is not always possible to separate religious from cultural practices. Many Hindus who may not necessarily perform daily religious rituals and practices also observe occasional festivals of a religious nature as part of the culture. On the other hand, many festivals, though religious in origin, are predominately cultural events where large sections of the population participate .

The question of 'impact on places of religious and cultural importance' can be framed in a number of ways. In approaching this study, the frame of analysis has focused on three particular areas:

1. **The Ganga as a Goddess and Aviral Dhara:** Many Hindus consider the river itself as a Goddess. For these people the question of the impact of hydropower projects on places of religious or cultural significance might be considered a 'misguided' question since the entire river is sacred. People may hold such views

without ever having visited the Ganga. The key stakeholders in relation to this perspective would be religious leaders and scholars (whether living near the Ganga or otherwise). The concept of uninterrupted flow and unaltered course of the two rivers is a prime concern of the religious community and organizations/bodies like the *Ganga Sabha,* heads, members and followers of *maths* and religious institutions located in places outside Uttarakhand like Hardwar, and some environmentalists, academics and activists. Within this stakeholder group too there were voices (such as, for example, the *Mahant* of Vishwanath Temple in Uttarkashi) that seemed comfortable with the idea of hydropower projects. Their support was couched in terms of development of the area and economic well-being of the local people.

2. **The Importance of Particular Sites Along the River, for Example the Panch Prayag:** Key stakeholders in relation to this perspective include: those living at these sites, and those who might travel on religious pilgrimage to such sites. A divide is to be seen in the views of 'outsider' and 'insider' stakeholders. Outsiders are people who come to the region as tourists, whether religious or otherwise, while 'insiders' are people living in the area. Outsiders were, by and large, opposed to the construction of power projects in the region. Their opposition, in addition to being based on religious grounds and matters of faith, was also expressed in terms of the adverse effect of such projects on the 'pristine' nature of the area, the downstream effect of such projects on the Gangetic plain, to which many of them belonged, and the long term effect of such development on seismic stability and climate. For the 'insiders', on the other hand, supporting or opposing hydropower projects is not a simple matter of choosing 'one or the other'. Given the fact that the local people are keen on development of the region and employment opportunities generated as a consequence, they welcome development projects. At the same time, when pressed they underlined the need to have enough water in the river to maintain its natural course, allow people to perform lifecycle rituals, especially cremation, and be generally designed in a manner that does not threaten the existence of places of religious and cultural importance such as *prayags* and *ghats*.

3. **The Cultural and Religious Importance of the Rivers for Those who Live Along Their Banks:** Cultural and religious significance and practices are not only limited to what outsiders or religious texts might consider important. Particular sites and practices of people at the local level should be captured as well. Key stakeholders would be those living in villages along the banks of the rivers. These people are divided on the issue. Their attitude to projects depends on whether their village has been declared a 'project affected' village or not. Those that are declared project affected are more likely to be supportive of projects than those that are not. .Villages adversely affected by any project related development (many villages which were earlier on road head have now become isolated) are far more vocal in their opposition to hydropower projects. The size of a project and the stage of its construction also have a bearing on the attitude of the locals. Small projects are opposed to a lesser degree than large projects. The opposition

to projects seems to intensify at the early stages while negotiations for concessions are on and then towards later stages when it is felt, justly or unjustly, that the project company has not kept its promise or concealed facts.

9.2.2 Ganga as Goddess and Aviral Dhara

When approaching the question of 'impact on places of cultural and religious importance' it is easy to miss the wood for the trees.[1] There are indeed places that are of particular significance along the Ganga, however, it is important to recognise that the river itself is considered by many to be sacred.

The popular myth about the 'descent of the Ganga' attributes its origin to the hard penance (*tapasya*) undertaken by sage Bhagirath, which ultimately pleased the Gods and bore fruit in the form of the descent of the river. However, the primeval force of the river would have caused havoc had it not first been tamed by Lord Shiva who took it in his matted tresses before allowing it to fall to the earth. What is significant about this 'creation myth' is the central role of a venerated sage (*rishi*) and an important God (Shiva) who forms a part of the Great Hindu Trinity in the form of the destroyer so essential to keep the cycle of creation and destruction going in the universe. According to another tradition, Ganga is considered a consort, along with Parvati, of Shiva.[2]

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[1] For example the cumulative impact assessment report commissioned by the World Bank on large-scale hydropower on the Alaknanda River does not mention in any detail the concept of *Aviral Dhara* (uninterrupted flow of the Ganga) see: Mott MacDonald (2009) "Large-Scale Hydropower on the Alaknanda River – Cumulative Impact Assessment", Final Report dated 9 October 2009.

[2] There seem to be more than one version of the myth. The central myth of the Ganges is the story of her descent (*avatāra, avatarana*) from heaven to earth, a story narrated with variations in several texts (*Rāmāyana*, "Bāla Kāṇḍa" 38–44; *Mahābhārata* 3.104–108; *Skanda Purāna*, "Kāśī Khanḍa" 30). In response to the great and steadfast penance of King Bhagīratha, the sky-river Ganges agreed to descend to earth in order to purify the ashes of the sixty thousand sons of Bhagīratha's ancestor Sagara, who had been burned by the wrath of a sage (Kapila) whom they had offended. The great ascetic god Śiva caught the falling stream in his matted hair in order to soften the blow on earth; the Ganges followed Bhagīratha to the sea, whence she flowed into the netherworld to fulfill her mission. This myth explains several of the Ganges's names, including Bhāgīrathī ("she who descended at Bhagīratha's request") and Tripathagāminī ("she who flows through the three worlds").

In the Vaiṣnava version of the descent myth, the Ganges is said to have descended when Viṣnu, as Trivikrama who measured heaven and earth, pierced the vault of heaven with his upraised foot. The association of the river with both great gods of Hinduism points to the universality of the Ganges in Hinduism. In minor myths the river is portrayed as the mother of the *Mahābhārata* hero Bhīṣma and the mother of Skanda-Kārttikeya, who was born from Śiva's seed flung into the Ganges.

The Ganges' most sustained association is with the god Śiva himself. Not only does she flow through his hair, she is considered to be his wife, along with Pārvatī, the other daughter of the god of the Himalaya, Himavat. As powerful river and goddess-consort, the Ganges is *śakti*, the feminine energy of the universe, and the female aspect of the androgynous Śiva. Like Śiva and the ambrosial moon on his head, the Ganges—whose life-sustaining ambrosial waters flow from the realm of the moon—is connected with both life and death." http://www.bookrags.com/research/ganges-river-eorl-05/

A fuller version of the myth can be found in Steven G. Darian, *The Ganges in Myth and History* (New Delhi: Motilal Banarsidas, 2001)

As mentioned previously, there are differences of opinion on how this religious significance is expressed, and how such religious sentiments are to be respected.[3] For those who consider the river itself to be sacred three key issues emerge which have a bearing on the development of hydropower projects in the Bhagirathi and Alaknanda basins. These are:

(i) *Aviral Dhara* or 'uninterrupted flow' of the Ganga;
(ii) Diversion of river from its course and leaving large stretches with little water or dry; and
(iii) Effect of hydropower projects on the purificatory quality of the water.

Ganga as Goddess

The concepts of Ganga as Goddess and of *Aviral Dhara*, or the uninterrupted flow of the river, are closely related. The argument goes that as Ganga is a Goddess, her flow should not be interfered with by any man-made structures such as dams and barrages, nor she should she be forced through tunnels, rendering the main river bed dry for even a short stretch. The argument is generally advanced in terms of the faith that countless Hindus have in the divine nature of the Ganga. As against this it may be pointed out that in Uttarakhand, *Gharats* (water mills) with small diversion channels taking water from the main channel have been functioning since time immortal on different rivers and streams including tributaries of Alaknanda and Bhagirathi rivers. For setting up a *Gharat* water is diverted in a canal and flows through a turbine like system. This is similar to a mini power plant. This intervention in the river is now part of the tradition. Nobody argues that it diminishes the water quality or has any adverse religious impact.

There is also an ecological interpretation of the myth in which Shiva's matted tresses are supposed to represent forests. See Vandana Shiva, "Save the Ganga", *The Asian Age* (December 13, 2010). Shiva quotes the Himalayan ecologist H. C. Reiger .who says "In the scriptures a realisation is there that if all the waters which descend upon the mountain were to beat down upon the naked earth (it) would never bear the torrents (sic.)... In Shiva's hair we have a very well known physical device which breaks the force of the water coming down..."
The myth can also be interpreted scientifically. The notion of the descent of the Ganga from the heavens is another way of saying that the source of water is rain and snow falling from the sky, the numerous trees and dams are the locks of Lord Shiva and the river flows through them to the dry plains. When people (or the sons of king Sagar) drink the river water or eat the food grown using this water, they get life energy or 'their souls are liberated'.

[3] According to one widely held belief among Hindus, Ganga is not the only holy river. According to the popular version "The Vedic Aryans celebrated the Indus, not the Ganges, and her tributaries as their "seven sacred rivers." Hence a *shloka*, which every Hindu is expected to chant while bathing, mentions these seven rivers: *Gange cha Yamune chaiva Godavari Saraswathi, Narmade Sindhu Kaveri Jale asmin sannidhim kuru.*
It is in the epics *Mahābhārata* and *Rāmāyana* (roughly fourth century BCE), which reflect Aryan settlement in the Ganges Plain, that the Ganges takes her place at the head of seven holy rivers that are now geographically spread over all of India. The principal myths of the Ganges are found in the epics and the Purānas (mythological texts that include the lore of sacred places), and in Sanskrit hymns of praise such as the *Gāngālaharī* (The waves of the Ganges) by the seventeenth-century poet Jagannātha.

It is claimed that whenever attempts have been made to tie the Ganga down, such attempts have met with divine punishment. For instance some people. using an example from the Mahabharata, claim that because Bhishma as the young prince Devvrat tied down the Ganga with a wall of arrows, he paid for this act by ending his life on the battlefield of Kurukshetra on a bed of arrows. Related to the first issue is that of the diversion of the Ganga through tunnels or other channels. Those who consider the Ganga a Goddess also consider her course to be divine. To alter this course, according to them, amounts to interfering with the divinity of the Ganga.

Many Hindus also believe that the water of the Ganga has purifying qualities. As a result the Ganga is variously referred to as life-giver (*Jeevan Dayani*), destroyer of sins (*Pap Nashini*) or salvation-giver (*Moksha Dayani*). For a devout Hindu a dip in the Ganga is a supremely holy experience. Apart from the general Hindu belief that a dip in the river purifies the soul by washing away accumulated sins, the water of the Ganga is believed to have unique spiritual and curative properties proved by the fact that it can be preserved almost indefinitely without any deterioration. The purifying quality of the river is attributed by some people to the 'unique mineral composition of the water of the Ganga'. In their view damming of Ganga water, routing it through man-made tunnels and 'assaulting it' with turbines, destroys the purifying quality of the water. The opposition to the river flowing through a tunnel for short distances does not appear to have a logical basis, given the fact that the Ganga originates in a cave.

The importance of the uninterrupted flow of the Ganga and the need to preserve its purity was emphasized time and again in the stakeholder meeting with religious leaders in Haridwar held in September 2010. The noted ecologist Vandana Shiva, has also, in a recent article[4] referred to the river as Mother Ganga or "Ganga *Ma*" calling it India's ecological, economic, cultural and spiritual lifeline. She further argues that the "movement to Save the Ganga and its "*nirmal* (clean)" and "*aviral* (uninterrupted)" flow is not just a movement to save a river. It is a movement to save India's troubled soul that is polluted and stifled by crass consumerism and greed, disconnected from its ecological and cultural foundations."

It would be relevant to mention here that a study on "Self-Purification Capacity of River Bhagirathi: Impact of Tehri Dam" conducted by NEERI for the THDC in 2004 concluded that "the uniqueness of river Bhagirathi/Ganga lies in the sediment content which is comparatively more radioactive compared other river and lake water sediments investigated, and can release Cu and Cr which have bactericidal property and can harbor and cause proliferation (under static condition) of coliphages which reduce and ultimately eliminate coliforms from the overlying water column." The study therefore concluded that the "Tehri dam is not likely (to) affect the quality of self-preservation quality of river Bhagirathi/Ganga as it mimics a static container which is conducive for conditions responsible for maintaining water quality." Based on the conclusion of this study it may be claimed that the self-purificatory quality of the Bhagirathi or Alaknanda is not likely to be adversely affected by any reservoir or tunnel through which the water of the river is made to pass.

[4] See: "Save the Ganga" *The Asian Age* (December 13, 2010).

9.2.3 The importance of particular sites along the Bhagirathi and Alaknanda Rivers

The basins of Bhagirathi and Alaknanda are of immense religious and cultural importance to Hindus and Sikhs[5]. There are sites venerated by Hindus along both the rivers and also away from the rivers. Among the sites of cultural and religious significance along the two rivers are Gaumukh, Gangotri, Uttarkashi, and Tehri[6] in the Bhagirathi basin, and Badrinath, Vishnuprayag, Nandaprayag, Karnaprayag, Rudraprayag and Srinagar in the Alaknanda basin[7].

Fig. 9.1 Confluence of Alaknanda and Dhauli Ganga at Vishnuprayag (Photograph taken on January 23, 2011)

Devprayag – is famous for the confluence of two holy rivers, the Bhagirathi and Alaknanda. Here the two rivers meet to form the holy river Ganga. It is believed that Lord Rama came here for penance after having killed Ravana. The temple of Raghunath, houses a tall image of Lord Rama made of black granite. The Ram Temple is known as Raghunath temple. Srinagar, the earlier capital of Tehri Garhwal is approximately 30 km away. This is the first Prayag on the way to Badrinath.

Rudraprayag – is where the Alaknanda and Mandakini rivers meet. It is said that Lord Shiva performed his famous Tandav Nritya and played his Rudra-Veena here. With his Raga-Raganees he compelled Lord Vishnu to appear in front of him and with music of his veena, he turned Lord Vishnu to water. Rudraprayag is named after Lord Shiva (Rudra).

Karnaprayag – is at the confluence of the Alaknanda and Pindar Rivers. It is said that Karna of Mahabharata meditated here for many years to acquire the impregnable shield, which made him a formidable warrior in the battlefield. Swami Vivekananda meditated here for eighteen days with his Guru Bhai, Guru Turianand ji and Akharanand ji.

Nandprayag – is where the Alaknanda and Nandakani rivers meet and is a major tourist stopover point. Nandprayag honours the pious and truthful King Nanda, who performed a 'Yagya' and gave donations to the brahmins to win the love and blessings of God. It is home to the famous Gopalji temple.

Vishnuprayag – is the holy confluence of Alaknanda and Dhauliganga rivers. In mythology, this is the place where the divine Narad had meditated and received the blessings of Lord Vishnu.

Fig. 9.2 Panch Prayag– Five Holy Confluences[8]

[5] Hemkund Sahib in Alaknanda Basin
[6] Now submerged by the Tehri reservoir
[7] Joshimath, an important town is above the river on a slope
[8] Description taken from Mott MacDonald (2009) "Large-Scale Hydropower on the Alaknanda River – Cumulative Impact Assessment", Final Report dated 9 October 2009, page 7-2

In the Bhagirathi basin, one important Prayag, the Ganesh Prayag which was the confluence of the Bhagirathi and Bhilangana rivers is now submerged by the Tehri reservoir. As it was the site of Ganesh Prayag it also had important temples such as Badrinath temple, Atteshwar Mahadev in the middle of the Bhagirathi River and Sateshwar Mahadev. The Badrinath Temple could not be removed and was submerged by the Tehri reservoir, nor could Atteshwar Mahadev – especially sacred to the people of Atoor Patti.

The Bhagirathi basin has two of the most venerated sites of Hinduism, namely Gaumukh and Gangotri. Similarly, the Alaknada basin also has two highly venerated sites namely, Badrinath and Kedarnath. Badrinath, Kedarnath and Gangotri along with Yamunotri in the Yamuna basin constitute the *Char Dham*.

Badrinath – Located on the Alaknanda River, Badrinath is an important temple to Lord Vishnu. The temple dates back to the vedic times. Situated at an altitude of 3,133 m., the present temple is believed to have been built by Adi Guru Shankaracharya- an 8th century philosopher-saint, who also established a 'math' here. Also known as 'Vishal Badri', Badrinath is one of the Panch Badris

Kedarnath - Is one of the holiest Hindu temples dedicated to Lord Shiva. Here Lord Shiva is worshipped as Kedarnath, the 'Lord of Kedar Khand', the historical name of the region. The temple is one of the twelve Jyotirlingas, the holiest Hindu shrines of Shiva. The older temple existed from the times of Mahabharata, when the Pandavas are supposed to have pleased Shiva by doing penance in Kedarnath.

Gangotri – Gangotri, located on the Bhagirathi river is believed to be the place where the Ganga descended to the earth. According to another legend the Pandavas performed the great 'Deva Yagna' here to atone the deaths of their kinsmen in the epic battle of Mahabharata.

Yamunotri – The sacred site of Yamunotri is the source of the river Yamuna. Two hot springs are also present at Yamunotri, *Surya Kund*, has boiling hot water, while *Gauri Kund*, had tepid water suitable for bathing. A unique aspect of ritual practice at this site is that raw rice is cooked in the hot springs as an offering to the Goddess.

Fig. 9.3 Char Dham

The Alaknanda basin is also home to Hemkund Sahib, a sacred site for Sikhs. Hemkund, as the name suggests, is a high-altitude lake (4329 m) surrounded by seven snow-covered mountains, which are collectively called Hemkund Parvat. Close to the lake is a sacred Gurudwara that is a pilgrimage centre. It is said that Shri Guru Govind Singh (the Tenth Guru of the Sikhs) meditated on the banks of this lake. The lake is the source of the Laxman Ganga (alternatively called Hem Ganga) stream that merges with the Pushpawati stream flowing from the Valley of Flowers, at Ghangaria. From this point on, the river is called Laxman Ganga.[9]

While it is futile to construct a hierarchy of religious and cultural sites, most such sites in the two basins are transit points en route to the Char Dham and Hemkund Sahib. For instance, the *Panch Prayag* are important religious places being the confluence of rivers which are considered sacred by the Hindus. Though these places occupy a significant place in the cultural and mythological lore of Hinduism, they do not attract

[9] Source: Garhwal Mandal Vikas Nigam

pilgrims independently. They are, nevertheless, important and preferred spots for life cycle rituals, especially cremation, among local people. All towns of religious and cultural significance along the two rivers have also grown in importance as market centres for neighbouring villages. Thus they perform more than one function.

9.2.4 The cultural and religious importance of the rivers for those who live along their banks

In addition to the religious importance of the rivers themselves and of particular places in the basins, in keeping with the traditions of popular Hinduism, the rivers have their own importance in the local customs and life cycle rituals. The banks of the rivers are the preferred sites for burning *ghats* and temples of local deities. The water from these rivers is offered to the deities while the ashes of the dead are immersed in the rivers.

The banks of the rivers are also sites of fairs and festivals like the famous *Magh Mela* of Uttarkashi held on *Makar Sankranti* (known locally as *Uttarayani*). Similarly, the *Pandav Lila* in Alaknanda basin recreates the experiences of the Pandavas of the Mahabharata during their travels in the Alaknanda and Mandakini valleys.

9.2.5 Data Collection

The data for the study is qualitative, and not quantitative, in nature. This study captures the perceptions of people, using qualitative techniques of data collection based primarily on key informant interviews. It does not rely on large-scale surveys, either random or purposive, to generate summary and inferential statistics. In other words, the study methodology and approach aim to capture the spectrum of opinion across a broad range of stake holders. Accordingly, key informant interviews were conducted with members of the religious community, business community, academic community, political groupings, staff of power companies and the residents of towns and villages in the basins. However, it should be borne in mind that this study did not aim to be either an opinion poll or a public hearing. To that extent it was guided by quality of information rather than its quantity.

This study has relied on judgment and convenience sampling. While towns of religious and cultural significance present themselves for automatic selection, the study methodology also interviewed respondents from the villages affected by selected existing projects. At each site and for each stakeholder group, attempts were made to interview influential members of the community and those who agreed to express their views on the issue of the impact of hydropower projects. In addition to this, there was also a detailed interaction at Hardwar with members of the Ganga Sabha on September 13, 2010.

9.2.6 Sites for Data Collection

The selection of sites for fieldwork was guided by the need to examine both religious places and the areas around existing and under-construction projects.

Accordingly, the focal point for the study in the Bhagirathi basin was Uttarkashi, while in the Alaknanda basin it was Joshimath.

Uttarkashi and Joshimath are located near large commissioned projects, and also have large under-construction hydropower projects in their vicinity. These are towns of religious and cultural significance in their own right, and also important transit points on pilgrimage routes to *Char Dham*. In addition to these two major towns and large projects in their vicinity, the study also looked at smaller projects on the tributaries of the two trunk rivers and smaller towns and villages close to such projects.

In each basin this study examined at least three commissioned projects and one under construction hydropower project. The commissioned projects were of varying sizes, while the under construction projects were both large. Projects of different sizes – small, medium and large – were selected to see if the impact on places of religious and cultural importance has any relationship to size. That is to say does the impact vary with size or is it neutral to size.

In the Bhagirathi basin the projects selected were:

(i) Maneri Bhali, Phase I (90MW) – Commissioned
(ii) Tehri, Phase I (1000MW) - Commissioned
(iii) Bhilangana, Phase I (23MW) - Commissioned
(iv) Lohari Nagpala (600MW) – Under-Construction (construction now stopped)

Three of these projects, namely, Maneri Bhali I, Bhilangana I and Loharinag Pala are “run of the river” projects, while Tehri I is a “storage-based” project with a large dam and reservoir.

In the Alaknanda Basin the projects selected were:

(i) Vishnuprayag I (400MW) - Commissioned
(ii) Vanala (15MW) - Commissioned
(iii) Rajwakti (3.6MW) - Commissioned
(iv) Urgam Power (3MW) - Commissioned
(v) Tapovan-Vishnugad (520MW) – Under Construction

All the projects selected in the Alaknanda basin are ‘run of the river’ projects.

In addition to interviewing people from villages and towns around the selected project site, the study also interviewed people living at places of religious importance including: Nandprayag, Karnaprayag, Rudrapryag, Srinagar, and Devprayag, in the Alaknanda basin;[10] and New Tehri, Ghansali and Vriddha Kedar in the Bhagirathi basin. At such places various stakeholders were interviewed using techniques of qualitative data collection.

[10] Vishnuprayag does not have any settlement or population.

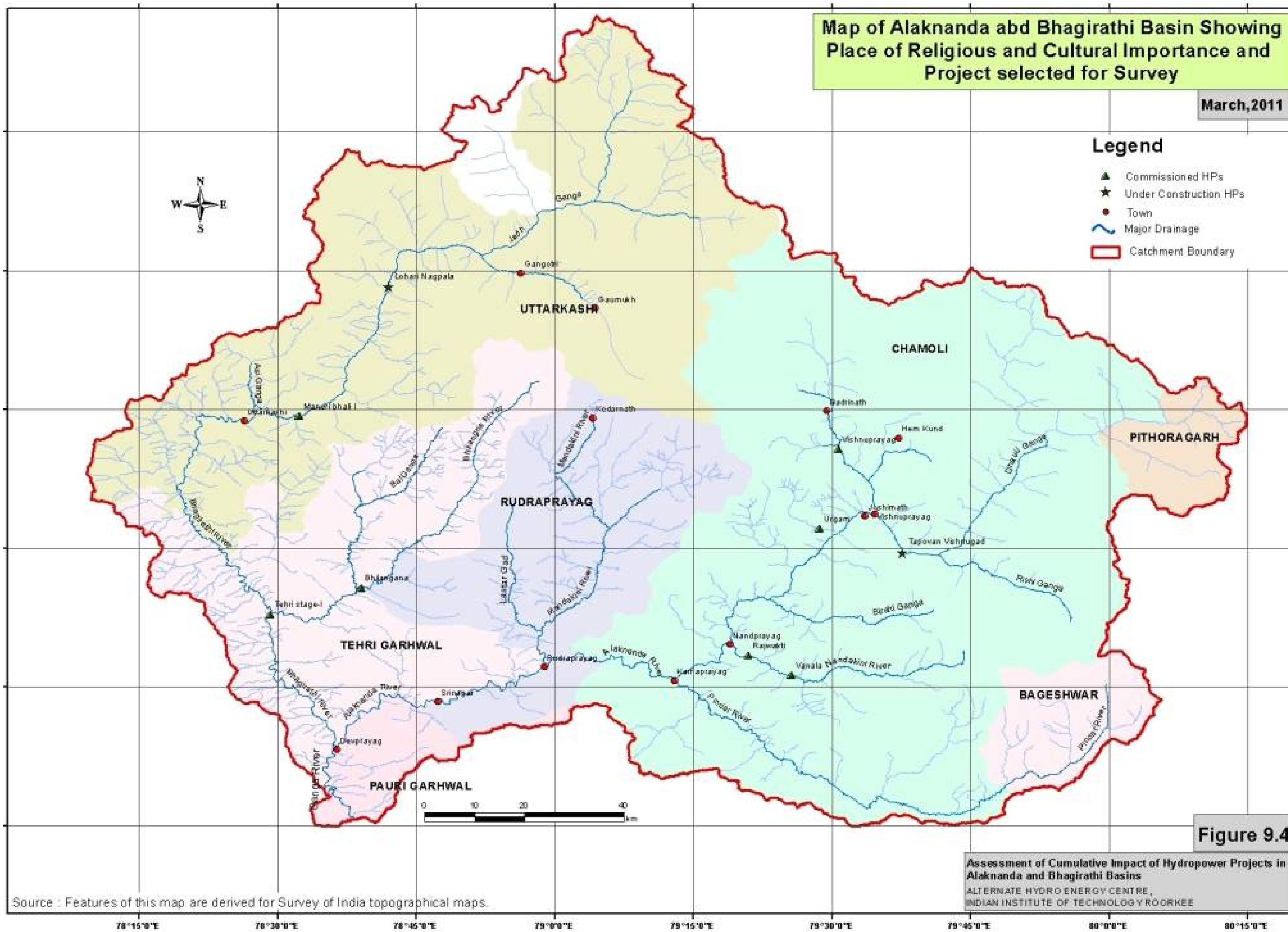

Fig. 9.4 Maps of Alaknanda and Bhagirathi Basins showing places of Religious and Cultural importance and project selected for survey

9.3 DATA USED

As mentioned earlier, this study relied on primary and secondary sources of information. Primary data was collected with the help of key informant interviews with various stakeholders during the fieldwork. A list of people interviewed and secondary sources is listed in part 9.8. Secondary sources used are given in the references

9.4 ANALYSIS

9.4.1 The Ganga as Goddess and Aviral Dhara

For those who believe that the Ganga is a Goddess whose flow must not be interrupted, the cumulative impact of hydropower projects on the river is immense. The degree to which the flow is interrupted or diverted from its natural course is evident when we consider the example of the Maneri Bhali I Project.

Water from the Bhagirathi for the 90 MW power station is conveyed by a 8.5 km. long tunnel which starts from the barrage on the Bhagirathi river at Maneri and ends at Tiloth, where the power station is located. The 11 km stretch of river between Maneri and Tiloth is practically dry between October and March. The water availability improves between April and October. The drying of this stretch of the river is on account of the diversion of the Bhagirathi water into the tunnel of Maneri Bhali I. As the mouth of the tunnel, beneath the Tiloth Power Station, is in Uttarkashi town, the stretch of river between Tiloth and Maneri Bhali II in Joshiada, 2 km downstream from Tiloth Power Station, has a much better availability of water. At Joshiada the river enters the 19 km. long tunnel of Maneri Bhali II. As a result, the natural course of the river downstream is reduced to a trickle, only supplemented by the waters of minor streams that join the main channel of the river. As the drying up of the natural course of the river here is a direct outcome of its diversion into the tunnel, this stretch of the natural course of the river had plenty of water prior to the commissioning of the diversion tunnel The outlet from the tunnel rejoins the natural course of the river at Dharasu, and almost immediately after that enters the huge reservoir of the Tehri dam. The photographs on the following page illustrate the degree to which just one project 'ties the river down'.

The concerns about tying the river down were strongly expressed during the meeting with the *Ganga Sabha*. The opposition to interrupting the flow of the Ganga is an 'absolute principle' in the sense that even one diversion or restriction offends the principle. The significance of multiple projects is that it heightens the degree to which people might feel that a moral transgression has occurred.

However, it may be pointed out that in Haridwar the diversion of the river into a canal has not only been accepted by Hindu society in general and the religious leaders in particular, but it has also been accorded a especially venerated status. The Har-Ki-Pauri bathing ghat at Haridwar is actually located on the Upper Ganga Canal and not on the main river. Over the years everyone, including the Sadhu Samaj, have accepted the changed river course and diversion. The water at Har-ki-Pauri is considered as sacred as that of the main Ganga river. In fact it, and not the main river, is the prime bathing area during the all important *Kumbha Mela,* held after every twelve years. This diversion and construction of the canal was done in the year 1847.

Fig. 9.5 River Upstream of Maneri Bhali I (Photograph Taken on 28/11/2010)

Fig. 9.6 Reservoir of Maneri Bhali I (Photograph Taken on 28/11/2010)

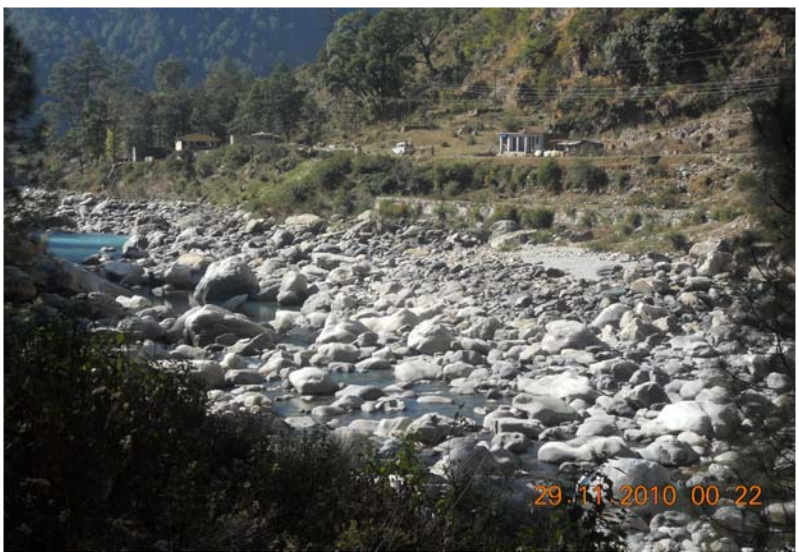

Fig. 9.7 River Downstream from Maneri Bhali I Diversion Point (Photograph Taken on 29/11/2010)

One way to address the problem of the river drying up almost totally between the intake tunnel and the point where the water is discharged back into the river, is to release water in excess of the minimum quantity in consultation with the affected population. This may mean power generation at a lower than installed or planned capacity, but it would perhaps be a small price to pay for addressing people's concerns and getting their support. In any case, it is far more preferable to abandoning projects midway through the construction phase or not starting them at all, as has happened in Uttarakhand in a few well-known cases. Additionally, the project managements may be convinced to agree to release extra water whenever it is needed by the people downstream of barrages and reservoirs. This is already being done by many projects including Maneri Bhali I.

While some people may advocate that all restraints on the Ganga should be removed – whether in Uttarkashi or Kanpur – it is important to recognize that often for outsiders the hill regions of India are an imagined place of purity. So though pollution at Kanpur or diversions at Haridwar are of concern, restraining the Ganga in the *Dev Bhoomi* is viewed as a much greater offence.

That the hill areas can become the 'imagined paradise' or 'holiday home' for outsiders is something that was frequently expressed by local people. When visiting the river basins it appeared that the principled or more abstract issue of *Aviral Dhara* was not at the fore front of local people's concerns. People interviewed in the Bhagirathi Basin focused more on economic and environmental issues and the importance of life cycle rituals rather than the 'high level' issue of *Aviral Dhara*. However, when asked about their opinion on *Aviral Dhara* the response frequently given was: "if Tehri Dam has already been constructed then why are we even having this conversation? *Aviral Dhara* has already been destroyed."[11] Another frequent response was, "if people are so concerned about the Ganga, why aren't they concerned about the Ganga in the plains? Why is the river only sacred in the mountains? They should focus on stopping pollution downstream."[12] People living in the Bhagirathi Basin were focused more on issues of livelihood and development with a strong resentment of the political 'game playing' around the use of the river to the detriment of the local people, rather than issues of obstruction caused to the flow of the river and the presumed hurt to religious sentiments.

Interestingly, political motives were attributed not only by local people who saw 'political games' in commissioning and suspending projects but also by some religious leaders who attributed commissioning of power projects on Bhagirathi and Alaknanda as politics of development for 'shameless profiteering' by not sparing even the most sacred and revered symbol of the people, mainly Hindus. Priest Saswatanand Brahmachari of the *Joshimath Math* echoed this sentiment when he said 'would you cut of the limb of your mother, or sell her kidneys just because it can get you some money? The Muslim and Christian[13] rulers of India did not interfere with the Ganga – it is only the Hindus who are killing their own mother to make a profit.'

Swami Ramangiri[14] from Sunderban near Kalpeshwar Mahadev Temple in Urgam Valley, noted that the problem is not about hydropower projects; the problem is with the development model that India has adopted. India could have chosen the Gandhian model of village republics, but it did not. The current model requires electricity, and so we cannot consider the impact of these projects without evaluating the impact of the development model as a whole. Priest Balram Das of Ganga Mandir Karnaprayag

[11] Mahant Puri, Vishwanath Temple Uttarkashi
[12] Mahant Puri, Vishwanath Temple Uttarkashi
[13] Referring to the British
[14] Of *Juni Akhara*

expressed the view that these projects can co-exist with religious beliefs: 'Projects should be allowed if there is surplus water in the rivers, but *ghats*, temples and *prayags* should be protected.'

9.4.2 Impact on Sites of Religious Importance and Religious Practices

It is this more accommodating view that projects and religious practices can, in theory, co-exist that was the dominant perspective of people living in the basins. In this respect the size of the project does make a significant difference. In addition, the positioning of diversion points and powerhouses are also important. To explore this difference we will consider three projects Tehri Phase I in the Bhagirathi basin, and Vishnuprayag and Rajwakti in the Alaknanda basin.

Tehri was the capital of the State of Tehri Garhwal. In recent years it was the headquarters of Tehri district, which came into being with the merger of the State of Tehri Garhwal in the Indian Union after Independence. The original Tehri Garhwal district was bifurcated to form the new district of Uttarkashi in 1960. Tehri town was a focal point in that it was easily accessible from various directions and was relied upon by people living in villages and small towns surrounding it for various services including religious. As mentioned previously, Tehri was also a site of religious importance. The Ganesh Prayag is now submerged by the Tehri reservoir, as are the Badrinath temple, Atteshwar Mahadev and numerous small temples and *ghats*.

The reservoir of Tehri I dominates the physical, social, and cultural landscape and dwarfs everything else around. It has a surface area of 42 sq. kms. The reservoir has submerged large tracts of fertile agricultural land. Its vast width has sliced the landscape into two for most of its length, with the habitations on the left bank being practically inaccessible at many points now. The reservoir was created by building a 260 meter high earth and rockfill dam and meets the need of power generation, irrigation, urban water supply of Delhi and also provides flood control. There is an underground power house of 1000 MW capacity.

As a result of the submergence of such a large area the fairs that were held at Tehri have slipped into the pages of history, displaced families have left, taking away with them the feeling of organic community, and social ties have weakened. As mentioned earlier, the reservoir has virtually cut off the villages and settlements on the left bank, as they are left with no easy access to the main road that follows the alignment on the right bank. They can either cross the reservoir by an unreliable motor boat service or take a long detour. As a result the area is now popularly referred to as '*kala pani*'[15]. The study team was told that people now do not want to marry their daughters into the villages on the left bank of the reservoir!

[15] A reference to the cellular jail in the Andaman Islands where dangerous convicts, and even freedom fighters, were incarcerated by the British. It was generally believed that those sent to *'kala pani'* seldom returned alive to the mainland.

Tap water replaces *Ganga Jal* as offering

During the course of the field work, we met a group of women carrying offerings to a temple near the Tehri reservoir. When we asked them what they were carrying they replied that they were taking offerings of water to the temple. When asked whether it was '*Ganga Jal'*, they laughed and asked whether we had seen the state of the water in the reservoir. One of them then said that the water was putrid and they could not access it anyway, so they use tap water.

Fig. 9.6 Tap Water Replaces Ganga Jal

As the ghats have disappeared and the slopes leading to the reservoir are very steep, it is nearly impossible to either cremate the dead on the "banks of the river" or to immerse the ashes. Furthermore, the study team was informed that when such cremations do take place the cremated bodies float in the reservoir, as the river is not flowing in the reservoir (it is a still water body), traumatizing relatives of the deceased.[16] The destruction of the forests by the reservoir has also meant that sourcing firewood for cremation has become a problem. In the case of other large projects such as Maneri Bhali I, villagers along the dry stretches of the river now take their dead to Uttarkashi to be cremated.

The elderly, whose presence at cremations was considered essential, are now finding it difficult to be present. It has also meant an added cost in two ways: firstly, the dead body and those accompanying it (traditionally all the adult males in the village) have to be taken by hired transport to the cremation site; and secondly, wood for the cremation has now to be purchased at the cremation site, whereas earlier, when the cremation site was near the village, every family contributed a log or two which the men carried along to the cremation.

Vishnuprayag is a 400MW project on the Alaknanda river developed and operated by the Jaypee Group. While the power station of the project is located a few kilometers *down stream* of Vishnuprayag, the diversion tunnel and reservoir are located *upstream* of Vishnuprayag. As a result of this positioning, there is very little water in the Alaknanda at Vishnuprayag where it meets the Dhauli Ganga. The diversion point for the tunnel of the under construction Tapovan- Vishnugad (520 MW) project of NTPC is located on the Dhauli Ganga at Tapovan, which is *upstream* of Vishnuprayag. Once this project is commissioned, the reduced flow of water in both the Alaknanda and the Dhauli Ganga at Vishnuprayag will significantly alter the existence of Vishnuprayag as it is known today.

In contrast, the 3.6 MW Rajwakti project of Him Urja on river Nandakini is an example of how a small project can have a minimal impact on sites of religious significance, in this case Nandaprayag, and on local practices. The Rajwakti project is located approximately three kilometers upstream of Nandaprayag. The water for the

[16] Pramod, Badli (Gram Pradhan) and Ramesh Kumar Village Saror Tehri

turbines is brought to the power station through a three kilometer long pipeline and released from the powerhouse so that it has no effect on the availability of water in the river at Nandprayag. The project, however has affected the availability of water in the cremation *ghats* of Jakhu, Khunana, Manki, Chari, Choprakot, Tonla, Hend and Sera villages because the diversion through the pipeline has reduced the flow of the water at these places. However, the project releases additional water when this is required for cremation and immersion purposes.[17]

The respondents living near the Rajwakti project are not opposed to this project. Since the project employs 56 staff, half of whom are local residents they welcomed the employment and business opportunities provided by it: *'Projects should go on. At least local people get employment and we will get business. We are Dev Bhoomi and that is important too, but hopefully* prayags *will not get affected. In any case the Ganga comes into existence only after Dev Prayag'*[18] However, when asked about larger projects, particularly those that required a degree of tunneling some residents expressed their concern: *'This is a prayag. If this ceases to exist then people's sentiments are hurt. Him Urja has two projects in close vicinity, but these have not hurt local sentiments or culture. But this large Mangroli [Deoli Bagad]* [19] *Project of Him Urja is threatening Nandaprayag. This will hurt local people and their culture.'*[20] Another resident echoed similar sentiments in pointing out that while development is needed, this kind of haphazard development has caused instability and torn apart the cultural fabric of the area: *'Look at Dhari Devi Temple in Srinagar. It is being moved from sacred ground where it has existed for hundreds of years.'*[21]

9.4.3 The Local Economy

'Agriculture and allied activities' is the mainstay of the local economy in the two river basins. Tourism, especially the *Char Dham yatra* is also important to the local economy. The two basins have little by way of industry. Agriculture is important not only as the most important economic activity and source of employment but also as the bedrock of the local culture. The fairs, the festivals, the offerings to Gods, the daily rituals, the existence of village communities themselves are all inextricably linked to the practice of agriculture. Unfortunately this is one activity that is most likely to be adversely affected by certain hydropower projects. For instance one of our respondents at Nandprayag said '*If projects are developed downstream from habitations/populations, their water and land will be affected…the tunnel borer of Tapovan Vishnugad project (operated by L&T) got stuck and tore an important aquifer of this area on the 25th of December 2009. Water gushed out at the rate of 6000 LPM. One year later the discharge of water from this aquifer continues uninterrupted drying our water sources… Our*

[17] Rajesh Muniyal, Bhagwati Sati and BS Rana Him Urja
[18] Ashutosh Nautiyal, Vikram Sing Rawat, local residents Nandaprayag
[19] A proposed large run of the river project upstream of Nandaprayag
[20] Inder Singh Kathet, local resident Nandaprayag
[21] Balbir Singh Rawat, local resident Nandaprayag

agriculture is not based on irrigation from rivers, but on springs and naulas. *If these dry up what will people grow and eat?*'[22]

Like Uttarkashi, Joshimath has historically been known for both the quality and quantity of agricultural produce. Famous for apples, *rajma* and potatoes, its prosperity obviated the need for large scale migration in search of employment. Chai village near Joshimath situated directly above the power station of Vishnuprayag project, was reported to be *'once known for malta and livestock, including cows and goats'*. We were informed *'During the Yatra season, the milk from this village would go all the way to Badrinath. However, in the wake of the construction of the Vishnuprayag project, the water sources of the village dried up, the land and the village along with it caved in, and the livestock population dwindled as a result of contamination of fodder by dust from blasting and residue of explosives. Today, most of the village has been abandoned and the residents have been reduced from land-owning farmers to non-farm labour. If this trend continues it will trigger mass migration out of the region'*[23] It seems some of the changes in spring and ground water supply, as well as contamination, not necessarily caused by hydropower plants, are ascribed erroneously to them. For example, while villagers in Chai attributed the death of livestock to contamination of fodder by the residue of explosives, many in Joshimath thought that the death of livestock in the area was a result of a disease that swept the area around the same time as work on Vishnuprayag project was on. Some of the respondents also expressed the view that though agriculture would probably not derive any direct benefit from the projects, the indirect benefits by way of better linkages and supply of inputs, access to markets, better prices as a result of increased prosperity and year round demand would definitely benefit agriculture in the area.

Char Dham yatra attracts a large number of pilgrims and tourists to the two river basins each year. As a result of increased prosperity and mobility, the number of tourists has risen steadily each year. The *yatra* season is of immense importance to the economy of the two basins. While the roads in both the basins suffered extensive damage due to the heavy rains of 2010, the roads have, on the whole, improved in the last decade. This is a result not only of large investment in road building under various government schemes, but is also due to the necessity for ferrying large machinery to the sites of hydropower projects. Driving from Dev Prayag towards Joshimath, one can see the ongoing road widening project of the Border Roads Organization. Improved roads mean improved accessibly, and this helps in attracting tourists. There have been other benefits as well: *'Ten years ago, Joshimath was a small sleepy town which would wake up only for the yatra season. Then came the power projects and their staff. They needed places to live, hotels to eat at and shops to buy things from. The biggest problem in our hills is the market. In this case the market came to us and overnight hotels and guesthouses sprang up. As a result, today we can accommodate more tourists and offer them better services. And they come back.'*[24]

[22] Laxman Singh Negi, *Jandesh* Joshimath
[23] Comrade Atul Sati CPI-ML
[24] Dr Mohan Singh, guesthouse owner Joshimath

In this way it is possible that the existence of these projects will indirectly benefit the tourist industry. At the same time there is a danger that it may have a negative impact on the non-religious tourism sector, unless proper ameliorative measures are taken. Tourism, particularly adventure and eco-tourism, has been identified as a potential growth sector in Uttarakhand. The sight of stretches of dry river bed diminishes the attractiveness of the region to those who are visiting for purposes other than religious pilgrimage. During the field work it was also observed that debris from construction activities is simply being dumped into the river. To balance the equation, while the commissioned and proposed projects are likely to affect the pristine and idyllic image of the hills, they are also likely to give a boost to various forms of tourism. We have already noted the positive effect of these projects on roads and other facilities. Similarly, there are big plans to develop the area adjoining the Tehri reservoir as an important tourist destination, tapping into the potential of the reservoir for water sports.

9.4.4 Community Concerns

Although this study was concerned with places of religious and cultural significance, during the course of the field work it became apparent that many people were angry about the manner in which decisions are being taken about the hydropower projects in the state. The people found it intriguing and troubling that projects are approved, construction started and then stopped mid-way because of pressure from 'outsiders'. There was frustration that the people and livelihoods of the area are being used as pawns in 'political games', or that the hills are considered the 'playground of other people': *'Are we expected to grow and eat potatoes and drape a blanket around us, so that people from other parts can visit the area occasionally and feel good about it?'*[25] The debate then centres around who the resources are for and who should control them, and ultimately the rationale for the formation of a separate state of Uttarakhand. A further concern is that 'if so much money has already been invested, then why stop the projects now?' Furthermore, the fact that projects are being stopped at such a late stage, has led people to believe that the motivation for stopping these projects is neither environmental, nor religious in nature – but rather political.

Furthermore, the fact that the most vocal opponents of the hydropower projects are from outside the area, or even outside the state, is resented by people who then couch the debate in terms of the 'insider/outsider' divide. For example, one respondent even suggested that the hill districts of Uttarakhand needed to separate and form a new state/autonomous region. The local people, in fact, viewed the proponents of maintaining the status quo as outsiders who were working against the desire of the locals for a better life. The outsiders, in their view, only came to admire the beauty and serenity of the river and had no connection with the lives of the people living there. For the locals, the issue of the purity and uninterrupted flow of Bhagirathi had become irrelevant after the construction of the Tehri Dam. As a counter argument they asked why were the opponents of projects in the Himalayas not concerned about the pollution of the river in the plains. Such questions then inevitably provide a fertile ground for conspiracy theories.

[25] Dr Harshvanti Bisht, mountaineer, environmentalist, academic and resident of Uttarkashi

In fact conspiracy theories are also not quite absent in the arguments of the other side. Neither, however, contributes to a reasoned debate.

In general the local people in the Bhagirathi valley were all in favour of resuming work on the abandoned hydropower projects, especially the Loharinag Pala project on which substantial work had already been done. The justification was invariably given in terms of the economic benefits of the project in terms of employment and other secondary activities, and the fact that since the damage had already been done, the people gained nothing from stopping the half-constructed projects. People even denied getting any economic benefit from the river, either for irrigation or for drinking water as they were dependent on hill streams and springs for these. Even the priest of the Vishwanath temple voiced this sentiment in rather strong terms. The only contrary view was expressed by the Bhagirathi Bachao Andolan Samiti. According to their representative, the Ganga, being a national river, is not the property of the local people alone. Rather the entire country should have a voice in how it is to be managed. A related issue underlying this divergence of views is concerned with who had the first right on the resources of the region, more specifically on the water resources – the local communities or the outsiders?

9.5 CONCLUSION AND RECOMMENDATIONS

In conclusion we feel that a few points need to be kept in mind while analyzing the impact of the hydropower projects:

1. The Bhagirathi and Alaknanda valley and its people have not remained unaffected by the major changes brought about by the recent spurt in economic growth in the country as a whole, and they have a legitimate desire to be part of the growth story, so to speak, and share in the gains;
2. There is no denying that as far as the local people are concerned the projects do have positive economic impact in the form of employment opportunities, secondary economic benefits like opportunities for small contractors, transport, hotels and guest houses, spurt in trade and business especially market for local business, overall development of the area through roads, schools, and hospitals;
3. For the people economic considerations apparently seem to outweigh the social, cultural, and religious considerations, but if challenged and presented with feasible alternatives they may not be averse to accept a compromise that assures them a better economic status through assured livelihood opportunities along with preservation of the ecological health of the river;
4. The Tehri Dam has affected the Bhagirathi basin much more than all other projects put together both in size and in the trend it has set. As a result, having accepted the Tehri dam with the attendant displacement and disruption, the people feel cheated in being denied the benefits of project construction that promises them jobs and improved economic status without causing any significant displacement or disruption;
5. An issue that has been relatively neglected, but which deserves serious attention is that the local people, especially those likely to face any adverse impact of project construction activities e.g., damage to houses and property, agricultural fields, water sources etc., must be taken into confidence prior to commencement of construction and also informed of the rehabilitation and compensation measures

that are proposed. This should mitigate to a large extent some of the resentment that some projects generate. Though there is a provision for public hearings on environmental issues, these more often than not turn out to be mere formalities without much advance publicity and with minimal public participation. Public hearings should be given greater importance.

6. A continuation of this point would be to ensure that the sites of religious and cultural importance at the local level, and mentioned in this chapter, are clearly identified and efforts made to minimize the adverse effects on them on account of the projects. For instance, it is quite likely that people would resent the 'disappearance' of Vishnuprayag and other such sites on account of hydropower projects.
7. The study on "Self-Purification Capacity of River Bhagirathi: Impact of Tehri Dam" conducted by NEERI for the THDC in 2004 concluded that "the uniqueness of river Bhagirathi/Ganga lies in the sediment content which is comparatively more radioactive compared other river and lake water sediments investigated, and can release Cu and Cr which have bactericidal property and can harbor and cause proliferation (under static condition) of coliphages which reduce and ultimately eliminate coliforms from the overlying water column." The study therefore concluded that the "Tehri dam is not likely (to) affect the quality or self-preservation property of river Bhagirathi / Ganga as it mimics a static container which is conducive for conditions responsible for maintaining water quality." Based on the conclusion of this study it may be claimed that the self-purificatory quality of the Bhagirathi or Ganga is not likely to be adversely affected by any reservoir or tunnel through which the water of the river is made to pass.
8. In Haridwar the diversion of the river into a canal has not only been accepted by Hindu society in general and the religious leaders in particular, but it has also been accorded a especially venerated status. The Har-Ki-Pauri bathing ghat at Haridwar is actually located on the Upper Ganga Canal and not on the main river. Over the years everyone, including the Sadhu Samaj, have accepted the changed river course and diversion. The water at Har-ki-Pauri is considered as sacred as that of the main Ganga river. In fact it, and not the main river, is the prime bathing area during the all important *Kumbha Mela,* held after every twelve years. This diversion and construction of the canal was done in the year 1847.
9. The impact of smaller projects seems to be much less damaging than that of large projects. The 3.6 MW Rajwakti project of Him Urja on river Nandakini is an example of how a small project can have a minimal impact on sites of religious significance, in this case Nandaprayag, and on local practices. The project has absolutely no effect on the availability of water in the river at Nandprayag, though it has affected the availability of water in the cremation *ghats* of Jakhu, Khunana, Manki, Chari, Choprakot, Tonla, Hend and Sera villages because the diversion through the pipeline for the turbines has reduced the flow of the water at these places. However, the project releases additional water when this is required for cremation and immersion purposes.
10. Though agriculture in the Bhagirathi and Alaknanda basins may not benefit directly from hydropower projects, the indirect benefits by way of better linkages and supply of inputs, access to markets, better prices as a result of increased

prosperity and year round demand would definitely prove beneficial. Furthermore, there has been a marked improvement in condition of roads during the last decade. This is a result not only of large investment in road building under various government schemes, but is also due to the necessity for ferrying large machinery to the sites of hydropower projects. Improvements in roads will indirectly benefit the tourist industry, though there is a danger that it may have a negative impact on the non-religious tourism sector, unless proper ameliorative measures are taken.

11. The local people in the Bhagirathi valley are by and large in favour of resuming work on the abandoned hydropower projects, especially the Loharinag Pala project on which substantial work has already been done. The justification was invariably given in terms of the economic benefits of the project viz., employment and other secondary activities, and the fact that since the damage had already been done, the people gained nothing from stopping the half-constructed projects. People even denied getting any economic benefit from the river, either for irrigation or for drinking water as they were dependent on hill streams and springs for these. The only contrary view was expressed by the Bhagirathi Bachao Andolan Samiti. According to their representative, the Ganga, being a national river, is not the property of the local people alone. Rather the entire country should have a voice in how it is to be managed. A related issue underlying this divergence of views is concerned with who had the first right on the resources of the region, more specifically on the water resources – the local communities or the outsiders.

12. Finally, when projects give tangible benefits to the local people, especially the youth, in terms of employment opportunities and other livelihood possibilities, a constituency in their favour is also created. In the absence of such benefits flowing to the locals, resentment builds up which, if not addressed can also develop into serious social unrest as has happened in some parts of the country. We have to guard against such a thing happening.[26] To ensure that the opposition to such projects is minimized, the projects should ensure that a fair deal is offered to the affected areas and inhabitants and that the promises made, such as those relating to jobs, minimum water discharge, etc, are adhered to in 'letter and spirit'. One of the recurring complaints that the study team encountered was that most projects had 'reneged on their promises'. It may be worthwhile to consider the imposition of a cess on power generation from the projects and spending the money so collected on the development of the affected areas.

[26] This point was made by Shri Chandi Prasad Bhatt in a conversation. He referred to how the spread of Naxalism was arrested in parts of Andhra when the Forest Department of the state reached out to the tribal population and provided tangible benefits to them through involvement in forestry activities.

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Ashutosh Nautiyal, shopkeeper from Nandaprayag

Badli (Gram Pradhan), from Village Saror, Tehri

Balbir Singh Rawat, serviceman, Nandaprayag

Priest Balram Das of Ganga Mandir, Karnaprayag

Bhagwati Sati from Him Urja Rajwakti

B.S. Rana from Him Urja Rajwakti

Comrade Atul Sati CPI-ML, Joshimath

Dr Harshvanti Bisht, Government PG College Uttarkashi

Inder Singh Kathait, ex-serviceman, Nandaprayag

Laxman Singh Negi, *Jandesh* Joshimath

Dr Mohan Singh, Guesthouse owner from Joshimath

Pramod from Village Saror, Tehri

Mahant Jayendra Puri, Vishwanath Temple, Uttarkashi

Members of the Ganga Sabha, including Dr G.D. Agrawal and Dr. Bharat Jhunjhunwala

Swami Ramangiri from Sunderban near Kalpeshwar Mahadev Temple, Urgam Valley

Ramesh Kumar, from Village Saror Tehri

Rajesh Muniyal from Him Urja Rajwakti

Priest Satswatanad Brahmachara of the *Joshimath Math*

Vikram Sing Rawat, shopkeeper, Nandaprayag

Additional Respondents[27]

In addition to the above cited respondents, the study team also interviewed:

Ajay Pal Singh Negi, Nagrik Manch, New Tehri; Akelesh Pandey, Junior Engineer Tilot; Anil Singh, Gusatgaon-Kuheri; Ashok Kanpal, restaurant owner, Chamoli; Avtar Lal, Patal Ganga; Badri Kothiyal, Tenduli Chakat, Pipal Koti; Balwant Singh Bhandari, Badagaon; Bhagwan Singh Negi, Khand Village; Bhagwati Prasad, Shopkeeper, Karnaprayag; Bharat Singh Rawat, Badagaon; Bharat Singh, Tapovan; Bhupendra Singh Chauhan, Chairman Nagapalika Uttarkashi; Bihari Lal, Helong; BP Sati, Government Employee, Vaidanu; Brahmachariprasanand, Pracheen Gangeshwar Mandir; CS Ghosh, Calcutta; Dev Singh Rawal, Tapovan; Devendra Lal Khanera, Tapovan; Devendra Singh Rawat, Badagaon; Devendra Singh, Gusatgaon-Kuheri; Dhan Singh Rana, Ex-Gram Pradhan Lata; Dharmedra Singh, Ex Engineer Tunnel Pala Maneri Project; Dinesh Chand Nautiyal, Gangori; Dinesh Lal, Patal Ganga; Gajendra Singh, Patal Ganga; Gajendra, Nanda Devi Taxi Union; Gogeshwar Kanduri, Gusatgaon-Kuheri; Gopal Ram, Siror; Gopal Singh Rawat, MLA Gangotri; Gopal Singh Thapliyal, Badagaon; Goswami Ganesh Dutt, Principal Saraswati Vidyamandir; Govind Singh, Urgam Power House; Harish Lal, Helong; Hemant Singh, Tapovan; Jawahar Singh, Badagaon; Joginder Singh, Gusatgaon-Kuheri; Kailash Saimwal, Dhak; Kamal Singh Mehar, Nagrik Manch, New Tehri; Kaushal Chauhan, Advocate District and Sessions Court, Uttarkashi; Kedar Singh Mehar, Siror; KK Jaiswal, Executive Engineer Tilot; Kundam Singh, Pata Nandgaon; Kundan Singh Rawat, Tenduli Chakat, Pipal Koti; Lalit Kumar, Assistant Engineer Pala Maneri I; Laxmi Lal Shah, former chairman Nagar Palika Joshimath; Leelawati, Tenduli Chakat, Pipal Koti; Madan Lal, Tenduli Chakat, Pipal Koti; Mahan Kalyan Giri, Awahan Akhara, Karnaprayag; Mahendra Singh Chauhan, Badagaon; Mohan Singh Kande, Badagaon; Mohan Singh, Selang; Mohan Singh Rana, Garhwal Adventure School and Mountain Services; Nandan Singh Dungriyal, Tapovan; Narayan Bhandari, Badagaon; Narendra Kumar, Patal Ganga; Narendra Lal, Tilni, Rudraprayag; Niloy Chakravorty, Calcutta; Prem Singh Panwar, Gram Pradhan Laung; PS Rawat, lecturer of Sociology, Government Inter College Uttarkashi; Raghunath Singh Rana, Nagrik Manch, New Tehri; Rahuvir Singh, Patal Ganga; Rai Singh, Jamak; Rai Singh, Pata Nandgaon; Ratan Singh Kanderi, Ex-Service Man, Vaidanu; Rohini Rawat, Former Member State Women's Commission Uttarakhand; Shambhu Nautiyal, Bhagirathi Bachao Andolan; Shankar Kumar, Tenduli Chakat, Pipal Koti; Shanti Thakur, President Janjati Mahila Kalyan Aiwam Balothan Samiti, Uttarkashi; Kaushlanand Dobhal, Tapovan; Shri Chand, Tuna, Rudrapryag; Subir Bhandari, Badagaon; Subir Singh, Gusatgaon-Kuheri; Sunder Singh, Tilni, Rudraprayag; Surat Singh Rawat, Amar Ujala, Uttarkashi; Vasant Singh Chauhan, Badagaon; Vijay Bairwan, Baheda; Vijay Lal, Tilni, Rudraprayag; Vijay Pal Singh Sajwan, Ex-MLA Gangotri; Vipin Singh Pawar, Siror; Virendra Singh, Patal Ganga; Vishnu Pal Singh Rawat, President Vyapar Mandal Uttarkashi; Vivek Bishnoi, Assistant Engineer Bhilangana I;

[27] These are mostly villagers and town dwellers who were interviewed in the course of field work. While their opinions and views have informed the study, they have not been quoted or cited in the body text. These were mostly farmers. Where they had occupations other than farming, especially for town dwellers, the same have been mentioned

CHAPTER – 10

HYDROPOWER AND STAKEHOLDERS

Development of hydropower projects in an area play an important role in transforming the lives of communities living in the vicinity of the projects. On the one hand they bring in economic benefits and infrastructural development in the area, on the other they may cause dislocation and changes in life styles of communities in myriad ways affecting their social fabric and cultural values. It is also accompanied by influx of people from other regions.

The stakeholders in hydropower projects in the Alaknanda Bhagirathi Basin can be broadly divided into three main groups: (a) communities living in and around the project area, (b) people from other areas who migrate to the project and surrounding areas for varying durations and tourists who visit the area for short durations and (c) people living outside the area, who believe that the region is a repository of number holy places which represent the most sublime in religious and cultural ancient values and who are of the view that the region should be left largely undistributed. In the first category are local communities comprising communities living in the area, which are made up of farmers, local labourer, porters and government service men, army men retired people (mainly ex-service men), traders (shopkeepers, restaurant and hotel owners, taxi and other vehicle drivers, tourist guides, etc.), priests and people related with pilgrim tourism. The second category consists of people who immigrate from other areas looking for new trade / work opportunities due to construction of hydropower projects and development of other infra structural facilities. Tehri dam has created a large reservoir and it is expected that it will develop into a major tourist destination for recreation and water sports in the long run. In addition to this are the tourists which can be broadly classified into tourists who come to the area as pilgrims to visit the 'Char Dhams' and other pilgrim centres and tourists who come to visit the area for enjoying the natural beauty and/or for adventure and sports.

Alaknanda and Bhagirathi valleys popularly known as 'Dev Bhoomi' or 'the abode of Gods' is endowed with unparalleled natural beauty. The area is known for the many places of religious importance and a large number of pilgrims from all over the country visit it for both religious and tourism purposes. In the recent time the area has also become very popular as a preferred tourist destination with added attraction of adventure sports like hiking, trekking, mountain and rock climbing white water rafting and skiing. Tourism thus plays an important part in the economy of the state and the expenditure of the State on building up of infrastructure in this region for contribution from tourism had gone up from Rs. 7.75 crores in the sixth plan to Rs. 300 crores in the tenth plan (Kumar 2010). This has lead to an unprecedented growth in urbanization and infrastructural development in the area including construction of roads, hotels restaurants, and recreational facilities to cater to the large influx of tourists coupled with increase in local population. These developments have led to their impact on environment in general and rivers in the region in particular. Hydropower projects are one more component in this process of change.

10.1 HYDROPOWER PROJECTS – VIEWS EXPRESSED BY PEOPLE IN PRINT MEDIA

The subject of Hydropower Projects in Uttarakhand have been a highly debated topic, where persons from different parts of the country and also local people have expressed different views. The construction of Tehri Hydropower project was discussed for decades before its final clearance and construction. The delay resulted in the cost of the project increasing enormously between the time the project was conceived and completed.

In the last decade a number of Hydropower Projects have been commissioned, are under construction or are in planning stage. In the last few months the topic of Hydropower Projects has again attracted attention of the print media. Persons from varied background have been expressing their views on this topic. The concern and topics of discussion range from environmental issues, social impact, economic impact, impact on cultural activity, religious activity etc. There are also discussions on climate change and other global issues. The spectrum of views is wide.

One of the main concerns related to the construction of hydropower projects is that it would strongly affect the environment and cause many undesirable consequences.

In the Uttarakhand Himalaya, there are evidences that in the past few thousand years there were cyclic changes in nature of vegetation, development of lakes, glaciers, sediment and water discharge of rivers, landform evolution, frequency and intensity of landslides. These changes are essentially natural cycles with negligible intervention of humans. In several cases such changes have been intensified by the human activity. However, it is important to distinguish between the natural causes of environmental and climate change and those triggered by the human activity.

"Dainik Jagran" a Hindi Newspaper which is widely read and circulated in Uttarakhand and surrounding regions started a debate "*Urja Pradesh-Sach ya Sawal*" (Energy State – Truth or Question) and invited people to express their news on the issue with reference to the state of Uttarakhand. The views, expressed by a wide section of society and published in the newspaper between the period August 30, 2010 and September 26, 2010.

The views expressed cover a wide range of questions and problems related to stoppage of construction and completion of hydropower projects. In general, people would like the hydropower projects to be completed. The people are generally in favour of the development of the hydropower projects and would like the hydropower projects to be completely abandoned. However, some have expressed concern that the development should be sustainable. The views expressed can be summarized as follows:

- Incomplete hydropower projects should be completed without further delay.
- Before start of the hydropower projects more rigorous environmental assessment should have been done.
- Hydropower Projects are the only energy alternative for the Uttarakhand.
- Some people are using hydropower projects as political tool and they are not concerned about environment, development or welfare of the people.

- Environment is more important than development; more emphasis should be on preserving the environment.
- Ganga River is not meant only for bathing and religious activity. Government should not have agreed to the movement run for closure of hydropower projects. Local people were not asked before ordering the closure of hydropower projects.
- Passing of Ganga water through tunnel cannot decrease the importance of Ganga River.
- People of Uttarakhand should have right to use its natural resources, like rivers, for development.
- Why people are concerned only about Ganga in Uttarakhand. They are doing nothing to stop pollution in Ganga River in the plains. Kanpur and Banaras too should have been considered.
- Approach should be for sustainable development, maintaining a balance between nature and development.
- Hydropower Projects should be decided based on the opinion of the experts, and not by the political and religious leaders.
- Himalayas are fragile and vulnerable and have been a source of natural efforts should be made to generate awareness, sense of participation and ownership, among the common man.
- Considerably smaller projects than Tehri such as Lohari Nagpala cannot be harmful. Ganga should not be confined to spirituality and faith. It can be a source (mother) of development and the two should be harmoniously integrated – Lohari Nagpala should be revived.
- Is Ganga polluted or the intention?
- Works started should not be stopped as the damage could be much longer. Local people on the margin of consideration.
- Windings up cost may be more than required for the completion of the project.
- Demand to take decision in the interest of the State.
- Energy is necessary but Ganga should also receive attention.
- Cancellation of Lohari Nag Pala will not benefit environment. Nearly 40% of the work has been done. How can the loss be made up? Closure of the project will not more than the money required in completing it. The decision to revoke permission to Lohari Nagpala is short and motivate by politics. The development of the state will suffer.
- Eco-sensitive zone declared over 135 km stretch from Gaumukh to Uttarkashi. It is causing immense loses to the people of the state. The projects will be given go-ahead again before the elections.
- Ganga is not polluted by flow through tunnels but is polluted by waste-water from sewers and effluent from industries such as leather.
- The issue should be discussed by the Govt. with Saints and Environmentalists
- Promoting HPS is it a question of faith or political game?
- Hydropower is the cleanest form of energy. Other sources of energy have many negative point and HP option should be examined first.
- Since in the dry winter months, the flow is sharply reduced the capacity of Lohari Nag Pala should be reduced to 150-200 MW.
- Those opposed to the HPs on Bhagirathi are hatching conspiracy against the interests of the state.
- The streams and tributaries joining it should kept free from pollution through concerted efforts.

- Committees of experts should deliberate on the various aspects of hydropower development and make recommendations. The Government should take decisions based on the recommendations.

10.2 AGREEMENTS BETWEEN THE LOCAL POPULATION AND THE HYDROPOWER PROJECTS DEVELOPERS

The cardinal principle that needs to be kept in mind while developing Hydropower Projects should be that the *quality of life* of people living in the area is enhanced. In run of river HPs there is hardly any dislocation of people. It is only in the reservoir based projects that people living in the area which come under submergence zone are rehabilitated. Legal frame work exists to deal with this and what needs to be ensured is that the laws are faithfully and enforced and there is no undue delay in the process. A general observation is that the local population has very little information about the projects before execution starts and hardly any consultation is done at the planning stages. If such consultations are carried out with the local population and they are taken into confidence a lot of misconception and misunderstandings can be avoided.

Local population in the vicinity of the HPs can be affected during the construction stages as well as after the projects have been completed as some effects of the HPs may be permanent. It is hence necessary to ensure that the project developers take the local population into confidence and proper public awareness and participation programmes are run to ensure cooperation of the local population. Consulting the various reports and write-ups on consultations between the project developers and the affected communities the following issues of concern of the local community come to light:

10.2.1 Issues of concern during construction and after commissioning of hydropower project stages:

a) During the construction stage the local community is affected by dust and noise pollution.
b) The local community is worried about the safety of local population specially the women due to large immigration of laborers from other areas.
c) Health and hygiene and spread of various diseases due to lack of sanitation facilities for construction labour.
d) The labour for construction is largely from other areas and the local population is not given employment.
e) Loss of forest / panchayat / land for construction of project or project related activities.
f) Loss / damage of property due to blasting or tunneling or other construction activity related with the HPs.
g) Loss of water availability due to drying up of local water sources (like springs).
h) Loss of crop due to drying up of water sources and damage to property due to blasting.

10.2.2 Issues of concern for local communities after completion of the project:

a) The river (or section of the river) does not have enough water for performing some religious sites like bathing on religious festivals, mela, cremation etc.

b) Loss of land for construction of HPs and related activities like roads etc.
c) Loss of crop, property, life due to accident or major failure of HP structures.
d) The local community does not get any share of the total revenue earned by the project for the development of infrastructure facilities in the affected villages.
e) Lack of proper and timely compensation for loss of land / property due to construction of the projects.
f) Loss of connectivity between villages and / or village and grazing land etc.
g) The aspirations of the local community from the project developers are not met or met partially

In order to safe guard the interests of the local community and to ensure a just and proper sharing of benefits derived from the projects it is necessary that the local community should be provided adequate information of about the projects right from the planning stage and periodic consultations / meetings held between the project developers and the local community.

If required some formal agreements in the form of Memorandum of Understanding (MoU) or agreements can be made between the project developers and the representative bodies of the local communities through *Gram Panchayats* in the region. This may also be viewed as a part of the Corporate Social Responsibility (CSR). In each hydropower project the local issues may be slightly different and hence the MoUs should be project specific and adequately address the local issues.

The MoU between the HP developers and the local communities may cover the above points with the guiding principle that the developers will make good the direct loss incurred by the local community during the construction and later during the operation of hydropower projects. The developers may ensure that adequate water is available for performing religious rites/ cultural activities, for a fixed period on pre-decided terms and conditions between the two parties (the developers and the local communities). As a part of ensuring participation of the local community in the project the project developers may take it upon themselves the responsibility of developing some facilities for the local communities like organizing training facilities for employment generation amongst local communities, supplementing facilities at the primary health centres, recreation facilities, cremation ground etc. Some of the agreements between HP developers and the local communities as illustrative examples. These may be suitably modified depending upon the local needs and conditions. The developer may also provide employment opportunities to the local people to the extent possible (on mutually agreed terms). In addition to this the developers may carry out some social work or participate in local social welfare schemes as a part of Corporate Social Responsibility (CSR). In return the local population will ensure that the work on the hydropower projects is carried out smoothly with full cooperation from local population during the construction period as well as later when the hydropower projects is commissioned and is in operation.

The hydropower project developers may take 3rd party insurance against life and property of local persons in case of a major mishap which cannot be compensated by the hydropower project developers from their own resources.

The above arrangements may go a long way in developing a good working relationship between hydropower projects developers and the local population and should be a built in component in the DPRs of the hydropower projects.

In order that the local population is aware of the timings frequency and schedule of release of water from barrage it is essential that there are set procedures for the same and they are made know to the local population. The standard operating procedure for release of water from barrage at Shivpuram, owned by Vishnuprayag Hydropower Project, Vishnupuram, Joshimath. It is recommended that similar procedures be adopted and known to the local communities through notice boards, leaflets, pasting them at public places and making public announcements from time to time.

Tehri Hydropower Development Corporation (THDC) in the past has held over 70 formal consultation sessions, numerous project-wide public meetings and informal meetings with project affected persons. The details of these can be seen on www.thdc.nic.in. These have been consulted and taken into account while summarizing the issues of concern for the local communities (Annexure 10.1).

10.3 INTERACTION WITH STAKEHOLDERS

While work on this project was being carried out in addition to the discussions / consultations carried out with a variety of stakeholders by the persons working on impact of hydropower projects on religious, cultural and tourism aspects, informal discussion were also held with a number of eminent persons who are knowledgeable about hydropower projects specially in Uttarakhand regions. These include Shri Chandi Prasad Bhatt, founder of Dasholi Gram Swarajya Sangh (DGSS) Gopeshwar (Garhwal) and recipient of Padma Bhushan & Raman Magsaysay Awards. Shri Bhatt was of the opinion that while developing hydropower projects it should be ensured that the quality of life of the people living in the area is enhanced and the positive effects of the hydropower projects outweigh the negative impacts (if any). Furthermore, the development of hydropower projects should be based on scientific facts and not started or stopped due to pressures / lobbing by individuals / groups and broad based consultations should take place with the local community and they should be made aware of the project plans right from the initial stages.

The investigators also had detailed discussions with Dr Ajai Gairola, Member Secretary, State Pollution Control Board, Uttarakhand, Dr Rajendra Dobhal, Director, Uttarakhand State Council for Science and Technology (UCOST) and others. These interactions have been highly informative and useful and their suggestions and comments have been incorporated in the report as for as possible.

In addition some written suggestions were received from Dr B Jhunjhunwala resident of Srinagar (Garhwal) and the response to these suggestions may be categorized broadly in three categories:

(A) Suggestions already being taken care in our study as per TOR

Suggestion 4 **:** Where applicable, Tennant Method with Tessman Modification shall be used.

Suggestion 5 **:** E-Flows may be specified in absolute numbers as well as percentages as per requirement

Suggestion 8	:	E-flow during different seasons may be specified
Suggestion 10	:	Different environmental impacts of tunnel-, canal-, and reservoir-based projects must be studied.
Suggestion 22	:	Impacts of all projects—large and small—should be studied. The term ‘large’ should be explicitly defined as ‘more than 25 MW’ as mentioned in Para 1.2 of TOR.
Suggestion 23	:	Parameters of water quality may include beneficent chemicals, micro invertebrates and coliphages; and that the comparison should be made before- and after situations. – Limited to the data available
Suggestion 25	:	Impacts on sediment regime, mechanical weathering, riparian life, reservoir-induced seismicity, and non-use-, religious- and aesthetic value of free flow of rivers may be studied.
Suggestion 21	:	Downstream impacts up to Ganga Sagar may be assessed

(B) Suggestions which require independent and long term study and are beyond the present TOR

Suggestion 7	:	Nature of blockage and quality, quantity and timing of water flows may be examined, not merely minimum E-Flows.
Suggestion 9	:	Instead of focusing on minimum environmental flows, IITR must focus on holistic impact of projects on ecology and culture.
Suggestion 11	:	The loss of benefits from less generation and gain of benefits from environment conservation from alternative methods of generation of hydropower should be examined. The study should not be limited to study of environmental impacts of present design of projects.
Suggestion 13	:	Social impacts such as those of displacement, loss of livelihoods, health impacts, cultural impacts, splitting of society into antagonistic groups should be examined.
Suggestion 15	:	A stakeholder-wise assessment of impacts and stakeholder-wise cost-benefit analysis may be done.
Suggestion 17	:	Study of Minutes of Public Hearings and representations given to various authorities by people’s organizations should be included in Para 4.5.
Suggestion 19	:	Primary data collection of methane emissions from Tehri and other reservoir-based hydro projects may be made. Impact on global warming due to fewer trees in tunnel-based projects must be estimated.
Suggestion 20	:	Carbon footprint of hydropower dams should be assessed and compared with that of thermal plants to assess the efficacy of hydropower in the Indian context.

(C) Suggestions which are not clear, are ambiguous, are hypothetical

Suggestion 3	:	E-Flow necessary for maintaining Ganga in Class 'A' alone should be assessed.
Suggestion 6	:	No adverse impact, howsoever small, on biodiversity may be permitted.
Suggestion 14	:	The loss of livelihoods like fisheries, navigation, firewood from

riparian areas, etc. must be examined.

Suggestion 16 : People's representatives, specifically including opponents of dams, should be involved in design, data collection and analysis of the data.

Suggestion 18 : Non-use values of free flows of Ganga River may be estimated and taken into account in making recommendations. Other data regarding cultural and social practices must be gathered and provided both quantitatively and qualitatively.

Suggestion 24 : The impact of dams on cellular memory of water and thus on the spiritual qualities of the Ganga may be studied.

Suggestion 26 : IITR may ask for a time frame of 3 years instead of the 6 months presently provided.

10.3.1 Ganga Delta Processes

It is sometimes argued by some that Ganga delta is experiencing rapid changes in response to the anthropogenic activity in the Himalayas. One group argues that due to dam building activities the supply of sediment to the Ganga delta area is highly reduced causing erosion in Sagar Island. Another group argues that deforestation has caused increased soil erosion in the Himalaya causing siltation in the Ganga Plain.

The delta building is a complex process essentially controlled by sediment supply, tectonic activity and eustasy. Studies in Ganga delta region show that delta building started around 3000 years B.P. Initially delta building was in the western part (area of Hugli estuary) and then it shifted westward. Present situation of delta building in eastern most part is in existence for last 3000 years. (Allison et al., 2003; Goodbred ad Kuehl, 2000). Area of Namkhana Island and Sagar Island are witnessing slight retreat in shoreline and erosion for the last 2000 years. It is a natural phenomena starting much before the anthropogenic activity. Thus, it cannot be related to the present-day anthropogenic activity in Alaknanda and Bhagirathi basins.

The sediment discharge of Ganga at Rishikesh sediment discharge is 33×10^6 t/year and at Hardwar the sediment discharge is 14×10^6 t/year. The estimated total sediment discharge of Ganga River is at Farakka, near the Head of the delta is 729×10^6 t/year. Thus the contribution of Alaknanda and Bhagirathi basin to the total sediment discharge of Ganga River in delta region is only 4%. The sediment measured during the year 2008-09 by CWC at Rishikesh during monsoon month in 18 m tone which is only 2.5% of total load at Farakka.

As discussed above Ganga delta shows changes on millennium and century scale in response to the interest delta processes, some of which are causing erosion in coastal areas. The contribution of Alaknanda and Bhagirathi basins to the sediment budget of Ganga River in delta region is too small to initiate or enhance any geomorphic changes in the delta region.

Wassan et al. (2008) evaluated the role of deforestation on the sediment yield of the Alaknanda basin. Using the geochemical tracers it was demonstrated that main source of sediment in the area of Tethyo zone and central crystalline zone and both these areas are located mostly above the tree line. Contribution from topsoil is minimal. Effect of deforestation is probably more or landslides. Deforestation may have effect on exceptional large erosional, catastrophic events.

It was reported that deforestation increased during the last 200 years and particularly since 1962 in the lesser Himalayas (LH). The sediment that is currently being transported by the Ganga river at the mountain front is derived from Higher Crystalline Himalayan (HCH) and LH in nearly equal amount. Hence, Wasson et al. (2008) concluded that the high relief HCH is not the major source of modern sediment. Deforestation occurs in concert with cutting of slopes on account of road construction and saturating rainfall that can trigger landslides even in well-forested land on steep slopes. An important conclusion was that reforestation will help to moderate the effect of some extreme rainfall events, but cannot be expected to stop erosion and destructive sediment transport.

10.4 SOCIO-ECONOMIC ENVIRONMENT

10.4.1 Introduction

This study concerns with some important issues concerning the sustainable development of Hydropower dams with respect to socio-economic environment.

The hydropower project inevitably bring economic and social changes to the project area. It may stimulate economic growth, the building of roads, schools, hospitals, cultural, and recreational facilities; and it may also have negative impacts on the lifestyles of some people. If the local population are indigenous people, the social and cultural aspects of the project have to be managed with particular sensitivity in order to avoid negative effects on their lifestyle and culture.

Many people have benefited from the services large dams provide, such as irrigation and electricity generation. The construction and operation of HP plants can lead to many positive social and economic impacts. The actual construction of a dam can provide employment to the local communities and also provide incentives for business and enterprises, e.g. setting up shop near the site of the dam. When locals are able to work on the dam, it is only for a limited period of time. When the dam is completed, the labour will no longer be required. If there is no other investment around the construction site, then those employment opportunities will diminish.

These aspects are always very specific with each dam, especially in developing countries where all the various conditions combine to form unique and problematic social problems. This is why there is no concrete set of guidelines that can be applied to avoid social problems.

In the following, socio-economic data of some project are presented:

10.4.2 Kotli Bhel HP 1A

The “Kotli Bhel HE Project (Stage-IA)” is envisaged to be constructed to generate 195MW electricity. “Kotlibhel HE Project (Stage-IA)” lies in Devprayag and Narendranagar tehsils of Tehri Garhwal district.

The complete catchment area is occupied by many villages of Tehri Garhwal district and Uttarkashi district. The area in general is having very good network of roads as two of the famous holy shrines of Yamunotri and Gangotri are located in Uttarkashi district.

10.4.2.1 DEMOGRAPHIC STRUCTURE OF THE LOCAL POPULATION

The social locale of this region comprises of mixed caste Hindu, consisting of three social groups i.e., the Brahmins, Rajputs and the Scheduled Caste. The total number of household in the Uttarkashi District is about 56000 with a population base of about 3 lakh people. The majority of the people live in rural areas as compared to urban areas. In district Tehri the number of household is about 1,01700 and the population base of about 6 lakh people. The majority of population is rural as compared to urban population. The total schedule caste population in Uttarkashi is 22.9% where as in district Tehri the total Schedule Caste population is only 14.4%. The sex ratio of district Uttarkashi is 941:1000 whereas, the ratio is 1049 in district Tehri. The literacy rate of both the district is nearly same that is around 66%. The society composed of 74% of agriculture worker in Uttarkashi and 76% in Tehri district. Work participation rate suggest that about 46% of the people in Uttarkashi district and 44% in district Tehri are engaged in different work.

In project affected village, 36.4 % of people constitute the work population. Most of them are involved in agricultural or labour activities; migration to bigger cities in search of better livelihood opportunity is high in all the villages. Average literacy rate of the area is very low being 55.5 while literacy rate of India is 64.8 and 71.6 of Uttarakhand.

10.4.2.2 Socioeconomic Status of the Project Affected Families

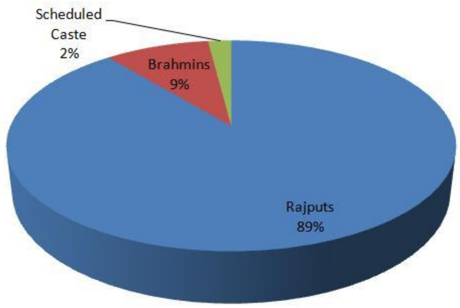
(a) Project affected families (PAF)

The project area of “Kotlibhel HP Project (Stage-IA)” consists of 11 villages with 662 families as per the census record of year 2001. Out of 662 families only 315 families will be affected due to construction of the project whose property (land/houses) are going to be acquired. Further, during the door to door socioeconomic survey it was found that out of 315 affected families of 11 villages, only 196 families are at present living in 8 villages, responded. The remaining 119 affected families did not respond since they are not living in these villages at present.

(b) Demography of the project affected families

The average household size of the 196 families from the eight villages was 6.34 and total population was 1224. These families belonged to three communities, 89% households belonged to Rajputs (175 families), 9% were Brahmins (17 families) and 2% belonged to SC category (4 families) Fig 10.1.

The project affected villages consist of 59% female population as compared to 41% male population (Fig 10.2).



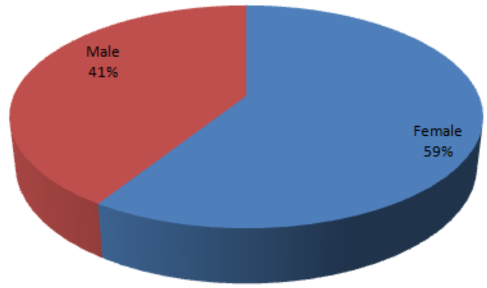
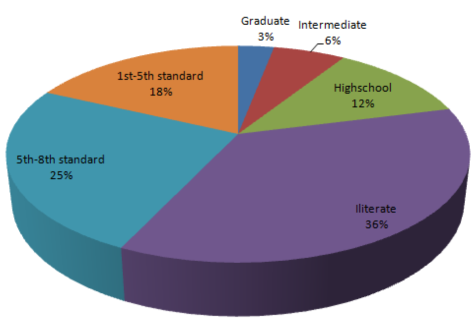


Fig. 10.1 Distribution of population according to caste

Fig.10.2 Distribution of population (male-female %)

(c) Education

The average literacy level was found to be 55.3 % (As per the 2001 census figures). During the intensive study of the affected families it was found that 36% population was illiterate and only 3.0% population has graduate degree (Fig 10.3).



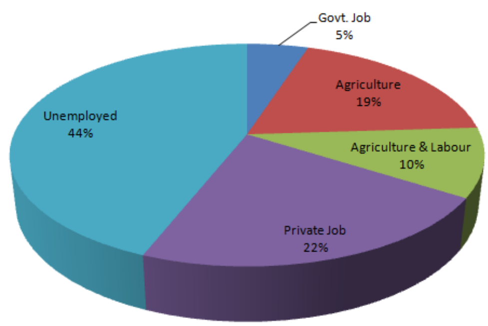


Fig. 10.3 Education level of population

Fig. 10.4 Employment distribution

(d) Employment

About 44% number of people are unemployed. Most of the people are either in private jobs or are involved in agricultural or labour activities, mostly farm labour (Fig. 10.4).

(e) Income Level

81% of people affected by the project were dependent on subsistence agriculture and were not able to quantify monetary value of their agriculture produce. Most of the families are agrarian; the agriculture produce is rarely sold and they have no fixed alternate source of income. 12.5% people earned Rs 1000-5000 per month and only 5% households have an income of more than Rs 5000 per month. Male members of some of these families work in nearby cities as unskilled labourers; they send money as and when possible.

(f) Livestock

The livestock owning families in the area is quite high, 74% of the population owned livestock. Most of the cattle were free range and allowed to graze in the open, buffaloes were stall-fed. Cow and buffalo formed the major part of livestock holding. Milk and milk products were used for self consumption and rarely sold.

(g) Agriculture

The major crops grown are paddy and wheat; both crops are cultivated by an almost equal proportion of people (87% and 86% respectively). Kodo (Barnyard millet) is also cultivated by a very high number (60%) of people. Millets, pulses, ginger, garlic, sugarcane and vegetables were also cultivated.

(h) Dependency on Natural Resources

Almost 90% of the population was dependent on various natural resources for firewood, fodder, timber, fish, etc. for their sustenance.

(i) Type of Houses, Sanitation and other Facilities

The existing sanitation condition of the houses is poor as only 37% houses have toilet facility. Water availability is very poor, most of the families use community tap. Most of the houses are constructed using traditional material. Electricity is available to 85.6% of houses.

(j) Expectations from "Kotli Bhel HP Project (Stage 1A)"

People were asked if they felt hydropower projects have any benefit to the society at large.

- 44.75% of the people think it helps in creating more employment opportunities,
- 50.83% of the people think it strengthens financial position on getting good compensation money for the land acquired,
- 20.99% of the people think better agricultural land is gained.
- 6.63% of the people think it helps in creating better basic amenities like drinking water, irrigation and electricity,
- 3.31% of the people think of getting good land and house in urban area.
- 13.81% people felt HP are not beneficial at all. They expected much personal benefit which was the main reason for the support to HP by 50.83% of the surveyed population. 28.73% of the people supporting HP perceived that it will help in generating new income sources and 11.6% people favoured HP as it will increase electricity production and lead to other development activities in the area (7.18%) and increase in availability of irrigation water (1.66%). Some people wanted to shift to other places from their villages and according to them (2.21%) construction of HP will provide them the opportunity for that as it will help them in getting good money for land (8.29%) and 0.55% people felt they will have employment opportunities. Opinion of some people depended on the

compensation package they will get (2.76%) and expected good land and monetary offer.

10.4.3 Kotli Bhel HE Project (Stage-1B)

"Kotli Bhel HE Project (Stage-1B)" Project is envisaged to be constructed to generate 320MW electricity. It lies in Srinagar tehsil of Pauri Garhwal district and Devprayag tehsil of Tehri Garhwal district. The social locale of this region comprises of mixed caste Hindu, consisting of three social groups i.e., the Brahmins, Rajputs and the Scheduled Caste. The area in general is having very good network of roads.

10.4.3.1 Demographic Structure of the Local Population

The total number of household in the Pauri Garhwal District is about 149987 with a population base of about 7 lakh people. The majority of the people live in rural areas. In Tehri Garhwal district the number of household is about 1,17754 and the population base of about 6 lakh people. The majority of population is rural. The total schedule caste population in Pauri is 15.3% whereas in Tehri Garhwal district it is only 14.4%. The sex ratio of Pauri Garhwal district is 1030:1000 whereas, the ratio is 1000:1000 in district Tehri. The literacy rate of pauri is 77.5%, which is higher than Tehri district that is around 66%. The society composed of 67% of cultivators in Pauri and 70% in Tehri district. Work participation rate suggest that about 46% of the people in Uttarkashi district and 44% in district Tehri are engaged in different work.

In project affected village, 46.5% of people constitute the work population. Most of them are involved in agricultural or labour activities; migration to bigger cities in search of better livelihood opportunity is high in all the villages.

10.4.3.2 Project Affected Families (PAF)

The project area of "Kotlibhel HE Project (Stage-IB)" consisting of 28 villages with 1536 families. Out of 1536 families only 27 families are going to be displaced, out of these, 12 families are from the 5 villages of Pauri Garhwal district and 15 families are from 3 villages of Tehri Garhwal district.

10.4.3.3 Demography of the Project Affected Families

The average household size of the 623 families from the 28 villages was 6.2 and total population was 3857. These families belonged to three communities, 71.8% households belonged to Rajputs, 16.6% were Brahmins, 10.6% belonged to SC category, 1.1% belonged to OBC category (Fig 10.5).

The project affected villages consist of 59% female population as compare to 41% male population (Fig 10.6).

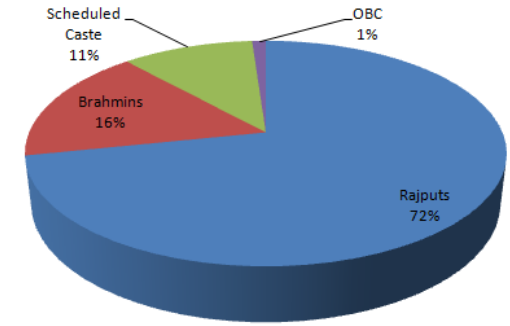


Fig. 10.5 Distribution of population according to caste

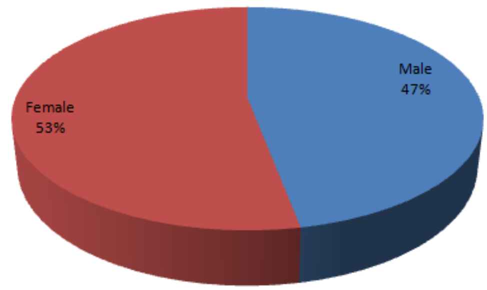


Fig. 10.6 Distribution of population (male-female %)

(a) Education

The average literacy level of the twenty four villages was found to be 55.3 % *(As per the 2001 census figures)*. During the intensive study of the affected families it was found that the 18% population was illiterate and only 3.0% population has postgraduate degree (Fig 10.7).

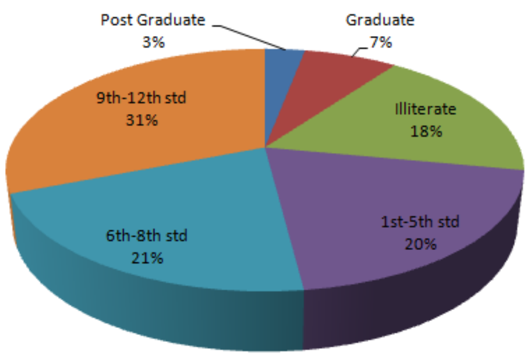


Fig. 10.7 Education level of population

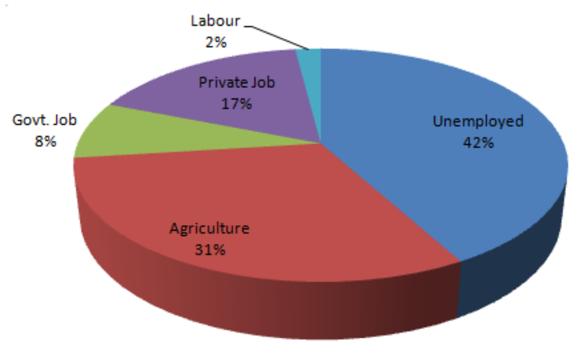


Fig. 10.8 Employment distribution

(b) Employment

About 42% numbers of people are unemployed. Most of the people are either in private jobs or are involved in agricultural (31%) or labour activities mostly farm labour (Fig. 10.8).

(c) Income Level

81% of Project affected people were dependent on subsistence agriculture and were not able to quantify monetary value of their agriculture produce. Most families are agrarians, the agriculture produce is rarely sold and have no fixed alternate source of income. Male members of some of these families work in nearby cities as unskilled labourers; they send money as and when possible. 24.6% people earned Rs 1000-5000 per month and only 9.6% households have an income of between Rs 5000-10000 per month.

(d) Livestock

The livestock owning family in the area is quite high, 78% of the population owned livestock. Most of the cattle were free range and allowed to graze in the open, buffaloes were stall-fed. Cow and buffalo formed the major part of livestock holding. Milk and milk products were used for self consumption and rarely sold.

(e) Agriculture

The major crops grown are paddy and wheat; wheat is grown by almost 82% people while about 615 people cultivate paddy. Tradutuinal crops like Barnyard millet (Jhangora) and Finger millet (Koda) are also cultivated by number of people (43% and 33% respectively). Millets, pulses, ginger, garlic, sugarcane and vegetables were also cultivated.

(f) Dependency on natural resources

Almost 87% of the population was dependent on various natural resources for firewood, fodder, timber, fish, etc. for their sustenance.

(g) Type of houses, sanitation and other facilities

The existing sanitation condition of the houses is poor only 37% houses have toilet facility. Water availability is very poor, most of the families use community tap, most of the houses are constructed using traditional material. Electricity is available to 85% of houses.

(h) Expectations from "Kotli Bhel HP Project (Stage-1A)"

People were asked if they felt hydropower projects have any benefit to the society.

- 47% of the people think it helps in creating more employment opportunities,
- 69.1% of the people think it strengthens financial position on getting good compensation money for the land acquired,
- 42.9% of the people think better agricultural land is gained.
- 4.6% of the people think it helps in creating better basic amenities like drinking water, irrigation and electricity,
- 2% of the people think of getting good land and house in urban area.
- 1.6% people felt HP are not beneficial at all. They expected much personal benefit which was the main reason for the support to HP by 61.8% of the surveyed population. 36.4% of the people supporting HP perceived that it will help in generating new income sources and 15.8% people favoured HP as it will increase electricity production and lead to other development activities in the area (15%) and increase in availability of irrigation water (1%). Some people wanted to shift to other places from their villages and according to them (0.5%) construction of HP will provide them the opportunity for that as it will help them in getting good money for land (13.3%).

10.4.4 Srinagar HP Project

The Uttar Pradesh State Electricity Board (UPSEB) envisaged the Shrinagar HP in 1981 with the capacity of 200MW. The Srinagar HP is constructed on River Alaknanda near Srinagar town of Pauri Garhwal district.

The project area includes both the submergence and the catchment areas of the proposed Srinagar HP. The catchment area is very large comprising most of the Chamoli district with small portions of Pauri Garhwal and Tehri Garhwal districts. The region experiences large scale outward migration of people, especially the male population to the plains for employment. The large number of male population in the area works in the army. The total population of the catchment area has been estimated to be about 413221 of which the majority lives in the rural areas. The demographic profile of the catchment area is given in Table 10.1.

Table 10.1: Demographic profile of catchment area

S. No	Parameter	Number
1	**Population**	
	Male	201483
	Female	211738
	Total	413221
2	**Population Density(No./km^2)**	74
3	**SC Population**	
	Male	36220
	Female	36119
	Total	72339
	Percentage of SC population to the total population	17.51
4	**ST Population**	
	Male	3748
	Female	4129
	Total	7927
	Percentage of ST population to the total population	1.92
5	**Number of females/males**	
	Total population	1051
	SC population	997
	ST population	1115
6	**Literacy Rate %**	
	Male	80.40
	Female	38.10
	Total	**58.60**

The population density of the catchment area is about 74 persons per square kilometre. Of the total population, 17.51% belong to Scheduled Castes (SC) and only 1.92% belong to Scheduled Tribes (ST). Generally, the emigration of SC and ST population to the plains for service, business, etc. is less as compared to the other caste groups. The overall literacy rate in the area is good (58.60%) with the male and female literacy rates being 80.40% and 38.10% respectively. The number of females per 1000 males in the project area is 1051.

10.4.4.1 Livestock

Livestock is complementary to agriculture and more so in the hills due to the shortage of arable land coupled with lesser avenues of employment.

The major livestock in the catchment area are goat (35%), sheep (27%), and buffalo (24.1%). The livestock per capita for the catchment area amounts to 0.66. This can be attributed to the needs of people living in hilly regions. Cattles occupy a very important position in the area. Male cattle is the main source of draught power in agriculture. The females are used for milk production.

10.4.4.2 Occupational Profile

The percentage of working population to the total population is 47.5%. The major occupation in the project area is agriculture, as 78.28% of the total workers are engaged in this occupation. The population engaged in other occupations like industries, trade and commerce, etc is quite low, which indicates the backwardness of the area.

10.4.4.3 Agriculture

Agriculture is the major occupation in the project area. About 12.82% of the catchment and 36.05% of the submergence area respectively is under agriculture. Cereals are the major crops grown in the area as they account for almost 92% of the cropped area. Rice and Wheat are the major cereals as they together account for more than 61% of the cropped area.

10.4.4.4 Irrigation

The project area in general, depends on rainfall for irrigation. Rainwater and snow are absorbed within the soil, which then percolates through pores and crevices and reappears in the form of springs.

The intensity of irrigation is poor in the area. The average irrigation intensity of the catchment area is 4.61%. The irrigated intensity is highest in development blocks Karanprayag and Tharali and even in these blocks also it ia as low as 7.95% and 6.65% respectively.

10.4.5 Phatabyung HP

The Phata-Byung HP project of 76 MW capacity on Mandakini river is located near Sitapur village, tehsil Okhimath of Rudraprayag district in Uttarakhand. The proposed dam site is connected by a metalled road to the nearest town of Okhimath situated about 43 km away.

10.4.5.1 Demographic profile

Rudraprayag was recognized as a district by Uttar Pradesh government in 1998. The head quarter of the district was established at Rudraprayag town, which connects Rishikesh and the famous Hindu shrine Badrinath by a National Highway. The total geographical area of the district is 232 sq km, which harbours a total population of 2,27,439 with a sex ratio of 1115. About 98.7% of the total population is rural. The population of Scheduled Castes and Scheduled Tribes account for 17.7% and 0.081% of the total population, respectively. Average literacy rate in the district Rudraprayag is 62.02%.

District Rudraprayag is comprised of two tehsils, namely Rudraprayag and Okhimath. Okhimath tehsil is smaller as compared to Rudraprayag. Total population of Okhimath is 80,185 comprising of 16,409 households and 246 villages. SC and ST populations account for 18.1% and 0.11%, respectively of the total population. The age class 0-6 years shares 15.9% of total population. Sex ratio in the tehsil is 1070.

10.4.5.2 Health facility

Okhimath tehsil lacks sufficient health facilities. Here 9 allopathic, 8 Ayurvedic and 2 homoeopathic hospitals are established. An average population of about 80,000 in Okhimath is dependent upon a primary health centre while one primary health sub centre caters to a population of 20,000.

10.4.5.3 Demographic Profile of Project Affected Area

Twenty-four villages are located within the Phata- Byung HP project area. Total human population of these villages is 9,762 belonging to 1,874 households. Scheduled Castes population accounts for 14.2% of the total population while ST population is very low. Trijuginarayan and Khumera villages have largest population while Lolchhara, Tarsali and Semkwerala villages are the smallest. The sex ratio in these villages is 988, which is less than sex ratio of tehsil.

(a) Educational Profile

The average literacy rate in the villages is high as compared to that of district and tehsil averages. Total literacy rate is 78.23%, which is significantly higher in the male population (93.15%). A total of 19 primary schools, 9 middle schools, 4 secondary schools and 2 senior secondary schools are located here. There is no college for higher education in the villages located in the vicinity of the proposed Phata-Byung HP project.

(b) Health Care

Health care facilities are not adequate in these villages. The inhabitants avail of health care facilities comprised of 3 allopathic hospitals, 1 ayurvedic hospital, 1 primary health sub-centre and 2 child welfare centres.

(c) Occupation Pattern

The economical profile is similar to the tehsil, which has been described above. Total work force in the vicinity is comprised of 45.06% of total population with higher in female population. The main workers account for 82.26% of the total work force, which is slightly high in males. The marginal workers account for 17.3%, dominated by the females. A major portion of the population comes under the non worker category (i.e., 54.93%).

(d) **Other Amenities**

Most of the villages are supplied with electricity. All the villages have drinking water supply. In all 6 post-offices cater to 24 villages.

(e) **Affected Villages**

Four villages are likely to be affected due to acquisition of land for various components and activities of the proposed Phata-Byung H.E project. All the villages are under the jurisdiction of Okhimath tehsil. The socio-economic profile of these villages is discussed in the following paragraphs.

10.4.5.4 Demographic profile of Affected Villages

Population of affected villages is comprised of Brahmins, Rajputs, Scheduled Castes and Scheduled Tribes. Total population of these villages is 1385 belonging to 258 households. Nyalsu is largest village while Byung is smallest. The average sex ratio is 918, which is maximum in Byung and minimum in Kungarh. The age group 0-6 years accounts for 16.68% of the total population. Scheduled Castes population is present in each village and accounts for 8.16% of the total population. Scheduled Tribes and OBCs are absent in these villages.

(a) **Educational profile**

The literacy rate ranged from 66.18 to 79.41% in affected villages, which is significantly higher in male population. All the villages have primary schools while only 2 middle schools are located in these villages for middle education. Only Nyalsu has schooling facility up to secondary education while there is no senior secondary school in any of the villages.

(b) **Occupation and cropping pattern**

Rice, wheat, millets and pulses are main crops in the affected villages. People rear cows, buffaloes, goats, sheep and oxen. In addition, villagers are engaged in the small scale business, government and non government services for their livelihood. About 48.23% of the total population makes work force in these villages. Of the total workers, 56.59% are main workers, dominated by the male workers. The marginal workers account for 43.41% of total workers, of which 33.38% are females.

10.4.5.5 Affected Families

A list of affected families along with their land holding and land to be acquired based upon the revenue records was procured from the project authorities. The socioeconomic profile of affected families is discussed below.

(a) **Demographic Profile**

The total population of affected families comprises of 181 with maximum in Nyalsu and minimum in Jurani. The sex ratio is 938. The age group 0-6 years accounts for 23.2% of the total population. Only two Scheduled Castes families are affected due to the project activity, which belong to Sitapur comprised of 14 members. None of the affected family belongs to OBC and ST categories.

(b) Educational Profile

The average literacy rate in affected families is 56.3% with a maximum of 71.4% in Kungarh. About 13.2% of total population has gone up to primary level education only, which goes down to 2.76% for post graduate level education.

(c) Livestock Population

Livestock population in the affected families comprises mainly of buffaloes, cows and oxen. Each family rears at least a cow or a buffalo. Though, milk is not a main source of income among these families. Five families in Rampur and two in Sitapur villages reared mule for their livelihood. Rearing of goat and sheep is not common among the affected families.

(d) Other amenities

All families have access to electrical supply and potable water. Thirteen families have a telephone connection and 10 families own television sets.

(e) Economy

The economy of the affected families depends mainly upon the agriculture, however, government services also strengthens their economy. 19 individuals among these families are engaged in government services and 16 own business. Rice, wheat, maize and finger millets are main crops grown by these families. The annual income per family ranges from Rs.20,000 to 5,00,000.

10.4.5.6 Community Development Work Done by Project Owner (Lanco)

(a) Employment Opportunities

LMHPL & its contractors are providing Employment to the Local people on the basis of their education. The first priority is given to the project affected families (due to land transfer).on the basis of their education we had given employment in skilled, semiskilled & unskilled categories.

Near about more than 250 local people are working as Employee with LANCO & its various contractors. On the basis of their educational qualification.

(b) Economic Opportunities

Award of the petty contract- The local people have been given contract of small activities like construction of drainage along the roads, protection works along new cuttings, plantation work, bush cleaning in the construction sites, etc. to benefit and facilitate economic opportunity.

Vehicle hiring- More than 20 No. of vehicles from Project Area Peoples (PAPs) have been hired and being used in different works. It has given good opportunity to the Local villagers to multiply their economic status.

Supply of Canteen Items is taken from Local shopkeepers.

(c) Social Welfare Activities

M/s LMHPL has been done/undertaking the following activities on regular basis for local area development as follow (Table 10.2)

Table 10.2: Activities undertaken by LMHPL for local area development

S. No.	Activities	Village
1	Construction of concrete Path from NH 109 TO Byung Village	Byung Village
2	Construction of Temple in Byung	Byung Village
3	Construction of path from CC korkhi village to Byung Village	Byung Village
4	Construction of water Tank & laying of Pipeline	Byung Village
5	Construction of CC path in byung village	Byung Village
6	Rehabilitation of Hanuman temple	Byung Village
7	Laying of Potable water pipe line	Byung Village
8	Financial aid to Mahila Mangal Dal	Byung Village
9	Distribution of School Uniform	In all the Primary Schools which come in the Project Area
10	Plantation along the Project Area by Van Panchayat & Mahila Mangal Dal	In all the Van Panchayat & Village Panchayat which come in the Project Area
11	Development of cremation path	Khumera Village
12	Development of cremation plateform	Khumera Village
13	Rehabilitation of Khumera Temple	Khumera Village
14	Construction of temple	Khumera Village
15	Construction of C.C path for	Narayankoti Village
16	Renovation of Temple	Narayankoti Village
17	Construction of culvert	Narayankoti Village
18	Providing utensils for marriage ceremoney and other purposes	Maikhanda Village
19	Rehabilitation of Maikhanda Temple	Maikhanda Village
20	Area development of maikhanda village temple	Maikhanda Village
21	Strengthening of Phata hospital Road	Phata Village
22	Construction of Phata Hospital Building	Phata Village
23	Construction of CC footpath at Khariya Village	Khariya Village
24	Construction of CC footpath at Khariya Village	Khariya Village
25	Construction of RCC culvert	Khariya Village
26	Construction of Toilets/bathrooms for Scholls	Khariya Village
27	Renovation works in Shiv Mandir	Khariya Village
28	Construction of cement concrete path for villagers at Adit III	Khat Village

S. No.	Activities	Village
29	Construction of Khat Temple	Khat Village
30	Construction of Bath room & toilet near Khat Temple	Khat Village
31	Construction of room adjecent to Khat temple.	Khat Village
32	Laying of water pipe line	Khat Village
33	Fencing of Play ground in Khat Village	Khat Village
34	Construction of boundary wall for khat village school	Khat Village
35	Construction for extention of existing boundry wall for khat village school	Khat Village
36	Construction of Boundary wall of Chandika temple	Jamu village
37	Laying of GI Pipe line in Jamu village	Jamu village
38	Construction of boundary wall for Jameshwar temple	Jamu village
39	Laying of new GI Pipe line in Jamu village	Jamu village
40	Construction of CC path for Panchayat Bhawan & Pri. School	Jamu village
41	Financial Aid to Mahila Mangal dal	Jamu village
42	Construction of Path for Ravigram Village	Ravigram Village
43	Development of Temple at Ravigram	Ravigram Village
44	Renovation of Panchayat Bhawan	Shersi Village
45	Renovation of Bhairavnath Temple	Shersi Village
46	Laying of Potable pipe line for shersi village	Shersi Village
47	Construction of concrete pavement footpath to sitapur village	Sitapur Village
48	Construction of CC path (450m length) in sitapur	Sitapur Village
49	Construction of CC path (350m length) in sitapur	Sitapur Village
50	Construction of RCC culverts in Sitapur	Sitapur Village
51	Repairing of CC Path in Sitapur	Sitapur Village
52	Construction of Road to Temple	Sitapur Village
53	Construction of Temporary school building in rampur Village	Rampur Village
54	Construction of temporary steel bridge in Rampur over Mandakini	Rampur Village
55	P/F hand railing in Rampur village	Rampur Village
56	Construction of Retaining wall for & Boundary wall for Durgamata temple	Rampur Village
57	Construction of RCC culvert for Jurani Village	Jurani Village
58	Construction of concrete path from existing NH109 to Tarsali village	Tarsali village
59	Laying of GI Pipe line in Tarsali village	Tarsali village
60	Financial Aid to Mahila Mangal dal	Tarsali village

S. No.	Activities	Village
61	Construction of Path to Kongarh Village	Kongarh Village
62	Construction of Tourist help center	Rudraprayag
63	Construction of Toilets & additional works for Tourist Help center st Rudraprayag	Rudraprayag

Figures 10.9 to 10.24 show various social welfare activities in the project areas.

(d) Medical facilities

In the project area we are providing medical facilities to the local villegers by visiting 17 villages and by conducting regular medical camps. One dedicated team of doctors, Pharmasists along with Mobile health vans (LANCO Mobile Health Service) is especially provided for local villagers.

(e) Hospital Renovation

To provide better medical facilities Lanco propose the up gradation /renovation of Phata Additional Primary Health Centre, the proposal was studied by Uttarakhand state Govt. & concerned Health Department & has been approved for the said activities by LANCO i.e. pathology lab, X-Ray & Labour rooms. Mega camp for ladies in the month of June 2010 and got good response from the villagers & local media. One Eye camp has been conducted on 19th Nov. & distributed reading glasses to the concern person.

(f) Celebration of Youth Day on 20th Nov. 2010

On this occasion we had organised various activities in Govt. Inter College Khumera & distribute the prizes for the winners of various competitions such as debate, painting, Essay writing etc.


केवल नौकरी करना ही नहीं पढ़ाई का मकसद : सिंगला

लैंको फाउंडेशन के तत्वावधान में जनचेतना कार्यक्रम आयोजित

छात्रवृत्ति देने की घोषणा

Fig 10.9 Media Coverage of the Youth Day Celebration

(g) Training

We are providing technical training to local unemployed youth as well as our own employees by short term (15-30 days) training program at different technical institutes. We have send 10 local Employees to ITI Srinagar for the short term technical training so far.

10.4.6 Singoli-Bhatwari HP

The proposed Singoli-Bhatwari HP Project of 99 MW capacity on Mandakini river is located near Kund village, tehsil Okhimath of Rudraprayag district in Uttarakhand. The proposed barrage site is connected by a metalled road to the nearest town of Okhimath situated about 6 km away.

Rudraprayag was recognized as a district by Uttar Pradesh government in 1997. The head quarter of district was established at Rudraprayag town, which connects Rishkesh and famous Hindu shrine Badrinath by a National Highway. The total geographical area of the district is 232 sq km, which harbours a total population of 2,27,439 with female to male sex ratio of 1115. About 98.7% of the total population is rural. Scheduled Castes and Scheduled Tribes populations account for 17.7% and 0.08%, respectively of the total population. The total literacy rate in the district is 62.02%.

District Rudraprayag is comprised of two tehsils namely Rudraprayag and Okhimath. Total population of Rudraprayag tehsil is 1,47,254 belongs to 31130 households and 434 villages. Scheduled Castes (SC) and Scheduled Tribes (ST) constitute 17.4% and 0.06%, respectively of the total population. The population in the age group of 0-6 years accounts for 15.69% of the total population. The sex ratio in Rudraprayag is 1139.

Okhimath tehsil is smaller as compared to Rudraprayag tehsil. Total population of Okhimath is 80,185 belongs to 16,409 households and 246 villages. The population of SCs and STs accounts for 18.1% and 0.11%, respectively of the total population. The population of age class 0-6 years comprises 15.9% of the total population. Sex ratio in the tehsil is 1070.

10.4.6.1 Educational Profile

Average literacy rate is more than 60%, which is slightly more in Okhimath tehsil as compared to that of Rudraprayag. Literacy rates in both the tehsils are considerably high in male population. Nearly 21% of the villages lack the primary educational facilities in both the tehsils. Single school caters to 3 villages in Rudraprayag and 4 to 5 villages in Okhimath tehsils for the middle standard educational facilities.

10.4.6.2 Health Facilities

There are 15 allopathic hospitals, 12 ayurvedic hospitals and 5 homoeopathic hospitals in the entire Rudraprayag tehsil. In Okhimath tehsli, there are 9 allopathic, 8 ayurvedic and 2 homoeopathic hospitals. The population of about 37,000 in

Rudraprayag and 80,000 in Okhimath depends only a single primary health centre while one primary health sub-centre serves a population of 24,500 in Rudraprayag and 20,000 in Okhimath.

10.4.6.3 Occupation Pattern

The economy of the villages in the area depends mainly on the government and non government services. In addition, livelihood of people depends on the agriculture, Rice, wheat, tomato, pulses are the main crops in area.

More than 45% of the total population comes under the worker category which slightly high or in the Okhimath tehsil. Female workers account for 55.4% of total work force with higher in Rudraprayag Tehsil (55.9%). Marginal workers contribute 25.4% of the total work force, dominated by females in both tehsils. About 55% of the total population comes in the non workers category.

10.4.6.4 Socio-economic profile of the project area

(a) Demographic Profile

A total of 85 villages are located in the proposed Singoli-Bhatwari HP project area, of which 20 villages belong to Rudraprayag tehsil and 75 belong to Okhimath Tehsil. Total population of these villages is 41,646 (81.2% alone in Okhimath), which belong to 8,592 households. SC population accounts for 17.8% of the total population in Rudraprayag tehsil while it is with little more in Okhimath tehsil. The percentage of ST population is negligible. Parkandi village is most populated while Mandali and Bedubagar villages are the least populated. The female to male sex ratio in the project area is 1100, which is higher in the Rudraprayag tehsil.

(b) Educational Profile

Average literacy rate in the villages of the project area is higher as compared to that of the district average. Overall literacy rate is 74.26% but it is significantly higher in the male population (91.92%). There is little variation in the literacy between the two tehsils, the villages is located in Okhimath tehsil have slightly higher literacy. On an average population of 411 and 490 is served by only one primary school in the respective tehsils. The ratio of middle and secondary schools to the population served in both the tehsils is low. For the higher education, there is a single college located in Daira village of Okhimath tehsil. There are only 9 secondary and 7 intermediate schools located in the project area.

(c) Health Amenities

The availability of health services in the proposed project area is poor. The villages of project area under the Rudraprayag tehsil do not have any allopathic, ayurvedic and homoeopathic hospital, primary health centre or primary health sub centre. The inhabitants of the villages under the Okhimath tehsil are served by from 4 allopathic hospitals, 1 ayurvedic hospital, 1 primary health sub-centre and 3 child welfare centres.

(d) Occupation Pattern

The general economical profile of the villages of the project area is similar to that of tehsils, which have been described above. Total work force is comprised of 44.6% with higher percentage of female workers. The main workers account for 74.5% of the total workers. The main as well as marginal workforce is also dominated by the females. A large number of inhabitants come under the non-worker category.

(e) Other Amenities

A total of 16 post-offices cater to the entire population of 85 villages out of which 6 are in Rudraprayag and 10 in Okhimath tehsil. Most of the villages have electrical supply.

10.4.6.5 Socio-economic Profile of the Affected Villages

A total of 8 villages are likely to be affected due to acquisition of land for various components activities of the proposed Singoli-Bhatwari HP project. Out of these, 6 villages fall under the jurisdiction of Okhimath tehsil while the villages Arkhund and Rayari fall under the Rudraprayag tehsil. The socio-economic profile of these villages is discussed in the following paragraphs.

(c) Demographic Profile

Population of affected villages is mainly comprised of Brahmins, Rajputs & Scheduled Castes and Scheduled Tribes. Total population of these villages is 5173 belonging to 1079 households. Jalai Sursal is largest village while Bashti is smallest. The sex ratio is 1161, which is maximum in Hat. The population in the age group of 0-6 years accounts for 14.5% of the total population. Scheduled Castes population accounts for 18.5% of the total population. Scheduled Tribes population is found only in Jalai Sursal village and constitutes only a small part of the population.

(b) Educational Profile

Average literacy rate in the affected villages ranges from 70.40 to 81.52% which is significantly higher in males. All villages have facility of primary schools while 5 middle schools cater to these villages for middle standard education. Only one senior secondary school is present in the Lamgondi village, which provides the intermediate education.

(c) Occupation and Cropping Patterns

Rice, wheat, maize and pulses are the main crops grown in the affected villages. People rear cows, buffaloes, goats, sheeps and oxen. In addition, villagers are engaged in the small scale business, government and non-government services for their livelihood. About 44% of the total population makes work force in these villages. Of the total workers, 67.4% are main workers, dominated by the female workers. The marginal workers account for 32.6% of total workers, in which females are 22.3%. A large number of villagers comes under the non-workers category, which includes mostly teanagers.

(d) Other Amenities

All affected villages are electrified and supplied with potable water. These villages have poor in medical health and communication facilities. Only an ayurvedic hospital is present in Lamgondi whereas post offices are located in Jalai Sursal and Arkhund villages.

10.4.6.6 Affected Families

Land holding data was taken on the basis of old revenue records. Therefore, the land presented is divided in many families. The various socio-economic aspects of affected villages are discussed below.

(a) Demographic Profile

The total population of affected families comprises of 2163 with maximum in Rayari village and minimum in Semi Talli. The sex ratio is 1021. The age group of 0-6 yrs accounts for 13.3% of the total population. Scheduled Caste population inhabits Lamgondi, Bashti, Phalai Tadiyal, Hat and Rayari villages and contribute 8.5% of the total population. None of the village harbours ST population while other backward caste (OBC) population is found in Hat village.

(b) Educational profile

The average literacy rate of affected families is 53.5% with maximum in Semi Talli. It is far below than the village average. About 13.5% of total population has got primary level education, which gradually decreased to 3% for post graduate level education.

(c) Livestock Population

Livestock population of the affected families comprises mainly of buffaloes, cows and oxen. Each family owns at least a cow or a buffalo. Although, milk is not a main source of income generation among these families. A few families in Bashti and Hat villages rear horse/ mule for their livelihood. The goat and sheep rearing is not common in these families, however, a few families of Bashti, Hat and Rayari kept goats and sheeps.

(d) Other Amenities

Almost all families have electric supply whereas drinking water is supplied through natural springs, tap and river. About 39 families are connected with telephones. A total of 47 families have access of television.

(e) Economy

The economy of the affected families depend mainly on the agriculture, however, government and non-government services also strengthens their economy. About 135 individuals among these are engaged in government and 50 individuals in non – government services, respectively. About 8 -10 families depend on the small scale business for their livelihood. Rice, wheat, maize and finger millets are main crops of these families. The annual income per family ranges from rupees forty thousand to rupees three lakhs.

10.4.6.2 Community Development Work Done by Project Owner (L&T)

- Construction of footpaths as connectivity with various villages.
- Renovation of Temple.
- Water tank for irrigation pool.
- Construction of cremation shed.
- Training for local people.
- Construction of computer training centres & coaching classes.
- Distribution of sewing machines.
- Police check post.
- Construction of maternity home.
- Construction of cow shed.
- Repair of canal.
- Mobile medical camps.
- Other (Donation to temple, mela, sponsor of sports activities,etc)

Fig. 10.10 Temple at Falai Village

Fig. 10.11 Sewing Centre at Village Singoli

Fig 10.12. Pathway to Village Basti

Fig. 10.13 Pathway to Village Banswara

Fig. 10.14 Medical Camp

Fig. 10.15 Computer Centre

Fig. 10.16 Cowshed at Augustyamuni

Fig. 10.17 Police Help Centre

Fig. 10.18 150 Traffic Sign Boards along NH-109

Fig. 10.19 Tree Plantation at Village Fali Fasalat

Fig. 10.20 Tree Plantation at Village Bhere

Fig. 10.21 Path for cremation Ghat (Damar Village)

Fig. 10.22 Sewing Machines to Local Villagers

Fig. 10.23 Maternity home at Kakola Village

Fig. 10.24 RCC Culvert at Kakola Village

(a) Tapovan Vishnugad HP

Tapovan Vishnugad HP 520MW located in Chamoli district of Uttarakhand. The project site is on the Dhauliganga and Alaknanda rivers in the Garhwal Himalaya. The barrage site is adjacent to Tapovan village, about 11 km upstream of the confluence of the Dhauliganga and Alaknanda rivers near Joshimath, next to the Joshimath Malari road 15 km southeast of Joshimath.

(b) Economic Development

Livestock grazing and cultivation are the dominant land-use activities in the area. The two cropping seasons are kharif (monsoon season, from April to October) and rabi (winter, from October to April). The major kharif crops are maize and pulses, while the main rabi crops are wheat, barley, mustard, and peas. Dryland cultivation is the dominant form of cropping, accounting for 85% of cultivated land in the area. Irrigation is practiced on terraced fields, where water is available. Fruit is also grown in small orchards in the area, as well as house garden crops.

Forest products harvested in the area include wood for construction, furniture, and implements; fodder; fuelwood; fruits and berries; medicines; and essential oils. Fishing is only a part-time activity; some of the catch is sold locally.

(c) Social and Cultural Resources

Twelve villages with a combined estimated population of 3,500 people are in the project area. The population consists of general caste (50.4%), scheduled tribes (39.2%), and scheduled castes (10.4%). The literacy rate is 43%. The main occupation is crop cultivation (78.3%); other agricultural activities (labor, livestock rearing) make up 3.5% and a range of occupations compose the remaining 18.2%. However, land is being acquired only from eight villages.

The local settlement pattern is characterized by the 12 small rural villages, plus the district center of Joshimath with its population of about 13,204. Eight of the local villages are accessible via kutchha road, three via pucca road, and three via foot tracks only. Medical facilities in the project area villages are poor; they are limited to a health center/hospital in Tapovan and child welfare centers in Tapovan and Lata. But the villages have well-developed educational facilities: a primary school in each village, middle schools in five villages, and a pre-university college in Tapovan. The major town of Joshimath is on National Highway (NH) 58, 12 km downstream of the barrage site. This town is the local service center, providing a base station for pilgrims/tourists visiting Shri Badrinathji, Hemkunt Sahib, and the Valley of Flowers.

Land and project affected persons are given in Table 10.3.

Table 10.3. Land and Project Affected Persons

Description	Quantity
Private Land (Ha)	62.228
Forest Land (Ha)	82.730
Total	144.958 Ha
Number of Villages affected	8
Homestead shifted from Project area	46
Number of Land Owners	841
Local village population affected	3072
Total Number of People Employed	1655
No. of people employed among PAPs	405
No. of people employed from Uttarakhand	1195
% of people employed from Uttarakhand	72.77%

(i) Community Development Work by Project Owner (NTPC)

The project owner has identified the areas for socio-economic development through community development programme, which includes:

- Pathways & Approach Roads to Project Affected villages
- Infrastructure Development
- Education
- Health
- Training
- Afforestation
- Natural Calamity

(ii) Work Done in Project Area

- Augmentation of Water supply system for villages Tapovan, Dhak, Chamtoli, Paini, Shalang & Behngule Cost. Rs.61.85 Lakhs.
- Construction of Temples, Bus Shelters, Anganwaris, Cremation Grounds & Prasuti Snan Grih
- Augmentation of rooms in schools.
- Development of infrastructure for Social & Cultural activities.
- Renovation & Strengthening of protection walls.
- Construction of Pathways & Drainage System in PAVs.
- Bridge on Dhauli Ganga to connect Belagarh (PAV).
- Installation of Street Lights in PAVs.
- Restoration of various Common Property Resources.
- Insurance of all Houses of Project affected Village Shelong.
- Augmentation of water supply scheme to Joshimath Town.
- Adopted ITI at Tapovan situated in project affected area.
- Financial support of Rs. 49.9 lakhs to Sri Badrinath-Kedarnath Mandir Samiti for renovation of various Temples & other activities.
- Two nos. Vocational Training Centre on Stitching & Weaving in every Project Affected Village.
- Assistance to Mahila Mangal Dal in every PAV to empower the Rural Women.

- Regular Health Camp & distribution of Medicine at PAVs.
- Financial support to strengthen Education, Sports, Art & Culture and sanitation.
- Electrification of Gaurikund – Kedarnath Road (Rs. 78.5 lakhs).
- Providing 5 nos. PCs each for Rath Mahavidyalaya, Pauri and Inter College, Maneri.
- Financial Assistance of Rs. 10 lakhs to Him Jyoti Foundation for creation of two perpetual scholarships in the name of NTPC.
- Financial Assistance towards CT scan and MRI equipment worth Rs 650 lakhs to Uttarakhand Forest Hospital Trust.
- Creation of NTPC chair at Doon University (Rs. 300 lakhs).
- Opening of Polytechnic at Kaladungi and Women's Polytechnic at Gopeshwar (Approx. Rs. 30 Crores).

Fig. 10.25 Street Lighting in Project Affected Villages

Fig. 10.26 Bridge & Pathway at Village Bhangul

Fig. 10.27 Shifting of Temple from its original place maintaining Archeological Structure of the Temple.

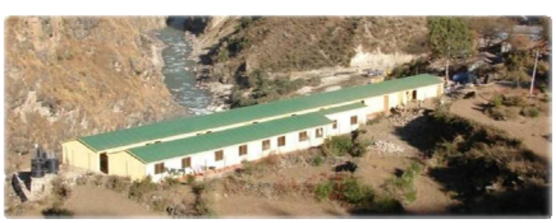


Fig. 10.28 Government Inter College (temporary) Village Tapovan

Fig. 10.29 Primary School at Village at Selong

Fig. 10.30 Footpath from NH-58 for Village Selong

Fig. 10.31 ITI adopted by NTPC at Joshimath

Fig. 10.32 Insurance Coverage-All project affected villages

Fig. 10.33 Wooden Flooring & Tile Work at Badrinath Temple

Fig. 10.34 Medical Camp in Project Affected Villages

(a) Alaknanda HP

The proposed Alaknanda HP project is located in the Joshimath tehsil of Chamoli district of Uttarakhand. District Chamoli is bordered by Tibet in the north – east, district Pithoragarh of Uttarakhand in the north – east, district Uttarkashi in north-west, district Rudraprayag in west, district Bageshwar in south –east and districts Pauri and Almora in south. District is divided into 7 sub-divisions (tehsils) namely Chamoli, Joshimath, Pokhari, Karanprayag, Gair Sain and Tharali. The total population of district Chamoli is 3,70,359 with a sex ratio of 1015. About 86.3% of the total population inhabits the rural areas. Total literacy rate of district is 75.4% with maximum in males. Joshimath is one the largest tehsils of Chamoli district in term of area. It is comprised of

93 villages and 27 notified wards. Total population of tehsil is 39,919 with a sex ratio of 774. Literacy rate of Joshimath tehsil is 78.8%. About 62.7% of the total population is rural.

Five villages and a notified ward are located in the 10 km radius of the proposed Alaknanda HP project. Total population of these villages is 4701, which belong to 1038 households. Badrinath is largest unit, however, the inhabitants are seasonal migrant. They reside it from mid April to September. Scheduled Castes (SC) and Scheduled Tribes (ST) account for 5.7% and 15.6% of the total population, respectively. These populations are absent in Lambagar village. An average literacy rate in these villages is 89.1% with considerably higher in males. Seven schools cater the facility of primary education, which is absent in Badrinath and Binaik. Middle schools are present in the Mana and Pandukeshwar villages while secondary school is located only in Mana village. Potato, beans and finger millets are main crops in these villages except Badrinath. The inhabitants of Badrinath are engaged in business activities. About 54.7% of the total population comes under the workers category. In which 38.3% are main workers and 16.4% are marginal workers. Land of Bardrinath town is notified, therefore, is not divided into different categories. Khirao is largest village, covers about 97% of the total land. About 37.6% of total land is forest land while 30.1% land is not available for cultivation.

Only 2 hamlets in the revenue Dewagni and Benakuli under the revenue village Khirao are affected due to the Alaknanda HP project. The socio-economic profile of affected village is described in the following paragraphs. Total population of Khirao village is 132 belonging to 44 households. The sex ratio is 1062. ST population accounts for 59% of the total population while SC population accounts for only 6%. An average literacy rate of the revenue village Khirao is 61.86%. The literacy is considerably higher in males (84.3%) as compared to that of females (39.78%). Only 2 primary schools cater to this revenue village. About 75.7% of the total population comprises total work force of the affected revenue village Khirao. In the total work force, main workers account for 98% while only 2% to the total work force comes in the category of marginal workers. About 24.2% of the total population is non-workers. Revenue village Khirao covers an area of 39139.4 ha, in which 15106.4 ha comes under the forest. About 30.65% of the area is not available for cultivation while only 0.08% is cultivable waste. Total unirrigated land accounts for 30.65%. There is no health facility available in this revenue village Khirao. The village has potable water supply. Post office facility is also available.

Total 12 families are affected due to proposed Alaknanda HP project, which were surveyed from the two affected villages of Khirao revenue village. The total population of affected families is 227 with maximum in Dewagni village and minimum in Benakuli. The sex ratio is 876. The age group of 0-6 yrs accounts for 6.60% of the total population. About 74.8% families belong to the Scheduled Tribe category among the total affected families. The average literacy rate of the affected families is 56.6% with maximum in Benakuli. Majority of the population is graduate i.e.16%, this percentage gradually decreases to 5% for primary level education. Livestock population of the affected families comprises mainly of goats, cows and oxen. Almost all families have electric supply and drinking water. About 9 families are connected with telephones. A total of 11 families have access of television. Most of the families use LPG and Kerosene for cooking purposes. The economy of the affected families depends mainly on agriculture, however, government services also strengthen their economy. About 51 individuals among these are engaged in agriculture, 34 individuals are engaged in government and private sector and 7 individuals are engaged in small scale business for their livelihood. Potato, Beans, Amaranths and vegetables are main crops of these families. The annual income per family ranges from rupees fifty thousand to rupees ten lakhs. The annual average income per family is around three lakhs.

The total land affected due to various project activities is 7.53 ha, which belong to 12 families of the two villages. The total land holdings of these families are about 11.6509 ha. The maximum land would be acquired from Benakuli village.

During field survey of the affected families of the Alaknanda HP Project it was observed that people were aware of the upcoming project. People gave positive as well as negative opinions about the proposed project as it was a matter of their infrastructural development and progress in the society besides loss of ancestral land. It was observed that out of the total people surveyed, around 70% of the people felt that due to constructional work of the project they will get more employment which is the basic need for sustaining their life. About 82% of the people surveyed felt that upcoming project would bring development to their area as it would improve educational, transportation and medical facilities. While 77% suggested that their area can become a tourist spot because of the barrage and powerhouse and most of the people are of the opinion that it would increase their welfare facilities and development. People were equally concerned about the adverse impacts due to project related activities. Around 77% of the people surveyed informed that their agricultural land will be lost due to acquisition and 38% of them felt that this will bring loss to their agricultural crops and this will further lead to decrease in crop production.

(b) Community Development Programme by Project Owner (GMR)

The project owner has worked on various areas for the upliftment of social, economical status of the project area. This includes:

(c) Education

- Working with 4 Anganwadis and reaching out to 48 children. Beautification of two Anganwadis was undertaken.
- School Bus facility for around 107 children.
- Creativity development activities and sports competitions for children in the schools
- Two After School Learning Centres at Lambagarh and Pandukeshwar covering 40 and 12 children respectively.
- Financial support to Kanhiya Chauhan, a student from the most deprived section of society (father not alive and mother handicapped) of GIC Pandukeshwar. He was highest scorer (75% marks) in Std.10 examination.
- Regular tuition support to the children by the Hydro Project Employee on Maths, English and Computer

(d) Health

- Availability of Ambulance service to the villagers of Pandukeswar and Lambagarh Gramsabha. A total 22 patients have availed the facilities in last six months.
- Regular health awareness meetings organized at project villages.

(e) Empowerment and Livelihood

- 16 SHGs are being promoted by the Foundation for social and economic empowerment of the rural women in the project villages in Uttarakhand. All SHGs are maintaining the documents as provided.
- Eight SHG members involved in plantation drive.

(f) Community Development

- Two community libraries are running in Pandukeshwar and Lambagarh villages where more than 550 visitors visited.
- In association with GMR Energy, Government schools, Forest Department, Management of Gurudwara Govindghat, Eco Development Committee Govindghat & Bhyundar GMRVF celebrated the World Environment Day.
- A tree plantation drive was organized in village Pandukeshwar in which a total 155 people including personnel of GMR energy, school children, teachers, forest department personnel and villagers participated.
- Vishwakarma Puja was celebrated at Lambagarh Village by GMRVF in association with GMR Badrinath HP.
- The 64th Independence Day was celebrated by the team of GMRVF and GMR Alaknanda Hydro Electric Project Team at Govt. Inter College, Pandukeshwar

(g) Education

Quality Education is a major programmatic area of the Foundation. Foundation has developed its own broad strategy to work with the Govt. education system. Foundation's interventions range from working with Anganwadis to working with schools. It works with children, their parents and other community members. In addition to the provision of infrastructural support and accessibility support, teachers' orientation, community mobilization, children's programs and other various activities are geared to improve the quality of education in the area.

(h) Working with Anganwadis

Anganwadis and other pre-schooling system provide institutionalized support for healthy development of children. Foundation works with four Anganwadis (two in Pandukeshwar Panchayat and two in Lambagarh Panchayat) and reaches out to 48 children. Foundation provided Teaching and Learning Materials and oriented the Anganwadi workers and helpers on the use of materials. Many creativity development activities like drawing and painting, sports and games etc. were organized for all Anganwadi children. Regular meetings are conducted with Anganwadi staff during their cluster meeting every month. This meeting provides a platform to reach out to other villages which are not under the area of Foundation.

(i) Accessibility Support to the Children

The hilly terrain of Uttarakhand and the scattered settlements pose a big challenge to children in terms of accessibility to schools. GMRVF provided a school bus to meet this challenge. The school bus is a big help to the children, especially for the girls who had to previously drop their education after primary level. Now the bus daily caters to the educational needs of an average 107 children from all the eight villages from the Foundation's working area. Occasionally the bus is also used for carrying the students for co-curricular activities like picnic cum exposure visit, sports competitions etc. The bus is being managed by the Grama Vikas Samiti (a people's group formed by the facilitation of the Foundation). The Samiti undertakes all the activities for the upkeep the of bus and ambulance services.

(j) Financial support to Gifted Children

On the request of PTA and teachers of GIC-Pandukeswar, the Foundation started supporting Kanhiya Chauhan, a student of GIC Pandukeshwar financially. He belongs to a very poor family whose father is not alive and mother is handicapped. He was the highest scorer (75% marks) in his Std. 10 examination.

(k) Tuition Classes

The Hydro Project (AHP) staff is voluntarily taking tuition for school going children. Mr. Amit Upraity, AHP is providing regular tuition on Mathematics to 8 children of Pandukeshwar village whereas the Preliminary English programme is being conducted by Mr. Anuj Verma, AHP. At present 5 girl students are attending the centre. Mr. Rajeev Kumar is conducting the computer literacy classes in the Pandukeshwar Library. At present 17 students (16 Girls & One Boy) are attending the class regularly.

(l) Various Activities Conducted at After School Learning Center (ASLC)

The After School Learning program was initiated to provide support to school going children from Lambagarh and Pandukeshwar villages. A total of 66 children are associated with this program. Drawing classes and general knowledge classes were organized for the ASLC children during the month of September. A General Knowledge test was organized in After School Learning Center (ASLC), Lambagarh for over 40 students. The winners were felicitated with prizes.

Teacher's day was organized in the Junior Hay School Lambagarh. Students presented cultural activities. The Foundation provided gifts to the teachers.

(a) Health

i) Ambulance services

Round the clock ambulance service has become the life line during emergency health needs of the people of this region. Ambulance service is also used for conducting the immunization program to the children and expecting mothers in various places. Ambulance service is also the senior itizens. During the last six months, 22 patients got benefitted by the Ambulance services.

A healthcare facility is being run at village Benakuli. Panchayat has provided the building free of cost to the Foundation to run the clinic. During this period more than 400 patients were counseled by the Paramedical Staff in the Health Centre, Bainakuli and the villages around the project.

Fig. 10.35. Teacher's day celebration in Lambagarh (Junior High School Lambagarh)

ii) Empowerment and Livelihood

Strengthening SHGs and reactivating village based Mahila Mandals, were some of the major initiatives of the Foundation.

iii) Strengthening of SHGs

16 SHGs have been formed by the Foundation with 160 members. Monthly meetings of SHG members are organized to discuss various social issues and take collective decisions, to keep the microfinance activities going and also to maintain the interest of the members. Foundation facilitates the meetings.

In order to revive the SHGs and their functioning, regular meetings were organized with the SHGs at different places. In the month of July, 14 meetings were organized with the SHGs. During the meeting, books of records and accounts were updated and the groups were reoriented on inter-loaning and record maintenance.

On 18 August 2010, forty members of four SHG groups of Lambagarh participated in the plantation drive organized by the Foundation and planted approximately 400 saplings on the wasteland & Salite-Joni area of Lambagarh Village. These SHGs also assured to take care of these saplings.

(b) Community Development
(i) Community Libraries

Two community libraries are running in Pandukeshwar and Lambagarh villages for improving the reading habits of the people and children. More than 550 visits happened in both the libraries.

(ii) Celebration of World Environment Day

World Environment Day was celebrated by GMRVF in association with GMR Energy, Government schools, Forest Department, Management of Gurudwara Govindghat, Eco Development Committee Govindghat & Bhyundar. A rally was organized by the children on the occasion which was followed by a cultural program led by the Children's Clubs of Pandukeshwar village. On this occasion, importance of sanitation and hygiene was communicated to the community through various programs by children.

(iii) Tree Plantation Drive

A tree plantation drive was organized in village Pandukeshwar in which a total 155 people including personnel of GMR energy, school children, teachers, forest department personnel and villagers participated. In the programme, 10 saplings were fenced and 24 flower pots were distributed.

(iv) Vishwakarma Puja Celebrations

Vishwakarma Puja was organized at Lambagarh Village by GMRVF in association with GMR Badrinath HP. All the members of GMR foundation, GMR Energy & villagers actively participated in puja & prayed for better future, safe working conditions; smooth functioning of various machines and above all success in their respective fields.

(v) Independence Day Celebration

Independence Day was celebrated by the team of GMRVF and GMR Alaknanda Hydro Electric Project Team at Govt. Inter College, Pandukeshwar. Students from 5 different schools and villagers of Pandukeshwar and nearby villages participated in the celebrations.

(vi) Employee Engagement

- The Alaknanda Hydro Project (AHP) staff, Mr. Amit Upraity , Mr. Anuj Verma and Mr. Rajeev Kumar are voluntarily taking tuition classes on Maths, English and Computer respectively for children.
- The Hydro project team participated in the World Environment Day celebrations.
- 155 people including personnel from GMR energy participated in the tree plantation drive organized at Pandukeshwar Village.
- Vishwakarma Puja was celebrated at Lambagarh Village by GMRVF in association with GMR Badrinath HP.

Hydropower Project Team at Govt. Inter College, Pandukeshwar.

Students from 5 different schools and villagers of Pandukeshwar and nearby villages participated in the program. The program was inaugurated by Mr. Vijay Kumar Singh, GMR. In the programme, children from different school presented colorful cultural programs. After the program GMR distributed prizes to the winners of different category.

As a whole Table 10.4 indicates the targets and achievements of such programmes.

Table 10.4. Achievement Oriented Programme Targets vs. Achievements

AOP Target	Half Yearly Targets	Target Vs. Achievements
Education	To support 4 Anganwadi centres (Two in Pandukeshwar and one in Arudi and Parghati each) for quality Early Child Care Services	4 Aganwadi centers were provided with TLMs and sitting mat Supported AWW in the enrollment of children
	To support 6 Government Schools (Inter College Pandukeshwar, Junior High School Lambagarh, Primary School Vinayakchatti, Lambagarh Primary School, Primary School Pandukeshwar, Primary School Govidghat) by organizing child centered activities	155 people including personnel of GMR energy, school children (from 5 schools), teachers, forest department personnel participated in tree plantation. Teacher's day organized in Junior School Lambagarh. Regular activities by at Bal Sansad organized.
	To run After School Learning Classes so that 48 students of Std. 8 and 10 could get effective support to improve their academic performance	48 students of class 8th to 10th of getting support from 02 ASLCs Creative activities organized regularly
	To provide regular School Bus services for more than 100 children of Project villages.	Total 107 children benefitted regularly from School Bus. 57 students from 5 different schools taken to block to participate sports programme
	To run tuition involving the Hydro Project (AHP) staffs are voluntarily taking tuition classes of school going children.	Mr. Amit Upraity, Mr. Anuj Verma and Mr. Rajeev Kumar are conducting Maths, English and computer classes A total 30 students benefitting from the tuition classes
Health	To provide Emergency Ambulance services to the project villages (2 Panchayats)	A total 26 patients of the project area availed the ambulance services
	To organize 2 Health camps in the project area with the help of district hospital.	Not organized (Due to rain, landslide and the unavailability of the doctors at the PHC.)
	Organize health check-up for the senior citizens once every month	The Foundation have examined 57 patients Medicines were provided free of cost to the needy patients.

AOP Target	Half Yearly Targets	Target Vs. Achievements
	To provide medical services to the villagers of Benakulli village from one medical clinic	More than 300 patients have received treatment and medicine from the clinic.
Empowerment and Livelihood	To strengthen 16 Self Help Groups in the project villages	A total 14 meetings have been organized. 4 groups of Lambagarh participated in plantation drive organized and planted approximately 400 saplings. In the month of September 40 more participants in Arudi village participated in the plantation drive.
Community Development	To provide a space to 150 children and villagers to access information and enhance their knowledge from the reading materials and magazines	2 community libraries covered more than 550 users
	To organize community events to encourage the participation of the villagers as well as the employees of the hydro electric project team	Independence Day was celebrated by the team of GMRVF and GMR Alaknanda Hydro Electric Project Team at Govt. Inter College, Pandukeshwar. AHP employees took part in a Viswakarma Puja was organized at Lambagarh.

10.5 IMPACTS OF HYDROPOWER PROJECTS DURING CONSTRUCTION

Construction of a hydropower project generally takes several years. During construction phase large-scale excavation of rocks, disposal of muck, construction of temporary and permanent roads and civil components of projects are the major activities. Moreover, during this period problems of noise and air pollution, damage to forests, displacement of population and change of landuse at site also takes place. There are direct socio-economic impact due to direct and indirect employment opportunities, migration of labour force etc. These impacts can be of temporary or permanent in nature and can have either negative or positive effects. Once the construction of the HP project is completed and it becomes operational, only very limited constructional activities related with reclamation of the area takes place.

Thus, it is important and necessary to document and monitor the impact of hydropower projects during construction phase. For the present study few projects in the Alaknanda valley have been investigated during construction period of the projects. Significant impacts during the construction of hydropower projects were identified through network method (Fig. 10.36). Most of the components were studied in the field during the visit to the project sites. Surroundings of the project sites were surveyed, concerned stakeholders were interviewed. Significant amount of data was also obtained from the project authorities.

10.5.1 Impacts of Hydropower Projects during Construction in Alaknanda Valley

In the Alaknanda valley, five power projects have been commissioned, namely Badrinath II, Vishnuprayag, Urgam, Rajvakti, and Vanala. Following projects are under construction, Tapovan Vishnugad, Visnugad Pipalkoti, Phata Byong, Singoli Bhatwari, and Srinagar.

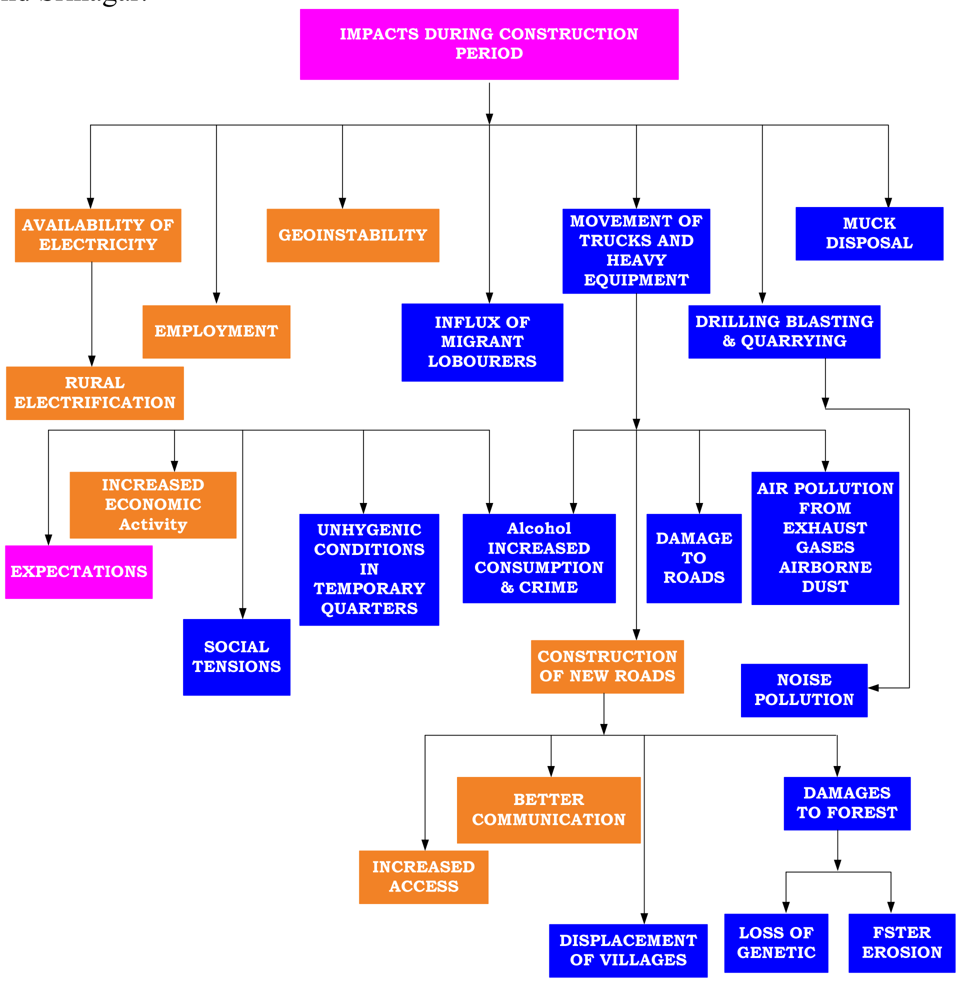


Fig. 10.36. Identifying the impacts during construction of hydropower projects

10.5.2 Geological Instability

In the Alaknanda Basin due to construction of hydropower projects any significant permanent impact on geological stability has not been noted. Visnuprayag HP is a major commissioned project of the area. Lambagarh slide close to the barrage site is an old slide mass which gets activated in the monsoon period. It seems that during the road construction the stable profile of glacial deposit occurring in the form of a wedge was disturbed and at later stages the runoff water activated the slide. A similar type of slide occurred in the upstream of diversion site of Urgam project in the much interior area where any kind of construction was not going on. There is no data to correlate this slide to the construction of the project. However it is possible that due to blasting in the area the cohesiveness in the loose sediments of glacial deposits was reduced and percolation of water increased during monsoon period which might have played a role in the activation of the slide. The slide needs a stable profile through bench cuttings otherwise backward movement of slide will keep on growing. A new face has started developing in the same area.

Recently, subsidence in Chain village just close to the power house cavity of Vishnuprayag project was observed. Villagers claimed that their settlements have been affected by blasting and tunnelling resulting in partial subsidence. Government of Uttarakhand had appointed a number of committees to find out the facts. As per the project authorities no finding has been reported to them; however, they have paid compensation to 22 villagers. It seems that the subsidence in the village located on old slide debris has taken place by the natural process.

Vanala HP is located on the Nandakini River. Surface power channel has been constructed over here. Due to cutting of platform for power channel, hill slope has been eroded at a number of places (Fig. 10.37). The reclamation of these slopes is in progress. Any other impact on stability of area is not observed.

Fig. 10.37. Erosion of slopes due to construction of power channel platform

Rajwakti HP is also located on the Nandakini River close to Vanala project on downstream side. At this project site, any damage or slope erosion is not observed, as they have been fully reclaimed. None of the projects under construction have shown any type of rock failure or mass flow. At the same time none of the project has triggered any landslide. In the Tapovan Vishnugad project in the TBM section of tunnel at a place water has gushed in the tunnel with very high speed and in huge quantity (700 lps). At this place considerable damage has been done to the equipment and the project progress. In this section work has been hampered since last seven months. Due to TBM operations the damage in the tunnel segment has been considerably checked.

Recently, in the month of March 2011 in the Asiganga I project due to collapse of half broken rocks few causalities have taken place. The accident was purely due to human error. Before removal of half broken over hanging material from the platform, for power channel, the drilling for further blasting was started, this caused the fall of overhanging material resulting in fatal accident.

10.5.3 Muck disposal

Nearly all the projects under construction have fairly long tunnels resulting into creation of huge amount of muck. Part of this muck is consumed in the civil work of the project and remaining quantity is dumped in the area.

Muck disposal is being done in proper manner at most of the places. In most of the projects these activities are being regularly monitored by MoEF. At Tapovan Vishnugad and Phata Byong projects, to contain the disposed muck, they have constructed RCC retaining walls along with wire crated boulder walls (Fig. 10.38 and 10.39). Similar to these projects, other projects are also disposing the muck properly (Fig. 10.40). At the same time at several places in nearly all the projects these retaining walls either have not been constructed or have been damaged due to over loading.

Fig. 10.38. Muck disposal sites of TapovanVishnuprayag HP

Fig. 10.39. Muck disposal sites of Phata Byong HP

At Srinagar project disposal of muck is being done in unplanned manner into the Alaknanda River. It needs corrective measures to avoid undesirable environmental effects.

Slope erosion due to dumping of muck and cutting of road and platforms etc. are also not noted at the sites of commissioned projects. It seems that during course of time the eroded surfaces have been reclaimed. At one place near the surge shaft site muck was observed disposed all over the slope (Fig. 10.41 (a) to Fig. 10.41 (c)). This area has not been reclaimed so far.

Field observations clearly point out that damages to the slopes of valleys during construction period can easily be reclaimed in due course of time.

10.5.4 Loss of Ground Water

In general ground water occurrence in the rocks is always poor. It is retained in the weathered and sheared and fractured zones only. Water is generally encountered while excavating tunnel. This water may come from sources in the nearby vicinity of tunnel or from a distant source. In some projects like Vishnugad project large amount of water is reported to have flooded the TBM section of tunnel. There was a discharge of 700 lps, which came down to 120 lps in several months. In case of Phata Byong, an adit portal was planned close to a spring which resulted in drying of the spring. To avoid such incidences in future the local geology and distribution of springs needs to be investigated carefully before project construction especially for excavation of tunnel.

Fig.10.41(a). Disposal of muck along the river in the Srinagar HP. At places wire crated boulder retaining walls have been placed.

Fig. 10.41(b). Muck disposal along Alaknanda River in Srinagar HP projects without any retaining walls.

Fig. 10.41(c). A view of Srinagar HP project. Constructed channel and haphazard dumping of material are seen

10.5.5 Employment

Nearly each project is trying to absorb local population for different works as per the provisions in the NOC's. They do not require any infrastructural facilities like accommodation etc. The local population invariably do not want to take up the job of labour, but are interested in the jobs of guards, cook, supervisor etc. This has posed a number of problems to the project developers, and has resulted in higher indirect employment over direct employment one.

Locals have provided taxies on regular basis to all the projects. They are also carrying out petty jobs at the sites. In this way locals are being benefitted in one or the other way.

In the Tapovan Vishnugad project, 210 locals have been employed and 35 vehicles have been hired from them. In the Phata Byong project 324 persons from Uttarakhand have been employed and 35 taxies have been engaged on permanent basis. At the same time they have hired accommodation at 33 places to accommodate their work force. Similarly Singoli Bhatwan Project has also provided employment to locals.

10.5.6 Influx of Migrant Labourers

In all the projects, skilled and unskilled labourers have been brought from outside area, though locals have been given priority over others. This labour force is camped in properly developed shelters with hygienic conditions as per guidelines of MoEF and Pollution Control Boards. Skilled personnel are being accommodated in the own constructed shelters and also in the rented houses in the nearby vicinity. This has caused a pressure on the limited accommodation available in these remote places. The high demand of accommodation by HP projects has resulted in higher rentals, which is causing inconvenience to the government staff and others looking for rented accommodation in the area.

This influx of manpower pressurises the demands on local resources also. This has both positive and negative impacts. Locals get opportunities to trade the goods of daily needs and eatables.Nearly in all projects and understanding has been reached between project management and locals that all the supplies of ration etc. will be through them only.

An indicative estimate of employees during construction stage and operation stage are given in the Table. 10.5 and 10.6.

Table 10.5: Number of employees for operation of hydropower station (Indicative)*

S. No.	Project Name	Name of River / Tributary	Installed capacity (MW)	Number of employees for operation for commissioned project	Number of employees for operation for projects under construction	Number of employees for operation for all allotted projects	Number of employees for operation for all commissioned and under development projects
COMMISSIONED							
1	Agunda thati	Dharam-ganga	3	25	25	25	25
2	Badrinath II	Rishi ganga	1.25	25	25	25	25
3	Bhilangana	Bhilangana	22.5	25	25	25	25
4	Debal	Kailganga	5	25	25	25	25
5	Jummagad	Jummagad	1.2	25	25	25	25
6	Maneri bhali I	Bhagirathi	90	300	300	300	300
7	Manaeri bhali-II	Bhagirathi	304	300	300	300	300
8	Pilangad	Pilangad	2.25	25	25	25	25
9	Rajwakti	Nandakini	3.6	25	25	25	25
10	Tehri stage-I	Bhagirathi	1000	300	300	300	300
11	Urgam	Kalpganga	3	25	25	25	25
12	Vanala	Nandakini	15	25	25	25	25
13	Vishnuprayag	Alaknanda	400	300	300	300	300
UNDER CONSTRUCTION							
1	Bhilangana-III	Bhilangana	24		40	40	40
2	Birahi Ganga	Birahi Ganga	7.2		25	25	25
3	Kail ganga	Kailganga	5		25	25	25
4	Kaliganga-I	Kaliganga	4		25	25	25
5	Kaliganga-II	Kaliganga	6		25	25	25
6	Koteshwar	Bhagirathi	400		300	300	300
7	Lohari Nagpala	Bhagirathi	600		300	300	300

S. No.	Project Name	Name of River / Tributary	Installed capacity (MW)	Number of employees for operation for commissioned project	Number of employees for operation for projects under construction	Number of employees for operation for all allotted projects	Number of employees for operation for all commissioned and under development projects
8	Madhmaheshwar	Mandakini	10		25	25	25
9	Phata Byung	Mandakini	76		150	150	150
10	Rishi Ganga	Rishi ganga	13.2		25	25	25
11	Singoli Bhatwari	Mandakini	99		250	250	250
12	Srinagar	Alaknanda	330		300	300	300
13	Tapowan Vishnugad	Dhauliganga	520		300	300	300
14	Vishnugad Pipalkoti	Alaknanda	444		300	300	300
UNDER OTHER STAGES OF DEVELOPMENT							
1	Alaknanda	Alaknanda	300			300	300
2	Asiganga-I	Asiganga	4.5			25	25
3	Asiganga-II	Asiganga	4.5			25	25
4	Asiganga-III	Asiganga	9			25	25
5	Balganga-II	Balganga	7			25	25
6	Bharon Ghati	Bhagirthi	381			300	300
7	Bhilangna-II A	Bhilangana	24			40	40
8	Bhilangna-II B	Bhilangana	24			40	40
9	Bhilangna-II C	Bhilangana	21			40	40
10	Bhyundar ganga	Bhyundar ganga	24.3			40	40
11	Birahi Ganga-I	Birahi ganga	24			40	40
12	Birahi Ganga-II	Birahi ganga	24			40	40
13	Bowla Nandprayag	Alaknanda	300			300	300

S. No.	Project Name	Name of River / Tributary	Installed capacity (MW)	Number of employees for operation for commissioned project	Number of employees for operation for projects under construction	Number of employees for operation for all allotted projects	Number of employees for operation for all commissioned and under development projects
14	Devsari	Pinder	252			300	300
15	Dewali	Nandakini	13			25	25
16	Gohana Tal	Birahi ganga	50			70	70
17	Jadh Ganga	Jadhganga	50			70	70
18	Jalandharigad	Jalandhari	24			40	40
19	Jelam Tamak	Dhauliganga	126			150	150
20	Jhala koti	Balganga	12.5			25	25
21	Kakoragad	Kakoragad	12.5			25	25
22	Kaldigad	Kaldigad	9			25	25
23	Karmoli	Jadhganga	140			150	150
24	Khirao ganga	khaiaoganga	4			25	25
25	KotBudhakedar	Balganga	6			25	25
26	Kotli Bhel-I A	Bhagirathi	195			100	100
27	Kotli Bhel-I B	Alaknanda	320			300	300
28	kotli Bhel-II	Ganga	530			300	300
29	Lata Tapovan	Dhauliganga	170			100	100
30	Limcha Gad	Limcha Gad	3.5			25	25
31	Malari Jelam	Dhauliganga	114			150	150
32	Melkhet	Pinder	15			25	25
33	Nand prayag Lan	Alaknanda	100			150	150
34	Pala Maneri	Bhagirthi	480			300	300
35	Pilangad- II	Pilangad	4			25	25
36	Ram Bara	Mandakini	24			40	40

S. No.	Project Name	Name of River / Tributary	Installed capacity (MW)	Number of employees for operation for commissioned project	Number of employees for operation for projects under construction	Number of employees for operation for all allotted projects	Number of employees for operation for all commissioned and under development projects
37	Rishi Ganga-I	Rishi ganga	70			150	150
38	Rishiganga II	Rishi ganga	35			50	50
39	Siyangad	Siyangad	11.5			25	25
40	Suwari Gad	Suwari Gad	2			20	20
41	Tamak Lata	Dauliganga	250			250	250
42	Tehri stage-II	Bhagirathi	1000			100	100
43	Urgam-II	Kalpganga	3.8			25	25
	TOTAL			**1425**	**3515**	**7820**	**7820**

*Indicative only – Based on the current practice observed at the some of commissioned hydropower projects

Table 10.6: Number of employees for construction at hydropower projects

				Under construction At Present			Under development			All projects		
S. No.	**Project Name**	**Name of River / Tributary**	**Installed capacity (MW)**	**Number of construction employees**	**Project construction period**	**Local population**	**Number of construction employees**	**Project construction period**	**Local population**	**Number of construction employees**	**Project construction period**	**Local population**
UNDER CONSTRUCTION												
1	Bhilangana-III	Bhilangana	24	100	3	100				100	3	30
2	Birahi Ganga	Birahi Ganga	7.2	100	2	50				100	2	25
3	Kail ganga	Kailganga	5	30	2	30				30	2	15
4	Kaliganga-I	Kaliganga	4	30	2	30				30	2	15
5	Kaliganga-II	Kaliganga	6	30	2	30				30	2	15
6	Koteshwar	Bhagirathi	400	2100	4	100				2100	4	100
7	Lohari Nagpala	Bhagirathi	600	2100	4	100				2100	4	100

				Under construction At Present			Under development			All projects		
S. No.	**Project Name**	**Name of River / Tributary**	**Installed capacity (MW)**	**Number of construction employees**	**Project construction period**	**Local population**	**Number of construction employees**	**Project construction period**	**Local population**	**Number of construction employees**	**Project construction period**	**Local population**
8	Madhmaheshwar	Mandakini	10	100	2	50				100	2	50
9	Phata Byung	Mandakini	76	1000	3	100				1000	3	100
10	Rishi Ganga	Rishi ganga	13.2	150	2	100				150	2	50
11	Singoli Bhatwari	Mandakini	99	1000	3	100				1000	3	100
12	Srinagar	Alaknanda	330	2100	4	100				2100	4	100
13	Tapowan Vishnugad	Dhauliganga	520	2100	4	100				2100	4	100
14	Vishnugad Pipalkoti	Alaknanda	444	2100	4	100				2100	4	100
	TOTAL			**13040**		**1090**				13040		1090
UNDER OTHER STAGES OF DEVELOPMENT												
1	Alaknanda	Alaknanda	300				2100	4	100	2100	4	100
2	Asiganga-I	Asiganga	4.5				30	2	30	30	2	15
3	Asiganga-II	Asiganga	4.5				30	2	30	30	2	15
4	Asiganga-III	Asiganga	9				100	2	50	100	2	50
5	Balganga-II	Balganga	7				100	2	50	100	2	50
6	Bharon Ghati	Bhagirthi	381				2100	4	100	2100	4	50
7	Bhilangna-II A	Bhilangana	24				100	3	100	100	3	50
8	Bhilangna-II B	Bhilangana	24				100	3	100	100	3	50
9	Bhilangna-II C	Bhilangana	21				100	3	100	100	3	50
10	Bhyundar ganga	Bhyundar ganga	24.3				100	3	100	100	3	50
11	Birahi Ganga-I	Birahi ganga	24				100	3	100	100	3	50
12	Birahi Ganga-II	Birahi ganga	24				100	3	100	100	3	50

				Under construction At Present			Under development			All projects		
S. No.	Project Name	Name of River / Tributary	Installed capacity (MW)	Number of construction employees	Project construction period	Local population	Number of construction employees	Project construction period	Local population	Number of construction employees	Project construction period	Local population
13	Bowla Nandprayag	Alaknanda	300				2100	4	100	2100	4	100
14	Devsari	Pinder	252				2100	4	100	2100	4	100
15	Dewali	Nandakini	13				150	2	100	150	2	50
16	Gohana Tal	Birahi ganga	50				100	3	100	100	3	50
17	Jadh Ganga	Jadhganga	50				100	3	100	100	3	50
18	Jalandharigad	Jalandhari	24				100	3	100	100	3	50
19	Jelam Tamak	Dhauliganga	126				1000	4	100	1000	4	100
20	Jhala koti	Balganga	12.5				100	2	50	100	2	50
21	Kakoragad	Kakoragad	12.5				100	2	50	100	2	50
22	Kaldigad	Kaldigad	9				100	2	50	100	2	50
23	Karmoli	Jadhganga	140				100	4	100	100	4	500
24	Khirao ganga	khaiaoganga	4				30	2	30	30	2	15
25	Kot Budha kedar	Balganga	6				30	2	30	30	2	15
26	Kotli Bhel-I A	Bhagirathi	195				1000	4	100	1000	4	100
27	Kotli Bhel-I B	Alaknanda	320				2100	4	100	2100	4	100
28	kotli Bhel-II	Ganga	530				2100	4	100	2100	4	100
29	Lata Tapovan	Dhauliganga	170				1000	4	100	1000	4	100
30	Limcha Gad	Limcha Gad	3.5				30	2	30	30	2	15
31	Malari Jelam	Dhauliganga	114				1100	4	100	1100	4	100
32	Melkhet	Pinder	15				100	2	50	100	2	50
33	Nand prayag Langasu	Alaknanda	100				1000	4	100	1000	4	100
34	Pala Maneri	Bhagirthi	480				2100	4	100	2100	4	100

				Under construction At Present			Under development			All projects		
S. No.	Project Name	Name of River / Tributary	Installed capacity (MW)	Number of construction employees	Project construction period	Local population	Number of construction employees	Project construction period	Local population	Number of construction employees	Project construction period	Local population
35	Pilangad- II	Pilangad	4				30	2	30	30	2	15
36	Ram Bara	Mandakini	24				100	3	100	100	3	50
37	Rishi Ganga-I	Rishi ganga	70				100	4	100	100	4	50
38	Rishiganga II	Rishi ganga	35				250	3	100	250	3	60
39	Siyangad	Siyangad	11.5				150	2	100	150	2	60
40	Suwari Gad	Suwari Gad	2				30	2	30	30	2	15
41	Tamak Lata	Dauliganga	250				1100	4	100	1100	4	100
42	Tehri stage-II	Bhagirathi	1000				1000	4	100	1000	4	100
43	Urgam-II	Kalpganga	3.8				30	2	30	30	2	15
							24490		3440	37530		2990

10.5.7 Noise Pollution / Blasting

Noise pollution is being caused by the movement of trucks and heavy equipments in the project areas. Blasting is another irritating source of noise in and around the project sites.Excavations at the project sites are being done through blasting. It is an essential activity during hydropower project construction for roads, headwork's (diversion tunnel, diversion dam, intakes, sedimentation chambers etc works), headrace tunnel, adits and the powerhouse complex. Tunnel size in all the projects is above 5.5 m, which means blasting is to be done with higher charge.

Humans are quite sensitive to motion and noises that accompany blasting. Vibrations and noise from blasting can be highly irritating and injurious in case it is regularly repeated over a long period. It can also lead to various behaviourial and physical changes in humans. Blasting produces both the ground and air borne vibrations which excite walls, rattle windows and dishes, and together tend to produce more noise inside a structure than outside. It may cause development of cracks is in the houses or ground in the immediate vicinity.

A number of agitations have been made by locals against blasting in all of the projects. Local inhabitants remain concerned about blasting leading to cracks in houses, waking people including children, pregnant women, and those with illnesses; and rerouting or loss of water sources.

In 1998 there was a court case related to blasting for the Vishnuprayag HP in which after two years clearance for about 50 and 75 blasts per day for both the project site and the proposed bypass road was allowed (Diduck et al, 2007). Villagers had been alleging that blasting continued with as much as 125 blasts per day.

The affect of blasting on wildlife and domestic animals is also noticeable in the area. Even animals and birds get a shock due to noise and vibrations due to which their behaviour changes. Once they get use to it then only their behaviour changes back to normal.

Impact of blasting in the surrounding areas of operation had been a source of complaint by locals at every place of works. Management of every project has got the blast induced ground vibrations and air overpressure monitored at different distances through various government agencies. Now every project is adopting blasting practices under the guidance of these institutions. The basting practice being adopted by various is generally based on the experimental studies carried out by a group of experts from various institutes. Tapovan Vishnugad project is adopting 18 hole cycle with 1 blast per day per face. Phata Byong project is carrying out two blasts per day in each face with 50 to 60 holes cycle. Singoli Bhatwan Project is taking 4 to 5 blasts per day with 76 to 80 holes cycle. With higher numbers of holes having alternate changing and delayed sequence of blasting minimum vibrations are generated. It has been found true in the various monitoring studies carried out in the area.

10.5.8 Air Pollution

Air pollution is considerable at the project sites during the construction period due to plying of vehicles and earth moving equipments. Blasting in open areas also contributes to the air pollution in the area. Gaseous pollution is also higher in these areas due to exhaust fumes from these vehicles and equipments deployed there. Project authorities are getting the air pollution monitored through established laboratories and their results show slightly higher or normal values of air pollution over the prescribed limits. In general water is being sprinkled over the roads to settle the airborn dust.

10.5.9 Water Pollution

Water around the project sites is found to be rich in turbidity and suspended solids due to flow of fines from excavations. Sedimentation chambers have been invariably constructed at the outlet of tunnels, still certain amount of suspended solids goes in to river. Due to increased human and animal activity slight increase in organic pollution of water also takes place.

10.5.10 Social Impacts

It is observed that in the vicinity of projects power supply has become better and people are satisfied with it. On the other hand, people remain in pressure and tension due to fear from blasting, resettlement and revenue loss/gain. A considerable time is wasted in planning the agitations and strategies. There are instances of excess drinking in the area and tendency of depression is also developing fast.

Protests on various issues by local villagers as well as by group of villagers are very common. Forced stoppage of works at the site, demonstrations, hunger strike etc. are common features in the area. Most of the agitations are taking place due to lack of information regarding the project development to the villagers.

There are unlimited benefits which locals are receiving through these projects. Common benefits are in the form of better improved facilities in the field of health, eduction, transport, communication, water supply, employment, business opportunities etc. Nearly every project has constructed rural roads to facilitate the villagers. At number of places various extension services centres have been opened for direct benefit of rural people.

10.5.11 Impacts on Landscape

Outstanding wilder ness landscape of Alaknanda and its tributaries especially Dhauliganga is going to have immense effect due to rapid urbanization, network of roads and dominating engineering structures. Reduced vegetation will also degrade the landscape quality in the area.

Cumulative impact of succession of projects will urbanize large segment of rivers and the project structures will adversely affect the visual and aesthetic beauty of the area, which is known for its serene, great tranquillity and wilderness.

10.5.13 Environmental Resources

A number of Hydropower Projects fall in the buffer zones of Valley of Flowers and Nanda Devi Biosphere Reserve (Figs.10.42 and 10.43). Nearly all the projects have submitted EIA reports to MoEF and have taken clearances except Bhyunderganga HP which also falls within 10 km radius from Valley of Flowers. So far any adverse impact due to the construction of these projects has not been reported from the sensitive zones. Rambara project falls on the boundary of Kastura Mrag Vihar, which is an important project to save the endangered species of deer family. With the improved infrastructural facilities due to these projects, tourism in these rare locations will increase.

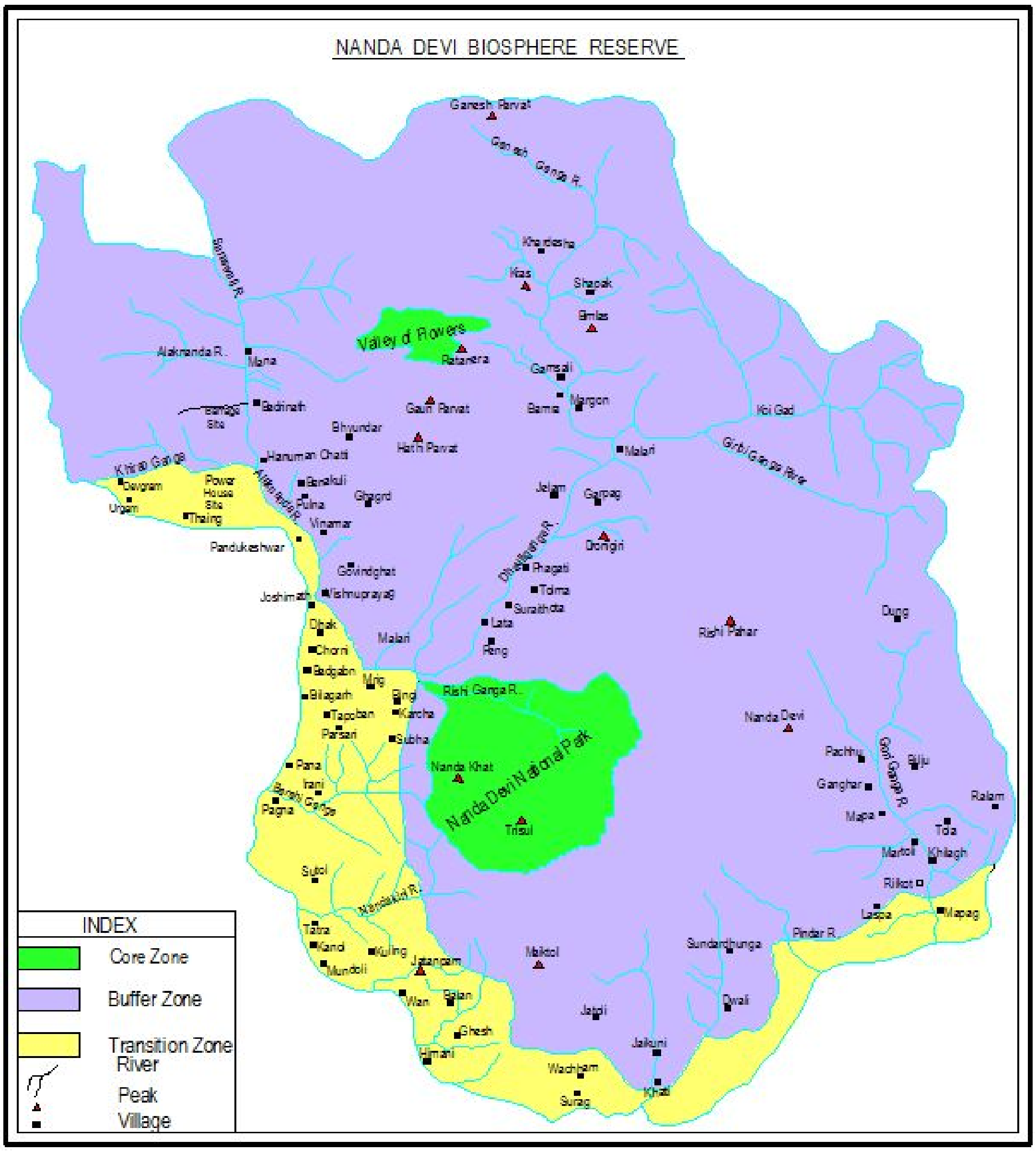


Fig. 10.42. Map of Nanda Devi Biosphere Reserve

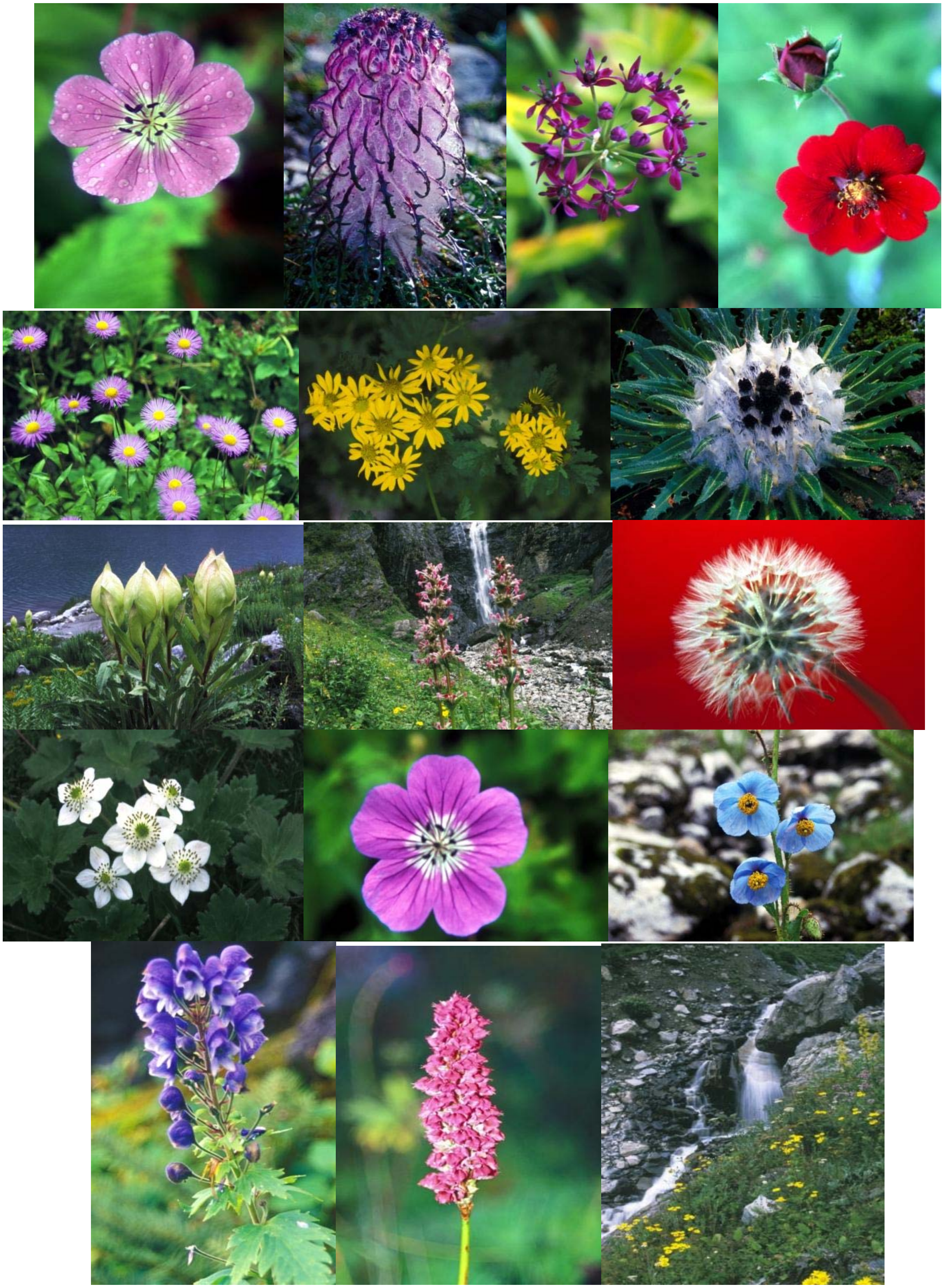


Fig. 10.43. Some of the precious flowering species of Valley of Flower

10.5.13 Deforestation

Each project is denuding forest land to large extent depending upon the capacity and length of the tunnel. For compensatory afforestation, developers giver money to government, and Forest Department is taking care of plantation in the area on the land double the size acquired by the HP operators.

Other than the aforestation scheme plantation is also being done under the catchment area development plan by the Forest Department. Work on these schemes has not started yet.

Nearly all the developers are having their own scheme for plantation under Corporate Sector Area Development Programmes. Singoli Bhatwari project has so far planted 53445 saplings in the area falling within 13 villages. Success rate is only 35%. Phata Byong project has so far planted 14400 plants. They have not checked the success rate of their plantation programme. Tapovan Vishnuprayag project has also done massive plantation on large scale but the success rate is poor.

10.5.14 Post Construction Impacts

No systematic data on this aspect is yet available, as the projects in Alaknanda valley are all very new and mostly under construction.

The network identifying the post construction impact of Dam based and RoR projects are given in the Fig. 10.44 and 10.45. Following are the possible positive impacts of HP projects.

- After implementation of the scheme the problems generated during the construction will die out automatically.
- Better infrastructural facilities in the field of health, education, communication, water supply etc. will be available in the area, which will improve the living standard of the people.
- Increased income will change the economic status of the people.
- The creation of the tourism related avenues will provide permanent source of earnings to the locals of the surrounding areas.
- The overall social environment will improve.
- Aforestation will create better forest in the region.
- Agricultural activities will be more paying.
- People will adopt dairy, poultry, piggery etc. as additional source of income due to increased demand and faster communication with the markets.

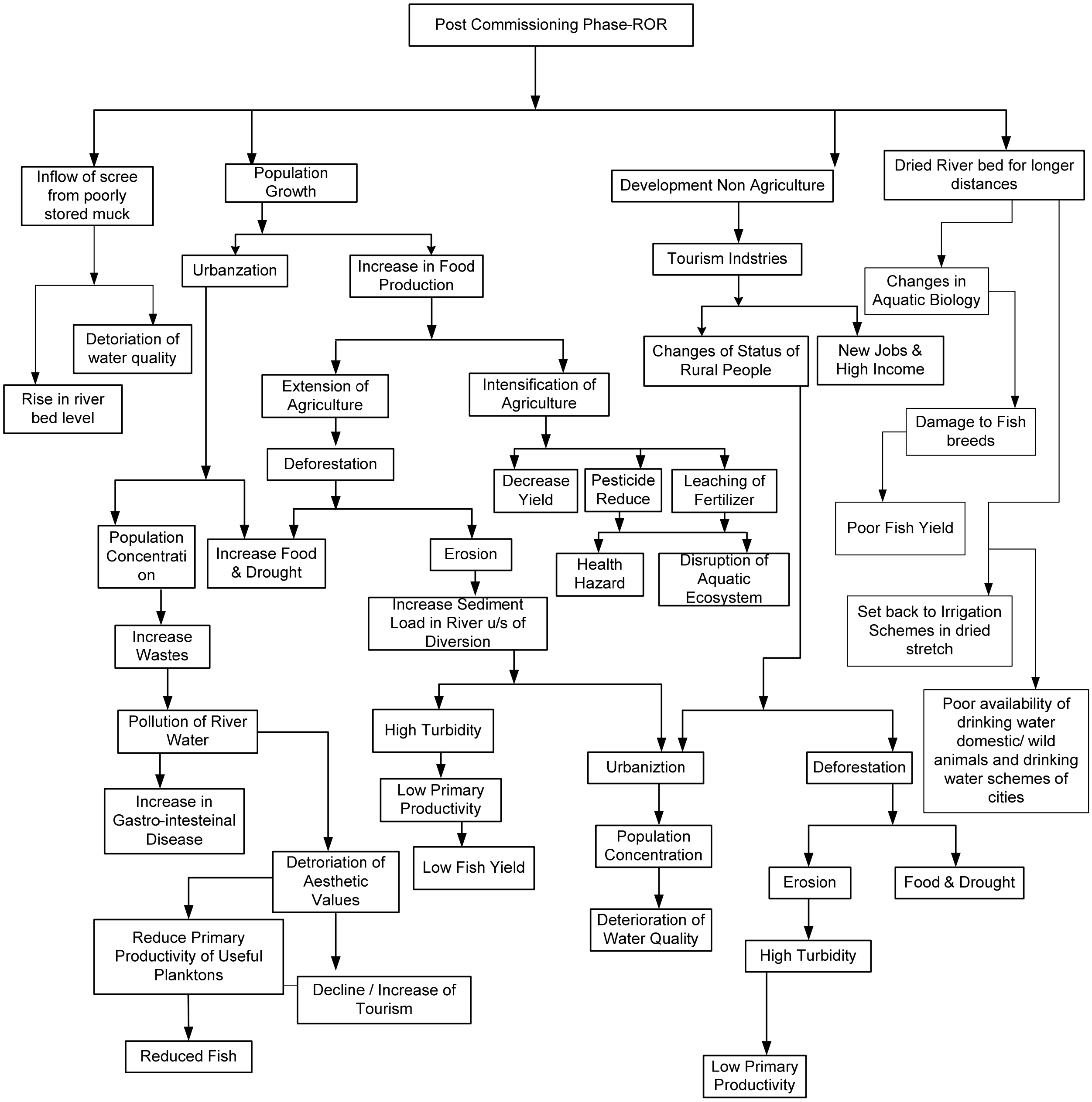


Fig. 10.44 Networking identifying the impacts after the commission of HP project

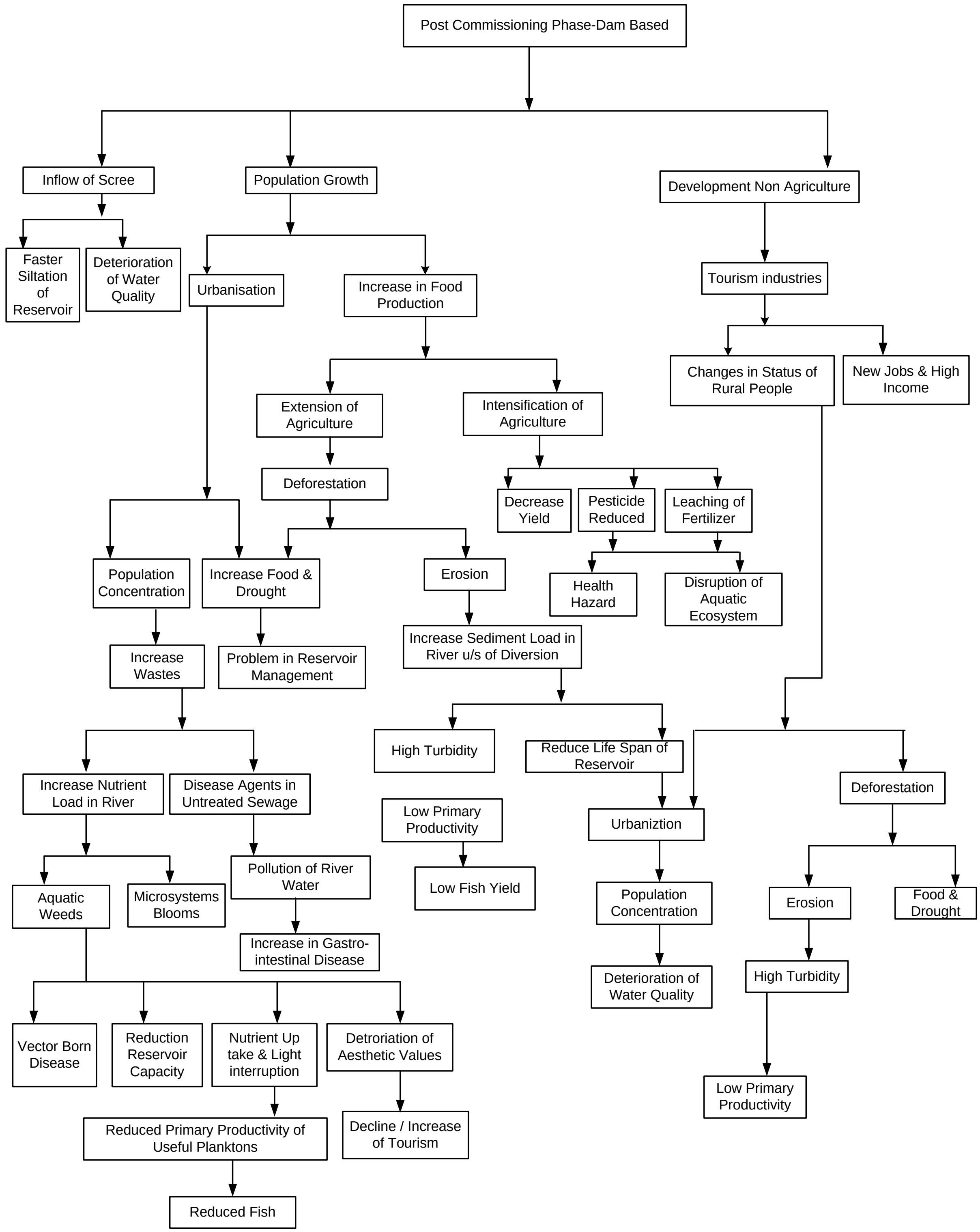


Fig. 10.45 Network identifying the impacts after the commissioning of ROR Project

10.6 SUBMERGENCE AREA AND AFFECTED VILLAGES

The only major projects in this region which is causing large submergence is the Tehri dam (Table-10.7). Submergence under Tehri reservoir is 500 ha and nearly 60% of it (3182 ha) is forest area. This reservoir is also responsible for submergence of 1000 Ha of agriculture land and 95 villages.

Besides Tehri, the submergence due to the remaining projects is about 1400 ha is land and so villages which is a relatively small number.

Table 10.7: Submerged Area and River stretches for Bhagirathi and Alaknanda Basin

S. No.	Project Name	Project Owner	Name of River/ Tributary	IC (MW)	Submerged Area (Ha)	Reserve Forest / Pasture including River bed Land	Barren/Civil Forest Land (Ha)	Agricultural/Private Land (Ha)	Villages Submerged	River Stretch Submerged (km)
1.	Karmoli	THDC	Jadh Ganga	140	9.94	0.84	9.1	0	0	0.8*
2.	Jadh Ganga	THDC	Jadh Ganga	50	8.35	0	8.35	0	0	0.8*
3.	Pala Maneri	UJVNL	Bhagirthi	480	20	19.24	0	0	0	1.1*
4.	Maneribhali I	UJVNL	Bhagirathi	90	UA	1.42	0	0	0	1.2
5.	Tehri stage-I	THDC	Bhagirathi	1000	5200	3182	1018	1000	95	44.0
	Tehri stage-II	THDC	Bhagirathi	1000	5200	3182	1018	1000	95	44.0
6.	Koteshwar	THDC	Bhagirathi	400	250	2	218	30	16	20.7
7.	Kotli Bhel-IA	NHPC	Bhagirathi	195	217.27	143.3	68.4	5.47	11	22.0
8.	Phata Byung	LANCO	Mandakini	76	3.68	2.97	1.03	0	0	0.5
9.	Rishiganga-I	UJNVL	Rishi ganga	70	6.2	4.34	1.86	0	0	0.5*
10.	Rishiganga II	UJNVL	Rishi ganga	35	1.65	1.49	0.16	0	0	0.1*
11.	Vishnugad Pipalkoti	THDC	Alaknanda	444	24.5	24.5	0	0	0	7.0
12.	Devsari HE	SJVN	Pinder	252	70	60	0	10	1	10.0

S. No.	Project Name	Project Owner	Name of River/ Tributary	IC (MW)	Submerged Area (Ha)	Reserve Forest / Pasture including River bed Land	Barren/Civil Forest Land (Ha)	Agricultural/Private Land (Ha)	Villages Submerged	River Stretch Submerged (km)
13.	Srinagar	GVK	Alaknanda	330	324	66	2.73	25.4	24	13.1*
14.	Kotli Bhel-I B	NHPC	Bhagirathi	320	502.347	251.7	202	48.5	28	27.0
15.	Kotli Bhel-II	NHPC	Ganga	530	607.569	401	189	14.9	13	31.2

Submerged River length not available in the DPR, thus were measured on the basis of
L (m) = Submergence Area in Hactares X 10000 / Dam width in meters.
Hence this River length can be taken as minimum River Streatch submerged.

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उत्तरांचल UTTARANCHAL

00AA 113567

: : **इकरारनामा** : :

यह इकरारनामा आज दिनांक सितम्बर सन् 2006 को स्थान घनसाली टिहरी गढ़वाल में श्री सुमरेसिंह निदेशक तकनीकी स्वास्ति पावर इंजीनियरिक लि0 हाल कार्यालय सेमली (गिरगॉवं) घनसाली– जिला टिहरी गढ़वाल एतद पश्चात इस इकरारनामे का–

प्रथम पक्ष

एवं

ग्राम पंचायत सरूणा पट्टी केमर तहसील घनसाली जिला टिहरी गढ़वाल श्रीमती माया देवी प्रधान ग्राम पंचायत सरूणा तथा श्री देवसिंह रमोला अध्यक्ष भिलंगना बांध परियोजना निजिकरण विरोधी संघर्ष संगठन समिति फलेण्डा पट्टी–नैलचामी तहसील घनसाली जिला टिहरी गढ़वाल एतद पश्चात इस इकरारनामें का–

द्वितीय पक्ष

यह कि प्रथम पक्ष एवं द्वितीय पक्ष के मध्य 29–9–2005 को श्रीमान उप जिलाधिकारी घनसाली की अध्यक्षता में हुई वार्ता तथा 2–12–2005 को श्रीमान जिलाधिकारी महोदय टिहरी गढ़वाल की अध्यक्षता में हुई वार्ता एवं 4–5–2006 को श्रीमान आयुक्त गढ़वाल मण्डल पौड़ी की अध्यक्षता में हुई वार्ता में हुई सहमति के आधार पर यह इकरारनामा निष्पादित किया जाता है। दोनों पक्ष इस इकरारनामें की शर्तों का पालन करने के बाध्य रहेगें। उपरोक्त सन्दर्भित वार्ताओं में हुई सहमति के आधार पर इस इकरारनामें की शर्त इस प्रकार करार पाई गई।

1– जन सुनवाई डी0पी0आर0 एवं ई0आई0ए0 की रिपोर्ट आदि तकनीकि विन्दुओं पर भारत सरकार के सम्बन्धित विभाग से स्वीकृति प्राप्त है। ग्रामीणों के प्रतिनिधियों द्वारा माननीय न्यायालय नैनीताल में जिन विन्दुओं पर रिट याचिका दायर की गई है। कोई भी समझौता नहीं किया जा रहा है। न्यायालय द्वारा पारित निर्णय का सभी पक्ष सम्मान करेगें।

2– ग्राम सरूणा की डाउनस्ट्रीम की नहर को कम्पनी अपने वियर से जोड़ने हेतु सहमत है, एवं नहर के हेड से वियर तक के भाग में यदि कोई क्षति होती है तो उसके मरम्मत का उत्तरदायित्व कम्पनी लेने हेतु सहमत है। नहर का रख रखाव एवं संचालन ग्रामवासी स्वंय करेगें। ग्रामीणों द्वारा इस व्यवस्था पर सहमति दी गई।

सिंचाई घराट इत्यादि सभी आवश्यकताओं का आंकलन ग्रामीणों की उपस्थिति में करा लिया गया है। ग्रामीणों हेतु आवश्यकतानुसार पानी निरंतर उपलब्ध करवाया जायेगा,दाह संस्कार इत्यादि कार्य हेतु नदी में पर्याप्त

कमशः–2//

For Swasti Power Engineering Limited

Director (Technical)

ग्राम पंचायत सरूणा
दिनांक 3-11-2-1-
वि० ख० भिलंगना (टिहरी-गढ़वाल)

अध्यक्ष/उपाध्यक्ष
भिलंगना घाटी बाँध विरोधी संगठन
ग्राम सरूणा टिहरी गढ़वाल

भारतीय गैर न्यायिक

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Rs.20

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पानी उपलब्ध रहेगा। यदि ग्रामीण अतिरिक्त पानी नदी में उपलब्ध करवाने की मांग करते है तो आवश्यकतानुरूप दाह संस्कार सम्पन्न होने तक नदी में पानी उपलब्ध रहेगा।

सिचांई हेतु ग्रामीणों को आवश्यकतानुसार पानी उपलब्ध करवाने का दायित्व जिला प्रशासन का होगा एवं जिला प्रशासन द्वारा कम्पनी प्रबन्धन से उक्त व्यवस्था सुनिश्चित कराई जायेगी। कृषि योग्य क्षेत्रफल हेतु पानी का आंकलन लघु सिंचाई विभाग से करवाने के उपरान्त आवश्यकतानुसार पानी पहले ग्रामीणों को दिया जायेगा। तद्परान्त परियोजना हेतु उपलब्ध होगा।

3 – परियोजना निर्माण के दौरान एवं निर्माण के वाद कम्पनी स्वास्थ्य शिविर लगाकर ग्रामीणों का स्वास्थ्य परीक्षण करायेगी। परियोजना के कारण यदि कोई व्यक्ति घायल या दुर्घटनाग्रस्त होता है तो कम्पनी नियमानुसार उचित मुआवजा देगी।

4– एक कान्वेन्ट स्कूल प्रभावित ग्रामों हेतु प्रभावित ग्राम सभाओं द्वारा चयनित स्थान पर निर्मित किया जायेगा। इस विद्यालय के निर्माण एवं अन्य व्यवस्थाओं तथा 5 वर्ष का संचालन का व्यय कम्पनी वहन करेगी। विद्यालय के संचालय हेतु कमेटी प्रभावित ग्राम सभाओं द्वारा गठित की जायेगी।

5– परियोजना में कोई पृथक से क्वैरी नहीं लगनी है, टनल अथवा अन्य कार्यो में निकलने वाले पत्थर आदि का प्रयोग किया जायेगा, आवश्यकतानुसार ही नदी से पत्थर आदि का प्रयोग किया जायेगा। परियोजना निर्माण के दौरान एवं उपरान्त नदी में उपलब्ध रेत/पत्थर आदि का प्रयोग ग्रामीण पूर्ववत नियमानुसार करते रहेगें।

6– ग्रामीणों के द्वारा घास व चारा पत्ती पर प्रतिकर की मॉग की गयी इस पर प्रभागीय वनाधिकारी द्वारा अवगत कराया गया है कि घास चारा पत्ती हेतु राज्य सरकार की 95 प्रतिशत भूमि पूर्ववत्त उपलब्ध रहेगी। मात्र 05 प्रतिशत भूमि पर अस्थाई रूप से प्रतिकूल प्रभाव पड़ने की सम्भावना है। कम्पनी को हस्तान्तरित भूमि राज्य सरकार की भूमि है एवं इसका स्थानान्तरण समस्त औपचारिकताओं की पूर्ति उपरान्त किया गया है तथा राज्य सरकार की भूमि का प्रतिकर ग्रामीणों को नहीं दिया जा सकता। इस भूमि पर चारा पत्ती के नुकशान की भरपाई हेतु प्रभागीय वनाधिकारी द्वारा प्रस्ताव दिया गया है कि ग्राम में जल्दी विकसित होने वाली घास लगाई जा सकती है एवं चारा पत्ती के पौधों का वृक्षारोपण कर भूमि पर पूर्ववत चारा पत्ती प्राप्त की जा सकती है। इस पर ग्रामीणो द्वारा सहमति दी गयी है। घास चारा पत्ती हेतु प्रतिपूरक वृक्षारोपण आदि हेतु प्रदत्त धनराशि का उपयोग हेतु ग्राम सभाओं के माध्यम से प्रभावित ग्रामों में कराया जायेगा।

क्रमशः–3//

r Swasti Power Engineering Limited

Director (Technical)

ग्राम पंचायत

दिनांक.........

अध्यक्ष

बिरधी घाटी बांध विरोधी संगठन

टिहरी गढ़वाल

भारतीय गैर न्यायिक

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उत्तरांचल UTTARANCHAL

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6– परियोजना निर्माण से यदि ग्रामीणो की फसल क्षतिग्रस्त होती है तो कम्पनी उसका प्रतिकर देगी। तथा यदि कोई निजि भूमि परियोजना में अतिरिक्त प्रयोग में लाई जाती है तो इस हेतु ग्राम में दिये गये अधिकतम दर से कम्पनी भुगतान करेगी।

7– परियोजना का निर्माण कार्य **Turnky basis** (टर्नकी बेसिस) पर उत्तराचंल शासन के साथ हुए अनुबन्ध के अनुसार कराया जा रहा है, फिर भी परियोजना निर्माण में प्रभावित ग्रामवासियों को आवश्यकता एवं योग्यतानुसार यथा सम्भव संख्या में बेरोजगारों को रोजगार देने के लिये सहमत है। ग्रामीणों की मांग पर कम्पनी प्रबन्धन द्वारा स्थानीय स्तर पर किये जा सकने वाले कार्य स्थानीय ग्रामीणों से करवाये जाने पर सहमति दी गई है। कम्पनी प्रबन्धन द्वारा लगभग 25 कर्मचारियो को परियोजना निर्माण के उपरान्त आवश्यकता बताई गई, जिसमें से 09 पदों पर विशुद्ध रूप से तकनीकि एवं अनुभवी कर्मचारियों की आवश्यकता होगी जबकि शेष 16 पदों पर प्रभावित ग्राम सभाओं के साथ बैठकर संख्या तय कर प्रभावित चार ग्रामों के योग्य व्यक्तियों को रखा जायेगा।

8– ग्रामीणों की मांग पर विभिन्न ग्रामीण विकास कार्यो एवं विभिन्न प्रकार की असुविधा को दृष्टिगत रखते हुए कम्पनी द्वारा ग्राम सभा फलेण्डा एवं सरूणा हेतु एक बार एक मुश्त चार लाख रूपये देने हेतु सहमत है। इसका वितरण सम्बन्धित ग्राम सभायें परस्पर कर लेगी।

9– ग्रामों में चलने वाले विभिन्न विकास कार्यो हेतु कम्पनी ग्राम सभा फलेण्डा को एक लाख दस हजार एवं ग्रामसभा सरूणा को 50,000 हजार रूपये प्रतिवर्ष विद्युत उत्पादन की तिथि से देने पर सहमति दी गई।

10– परियोजना क्षेत्रान्तर्गत सभी सिविल सुविधाओं को चिन्हित कर वीडियो ग्राफी, फोटोग्राफी कर ली जायेगी एवं परियोजना निर्माण से यदि इन पर कोई प्रतिकूल प्रभाव पड़ता है तो जिला प्रशासन कम्पनी प्रबन्धन से वैकल्पिक व्यवस्था सुनिश्चित करायेगा जिसका व्यय कम्पनी वहन करेगी।

11– झूला पुल जूनियर हाई स्कूल का उच्चीकरण एवं गांवों में आन्तरिक मोटर मार्ग हेतु जिला प्रशासन द्वारा राज्य सरकार को संस्तुति सहित सन्दर्भित किया जायेगा। तथा समय–समय पर इसका अनुश्रवण किया जायेगस।

For Swasti Power Engineering Limited

Director (Technical)

क्रमशः–4//

ग्राम पंचायत सरूणा
दिनांक
पो० चिलंगना (टिहरी–गढ़वाल)

भिलंगना घाटी बाँध विरोधी संगठन
टिहरी गढ़वाल

भारतीय गैर न्यायिक

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12– प्रभावित ग्रामों को निःशुल्क विजली उपलब्ध कराना एक नीतिगत मामला है इसे जिला प्रशासन द्वारा शासन को सन्दर्भित किया जायेगा।

13– परियोजना के शेयर ग्रामीणों को निशुल्क दिये जाने का प्रकरण नीतिगत है तथा इसे राज्य सरकार को जिला प्रशासन के माध्यम से सन्दर्भित किया जायेगा।

14– एक हैण्ड पम्प ग्राम सरूणा हेतु सड़क के किनारे ग्रामवासियों द्वारा चयनित स्थान पर कम्पनी लगवाने हेतु सहमत है।

15– ग्राम सरूणा के मुर्दाघाट तक जाने वाले मार्ग पर पी.सी.सी. लगवाने हेतु तथा मुर्दाघाट पर एक टिन शेड मुर्दा जलाने हेतु बनवाने हेतु कम्पनी सहमत है।

16– ग्राम सरूणा में सड़क के किनारे ग्रामवासियों द्वारा चयनित स्थल पर एक प्रतीक्षालय बनवाने हेतु कम्पनी सहमत है। इस हेतु ग्रामीण निःशुल्क भूमि उपलब्ध करायेंगे।

सभी ग्रामीणों द्वारा निर्धारित कार्यक्रमानुसार परियोजना निर्माण में कोई व्यवधान न डालने पर सहमति दी गई एवं पूर्व में कार्य में व्यवधान डालने तथा शांति भंग करने हेतु चल रहे मुकदमा समाप्त करने की मांग की गई बैठक में उप जिलाधिकारी महोदय द्वारा अवगत कराया गया कि न्यायालय परगना मजिस्ट्रेट घनसाली में ग्राम फलेण्डा/ सरूणा के ग्रामीणों पर कोई भी शांन्ति भंग का मुकदमा वर्तमान में नहीं चल रहा है।

कमशः–5//

For Swasti Power Engineering Limited

Director (Technical)

ग्राम पंचायत सरूणा

अध्यक्ष/उपाध्यक्ष

भिलंगना घाटी बाँध विरोधी संगठन

ग्राम सरूणा टिहरी गढ़वाल

उत्तरांचल UTTARANCHAL

0QAA 113571

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अतः यह इकरारनामा आज दिनॉक 14–09–2006 को स्थान न्यायालय परिसर घनसाली जिला– टिहरी गढ़वाल में दोनो पक्षो ने अपने–अपने स्वस्थचित स्थिर बुद्धि बिना किसी नशीली बस्तु का सेवन किये एवं बिना किसी के डराये धमकाये स्वइच्छा से लिखवाकर व दोनो पक्षो ने सोच–समझकर पढ़कर व सुनकर साक्षीगणों के समक्ष अपने–अपने हस्ताक्षर कर दिये हैं। ताकि सनद रहे और बक्त जरूरत पड़ने पर प्रमाण को काम आवे।

प्रथम पक्ष

द्वितीय पक्ष

प्रधान ग्राम पंचायत

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Director (Technical)

इस इकरारनामे पर दोनो पक्षकारों ने हमारी उपस्थिति में हस्ताक्षर किये।

Sohan सोहनलाल पुत्र शिवराम ग्राम लस्या, पट्टी कैमर

दयाशंकर

दयाशंकर

टीकाराम S/O गोवर्धन प्रसाद

टीकाराम

लुद्री पट्टी जोशी पुत्र मक्खन लाल ग्राम लस्या पट्टी कैमर

हरीलाल

हरीलाल पुत्र स्व. श्री महानन्द

शिवप्याली

शिवप्याल पुत्र शिवराम ग्राम लस्या पट्टी कैमर

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उप जिलाधिकारी घनसाली टिहरी गढ़वाल

अनुबन्ध/इकरारनामा

हमकि हिम उर्जा प्राईवेट लिमिटेड प्रधान कार्यालय ई–14, ईस्ट आफ कैलाश, नई दिल्ली हाल ग्राम तैफना पटवारी वृत गंगरोली तहसील–कर्णप्रयाग, जिला–चमोली, उत्तराखण्ड द्वारा कार्यरत बतौर श्री एम0 के0 श्रीवास्तव पुत्र आर0 पी0 श्रीवास्तव, परियोजना प्रबन्धक व श्री संजय शर्मा चीफ जनरल मैनेजर पुत्र श्री निर्मयसिंह जोकि आगे चलकर प्रथम पक्ष कहलायेगा और ग्राम प्रधान चोपड़ाकोट द्वारा श्रीमती विजयलक्ष्मी सती, प्रधान ग्राम पंचायत चोपड़ाकोट पटवारी वृत माणखी तहसील चमोली स्वयं व ग्राम पंचायत चोपड़ाकोट की जनता की ओर से जोकि आगे चलकर द्वितीय पक्ष कहलायेगी, आपस में अपने होश हवास व पूर्ण स्वतंत्रता से यह अनुबन्ध एक दूसरे के हक में इस प्रकार लिख देते है/–

1– कि प्रथम पक्ष की हिमउर्जा प्राईवेट लिमिटेड कम्पनी है जोकि वर्तमान समय में बनाला विद्यत जल परियोजना का कार्य कर रहा है।

2– कि प्रथम पक्ष तोनला गधेरे से नाग देवता के मंदिर तक सी0सी0 रोड ढाई फीट का निर्माण कर देगी। और अपने खर्च पर ही मार्ग बनायेगी।

3– कि नाग देवता का सौन्दर्याकरण व मंदिर का निर्माण भी प्रथम पक्ष अपने खर्च पर करके देगा।

4– कि प्रथम पक्ष महिला मंगल दल के लिये दो दरी 12 x 12 फीट की देगा।

5– कि किक्रेट मैदान का निर्माण नवयुवक मंगल दल के लिये प्रथम पक्ष करके देगा तथा मैदान निर्माण के लिये पुराने पत्थरों का प्रयोग प्रथम पक्ष करेगा।

6– कि ग्राम सभा चोपड़ाकोट के अन्तर्गत ग्राम तोनता से सिंचाई/पेयजल/पनचक्की/घराट एवं शव दाह के लिये विनाकिसी रूकवाट को पानी उपलब्ध प्रथम पक्ष करायेगा। शव दाह गृह गांव के द्वारा उपलब्ध कराई गयी जमीन पर प्रथम पक्ष करायेगा और विघुत व्यवस्था भी उपलब्ध करायेगा।

7– प्रथम पक्ष अपनी आवश्यकता एवं योग्यता अनुसार ग्राम सभा (द्वितीय पक्ष) के बेरोजगारों को जो ग्राम तोनता के दृ परिवार–वार कम्पनी व नियमों बशर्तो के आधार पर स्वर्ग रोजगार देना। जो कम्पनी के रहने तक लागे होगा।

8– कि द्वितीय पक्ष प्रथम पक्ष कम्पनी को जमीन उपलब्ध कराता है तो कम्पनी आवश्यकतानुसार अपने कर्मचारियों के लिये आवास की व्यवस्था करेगी। ग्राम तोनला के लिये वर्तमान सूची अनुसार (सहमति अनुसार) प्रथम पक्ष कम्पनी देगी।

9– कि परियोजना के निर्माण के दौरान ग्राम सभा के किसी भी व्यक्ति या सामान का नुकसान होता है तो कम्पनी उसका उचित मुआवजा देगी। बीमा के अनुसार भुगतान करेगी।

10– कि प्रथम पक्ष व द्वितीय पक्ष के बीच उपर्युक्त समझौते के बाद यह तय हुआ है कि उपर्युक्त शर्तो का निष्पादन दो वर्ष में पूरा किया जायेगा तथा ग्राम सभा निर्माण कार्य में पूर्ण रूप से सहयोग करेगी तथा ग्राम सभा की जनता प्रथम पक्ष निर्माण में कोई व्यव्धान नही करेगी।

अतः यह इकरारनामा/अनुबन्ध आज दिनांक 13/6/2007 को लिख दिया तथा दोनों पक्षों के अनुसार लिखा गया है ताकि प्रमाण रहे व वक्त जरूरत काम आवे। व0 रवीन्द्र कुमार दस्तावेज नवीस गोपेश्वर 13/6/2007

ह0 द्वितीय पक्ष

हस्ताक्षर गवाह–

ह0 प्रथम पक्ष

1– श्री राघवानन्द सती पुत्र श्री चन्द्रमणी सतीश
ग्राम तोनला प0 वृत माणखी तहसील व जिला–चमोली

2– सुरेन्द्र सिंह बिष्ट पुत्र स्व0 श्री रायसिंह ग्राम
कुरूड प0 वृत फरखत तहसील व जिला– चमोली

Annexure – 10.2

02nd August 2010

Vishnuprayag Hydro Power Project (400 MW)
Vishnupuram, Joshimath

Standard Operating Procedure for Release of Water from Barrage at Shivpuram, Located Near Lama Bagarh Village

Preamble

1. Vishnuprayag Hydro Power Project (400 MW) is a 'Run of the River (ROR) Project', with only a low level Barrage, for diverting the water for the generation of electricity at the Power House. After which, the water is again let out in to the River.
There is no facility/capability for storage/ponding of water upstream of the Barrage, or elsewhere in the entire Project. Depending upon the inflow in the River, water on release from the Barrage, takes about 45 to 60 minutes to reach the area of the Govindghat Gurudwara Saheb.

2. For a Run of the River Project in operation, certain situations do arise when it becomes inevitable to release the water from the Barrage, even during the lean period. Notwithstanding that, it is ensured that prior to the release of the water, the intimation is given in advance to all concerned to the maximum possible extent. In addition, a large number of other measures are adopted as enunciated in this Standard Operating Procedure, for providing advanced information to all concerned about the release of water from the Barrage. Based on the experience, and interaction with the Police and Gurudwara Saheb Officials at Govindghat, about the utility of conveying information about the release of water from the Barrage at night, the same is not being done between 10.00 P.M. and 04.00 A.M.

3. It is also pertinent to note that, the water level in the River at Govindghat, is the sum total of the water released from the Barrage and the inflow from various gaderas/nalas and other tributaries of Alaknanda River, down stream of the Barrage up to Govindghat.

Conditions Under Which the Water is Released From the Barrage

4. There are three major contingencies, as follows, under which it becomes essential to release the water from the Barrage:-

(a) Planned Situations. When the spilling of water from the Barrage can be foreseen, and it is possible to give an intimation to all concerned well in advance about the same. Such situations could be like a 'Planned Shut Down of the Plant for Various Reasons', or for 'Release of Water on the Specific Request of the Locals'. The latter could be for Religious Ceremonies, or for performance of the Last Rites etc.

(b) Release of Water Under Unforeseen Circumstances. It becomes inevitable to release the water from the Barrage which is instantaneous/ at a very short notice due to the following reasons. Even then, in such cases an effort is made to provide the intimation as early and to the extent as possible.

(i) Sudden Closure of the Plant due to 'Fault in the Transmission Line', or 'Tripping of the Machines'.
(ii) Sudden Increase of the Silt Levels in the River Water.
(iii) Flash floods/sudden spates in the River.

(c) During Monsoons. Excess water is continuously released from the Barrage. In this case only the initial release can be, and is intimated, and thereafter further flow of water is continuous till the end of the monsoons. The quantum of water released from the Barrage during the Monsoons depends upon the amount of rainfall in the catchments area upstream of the Barrage.

Warning Boards

5. As per the Directions of the District Administration, suitably located 'Warning Boards' in Hindi (White letters over Red background), have been prominently displayed at 12 sites, besides one in 'Gurumukhi', just outside the "Gurudwara Saheb" at 'Govind Ghat'. The 'Location State of the Warning Boards' is attached as per 'Annexure 1'. Photographs of Warning Boards, one each in Hindi & Gurumukhi are attached as per 'Annexure 2' with this SOP.

Sirens

6. Sirens have been installed under arrangements of the Project at the :-

(a) Right Bank Security Post of the Project.
(b) Pandukeshwar Police Chowki.
(c) Gurudwara Saheb at Govindghat.

Public Address System

7. As desired by DM, Chamoli, two sets of portable Public Address Systems had been Provided, one each to the Police Chowkies at Pandukeshwar and Govindghat, on 24^{th} August 2007, for making the announcements about release of water from the Barrage for the information of all concerned. Gurudwara Saheb at Govindghat has its own Public Address System, which is very effective.

Sequence of Events/Actions Taken Prior to Release of Water From the Barrage Under the Planned Contingencies

8. Shift-in-Charge Engineer at Barrage Main Control, will intimate Right Bank Security and the Camp Security, regarding the expected/actual time of release of water from

the Barrage; as also the reason(s) for the release. This intimation will be given on telephone/wireless, and if required through the SI on duty at the Barrage in a vehicle, in case the communications are not through.

9. Right Bank Security shall immediately intimate Police Official on Duty at Daiyya Bridge Police Post, about the impending release of water from the Barrage. He will also arrange to send a message to Pandukeshwar / Govind Ghat Police Chowkies, through the Police Wireless Set. He shall sound the siren installed at Right Bank Security Check Post. He shall also intimate the BRO Personnel, in case they are working nearby. Thereafter he shall confirm all the actions taken by him to the Shift Engineer at the Barrage Main Control by the fastest means.

10. The Right Bank Security will then record all the actions taken by him and that of the Police Official on Duty at Daiyya Steel Bridge, as per 'Annexure 3' attached.

11. On receipt of the message from Barrage Shift Engineer, about release of water from the Barrage, Camp Security, shall immediately sound the siren located in the Camp Area and shall confirm the same to Shift Engineer at the Barrage. The Security Inspector on duty at the Camp, will immediately proceed to Pandukeshwar in a vehicle, to intimate Pandukeshwar Police Chowki, and request them to sound the siren fitted at the Police Chowki. The Security Inspector shall also ask the Police Official on duty there to make the announcement about the release of water, on the Public Address System (PA System provided to Pandukeshwar Police Chowki by The Project). After completing these actions, Security Inspector shall confirm the Same to the Shift Engineer through the wireless.

12. Security Inspector shall then proceed to Govind Ghat Police Chowkie to intimate and request for making the public announcement (PA System provided to Govind Ghat Police Chowkie, by the Project), about the release of water from the Barrage. Security Inspector shall also inform the Official at the Govindghat Gurudwara Saheb, and make a request to sound the siren and also for public announcement on their own System about the release of water in the River. After completing all these actions, the Security Inspector shall confirm the same to Shift Engineer through the wireless.

13. Security Inspector shall then proceed up to Pinola, and give information about the release of water to the locals as available on the road side. Although the water in the River near Pinola Village is the sum total of the water of Alaknanda and Laxman/ Bhyundar Ganga.

14. After completing the above mentioned responsibilities, the Security Inspector, will make a record of all the actions taken at Pandukeshwar Police Chowkie as per 'Annexure 4'; and those taken at Govindghat Police Chowkie & Gurudwara Saheb as per 'Annexure 5' attached.

15. The Shift-in-Charge Engineer will make a record of details of various actions and activities by all concerned as per 'Annexure 6' attached.

16. In case a situation arises when the water is not required to be released, subsequent to the advanced information given to all concerned, then the same shall also be recorded in the respective Annexure(s) by the Shift-in-Charge Engineer, at the Barrage Main Control. Such contingencies could be under the following conditions when the generation at the Power House gets resumed within a short span of time :-

(a) Disruption/tripping of the Transmission Line gets restored.

(b) The machine(s) that tripped at the Power House are made functional.

17. 'Annexures 3 to 6' will be put up for the perusal of the Chief Engineer (Mech) and the Additional General Manager (Mech), for their perusal and endorsement(s), at the earliest. The same will also be put up for the perusal of the Director during his next visit to the Barrage after the event.

Actions to be Taken for Release of Water Under Unforeseen Circumstances

18. As enunciated in Paragraph 4 (b) above, under unforeseen circumstances which are beyond human control, the water is required to be released from the Barrage instantaneously. Notwithstanding this compulsion, the Shift-in-Charge Engineer at Barrage Main Control will immediately inform the :-

(a) Right Bank Security to sound the Siren, and also to inform the Daiyya Bridge Police Chowkie about the instantaneous release of water from the River. The Police Official at Daiyya Bridge shall be asked to inform his counter parts at the Police Chowkies at Pandukeshwar & Govindghat, about the same for their further actions of sounding the siren and making the announcements on the Public Address Systems available with them.

(b) Camp Security will immediately sound the siren. Notwithstanding the extremely short notice available, the Security Inspector on Duty at the Camp will take all the actions as per Paragraphs 11 to 14 above.

(c) All the Records as per 'Annexures 3 to 6' will also be maintained, and put up for perusal of all concerned as laid down.

Conclusion

19. Since the release of water from the Barrage is inevitable under the circumstances mentioned above, the instructions laid down in this SOP must be clearly understood by all concerned. Cooperation and timely actions by the Police Officials and the Gurudwara Prabandhak Committee, Govindghat Gurudwara Saheb, are of extreme importance to assist us in our utmost endeavour to prevent damage/loss whatsoever to anyone.

Chapter 11

CUMULATIVE IMPACT ANALYSIS - ASSESSMENT OF HPs ON COMPONENTS OF ECOSYSTEM

11.1. Awareness about Human Activities Affecting Environment

Natural Environment and Built Environment together constitute total environment. Natural Environment encompasses all living and non-living things occurring naturally on earth and the interaction of all living species. This again comprises (a) complete ecological units that have well defined boundaries and function as natural systems without massive human intervention, including all vegetation, microorganisms, soil, rocks, atmosphere and natural phenomena that occur within their boundaries and (b) universal natural resources and physical phenomena that lack clear-cut boundaries, such as air, water, and climate, as well as energy, radiation, electric charge, and magnetism, not originating from human activity. In contrast Built Environment comprises the areas and components that are strongly influenced by humans.

Awareness that human activities, especially developmental projects, affect environment and its components that may also be called natural resource in a major way gave rise to scientific study of the involved disciplines so that their impact could be assessed in advance to decide whether a project should be taken at all and if so, what measures must be taken to keep the adverse effects within acceptable limits, arose after the Second World War. The USA was at the forefront of this development. In that country increasing encroachment on wilderness land evoked the resistance of conservationists. Concern with the deteriorating environment led to the development of the trusteeship principle late in the 1940s, which stated, "No generation can exclusively own the renewable resources by which it lives. We hold the commonwealth in trust for posterity, and to lessen or destroy it is to commit treason against the future." As the public became more aware of environmental issues, concern about air pollution, water pollution, solid waste disposal, dwindling energy resources, radiation, loss of biodiversity, noise pollution, climate change, depletion of the Ozone layer and other environmental problems engaged a broadening number of supporters.

11.2. Development of Environmental Legislation

Modern international environmental law dates to approximately 1972 when countries gathered for the United Nations Stockholm Conference on the Human Environment, and the United Nations Environment Programme (UNEP) was established. Many important legal developments took place in the period surrounding the Conference, including negotiation of the Convention on International Trade in Endangered Species, the London Ocean Dumping Convention, the World Heritage Convention, and the first of the UNEP regional seas conventions. Since then, there has been a rapid rise in international legal instruments concerned with the environment, to the point that we are concerned today with developing new means for coordinating the negotiation and implementation of related agreements, in particular their administrative, monitoring, and financial provisions. Since 1970, hundreds of international environmental instruments have been concluded. Including bilateral and multilateral instruments (binding and nonbinding), there are close to nine hundred international legal instruments that have one or more significant provisions addressing the environment.

The Stockholm Action Plan on the Human Environment is a comprehensive document that includes a 'Framework for International Action' accompanied by a list of 69 specific recommendations. It concerned itself with the environmental effects of production of energy and its use and, among others, recommended taking of steps to ensure proper collection, measurement and analysis of data relating to the environmental effects of energy use and production,' better exchange of information on energy. The recommendation was motivated by the need for 'the rationalization and integration of resource management for energy' and sought mechanisms such as exchange of national experiences, studies, seminars, meetings, and a 'continually updated register of research' for accessing existing information and data, particularly on 'the environmental consequences of different energy systems'.

In the United States, prior to 1970s, project review was based on the technical/engineering and economic analysis and only limited consideration was given to environmental consequences. Environmental Impact Assessment (EIA) was introduced when the United States passed the National Environmental Policy Act (NEPA) in 1969. It instituted basic principles that included guidelines, procedures, public participation requirement and standard methodologies for impact analysis e.g. matrix, checklist and network. EIA diffused rapidly around the globe. Over 100 countries have adopted NEPA-like statutes; numerous international organizations require EIA for providing assistance. Canada, Australia and New Zealand became the first countries to follow NEPA in 1973-1974. While Australia provided for EIA by law; Canada and New Zealand established administrative procedures.

In the decade 1976 to mid eighties there was further progress in adopting EIA. France in 1976 and Philippines in 1977 introduced provisions for EIA. Netherlands in 1978 began to use the process informally. Some countries namely, Germany and Ireland adopted elements, such as impact statements or reports, as part of development applications for planning permission. Brazil, Philippines, China and Indonesia started the use of Effects Assessment, which included Strategic Environment Assessment (SEA), a Policy tool to assess the environmental consequences of development policies, legislation, plans and programmes and the assessments of impact on sustainability of the environment. With the formation of the European Commission and later European Union, the effects of human intervention and developmental projects on environment became a matter of serious concern.

Risk analysis was also included in Environmental Assessment (EA) processes. The process was further improved by placing greater emphasis on ecological modelling, prediction and evaluation methods and providing for public involvement and coordination of EA with land use planning processes. There is inherent uncertainty in environmental impact assessments because of natural variation, bio-physical measurements and the quality of data gathered and used in the EA process. The fundamental principles associated with risk assessment studies were enunciated in the 1970s. Early risk assessments focused on human health. Risk assessment studies in many countries were initially directed toward regulatory issues such as establishing environmental quality standards, and on the carcinogenic effects of synthetic chemicals on humans. In more recent years the emphases have been expanded toward ecological risks. Ecological Risk Assessment is a process that evaluates the probability or likelihood that adverse ecological effects will occur as a result of exposure to stressors from various human activities. Such effects can occur on non-human ecological components ranging from organisms, to organisation populations and communities, to ecosystems.

During the period mid eighties to 1990, the European Commission EIA established basic principles and procedural requirements on EIA for all member states. The issue of cumulative effects also started receiving attention. The World Bank and other lending agencies prescribed EA requirements. EIA started spreading in Asia.

The period of 1990s saw the introduction of global issues such as trans-boundary effects, increased use of Geographical Information Systems (GIS) and sustainability principle as part of EIA.

11.3. Principles of Sustainability

It is necessary to understand these concepts, which lie at the foundation of sustainable development and use it in carrying out Cumulative Impact Assessment of development projects including Water Resources Development Projects and Hydropower Projects.

11.3.1. Environmental sustainability

It is the process of making sure that the current processes of interaction with the environment are pursued with the idea of keeping the environment as pristine as naturally possible based on ideal-seeking behaviour. Environmental sustainability implies sustainability of systems that constitute the environment. So the question arises what the characteristics of a Sustainable System are.

11.3.2. Sustainable Systems

An ecologically sustainable system must:

i. Support biological processes;
ii. Maintain its level of productivity;
iii. Function with minimal external management; and
iv. Repair itself when stressed.

11.3.3. Natural Capital

It is the sum total of nature's resources. An "unsustainable situation" occurs when a natural resource is used up faster than it can be replenished. Sustainability requires that human activity uses nature's resources only at a rate at which they can be replenished naturally. Inherently, the concept of sustainable development is intertwined with the concept of carrying capacity of a biological species in an environment. It is the population size of the species that the environment can sustain indefinitely, given the food, habitat, water and other necessities available in the environment.

Theoretically, the long-term result of environmental degradation is the inability to sustain human life. Such degradation on a global scale could imply extinction for humanity. The following table shows the relationship among Consumption, State of Environment and Sustainability.

Consumption of renewable resources	State of environment	Sustainability
More than nature's ability to replenish	Environmental degradation	Not sustainable
Equal to nature's ability to replenish	Environmental equilibrium	Steady state economy
Less than nature's ability to replenish	Environmental renewal	Environmentally sustainable

11.4. Sustainable Development:

Concern with the degradation of environment led to the development of the concept of Sustainable Development and in 1987, the United Nations released the Brundtland Report, which defined sustainable development as 'development which meets the needs of the present without compromising the ability of future generations to meet their own needs. At the UN Conference on Environment and Development held at Rio de Jeneiro in 1992, the need for a global partnership to secure Sustainable Development was emphasised and it was declared that integration of environment and development concerns and greater attention to them will lead to the fulfilment of basic needs, improved living standards for all, better protected and managed ecosystems and a safer, more prosperous future. Principle 17 of what is known as Agenda 21 stated, “Environmental impact assessment, as a national instrument, shall be undertaken for proposed activities that are likely to have a significant adverse impact on the environment and are subject to a decision of a competent national authority.”

In the US Army Corps of Engineers (USACE), Environmental Operating Principles and Implementation Guidance (USACE, 2002) the following definition of sustainability was given: “a synergistic process whereby environmental and economic considerations are effectively balanced throughout the life cycle of project planning, design, construction, operation and maintenance to improve the quality of life for present and future generations.”

11.4.1. Pillars of Sustainable Development

That sustainable development was a much wider concept was emphasised in The United Nations 2005 World Summit Outcome Document that refers to the "interdependent and mutually reinforcing pillars" of sustainable development as

i. Economic development,
ii. Social development, and
iii. Environmental protection.

EIA thus aims to address the need of ensuring Sustainable Development. Many developing countries adopted the environmental assessment legislation. There was rapid growth of training in Environmental Assessment. India also adopted the EIA formally.

11.5. Evolution of EIA in India

The Indian experience with Environmental Impact Assessment began in 1976-77 when the Planning Commission asked the Department of Science and Technology to examine the river-valley projects from an environmental angle. This was subsequently extended to cover those projects, which required the approval of the Public Investment Board. Environmental clearance from the Central Government remained an administrative decision until 1994 when it was given legislative support and the Ministry of Environment and Forests (MEF), under the Environmental (Protection) Act 1986, promulgated an EIA notification making Environmental Clearance (EC) mandatory for expansion or modernisation of any activity or for setting up new projects listed in Schedule 1 of the notification. This notification was amended a number of times.

This concept has also been reflected in the notification relating to the Impact Assessment of Development projects replacing the 1994 notification. In India Environmental Impact Assessment (EIA) is an important management tool for ensuring optimal use of natural resources for sustainable development. In the light of experience gained, a revision of the provisions of the EIA notification was felt necessary and a new notification was introduced in September 2006 making it mandatory for various projects such as mining, thermal power plants, river valley, infrastructure (road, highway, ports, harbours and airports) and industries to get environment clearance. The state governments have been given powers to give clearance for projects if their size of capacity is within the prescribed limits.

Additionally, donor agencies operating in India like the World Bank and the Asian Development Bank (ADB) have a different set of requirements for giving environmental clearance to projects that are funded by them.

11.6. Cumulative Impact Assessment

11.6.1. Concept

The impact of human activity or a project on an environmental resource or eco-system may be considered insignificant when assessed in isolation, but may become significant when evaluated in the context of the combined effect of all the past, present, and reasonably foreseeable future activities that may have or have had an impact on the resources in question. The Council for Environmental Quality established under the US National Environmental Policy Act of 1969 (NEPA) came to the view that a conventional project and site-specific approach to environmental assessment has its limitations when it comes to assessing potential cumulative effects on environmental resources.

11.6.2. Definition of Cumulative Impact

Cumulative impact is defined by the US Council on Environmental Quality as "the impacts on the environment that result from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions (RFFA) regardless of what agency undertakes such other actions." Thus the practice of Cumulative Effects Assessment (CEA) of projects in a region began. Various aspects of CEA began to be studied.

There are several reasons why Cumulative Impact Assessments should be carried out i.e.,

i. Conceptual reasons – For a group of projects, the environmental effects of primary concern tend to be cumulative and it will not be advisable to consider simply the effects of individual projects
ii. Pragmatic reasons – CEA guidance and other EIA legislation of the 1990s requires that CEs be assessed
iii. Regulatory reasons – make "room" for future developments
iv. Idealistic reasons – minimize negative CEs, promote resource sustainability

In India, so far, there is no law requiring the conduct of Cumulative Environmental Impact Assessment before a development project is given Environmental Clearance.

During 1980s and 1990s, it became the practice in many countries to include Cumulative Effects in Environmental Impact Statements. CEA processes were also developed. Litigation in courts also clarified some of the concepts. With the dawn of the present millennium i.e., 2000s practice for project CEAs was improved; methods of analysis developed and existing methods expanded.

11.6.3. New Concepts in Cumulative Effects Assessment

The advances in the field of Cumulative Effects Assessment gave rise to several new concepts, some of which are briefly mentioned below.

i. Valued Ecosystem Component (VEC)

Any part, component or resource of the environment that is considered important by the proponent, public, scientists and government involved in the assessment process is Valued Ecosystem Component. A VEC can be assessed using following parameters:

Indicator
It is a feature of the environmental setting that describes, measures, manages and reports on factors of value (VEC). It needs to be measureable.

Thresholds values of Indicators
Value at which change becomes unacceptable.

Cautionary Threshold Values of Indicators
When Standard Protection Measures would do

Target threshold values of Indicators
Beyond which Enhanced Protection Measures are necessary

Critical Threshold values of Indicators
When exceeded restrictions need to be proposed.

Irwing et al. (1986) divided the impacts of development on the environment in two categories:

a) **Homotypic:** These are the impacts of developments of the same type.
b) **Heterotypic**: These are combination of two or more developments or land uses.

Stakhiv (1988) suggested that Cumulative Effects Assessment provides a frame work for three vectors

- **Direct-indirect or traceable cause effect sequence of impacts**
- **Collective or additive sequence**
- **Interactive or Synergetic Sequence**

Specifically there are three basic ways by which cumulative effects can occur. The first is additive or incremental impact in which the cumulative impact is the sum of the individual impacts.

A second way is supra-additive, also called synergetic in which the total cumulative impact on a species or resource is more than the sum of individual impacts. Finally there are Infra additive, also called antagonistic, impacts occur when a species or resource is exposed to a series of impacts wherein the total impact is less than the sum of the individual impacts.

It was also realised that the impact of human activities including developmental and others on environment, health, social aspects and economy are a function of policies, activities carried out in a region, the activities undertaken in a sector, carrying capacity of the region, which may make them sustainable or unsustainable.

Strategic Environmental Analysis

Cumulative Impact Assessment also provides valuable and important inputs as an element of Strategic Environmental Analysis, particularly in monitoring of environmental sustainability impacts of legislation, policies, programmes and projects and impact on health, social and economic aspects.

Now an explicit assessment of cumulative effects is considered desirable in environmental assessment practice. It is also critical to incorporate cumulative effects analysis into the development of alternatives for an environmental assessment, since it is only by re-evaluating and modifying alternatives in the light of the projected cumulative effects that adverse consequences can be effectively avoided or minimized.

11.6.4. Cumulative Effects and the Environmental Assessment Process

a) In most cases, it will be beyond the scope of an environmental assessment to include a full-fledged cumulative impact assessment. However, it is important that environmental assessment, where appropriate, includes a preliminary assessment of the potential for cumulative effects and specific recommendations on the need for, and the conduct of, a cumulative impact assessment. The key issues in considering a cumulative impact assessment relate to

i. defining appropriate analytical boundaries in time and space,
ii. identifying and predicting future resource use and impacts, and
iii. evaluating the significance of cumulative effects that are predicted to take place.

It may be difficult to precisely estimate the spatial boundaries in which the impacts are likely and, therefore, they should be determined flexibly so that during the assessment adjustment of process, if needed, can be made. The time period for which the impact will be assessed needs to be set. It depends on data availability as well as the degree of uncertainty and confidence in prediction. A concern is to determine the minimum data requirements that will allow defensible and robust impact predictions. The criteria for judging significance of cumulative effects are not different from those for other types of environmental assessment, but threshold effects and irreversible changes in the use of critical resources will generally be key concerns.

A number of Guidance Documents have been prepared to facilitate conduct of CEA in different parts of the world

*A list is given below:

Country /Agency	Year	Remarks
USA	1997	The process involves 11 steps
Canada	1999	The process involves 12 steps
Brazil	2007	Deals with hydropower
USA FHWA	2005	
US Army	2007	
Canada	-	tool kit related to fish habitat and productivity
USA Corps of Engineers	-	Water Resources Projects
South Africa & Australia	-	-

*Source: L. W. Canter, Professor Emeritus, University of Oklahoma

b) Analysing Cumulative Effects

The process of analyzing cumulative effects is an enhancement of the traditional environmental assessment components and consists of.

(i) Scoping,
(ii) Describing the affected environment, and
(iii) Determining the environmental consequences.

c) Breaking Down Components in to Steps

The above components are broken down to steps as below

i. Identifying the resources, ecosystems, namely, Valued Environmental Components (VECs) or human communities of concern that need to be considered in the cumulative impact analysis by gathering input from knowledgeable individuals and reliable information sources. This enables the selection of the environmental resources or components, ecosystems and human community concerns that are likely to be impacted.
ii. Identifying important cumulative impact assessment issues.
iii. Identifying the Impact Zone, the boundaries of CIA or the Resource Study Area (RSA) of each VEC i.e., zone in which this impact will take place. This helps to set appropriate time and geographical boundaries for analysis of each VEC,
iv. Identify the set of the past, current and reasonably foreseeable future actions or projects that have cause-effect relationships with the resources, ecosystems, and human communities of concern (VEC). The purpose of this step is to identify stresses and stressors, historical reference points, trends and thresholds along with other current and reasonably foreseeable projects to be considered in the cumulative impact analysis. It involves evaluation of data of development projects proposed or are likely.
v. Identify the direct and indirect impacts of the proposed project that might contribute to a cumulative impact on the identified resources.
vi. Identify agencies among which cooperation is needed to identify agency plans and other actions whose effects may overlap with those of the proposed action.
vii. Relevant data of the identified environmental components (VEC) to determine its health (baseline condition) that needs to be gathered to be able to study the impact. The health of a resource refers very broadly to its overall condition, stability, or vitality. For a species, health could refer to sustainability.
viii. Assess the potential cumulative impacts on VECs. Rather than identifying the life cycle of projects, it is important to identify the life cycle of effects or environmental consequences.

Determining the cumulative environmental consequences of an action requires.

a) Report the results of the cumulative impact analysis.
b) Assess the need for mitigation and/or recommendations for actions by other agencies to address a cumulative impact.

d) Other Items that need to be Addressed

The cumulative impact analysis should also address:

i. Other regional initiatives that are in place and could be built on
ii. The loss of locally important resource and its functions and values.
iii. The potential for successful compensatory mitigation,
iv. The time required for compensatory mitigation
v. The potential for increased habitat fragmentation.

vi. The potential to reverse a trend for the resource or related ecosystem restoration.
vii. The potential for cumulative impacts to the resource to affect other resources in the area, such as animal or plant species that depend on healthy wetland habitat.
viii. Determine trends in VECs from base line to the present and the future
ix. Look at other regional initiatives that are in place and could be built on
x. Apply adaptive management

e) Methods or Analytical Tool

There are 11 types of useful methods as below:

i. Questionnaires, Interviews, and Panels – Useful for gathering the wide range of information on multiple actions and resources (VECs) needed to address cumulative effects. Brainstorming sessions, interviews with knowledgeable individuals, and group consensus building activities can help identify the important cumulative effects issues in the study area or region.
ii. Checklists – Useful for identifying potential cumulative effects by providing a list of common or likely effects and juxtaposing multiple actions and VECs.
iii. Matrices – Use a tabular format to organize and quantify the interactions between human activities and resources of concern. Matrices can also be used to combine the values in individual cells in the matrix to evaluate the cumulative effects of multiple actions on individual resources, ecosystems, and human communities (typically referred to as VECs).
iv. Networks and System Diagrams – Useful for delineating the cause-and effect relationships resulting in cumulative effects. Can be used to analyze the multiple, subsidiary effects of various actions, and trace indirect effects to resources that accumulate from direct impacts on other resources (VECs).
v. Modelling – A potential powerful technique for quantifying the cause-and effect relationships leading to cumulative effects. Modelling can take the form of mathematical equations describing cumulative processes such as soil erosion, the use of VEC-specific software, or an expert system that computes the effect of various project scenarios based on a program of logical decisions.
vi. Trends Analysis – This methodology can be used to assess the status of VECs over time and to develop graphical projections of past or future conditions. Changes in the occurrence or intensity of stressors (contributing effects from other actions) over the same time period can also be determined. Trends can help the analyst identify cumulative effects problems, establish appropriate environmental baselines, and project future cumulative effects.
vii. Overlay Mapping and GIS – These methods incorporate locational information into cumulative effects analysis and help set the boundaries of the analysis, analyze landscape parameters, and identify areas where effects will be the greatest. Map overlays can be based on

either the accumulation of stresses in certain areas or on the suitability of each land unit for development.

viii. Carrying Capacity Analysis (a special method) – Carrying capacity analysis identifies thresholds (as constraints on development) and provides mechanisms to monitor the incremental use of unused capacity. Carrying capacity in the ecological context is defined as the threshold of stress below which populations and ecosystem functions can be sustained. In the social context, the carrying capacity of a region is measured by the level of services (including ecological services) desired by the populace.

ix. Ecosystem Analysis (a special method) – Ecosystem analysis explicitly addresses biodiversity and ecosystem sustainability. The ecosystem approach uses natural boundaries (such as watersheds and eco-regions) and applies ecological indicators (such as indices of biotic integrity and landscape pattern). Ecosystem analysis entails the broad regional perspective and holistic thinking that are required for successful cumulative effects assessment.

x. Economic Impact Analysis (a special method) – This method is an important component of analyzing cumulative effects, because the economic well being of a local community and region depends on many different actions. The three primary steps in conducting an economic impact analysis are (1) establishing the region of influence, (2) modelling the economic impacts, and (3) determining the significance of the impacts. Economic models play an important role in these impact assessments and range from simple to sophisticated.

xi. Social Impact Analysis (a special method) – Social impact analysis addresses cumulative effects related to the sustainability of human communities by (1) focusing on key social variables such as population characteristics, community and institutional structures, political and social resources, individual and family changes, and community resources; and (2) projecting future effects using social analysis techniques such as linear trend projections, population multiplier methods, scenarios, expert judgment, and simulation modelling.

f) Choosing a Method or Analytical Tool

There are a variety of methods or analytic tools available as mentioned above. A method, with appropriate input as needed, that makes sense considering the condition of and anticipated impacts to the resource, the type and amount of available information, and the type and size of the proposed project should be selected.

Lary W Canter and Kamath studied a number of projects and found that in preparing Environtal Impact Statements, the Checklist Methodology was used. They concluded that the Methodology should selected should desirably have the following features:

i. It should enable multiple developments or land used practices to be addressed.

ii. It should be practical with understandable results that would aid decision making process.
iii. It should be adaptable to allow for the large arrau of possible site resoiirce impact combnation.
iv. Method should allow flexibility of spatial and temporal boundaries.
v. It should enable aggregation or tallying of incremental and interactive impacts to give an estimate of over all impact to wwhich a resource is exposed.
vi. Allow for different levels of resolution(more genereal, extensive analysis of the cumulative impacts of all relevant developments or projects or land use practicesswhile still allowing intensive, site and project specific analysis Information related to EIA methodology was reviewed (Lahlou and Canter 1993, Cockin et al 1992).
vii. Lary and Canter felt that the most appropriate methodological approach should be one that would be simple and yet comprehensive enough to provide a broad perspective on Cumulative Impact Assessment. They chose the Questionnaire Check List (Table 4) for identifying and/or summarising the Cumulative Impact of projects. This has been used for two decades for EIA studies. It could be used in conjunction with delineating the study boundaries for addressing cumulative impact assessment depending on the study area, site visits. Information gathering may be necessary before applying the checklist.

g) Taking Precautions to Avoid Common Deficiencies

Care needs to be taken to pay attention to the following aspects

i. Environmental components need emphasis but economic and social components need even more.
ii. Proper scoping must be done upfront
iii. Adequate consultation must precede selection of VEC.
iv. Governance issues need to be identified and addressed.
v. Focus should be on Cumulative Effects Assessment rather than on management.
vi. There should be clarity of the roles of the proponent and that of the government.
vii. Multi-stake holder organisations should distinguish between their interests and responsibilities for CEA and should reconcile any conflict.
viii. CEA at sctoral level must consider, in addition to the impact of all the projects in that sector, the impact of other development projects in the region with in the spatial and time boundaries set.
ix. The study on CIA could be unending unless it was focussed on issues that are carefully selected. It should focus on resource sustainability in the expanded geographic and time boundaries . The USEPA document says, “A cumulative effects analysis should ‘count what counts’, not produce superficial analyses or a long laundry list of issues that have little relevance to the effect of the proposed action or the eventual decisions.”

h) Drawing Conclusions from CEA Analysis

In previous steps, the data and information are collected and method(s) applied to analyze it. Based on that analysis, conclusions are drawn about the cumulative impacts to resources by applying professional judgment to the results, and by coordinating with technical experts as warranted.

First, the question "Is there a cumulative effect?" needs to be answered. If the results of the analysis indicate that the proposed project, in combination with other actions, would affect the health of the resource or a trend associated with a resource, it is reasonable to conclude that the proposed project will contribute to a cumulative effect (either beneficial or adverse).

Next, the results of the analysis are used to characterize the severity or magnitude of the cumulative effect. The following question is then answered: "What do decision-makers need to know about the status of this resource within the RSA?" The following information is documented for each resource:

i. The health, status or condition of the resource as a result of past, present and reasonably foreseeable impacts.
ii. The contribution of the proposed project to the overall cumulative impact to the resource, in support of a significance determination.
iii. Avoidance and Minimization. Any project design changes that were made, or additional opportunities that could be taken, to avoid and minimize potential impacts in light of cumulative impact concerns.
iv. Any alternatives to the proposed project.

Once the cumulative impact analysis is complete, do a "reality check": compare the results of the cumulative impact analysis with the results of the direct and indirect impact analyses of the proposed project. This comparison can test the soundness of the conclusions about each resource.

i) Adaptive Management

The following text is an abstract from the Presentation "Adaptive Management and Integrated Decision Making – An Emerging Tool for Cumulative Effects Management" by Larry Canter and Sam Atkinson

Adaptive Management (AM) is being used as a follow-up tool within environmental impact assessment and cumulative effects assessment.

Typical AM processes incorporate

I. management objectives,
II. conceptual and or quantitative models,
III. management choices,
IV. monitoring,
V. systematic decision making, and
VI. stakeholder collaboration.

Such processes can be used to reduce cumulative effects uncertainties, and inform decision making relative to local and regional operational practices to minimize the incremental effects of proposed actions, as well as the management of regional cumulative effects resulting from multiple past, current, and future contributors. Based on an analysis of fundamental concepts, practices, and case studies the following key lessons and needs have been identified: (1) Due to numerous uncertainties associated with CEA, AM can be a useful tool for increasing the cumulative effects knowledge base, as well as determining the effectiveness of project mitigation and regional management measures. (2) Decision flowcharts and AM decision matrices can facilitate the learning and necessary decisions associated with AM programs. Such flowcharts and matrices should be both understandable to a range of audiences, and integrative in relation to developing a holistic perspective on management choices and their environmental implications.

However, AM may turn out to be expensive in cost time and and Central deterrents to AM include both additional budgetary and time requirements. Accordingly, there is a need to carefully delineate the actual benefits and costs of AM requirements in a series of case studies.

11.6.5. EIA of Hydropower Projects

Most developing countries are acutely short of energy, particularly electrical energy. Therefore, where circumstances are favourable, all energy sources have to be explored, for generation of electricity. Rivers and streams in the hills offer excellent conditions for setting up hydropower projects. Snow fed rivers in the hills supplemented by good rainfall provide high discharges and falls that enable the setting up of projects in cascade resulting in very high efficiency. However, cascade hydropower development in river basins may induce negative indirect and cumulative ecological impacts too, and sensitive ecological problems could, therefore, arise to restrict the sustainability of the river basin ecosystem.

11.6.5.1. Ecosystem Components With Potential to be Impacted

The components of the ecosystem that could be affected by hydropower projects would depend on the nature of the projects and on conditions prevailing in the region. As to the nature of projects, they are essentially of two types namely, reservoir based projects and run of river projects. Run of river projects put back the water in to the river where the tail race joins the river without significantly changing the discharge pattern. Dam based projects, in addition, change the flow regime of the river down stream. The flow regime in the stretch of the river between the barrage and the tail race gets drastically affected in both types of projects, and the stretch would be rendered dry when the water is stored or diverted through a tunnel or a channel for generation of power. Reservoir intercept and retain the water flowing to them and water is released to the extent it is required for generation of power. Thus reservoir based projects result in change in the flow regime even downstream of the tail race. While in the RoR projects, the barrage height is not very high and may not necessarily result in preventing the migration of aquatic life, particularly fish; the reservoirs create a very high barrier and migration of aquatic life is necessarily affected. The reservoirs also bring a large area under submergence. As a consequence land use and flow regime changes.

Other components of the ecosystem that are likely to be impacted by hydropower projects in the basins of Alaknanda and Bhagirathi need to be identified in the light of facts that the Himalayas are prone to earthquakes, the slopes are fragile, biodiversity is very rich and the region is full of places of pilgrimage. Thus the components of the ecosystem that could be impacted by the hydropower project constructed on identified sites could be the following:

i. Aquatic and terrestrial flora and fauna.
ii. Rivers and streams by horizontal and vertical fragmentation.
iii. Flow regimes in the streams, tributaries and rivers
iv. Ground water regime
v. Springs
vi. Tectonic stability.
vii. Seismicity
viii. Soils
ix. Places of pilgrimage and of tourist interest.

It needs to be studied whether the effect on the above components can have the following consequences:

i. Damage to biodiversity
ii. Change in availability of water
    - for drinking,
    - for irrigation,
    - at places of religious and cultural importance
iii. Damage to stability of slopes aggravating the problem of land slides.
iv. Increased incidence and intensity of earth quakes
v. Soil erosion reducing productivity of land and producing frequent floods
vi. Damage to protected area network.

In this case the scoping has already been done by the sponsor. On preliminary examination it appears that the greatest impact of development of hydro electric projects on the rivers and their tributaries is likely to be on aquatic life. This is due to the fact that hydro power projects will divert water through tunnels or channels to the power house leaving the stretch of the river between the barrage and the power house dry. This effect will be cumulative as the projects are in cascade on a river. It will be important to provide for measures to mitigate the adverse impact of this phenomenon.

11.6.5.2. Methodology

While the general principles and methodology of Cumulative Impact Assessment Procedure (CIAP) for hydropower projects would basically be the same as for other projects, in view of the unique character of these projects, they have been studied by scholars to identify how these impact studies can be done best. The findings in brief are given below:

i. In one case the resource identified studying impact (Valued Ecosystem Component) was aquatic and terrestrial life. Interaction matrix was prepared to evaluate cumulative impact of SHPs.
ii. In another case an impact scoring methodology was developed to assess cumulative impact on multiple resources. It uses models of response of population or resources to forecast induced environmental changes within the project impact zones. Cumulative impacts are calculated based on estimates of single project effects, interaction among projects, shared project features and an estimation of the impacts of existing projects. This methodology can assess impacts using both quantitative and qualitative data.
iii. In two case studies the resources for assessment of impact were mule deer and eagles.
iv. In another case study the resource was wetland and GIS was used as a tool to analyse temporal change in the regional context and depict relationship among 8 key variables such as wetland size, proximity, land use, soil, pH, erodibility, permeability of forest soils.
v. In another study geo-botanical maps and automated mapping techniques were used to asses effects on Bay Oilfield in Alaska.
vi. The river-lake system in Montana has a dam on the upstream and one on the downstream of the river. In providing hydropower, flood control and recreation, certain aspects of ecology are impacted. Multi-attribute trade off analysis was used and an impact index was developed.
vii. In yet another case the study involved a generic framework for biophysical impact analysis of offshore oil and gas development. The frame work incorporated both direct and indirect effects, positive and negative impacts and concerns at the individual, population, species and ecosystem level

11.6.5.3. Lessons

i. There is no universally adopted method for assessing cumulative impact of hydropower projects.
ii. Matrices or indices were used most frequently.
iii. A methodology that enables incorporation of both quantitative and qualitative data is preferable.
iv. Paucity and or low quality of both baseline data and impact information may limit the effectiveness of analysis.

The study areas relevant to the identified components of the ecosystem that are likely to be affected by the development of the vast potential for development of hydropower in the Alaknanda – Bhagirathi basin have been discussed in detail in the earlier chapters. Tables No1 and 2 contain assessment of the impact of each of the hydropower projects on the identified components in the Bhagirathi and Alaknanda Basins respectively.

11.7. CIA for this study

The earlier chapters have examined in detail the cumulative impact of hydropower projects on components of ecosystem and socio-economic environment. In this chapter all the components and projects have been brought together**.**

A matrix has been prepared in Table 11.1 for Alaknanda basin and Table 11.2 for Bhagirathi basin to depict the impacts. In these tables, a column is devoted to a project and rows are devoted to different components. Thus the impact of each project on various components can be seen in its column. The impact may be localised depicted by 'L' or cumulative depicted by 'C'. The impact is in increasing order of impact from negligible, low, medium and high. Quantitative assessment has not been possible for lack of data and, therefore, qualitative assessment has been done.

In the tables the HPs and the relevant information have been arranged river wise and tributary wise. The projects on the main stream of Bhagirathi are together following the direction of flow – from upstream to downstream. Similarly, the projects on the main stem of Alaknanda are together from upstream to downstream. The projects on tributaries of the two rivers also are depicted following the order of flow of the tributary. The tributaries are also are arranged from upstream to downstream of the river.

11.8. Components Studied For Assessment of Impact of Hydropower Projects

The HPs affect a large number of components of the ecosystem and socio-economic environment. In accordance with the Terms of Reference of this study, the following components are covered:

i. Seismicity
ii. Geological
    a. Landslides
    b. Sedimentation
iii. Fish (indicative of aquatic life)
iv. Environmental Flow
    a. Flow regime of the stream
    b. Whether the impact is remediable
    c. Impact of ensuring environmental flow on power generation.
v. Springs and Drinking Water
vi. Irrigation
vii. Places of Cultural and Religious Importance
viii. Tourism
ix. Socio-economic Environment
x. Submergence
xi. Water Quality

Table 11.1(a): Cumulative Impact Analysis Of HPs On Components Of Ecosystem

ALAKNANDA BASIN													
			Alaknanda main stream							Dhauliganga			
S. No.	Features	Project Name	Alaknanda	Vishnuprayag	Vishnugad Pipalkoti	Bowla Nandprayag	Nandprayag Langasu	Srinagar	Kotli Bhel-I B	Malari Jelam	Jelam Tamak	Tamak Lata	Lata Tapovan	Tapowan Vishnugad
1	Installed capacity (MV		300	400	444	300	100	330	320	114	126	250	170	520
2	Project Type		RoR	RoR	Storage	RoR	RoR	Storage	Storage	RoR	RoR	RoR	RoR	RoR
3	Location in Geotract		1	1	5	3	3	4	4	1	1	1	1	2
4	Location in Seismological Zone		5	5	5	5	5	4	4	5	5	5	5	5
5	Seismicity		Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
6	Geology	Landslides	L-Medium	L-High	L-High	L-High	L-High	L-High	L-Low	L-Medium	L-Medium	L-Medium	L-High	L-High
7	Geology	Sedimentation	C-Medium	C-Medium	C-High	C-Medium	C-Medium	C-High	C-Mediun	C-Low	C-Low	C-Low	C-Low	C-Low
8	Environmental Flow	Fish	No Fish Zone	No Fish Zone	C-High	C-High	C-High	C-High	C-High	No Fish Zone	No Fish Zone	No Fish Zone	No Fish Zone	No Fish Zone
9	Environmental Flow	Flow	L-Low	L-High	C-High	L-Low	L-Low	C-High	C-High	L-Low	L-Low	L-Low	L-Low	L-Low
10	Environmental Flow	Remedy	Remedy is Possible	Remedy is Possible	Remedy is Possible	Remedy is Possible	Remedy is Possible	No Remedy is Possible	Remedy is Possible	Remedy is Possible	Remedy is Possible	Remedy is Possible	Remedy is Possible	Remedy is Possible
11	Environmental Flow	Power Generation	Medium	Medium	Medium	Low	Low	Medium	Medium	Medium	Medium	Medium	Medium	Medium
12	Springs & Drinking Water		Negligible	Negligible	L-Low	Negligible	L-Low	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	L-Low
13	Irrigation		Negligible	Negligible	Negligible	L-Low	L-Low	L-Low	L-Low	Negligible	Negligible	Negligible	Negligible	L-Low
14	Cultural and Religious places		Negligible	Negligible	Negligible	Negligible	Negligible	Negative	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
15	Tourism		Positive	Positive	Positive	Positive	Positive	Positive	Positive	Negligible	Negligible	Negligible	Negligible	Negative
16	Socioeconomic Environment		Positive	Positive	Positive	Positive	Positive	Positive	Positive	Positive	Positive	Positive	Positive	Positive
17	Construction Activities		L-Medium	L-Medium	L-High	L-Medium	L-Medium	L-High	L-High	L-Medium	L-Medium	L-Medium	L-Mediun	L-Mediun
18	Submergence		L-Low	Low	L-Mediun	L-Low	L-Low	L-High	L-High	L-Low	L-Low	L-Low	L-Low	L-Low
19	Water Quality		Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
20	Protected/Forest area		L-Medium	L-Low	L-High	L-Low	L-Medium	L-High	L-High	L-Low	L-Low	L – Low	L-Low	L-Low
	L: Localized Impact					C: Cumulative Impact								

Table 11.1(b): Cumulative Impact Analysis Of Hps On Components Of Ecosystem

ALAKNANDA BASIN										
			Rishi Ganga			Bhyundar ganga	Birahi Ganga			
S. No.	**Project Name / Features**		**Rishi Ganga II**	**Rishi Ganga-I**	**Rishi Ganga**	**Bhyundar ganga**	**Gohana Tal**	**Birahi Ganga-II**	**Birahi Ganga-I**	**Birahi Ganga**
1	**Installed capacity (MW)**		35	70	13.2	24.3	50	24	24	7.2
2	**Project Type**		Storage	Storage	RoR	RoR	RoR	RoR	RoR	RoR
3	**Location in Geotract**		2	1	2	3	3	1	2	3
4	**Location in Seismological Zone**		5	5	5	5	5	5	5	5
5	**Seismicity**		Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
6	**Geology**	**Landslides**	L-High	L-High	L-High	L-Medium	L-High	L-High	L-High	L-Medium
7		**Sedimentation**	C-High	C-High	C-Low	C-Low	C-Low	C-Low	C-Low	C-Low
8	**Environmental Flow**	**Fish**	No Fish Zone	No Fish Zone	No Fish Zone	No Fish Zone	C-Low	C-Low	C-Low	C-Low
9		**Flow**	L-Low	L-Low	L-Low	L-Low	L-Low	L-Low	L-Low	L-Low
10		**Remedy**	Remedy is Possible	Remedy is Possible	Remedy is Possible	Remedy is Possible	Remedy is Possible	Remedy is Possible	Remedy is Possible	Remedy is Possible
11		**Power Generation**	High	High	High	High	High	High	High	High
12	**Springs & Drinking Water**		Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
13	**Irrigation**		Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
14	**Cultural and Religious places**		Negligible	Negligible	Negligible	Negative	Negligible	Negligible	Negligible	Negligible
15	**Tourism**		L-Positive	L-Positive	Negligible	Negative	Negligible	Negligible	Negligible	Negligible
16	**Socioeconomic Environment**		Positive	Positive	Positive	Positive	Positive	Positive	Positive	Positive
17	**Construction Activities**		L-Low	L-Low	L-Low	L-Low	L-Medium	L-Low	L-Low	L-Low
18	**Submergence**		L-Low	L-Low	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
19	**Water Quality**		Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
20	**Protected/Forest area**		L-High	L-High	L-Low	L-Medium	L-Low	L-Low	L-Low	L-Low
	L: Localized Impact									

Table 11.1(c): Cumulative Impact Analysis Of Hps On Components Of Ecosystem

ALAKNANDA BASIN											
			Mandakini				Nandakini			Pinder	
S. No.	Project Name / Features		Ram Bara	Phata Byung	Madhmaheshwar	Singoli Bhatwari	Vanala	Dewali	Rajwakti	Melkhet	Devsari
1	Installed capacity (MW)		24	76	10	99	15	13	3.6	15	252
2	Project Type		RoR	Storage	RoR	RoR	RoR	RoR	RoR	RoR	Storage
3	Location in Geotract		1	2	2	3	5	5	5	3	3
4	Location in Seismological Zone		5	5	5	5	5	5	5	5	5
5	Seismicity		Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
6	Geology	Landslides	L-High	L-High	L-High	L-High	L-High	L-High	L-High	L-High	L-High
7		Sedimentation	C-Low	C-Medium	C-Low	C-Low	C-Low	C-Low	C-Low	C-Low	C-Medium
8	Environmental Flow	Fish	C-Low	C-High	C-Low	C-Medium	C-Low	C-Low	C-Low	C-medium	C-High
9		Flow	L-Low	C-Low	L-Low	L-Low	L-Low	L-Low	L-Low	L-Low	C-Medium
10		Remedy	Remedy is Possible	Remedy is Possible	Remedy is Possible	Remedy is Possible	Remedy is Possible	Remedy is Possible	Remedy is Possible	Remedy is Possible	Remedy is Possible
11		Power Generation	High	High	Medium	Medium	High	High	High	Medium	Medium
12	Springs & Drinking Water		Negligible	L-low	Negligible	Negligible	Negligible	L-low	Negligible	Negligible	L-medium
13	Irrigation		Negligible	L-Low	Negligible	L-Low	L-Low	Negligible	L-low	Negligible	Negligible
14	Cultural and Religious places		Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
15	Tourism		Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Positive
16	Socioeconomic Environment		Positive	Positive	Positive	Positive	Positive	Positive	Positive	Positive	Positive
17	Construction Activities		L-Low	L-Medium	L-Low	L-High	L-Low	L-Low	L-Low	L-Low	L-High
18	Submergence		Negligible	L-Low	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	L-Medium
19	Water Quality		Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
20	Protected/Forest area		L-High	L-High	L-High	L-Medium	L-Low	L-Low	L-Medium	L-Low	L-Low
	L: Localized Impact				C: Cumulative Impact						

Table 11.1(d): Cumulative Impact Analysis Of Hps On Components Of Ecosystem

ALAKNANDA BASIN											
			Rishi ganga	Khiraoganga	Jummagad	Kaliganga		Kaliganga		Kalpganga	
S. No.	Project Name		Badrinath II	Khirao Ganga	Jummagad	Kailganga	Debal	Kaliganga-I	Kaliganga-II	Urgam	Urgam-II
	Features										
1	Installed capacity (MW)		1.25	4	1.2	5	5	4	6	3	3.8
2	Project Type		RoR	RoR	RoR	RoR	RoR	RoR	RoR	RoR	RoR
3	Location in Geotract		1	1	1	3	3	2	2	2	2
4	Location in Seismological Zone		5	5	5	5	5	5	5	5	5
5	Seismicity		Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
6	Geology	Landslides	L-Medium	L-Medium	L-Medium	L-High	L-High	L-Medium	L-Medium	L-High	L-High
7	Geology	Sedimentation	C-Low	C-Low	C-Low	C-Low	C-Low	C-Low	C-Low	C-Low	C-Low
8	Environmental Flow	Fish	No Fish Zone	No Fish Zone	No Fish Zone	C-Low	C-Low	C-Low	C-Low	C-Low	C-Low
9	Environmental Flow	Flow	L-Low	L-Low	L-Low	L-Low	L-Low	L-Low	L-Low	L-Low	L-Low
10	Environmental Flow	Remedy	Remedy is Possible	Remedy is Possible	Remedy is Possible	Remedy is Possible	Remedy is Possible	Remedy is Possible	Remedy is Possible	Remedy is Possible	Remedy is Possible
11	Environmental Flow	Power Generation	Low	Medium	Medium	Medium	Medium	Medium	Medium	Low	Low
12	Springs & Drinking Water		Negligible	Negligible	Negligible	L-low	Negligible	Negligible	Negligible	Negligible	Negligible
13	Irrigation		Negligible	Negligible	Negligible	Negligible	Negligible	L-low	L-low	Negligible	Negligible
14	Environmental Cultural and Religious		Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
15	Tourism		Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
16	Socio-economy Environment		Positive	Positive	Positive	Positive	Positive	Positive	Positive	Positive	Positive
17	Construction Activities		L-Low	L-Low	L-Low	L-Low	L-Low	L-Low	L-Low	L-Low	L-Low
18	Submergence		Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
19	Water Quality		Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
20	Protected/Forest area		L-Low	L-Low	L-Low	L-Medium	L-Medium	L-Low	L-Low	L-Medium	L-Low
	L: Localized Impact						C: Cumulative Impact				

Table 11.2(a): Cumulative Impact Analysis of HPs On Components Of Ecosystem

BHAGIRATHI BASIN													
			Bhagirathi Main Stream									**Jadh Ganga**	
S. No.	**Project Name Features**		**Bharon Ghati**	**Lohari Nagpala**	**Pala Maneri**	**Maneri bhali I**	**Manaeri bhali-II**	**Tehri stage-I**	**Tehri stage-II**	**Koteshwar**	**Kotli Bhel-IA**	**Karmoli**	**Jadh Ganga**
1	**Installed capacity (MW)**		381	600	480	90	304	1000	1000	400	195	140	50
2	**Project Type**		RoR	RoR	Storage	Storage	RoR	Storage	Storage	Storage	Storage	Storage	Storage
3	**Location in Geotract**		1	2	2	3	3	4	4	5	6	1	3
4	**Location in Seismological Zone**		4	4	4	4	4	4	4	4	4	4	4
5	**Seismicity**		Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
6	**Geology**	**Landslides**	L-Medium	L-High	L-High	L-Medium	L-Medium	L-Medium	L-Medium	L-Medium	L-Medium	L-Medium	L-High
7		**Sedimentation**	C-Medium	C-Medium	C-High	C-High	C-Medium	C-High	C-High	C-Low	C-Low	C-High	C-High
8	**Environmental Flow**	**Fish**	No Fish Zone	No Fish Zon	C-High	C-High	C-High	C-High	C-High	C-High	C-High	No Fish Zone	No Fish Zon
9		**Flow**	L-Medium	L-Low	L-Medium	L-Medium	L-Medium	C-High	C-High	C-High	C-High	C-Medium	C-Medium
10		**Remedy**	Remedy is Possible	Remedy is Possible	Remedy is Possible	Remedy is Possible	Remedy is Possible	No Remedy i Possible	No Remedy is Possible	Remedy is Possible	Remedy is Possible	Remedy is Possible	Remedy is Possible
11		**Power Generation**	Low	Low	Low	Medium	Medium	Medium	Nil	Medium	Medium	Low	Low
12	**Springs & Drinking Water**		L-Low	Negligible	L-Low	L-Low	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
13	**Irrigation**		L-Low	L-Low	L-Low	L-Positive	L-Low	L-Positive	L-Positive	L-Positive	L-Positive	Negligible	Negligible
14	**Environmental Cultural and Religious**		Negligible	Negligible	Negative	Negative	Negative	Negative	Negative	Negative	Negative	Negligible	Negligible
15	**Tourism**		Negative	Negative	Negative	Negative	Negative	Positive	Positive	Positive	Positive	Negligible	Negligible
16	**Socio-economy Environment**		Positive	Positive	Positive	Positive	Positive	Positive	Positive	Positive	Positive	Positive	Positive
17	**Construction Activities**		L-Medium	L-Medium	L-High	L-High	L-High	L-High	L-High	L-High	L-High	L-Medium	L-Medium
18	**Submergence**		L-Low	L-Low	L-Low	L-Low	L-Low	L-High	L-High	L-Medium	L-High	L-Low	L-Low
19	**Water Quality**		Negligible	Negligible	Negligible	Negligible	Negligible	Considerable	Considerable	Negligible	Negligible	Negligible	Negligible
20	**Protected/Forest area**		L-Low	L-Low	L-High	L-Low	L-Low	L-High	L-High	L-High	L-High	L-High	L-High
	L: Localized Impact			**C: Cumulative Impact**									

Table 11.2(b): Cumulative Impact Analysis Of Hps On Components Of Ecosystem

BHAGIRATHI BASIN														
S. No.			Asiganga				Balganga				Bhilangana			
	Features	Project Name	Kaldigad	Asiganga-I	Asiganga-II	Asiganga-III	Kot Budha kedar	Agunda thati	Jhala koti	Balganga-II	Bhilangana-III	Bhilangna-II A	Bhilangna-II B	Bhilangna-II C	Bhilangana
1	Installed capacity (MW)		9	4.5	4.5	9	6	3	12.5	7	24	24	24	21	22.5
2	Project Type		RoR	RoR	RoR	RoR	RoR	RoR	RoR	RoR	RoR	RoR	RoR	RoR	RoR
3	Location in Geotract		6	3	4	5	3	3	3	3	2	2	3	3	3
4	Location in Seismological Zone		4	4	4	4	4	4	4	4	4	4	4	4	4
5	Seismicity		Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
6	Geology	Landslides	L-Medium	L-Medium	L-Medium	L-Medium	L-High	L-High	L-High	L-High	L-Medium	L-High	L-High	L-Medium	L-Medium
7	Geology	Sedimentation	C-Low	C-Low	C-Low	C-Low	C-Low	C-Low	C-Low	C-Low	C-Low	C-Low	C-Low	C-Low	C-Low
8	Environmental Flow	Fish	C-Low	C-Low	C-Low	C-Low	C-Low	C-Low	C-Low	C-Low	C-Medium	C-Medium	C-Medium	C-Medium	C-Medium
9	Environmental Flow	Flow	L-Low	L-Low	L-Low	L-Low	L-Low	L-Low	L-Low	L-Low	L-Low	L-Low	L-Low	L-Low	L-Low
10	Environmental Flow	Remedy	Remedy is Possible	Remedy is Possible	Remedy is Possible	Remedy is Possible	Remedy is Possible	Remedy is Possible	Remedy is Possible	Remedy is Possible	Remedy is Possible	Remedy is Possible	Remedy is Possible	Remedy is Possible	Remedy is Possible
11	Environmental Flow	Power Generation	Medium	Medium	Medium	Medium	High	High	High	High	High	High	High	High	High
12	Springs & Drinking Water		Negligible	Negligible	Negligible	Negligible	L-Low	L-Low	Negligible	Negligible	L-Low	L-Low	Negligible	Negligible	Negligible
13	Irrigation		L-Low	L-Low	L-Low	L-Medium	L-Low	L-Low	L-Low	L-Low	L-Medium	L-Medium	L-Medium	L-Medium	L-Low
14	Environmental Cultural and Religious		Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
15	Tourism		Negative	Negative	Negative	Negative	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
16	Socio-economic		Positive	Positive	Positive	Positive	Positive	Positive	Positive	Positive	Positive	Positive	Positive	Positive	Positive
17	Construction Activities		L-Low	L-Low	L-Low	L-Low	L-Low	L-Low	L-Low	L-Low	L-Low	L-Low	L-Low	L-Low	L-Low
18	Submergence		Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
19	Water Quality		Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
20	Protected/Forest area		L-Low	L-Mediu	L-Low	L-Low	L-Low	L-Low	L-Low	L-Low	L-Low	L-Low	L-Low	L – Low	L-Low
	L: Localized Impact				C: Cumulative Impact									

Table 11.2(c): Cumulative Impact Analysis of HPs On Components Of Ecosystem

BHAGIRATHI BASIN											
			Jalandhari	Pilangad			Limcha Gad	Siyangad	Suwari Gad	Ganga
S. No.	Project Name Features		Jalandharigad	Pilangad	Pilangad-II	Kakoragad	Limcha Gad	Siyangad	Suwari Gad	Kotli Bhel-II
1	Installed capacity (MW)		24	2.25	4	12.5	3.5	11.5	2	530
2	Project Type		RoR	RoR	RoR	RoR	RoR	RoR	RoR	Storage
3	Location in Geotract		1	2	2	1	2	1	2	4
4	Location in Seismological Zone		4	4	4	4	4	4	4	4
5	Seismicity		Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
6	Geology	Landslides	L-Medium	L-High	L-High	L-Medium	L-Medium	L-High	L-High	L-Low
7		Sedimentation	C-Low	C-Low	C-Low	C-Low	C-Low	C-Low	C-Low	C-Medium
8		Fish	No Fish Zone	C-Low	C-Low	C-Low	C-Low	No Fish Zone	C-Low	C-High
9	Environmental Flow	Flow	L-Low	L-Low	L-Low	L-Low	L-Low	L-Low	L-Low	C-Low
10		Remedy	Remedy is Possible	Remedy is Possible	Remedy is Possible	Remedy is Possible	Remedy is Possible	Remedy is Possible	Remedy is Possible	Remedy is Possible
11		Power Generation	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
12	Springs & Drinking Water		Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
13	Irrigation		L-Low	L-Low	L-Low	L-Low	L-Low	L-Medium	L-Low	L-positive
14	Environmental Cultural and Religious		Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negative
15	Tourism		Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Positive
16	Socio-economy Environment		Positive	Positive	Positive	Positive	Positive	Positive	Positive	Positive
17	Construction Activities		L-Low	L-Low	L-Low	L-Low	L-Low	L-Low	L-Low	L-High
18	Submergence		Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	L-High
19	Water Quality		Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
20	Protected/Forest area		L-Low	L-Medium	L-Low	L-Low	L-Low	L-Low	L-Low	L-High
	L: Localized Impact				C: Cumulative Impact					

11.9. Cumulative and Localised Impacts

In the present study the impacts have been divided into categories, viz., Localised and Cumulative. Localised impact is confined to the area of influence of the project and is not transmitted beyond this area. On the other hand, cumulative impact is the aggregate impact of a number of projects on any component.

The impacts of HPs on most of the ecosystem components are localised, i.e., confined to the area of influence of a specific project, impacts on some of the components are cumulative i.e., the impact of one HP adds on to the impact of the downstream project. The manner in which the aggregation may occur varies from component to component.

In the tables qualitative assessment of the impacts on the components of the ecosystem has been made. It has not been possible to obtain the required baseline data. The data before the project was initiated. Also in almost all the projects, there has been very inadequate monitoring of the impacts on the various components.

11.10. Interpretation of Tables of Impact Assessment

The basis of assessment of impacts of HPs on the identified components as above and shown in Table 11.1 and 11.2 is explained below:

11.10.1. Localised Impact is depicted with 'L'. It implies that the impact does not extend beyond the area of influence of the specific project under consideration. Cumulative Impact is depicted with 'C'. It implies that the impact gets superimposed on projects beyond the area of influence of the specific project. In other words the impact of a HP on a component is the aggregation of the impact of the specific project and other projects that are transmitting the impact.

11.10.2. Classification of Impact into Four Categories:

The impact is divided in to four categories - High, Medium, Low and Negligible. Thus if the impact is high and localised it is written as L-High and if it is cumulative and high it is written as 'C-High'.

11.10.3. Seismicity:

All the HPs are located in Seismic Zone 4 and 5, which are earthquake prone. However, the study reveals that the Hydropower projects do not have any impact on seismicity. Thus the earthquakes will not be caused by the HPs; but the HPs should be designed taking in to account the factor of seismicity corresponding to the earthquake zone in which the project is located.

11.10.4. Geological Impacts:

Two aspects, namely landslides and sedimentation are considered.

Landslides: The impact of HPs on landslides is localised and is not transmitted to other downstream HPs. While the landslides are common in the area, experience has shown that the storage based HPs result in increased incidence of landslides at the rim of the reservoir; but over time the rim stabilises and the incidence of landslides comes down. Depending on the location of the project the impact has been assessed Localised - high to low.

11.10.5. Sedimentation:

Sedimentation takes place in the reservoir in a storage based HP as the dam is high and there is no flushing of the bed. Moreover, it is cumulative. Therefore, for storage base reservoirs it is assigned the category ‘C-High’. This phenomenon is observed also in RoR schemes. However, regular flushing takes place in most RoRs and therefore, the sediment accumulation is much lower. It has been assigned the category ‘C-Medium’ to ‘C- Low’.

11.10.6. Impact on Fish:

The status of aquatic life in a river can be gauged by the status of fish population. In storage based HPs the dam is high and rarely adequate provision is made for migration of aquatic life. The area under reservoir is large and it extends to considerable distance upstream. The deposit of sediment on the bed changes its nature. Hence the ecological conditions change and affect macro-invertebrates.

RoR projects do not cause these problems. However, it may have a long tunnel from the barrage to the power house and this river stretch becomes dry unless water is released to provide sufficient flow in the river (Environmental Flow). If there is provision for ensuring environmental flow, the impact on aquatic life is only Medium. Thus in a RoR project the affected length of the river is the length of the river under pondage and the length of the river diverted. Accordingly, the impact on fish population has been characterised from C-High to C-Low.

11.10.7. Environmental Flow:

The Chapter on hydrology discusses the Environmental Flow Requirements (EFR) at various HP sites and places of religious importance. Water resources have been appraised, flow variability of the two rivers has been worked out, and the range of EFR has been assessed at 31 sites using a variety of methods. Flow Variability as a result of operation of seven HPs has been analysed.

The run of river schemes do not disturb the discharges in a substantial way except that the stretch of the river between the barrage and the power house in bypassed. The situation created by diverting flow to the power house and depriving the river of water can be remedied by releasing the required Environmental Flow. In the storage based HPs, the discharge pattern is drastically altered but have also releases to the tune of environmental flow may be made so that the ecosystem does not suffer big damage.

The impact of RoR HPs on aquatic ecosystem is low to medium and localised while for storage based HPs it is high and cumulative. Accordingly, the impact is assessed from high to low. The tables indicate whether the situation is remediable, i.e., whether the EFR can be met at each HP or not.

11.10.8. Impact on Springs and Drinking Water:

A map showing location of major springs and HPs has been prepared. If the area through which the tunnel is laid has springs, they are likely to be impacted. Many project sites have been visited and the issue discussed with the people. The impact, if any, is always localised. Based on the knowledge so gathered and the map of springs the impact assessment has been made as shown in the table.

11.10.9. Impact on Irrigation:

In the basins, the main rivers flow in the valley and so are not used for irrigation. The streams and tributaries pass through the catchment and could be available for irrigating agricultural/horticultural fields.

In a storage based HP where the reservoir is extensive, cultivated area, including irrigated area, could be submerged. A large number of project sites have been visited, the area covered by reservoir or under pondage has been worked out and the information, the assessment so gathered has been used to determine the impact on irrigation.

11.10.10. Impact on Places of Cultural and Religious Importance:

If the HP affects a place of religious and cultural importance through reduction of available water, the impact is negative.

11.10.11. Impact on Tourism

In many cases the impact on tourism is positive since the reservoir enhances scenic beauty and water sports. In some places the impact is negative.

11.10.12. Socio-economic Impacts:

The socio-economic impacts are positive in all cases.

11.10.13. Impact of Construction Activities:

The impact of Construction Activities manifests in a variety of ways such as disposal of construction muck done in an environmentally unfriendly manner so as to result in sedimentation of the river bed, obstruction to flow of water and spoiling valley slopes. Excavation of building material may also result in impact on identified components of eco-system. This impact is also localised and not cumulative.

11.10.14. Impact on Water Quality

The impact on water quality for the parameters tested has been found to be negligible and it is localised.

11.11. The conclusions about cumulative impact on identified components are summarised below

i. The impact of HPs on seismicity is nil. It means that a HP will not induce earthquake. However, the region is in Seismic Zone 4 and 5 and therefore, the HPs should be designed to withstand earthquakes.
ii. The glaciers are much higher and distant to be affected by hydropower projects.
iii. The impact on tourism is generally positive.
iv. There are very few places of religious and cultural importance that will be affected by the HPs. However, in case there is some such place, it can be ensured that the needed water is released when ever required.
v. The impact on irrigation is generally positive.
vi. The impact on the economy is positive. It leads to migration from outside into the project area and creation of human settlements / urbanisation giving rise to waste generation and other developments associated with urban areas. Analysis of satellite

imagery has clearly established changes that have taken place at many project sites. Unless care is taken, the rivers may be polluted.

vii. The impact on water quality is low and in all projects the water after it comes out of the power house is well within the limits of environmental sustainability

viii. In storage based HPs, stability of slopes could be affected and landslides could take place at the rim of the reservoir. However, the slopes stabilise after a few years of operation of the project.

ix. During tunnelling ground water or water from springs may seep in to the tunnel unless through prior geological investigations, the springs and the ground water passage are avoided.

x. The sediment is transported from the catchment to the rivers and trapped at the dam/barrage. In RoR projects, the bed is flushed and so sediment does not pose much problem. However, in storage based projects the sediment collects on the bed and the sediment concentration in the water from the powerhouse has much lower sediment concentration.

xi. During construction unless sites for dumping muck, excavating building material are chosen after careful investigation, there is dust and noise pollution and erosion of slopes and flow of the muck into the river during rains.

xii. In storage based projects, the river is converted in to a big and deep reservoir and the migration of fish upstream from downstream and vice versa gets obstructed.

xiii. In RoR projects, there is considerable length of the river downstream of the barrage which is by passed and water is discharged into the river only after the powerhouse. Thus this length becomes dry. This fragmentation if unattended can be very harmful for the aquatic life.

xiv. There is no significant impact of the Hydropower Projects on the water quality in run of river projects. Out of 10 parameters only five namely, viz temperature, DO, BOD and FC and conductivity show minor changes in the vicinity of the hydropower projects. However, where habitations have come up because of the projects and waste water flows to the rivers, the parameters change. In most cases the habitations do not have very large population and so the impact also is small.

11.12. Cumulative Impact Assessment of Commissioned Large (25 MW And Above) Projects

In the basin only four large hydropower projects have been commissioned so far. This assessment is made river wise and project wise from upstream to downstream.

The study of impact of these projects has been done in a variety of ways as below:

- Impact of each project on the selected components
- Cumulative Impact of large projects that have been commissioned, namely Tehri, Maneri Bhali I, Maneri Bhali II and Vishnuprayag.
- Cumulative impact of all the projects on each tributary at the point of confluence with Bhagirathi
- Cumulative impact of all the projects on each tributary at the point of confluence with Alaknanda
- Cumulative impact of all the projects located on Bhagirathi at Devprayag
- Cumulative impact of all the projects located on Alaknanda at Devprayag.

11.12.1. Maneri Bhali I on Bhagirathi

(a) Important information of this project is given below:

- Landslide prone – Localised and Medium
- Presence of springs downstream of the project – Nil
- Type of Project – Storage
- Reservoir Area – 18 Ha
- Length of the river under reservoir – 1.2 km
- Bypassed Length up to the Power House – 18 km
- Catchment Area – 4024 sq.km
- Installed Capacity – 90 MW

(b) Impacts

i. This is a storage based hydropower project with an installed capacity of 90 MW. It is located in geotract III and seismological zone IV. Since seismicity is not affected by hydroelectric projects, its impact is nil. Since it is a storage based HP, its impact on landslides is localised and medium. Its impact on sedimentation is medium because the sediment is arrested in desilting tanks and there is regular flushing. The impact on aquatic life including fish is medium as there is provision for the biota to move across the dam. Moreover, on the upstream side, the nature of bed would changed because of sedimentation and also because the river gets converted into a reservoir leading to changes in biotic environment.

ii. The impact on environmental flow is localised and medium. However, the requirement of depth and velocity in the river downstream of the project has been worked out and it is possible to release the required quantity of water.

iii. Since environmental flow needs to be maintained and to that extent water will not be available for generation of power there will be reduction in the production of electricity. This impact is assessed as medium.

iv. As there are not many springs around the 8.6 km. long tunnel, the impact on springs is assessed as low. This impact is localised.

v. As no canal system originating from the main river exists in the area there are no likely impacts on irrigation. However, on the upstream side of the dam, ground water would have been supplemented. It may be reiterated that ground water levels are not being monitored and other baseline data are deficient. Therefore, it will not be fair to make a firm statement about this impact. It appears that it will not be reasonable to infer that the impact on irrigation will be positive.

vi. No religious /cultural place is affected by this project and therefore, impact is negligible.

vii. There is positive impact on tourism due to the creation of the lake. During construction activity positive impact would have been high. At the same time, negative impacts in the form of slope erosion and change in landuse would have been high. However, presently there seems to be no adverse impact due to natural reclamation process.

viii. The area submerged as a result of this project is only 1.2 km along the river and the bypassed length of the river downstream is only 18 km. As such the impact is assessed as low.

ix. The impact on water quality is low as the water quality both upstream and downstream of the project is well within the parameters required to sustain healthy aquatic life. Water is also fit for various human uses. The socio-economic impacts of the project have been positive.

x. Thus the only adverse impact of this project is by way of fragmentation of the river which prevents migration of aquatic life across the dam. It would have impact for benthic macroinvertebrates. In so far as the needed environmental flows from the reservoir or concerned, the required discharges can always be ensured.

11.12.2. Maneri Bhali II on Bhagirathi

(a) Important information of this project is as follows:

• Location in Geotract	–	3
• Location in Seismic Zone	–	4
• Landslide prone	–	Localised Medium
• Presence of springs downstream of the project	–	Nil
• Type of Project	–	RoR
• Reservoir Area	–	Nil
• Length of the river under reservoir	–	1.4 km
• Bypassed Length up to the Power House	–	22 km
• Catchment Area	–	4416 km^2
• Installed Capacity	–	304 MW

(b) Impacts

i. This is a RoR hydropower project with installed capacity of 304 MW. It has shallow pondage. It is located in Geotract III and seismological zone IV. Since seismicity is not affected by hydroelectric projects, its impact is nil. Since it is a RoR HP, its impact on landslides has been localised and low. Its impact on sedimentation is low because the sediment settles along the river course. The impact on aquatic life including fish is low.

ii. The impact on environmental flow is localised and medium. However, the requirement of depth and velocity in the river downstream of the project has been worked out and it is feasible to release the required quantity of water.

iii. Since environmental flow needs to be maintained and to that extent water will not be available for generation of power there will be reduction in the production of electricity. This impact is assessed as medium.

iv. As there are not many springs around the 16 km. long tunnel, the impact on springs is assessed as low. This impact is localised.

v. As no canal system originating from Bhagirathi exists in the area there are no likely impacts on irrigation.

vi. No religious /cultural place is affected by this project and, therefore, impact is negligible.

vii. There is positive impact on tourism due to pondage.

viii. During construction, negative impacts in the form of slope erosion and change in landuse would have been high. However, construction activity would have upgraded the social socio-economic life and thus made a high positive impact. Presently there seems to be no adverse impact due to natural reclamation process.

ix. The impact on water quality is low as the water quality both upstream and downstream of the project is well within the parameters required to sustain healthy aquatic life. It is also fit for various human uses. The socio-economic impacts of the project have been positive.

x. In so far as the needed environmental flows from the project is concerned, the required discharges can be ensured. Since it is a ROR project, arrangements for the migration of fish can be made at the appropriate time.

11.12.3. Tehri Dam and Hydropower Plant (Storage Based HP)

(a) Important information of this project is as follows:

Tehri Hydro Power Complex (2400 MW), consists of

1. Tehri Dam & Hydro Power Plant (1000 MW)
2. Koteshwar Hydro Electric Project (400 MW)
3. Tehri Pumped Storage Plant (PSP) (1000 MW)

Major Components of Tehri Dam & Hydro Power Plant are

Location		Geotract 1 Seismological Zone 4
Project Type		Storage
Dam	:	
Type	:	Rock and Earth Fill
Height	:	260.5 m
Base	:	1128 m
Width at top	:	25.5 m
Length at the top	:	592 m
Tehri Reservoir		
Water Spread	:	5200 Ha
Gross Storage	:	3540 Million m^3
Live Storage	:	2615 Million m^3
Power House		
Power House	:	Under ground

Cavern Size	:	197mx24mx63m
Type of Turbines	:	Francis
Rated Head	:	188 M
Speed	:	214.3 RPM
Installed Capacity	:	4x250MW
Annual Energy	:	3568 MUs

It has 2 nos. of Head Race Tunnels, an underground Hydro Power House Complex and Spillway System comprises Chute Spillway, 2 gated Shaft Spillways and 2 ungated Shaft Spillways. The Intermediate Level Outlet (ILO) enable's water releases to be tune of 1000 cumecs for irrigation purposes, when the machines are not in operation.

Due to the submergence caused by the dam, the Tehri Town and 24 villages have been fully affected, while another 88 villages have been partially affected. In addition, 13 more villages were fully affected due to acquisition of land for the project works and the colony. The people from these affected villages and Town have been properly rehabilitated in the new environment.

(b) Impacts

The impacts of this project on ecosystem component wise are given below.

i. Landslides

During reservoir operation and the associated draw-down conditions, the rim area of the reservoir has faced many small and shallow landsides (Fig.s 4.52 – 4.57). The rim area landslides are also observed near many villages. However, reservoir rim area is likely to be stabilised with operation for about 5-10 years. Over all impact of Tehri on landslides has been assessed as L-Medium.

ii. Sedimentation

During construction, the muck created was dumped on the valley slopes and to prevent it from coming into the river bed retaining walls have been constructed. Moreover, the high dam stores the water and the sediment settles down on the reservoir bed. Thus the sediment load in the river downstream of the project alters. Thus the impact on sediment has been taken as Cumulative and has been assessed as C-High.

iii. Impact on Fish and aquatic life

It is a very high dam and results in fragmentation of the river. The aquatic biota cannot migrate upstream and also downstream. The huge reservoir alters the flow regime completely. The river gets converted to a very big and deep reservoir completely changing the ecological environment. The impact is cumulative for all projects upstream as also for downstream projects. Therefore, the impact has been assessed as C-High.

iv. Impact on Flow Variability

The flow regime alters completely even though the project reduces stream flow variability since the generation of power takes place throughout and the flow gets regulated. The impact is cumulative as the projects downstream also get affected. The impact on this component is assessed as C-medium.

v. **Impact on Springs and Drinking Water**

Because of the huge storage in the reservoir, the ground water recharge and the recharge of springs has taken place. The impact is assessed as positive and localised.

vi. **Impact on Irrigation**

With increased availability of ground water and of recharging of springs, the impact on irrigation is positive and localised.

The impact has been assessed as Localised and positive.

vii. **Impact on Cultural and Religious Places**

Since quite a large areas have come under submergence, the impact on this component has been assessed as Negative.

viii. **Impact on Tourism:**

The new Tehri town is a pre-planned hill town with all modern facilities. Hence it is expected to develop as a major tourist centre. Due to the impoundment of water a big lake has been created, there is scope for water sports. There is also scope for construction of tourist resorts. Wider and improved roads are now available, communication has become easier and should lead to development of tourism. Hence the impact is positive.

ix. **Impact of Construction Activity**

To reduce the impact of the construction muck and its flowing in to the river, retaining walls have been constructed. During construction there is environmental impact due to production of noise, dust, excavation of building material, construction of roads and other activities related to construction. Mitigation measures were taken at the time of construction. However, these sources of environmental degradation are not relevant after the project is over and the things have settled down.

x. **Socio-economic Impact:**

It was apprehended that the project will result in large numbers of outsiders settling in this area and there will be pools of water in many places leading to the growth of mosquitoes and related diseases such as Malaria, Dengue, Philaria etc. A comprehensive study of the potential health impacts was conducted . Detailed field investigations were carried out ny the National Malaria Eradication Programme and Malaria Research Centre and Action Plan or preventive and mitigation measures was prepared and implemented.

xi. **Environmental Impacts were identified as below:**

- Likely change in water chemistry and impact on biodiversity
- Obstruction to the movement of fish species during breeding season
- Deposit of sediment on the bed of the reservoir.
- Inundation of land by the storage reservoir.
- One hundred nine villages were affected fully or partially and Tehri town and was fully affected involving provision of relief and rehabilitation to the large number of projected affected families.

xii. **Against the adverse impacts there have been positive results of the project.**

A Socio Economic Study of the families rehabilitated was conducted by the Administrative Staff College of India (ASCI) in March, 1993, who broadly concluded that the quality of life in respect of the re-settled families is far above and better than what was the situation before rehabilitation. Benefits can be summarized as follows:

- The value of assets of the oustees have increased after they got rehabilitated.
- Income from agriculture has increased after rehabilitation. No one is engaged as agricultural labour after rehabilitation.
- The annual income of the household after rehabilitation has risen by 34.67%.
- The new settlements are provided with pucca buildings with furnishings and electricity in Schools as against inadequate educational facilities provided earlier.
- The new settlements provide very good medical facilities which were not available to the rural house holds in the hilly area.
- Drinking water facilities have been provided in the new-resettlements and L.P.G. connections have been made available as against the traditional collection of water from springs and wood from forests in the hills.
- The new houses are bigger and modern
- Agricultural land allotted in consolidated holdings as against fragmented holdings earlier.

xiii. **Other Benefits from the Tehri Hydro Power Complex**

- Addition of 2400 MW installed generating capacity in the Northern Region (1000 MW on completion of Tehri Stage-I)
- Annual energy availability (Peaking) 6200 MU (3568 MU on completion of Tehri Stage-I)
- 2.7 ac ha Irrigation (additional)
- 6.04 ac. ha. Stabilisation of existing irrigation (besides above)
- 200 MW Additional Generation in downstream hydropower Projects due to regulated water
- 300 Cusecs (162 million gallons per day) of drinking water for Delhi which will meet the requirements of about 40 lac people.
- In addition, 200 Cusecs (108 million gallons per day) of drinking water for towns and villages of U.P. which will meet the requirement of 30 Lac people.
- Flood Moderation
- Integrated development of Garhwal region, including construction of a new hill station town with provision of all civic facilities; improved communication, education, health, tourism, development of horticultures, fisheries, and afforestation of the region.

11.12.4. Vishnu Prayag (Alaknanda River)

(a) Important information of this project is as follows:

Location in Geotract	–	1
Location in Seismic Zone	–	5
Landslide prone		
Presence of springs downstream of the project	–	Not many
Type of Project	–	RoR

Reservoir Area	–	Not applicable
Length of the river under reservoir	–	400 m
Bypassed Length up to the Power House	–	19 km
Installed Capacity	–	400 MW

(b) Impacts of this project:

i. Seismic: As the analysis in the chapter on Seismicity shows, the impact of HPs on seismicity is nil even though they are all situated in high Seismic Zone.

ii. Landslides:

Between Dec 2006 and May 2010, 16 landslides occurred in the Lambagarh Zone, which is upstream of the barrage. Between Jan 2007 and May 2010, 11 landslides occurred in Belakuche Zone, which is downstream of the barrage on the left bank of the river up to the powerhouse.

Between Jan 2007 and May 2010, 11 landslides occurred in Patal Ganga Zone, which is downstream of the barrage on the right bank of the river up to the powerhouse. Landslide data of earlier period in these three zones is not available for comparison. But it appears that downstream of the barrage, the frequency of landslides caused by the project has not increased as it is the same for downstream side of the power house.

Since it is a ROR HP, its impact on landslides is localised at diversion site and medium near power house site. It has been alleged that Chain village near power house has been impacted due to excavations of power house cavity, for which project has paid compensation. The impact is localised but has been assessed as High.

iii. Sedimentation: The impact is cumulative and Medium

iv. Impact on Fish and other Aquatic Life: The project is in 'no fish' zone hence this component is not relevant.

v. Environmental Flow:

The bypassed stretch of the river has a length of 19.4 km.

The impact on environmental flow is assessed as Localised and High. It is however, remediable through release of discharge corresponding to the EFR that has been calculated.

Since environmental flow needs to be maintained and to that extent water will not be available for generation of power there will be reduction in the production of electricity. This impact is assessed as medium.

vi. Impact on Drinking Water and Springs:

The length of the tunnel is long even though there are not many springs in the area through which it passes. As such the impact has been assessed as L-Medium.

vii. Impact on Irrigation

As no canal system originating from the main river exists in the area there are no likely impacts on irrigation. However, on the upstream side of the dam ground water storage conditions do not exists. Therefore, it would not have been impacted. It may be reiterated that ground water levels are not being monitored and other baseline data are deficient.

viii. The river flows in the valley and its water is not used for irrigation. The irrigation is done utilising the water of tributaries. The impact has been assessed as Localised and low.

ix. Impact on Cultural and Religious Places:
No religious /cultural place is affected by this project, however this project has repeatedly helped in evacuation of pilgrims stranded due to landslides and therefore, impact is negligible.

x. Impact on Tourism:
The creation of this project has made the area attractive for tourists and the impact is assessed as Positive.

xi. Socio-economic Impact of the project has been assessed as Positive.

xii. Impact of Construction Activities
During construction, negative impacts in the form of slope erosion, muck disposal, dust and noise, change in land use and excavation for building material and construction of roads are generated. However, presently there seems to be no adverse impact as the natural reclamation process seems to have undone the impact.

xiii. Submergence:
The submergence upstream of the barrage is small and has been assessed as Low.

xiv. Impact on Water Quality:
Impact on water quality of the project is negligible.

11.13. Impacts of hydropower projects at the points of confluence of tributaries of Bhagirathi and of Alaknanda

Cumulative impacts of HPs located on the tributaries of Bhagirathi are given in table 11.3.

Cumulative impacts of hydropower projects in the points of confluence of tributaries of Alaknanda are given in table 11.4.

11.14. Cumulative Impacts of all projects on Bhagirathi and of all projects on Alaknanda

Cumulative impacts of all hydropower projects on Bhagirathi and on Alaknanda are given in table 11.5.

Table 11.3:: **Impact of Hydro Power Projects at the Points of Confluence of Tributaries of Bhagirathi**

Tributary	Point of confluence	Landslide	Sediment	Fish	Environmental Flow		Springs	Irrigation	Places of Cultural and Religious Importance	Tourism	Construction Activities	Submergence
					Impact on Flow	Power Generation						
Jadhganga		L-High	C-High	No fish Zone	C-Medium Remediable	High	L-Low	L-Low	Negligible	Negligible	L-Medium	L-Low
Asiganga		L-Medium	C-Low	C-Low	C-Low Remediable	Medium	L-Low	L-Low	Negligible	Negative	L-Low	Negligible
Balganga		L-High	C-Low	C-Low	C-Low Remediable	Low	L-Low	L-Low	Negligible	Negligible	L-Low	Negligible
Bhilangana		L-Medium	C-Low	C-Medium	L-Low Remediable	Medium	L-Medium	L-Medium	Negligible	Negligible	L-Low	Negligible
Pilangad		L-High	C-Low	C-Low	L-Low Remediable	Medium	L-Low	L-Low	Negligible	Negligible	L-Low	Negligible
Jalandhari		L-Medium	C-Low	No Fish Zone	L-Low Remediable	High	L-Low	L-Low	Negligible	Negligible	L-Low	Negligible
Limchagad		L-Medium	C-Low	C-Low	L-Low Remediable	High	L-Low	L-Low	Negligible	Negligible	L-Low	Negligible
Siyangad		L-High	C-Low	No Fish Zone	L-Low Remediable	Medium	L-Low	L-Medium	Negligible	Negligible	L-Low	Negligible
Suwarigad		L-High	C-Low	C-Low	L-Low Remediable	Medium	L-Low	L-Low	Negligible	Negligible	L-Low	Negligible

L- Localised Impact; C- Cumulative Impact

In the above table only those components of eco-system have been taken as are significant. The following have been excluded for the reasons indicated against the component

Seismicity: The impact of HPs on seismicity is nil. The Socio-economic impact has been found to be positive in all cases

Impact on Water Quality is negligible in all cases.

Table 11.4: Impact of Hydro Power Projects at the Points of Confluence of Tributaries of Alaknanda

Tributary	Point of confluence	Landslide	Sediment	Fish	Environmental Flow		Springs	Irrigation	Places of Cultural and Religious Importance	Tourism	Construction Activities	Submergence
					Impact on Flow	Power Generation						
Dhauliganga		L-High	C-Low	C-Medium	L-Low Remediable	Medium	L-Medium	L-Low	Negligible	Negligible	L-Medium	L-Low
Rishiganga		L-High	C-High	No fish zone	L-Low Remediable	Medium	L-Positive	Positive	Negligible	Negligible	L-Low	L-Low
Bhyundar ganga		L-Medium	C-Low	No fish zone	C-Low Remediable	High	L-Low	L-Low	Negative	Negative	L-Low	Negligible
Birahiganga		L-High	C-Low	C-Low	C-Low Remediable	Medium	L-Medium	L-Medium	Negligible	Negligible	L-Low	Negligible
Mandakini		L-High	C-Low	C-High	L-Low Remediable	High	L-Medium	L-Medium	Negligible	Negligible	L-Medium	Negligible
Nandakini		L-High	C-Low	C-Low	L-Low Remediable	Medium	L-Medium	L-Medium	Negligible	Negligible	L-Low	
Pinder		L-High	C-Low	C-High	C-Medium Remediable	Low	L-Low	L-Low	Positive	Positive	L-Medium	Negligible
Jummagad		L-Medium	C-Low	No fish zone	L-Low Remediable	Medium	L-Low	L-Low	Negligible	Negligible	L-Low	Negligible
Kailganga		L-High	C-Low	C-Low	L-Low Remediable	Medium	L-Low	L-Low	Negligible	Negligible	L-Low	
Kaliganga		L-Medium	C-Low	C-Low	L-Low Remediable	Medium	L-Low	L-Low	Negligible	Negligible	L-Low	Negligible
Kalpaganga		L-High	C-Low	C-Low	L-Low Remediable	Medium	L-Low	L-Low	Negligible	Negligible	L-Low	Negligible
Khiraoganga		L-Medium	C-Low	No fish zone	L-Low Remediable	Low	L-Low	L-Low	Negligible	Negligible	L-Low	Negligible
Rishiganga		L-Medium	C-Low	No fish zone			L-Low	L-Low	Negligible	Negligible	L-Low	Negligible

Table 11.5: Cumulative Impact on Components of Ecosystem of All Hydropower Projects Located on the main stem of Bhagirathi at Devprayag

River	Landslide	Sediment	Fish	Environmental Flow		Springs	Irrigation	Places of Cultural and Religious Importance	Tourism	Construction Activities	Submergence
				Impact on Flow	Power Generation						
Bhagirathi	Medium	High	High	Low Remediable	Medium	Positive	Positive	Negative	In some places Negative; in some positive	High	Varies between Low and high
Alaknanda	L-High	High	High	High	Medium	Medium	Low	Negligible	Positive	Medium	Low

11.15. Inferences Drawn From the Study of the Impacts of Large Commissioned Projects:

Geological:

11.15.1. The permanent snow line falls well above the present and proposed elevation levels of HPs. Therefore, HPs do not impact glaciers of the area.

11.15.2. No change in the pattern of local seismicity within 40 kms of Tehri dam has been observed after the filling of the reservoir. In the entire basin values of earth quake occurrence probabilities are found to be less than 0.2, which is less than the critical probability. Hence the cumulative risk of occurrence of reservoir induced earthquakes is found to be minimal.

However, in view of the fact that the HPs are located in seismic zones 4 and 5, the HPs should be designed to withstand the earthquakes.

11.15.3. Impact on landslides

11.15.3.1. The construction of dam/barrage creates a relatively deeper water body just behind (upstream) the dam/barrage and shallow running water downstream. The valley slopes on upstream are submerged and get exposed downstream. This local change in environment may lead to destabilization of slopes and change in the sedimentation pattern.These may result in increased incidence of landslides unless preventive measures are taken.

11.15.3.2. Remedial measures:

- Geo-scientific studies need to be carried out to identify problematic areas of earth mass failure, and, site-specific, cost effective measures such as plantation on slope, re-grading of slope, shotcreting, grouting, anchoring, retaining and supporting walls, etc. along with proper drainage (surface and subsurface) measures to avoid saturation of earth mass, be taken up. The details of the studies that need to be conducted are provided in chapter 4.
- Since the hill slopes around the reservoir are likely to be affected by discrete, isolated shallow landslides in the initial stages of operation, a no-activity buffer zone above the Maximum reservoir level (MRL) along the rim of the reservoir may be created to avoid untoward incidences. The width of this zone may vary from a few meters to about 50m depending on the topography, lithology and structural attributes of the area. The zone be monitored for the change in the hill slope of the rim area.

11.15.4. Impact of Tunnelling on Springs.

11.15.4.1. Geotracts 2 and 5 are very fragile zones in the Garhwal Himalayas. In Geotract 2, there have been incidents of infiltration of substantial quantity of water during tunnelling. The projects falling in these Geotracts, especially Geotract 2, should be carefully investigated for slope stability, ground water and springs.

11.15.4.2. Remedial Measures:

Tunnelling as well as audit sites be chosen in such a manner that they don't cut through such zones specially the underground water flow regime.

11.15.5. Soil Erosion

There is no impact of HPs on soil erosion from the catchment. However, there is impact of soil erosion on the sediment deposit on the bed of the reservoir of a HP.

Remedy:

Catchment Area Treatment Plans are prepared. However, their implementation is a weak area. Their implementation needs to be monitored.

11.15.6. Sediment Accumulation on River Banks

It has been found that loose sediment vastly accumulated on the river banks in the vicinity of project site. This can be seen in Birahi Ganga where four projects are planned and one is already under construction. This sediment would be carried to the project and accumulate in the reservoirs/barrages'

Remedy:

For all projects the accumulation of sediment upstream of the project should be studied and measures for their stabilisation should be designed and implemented.

11.15.7. Impact During Construction of Projects:

11.15.7.1. Muck Disposal

It has been observed at many sites that the excavated muck is dumped in huge quantities over the river bank slopes (e.g., Srinagar Hydel Project, Tapovan - Vishnugad Hydel Project, Vishnuprayag Hydel Project, etc.). It results in erosion of large areas of hill slopes and the muck getting washed out continuously, particularly during high floods.

Remedy:

Suitable dumping sites for the disposal of the muck generated during construction should be identified well in advance. The dumped muck should be protected by a retaining wall at the toe up to HFL. This is equally necessary for small hydropower projects also.

11.15.7.2. Nuisance of Dust and Noise

Construction gives rise to large quantities of dust. During construction water should be regularly sprinkled on roads so that the dust does not become airborne. Water should also be sprinkled on crushing and batching plants. The HP at Srinagar is a case in point where dust and noise is a big nuisance. The generators and other equipment used need to conform to prescribed standards of CPCB.

11.15.8. Impact on Fish and aquatic life

Storage based HPs have high dams and big reservoirs. These prevent migration of fish across the project both ways i.e., from downstream to upstream and vice versa and has effect on its sustainability.

Remedy:

It is important that effective fish ladders are provided on all projects located below an elevation of 2500 meters including RoR projects.

11.15.9. Affected River Length

The hydropower projects (HPs) affect the river both upstream as well as downstream. The dam/barrage stores water that spreads along the river length upstream depending on the height of the dam/barrage.

Water is diverted from the river and rejoins the river only after the powerhouse. This length could be very long and the diverted stretch of the river has either no water or very little water. This stage could be fatal to aquatic life.

This diversion prevents prevents ritualistic bathing and observance of other rituals. In Chapter 8, for each project the diverted length of the river, its length under submergence has been worked out and shown in tables.

It has been observed that since the river becomes dry in the diverted stretch of projects, the people living in habitations along the river, are deprived of the water that they have been using as a matter of course.

Remedy:

The water requirement (depth and velocity) and its variability for sustainability of the species found in the different stretches of the rivers and their tributaries has been worked out. The water requirement changes from season to season and accordingly its requirement in different time periods should be worked out. This is the environmental flow which must be released to the river and is not available for power generation. To this extent the production of power will be reduced. For every project EFR has been worked out in the basin under study and the reduction in power generation has also been worked out. In line with the variability of natural flow, the EFR also varies in different parts of the year. Flow in the river should be regularly monitored to ensure that it is not less than the prescribed environmental flow. In this monitoring the local stake holders should be associated.

The water spread upstream of the dam/barrage should be worked out and it should be ensured that there is sufficient gap between the tail race and the submergence of the next downstream project so that opportunity is given to the river to recuperate its ecological environment.

Regarding the water requirement at places of religious importance, their needs on different festivals should be ascertained and the needed quantity of water should be released to meet the needs. In the river bed at suitable interval about one meter high check dams may be erected where water will collect to meet the needs of the local population.

11.15.10. Monitoring of the Project Post Commissioning

The project authorities of large projects are expected to send monitoring reports to the MoEF periodically.

It appears necessary to monitor, among others, the following parameters:

i. Aquatic biodiversity in the reservoir and in the river beyond the reservoir
ii. Landslides near the rim of the reservoir
iii. Water Quality at different depths and at different parts of the reservoir
iv. Impact on water table and springs in the catchment upstream of the project
v. Land slides down stream of the dam.
vi. Flow (discharge) downstream of the project in the diverted length of the river.
vii. Aquatic life in Ganga downstream of Devprayag
viii. Any springs that may have dried up

We did not have the benefit of seeing the data monitored or the periodical reports sent to the MoEF in respect of any of the four large projects that have been commissioned.

In Cumulative Impact Assessment literature, Adaptive Management is a recommended method of ensuring environmental and social sustainability of the developmental projects. For applying it, data on Valued Ecosystem Components needs to be collected on a regular basis, studied for deciding what measures need to be taken in the interest of sustainability.

In addition to the monitoring of physic-chemical characteristics of water, regular biomonitoring should be undertaken under the guidance of an expert environmental biologist for assessing the level of change with the help of potential bioindicators. The details are given in the Chapter on Environmental Aspects.

There should be a State Environmental Monitoring Mechanism to formulate a monitoring programme for all projects to generate data so that Adaptive Management can be practised. It is only appropriate that the monitoring is done with the association of the representatives of the civil society.

There should be a Depository where all the data generated in relation to the project should be deposited and it should be available to any interested person and , preferably, be on the internet. The projects in cascade on a stream should not abut each other. There should be some gap as may be recommended after a study of the stream, its biotic life and uses to which it is put.

11.15.11. Stakeholders Views - Public Perception of Benefits

i. Desirability of Harnessing Hydropower

Among the people there are two distinct views about the development of hydropower in the basin. The local people are strongly in favour of these projects. They feel that they have hardly any natural resource in the area which they can use for economic development other than water which is not being put to economic use. They see great opportunity for big growth of employment, business, and services as also for improvement of local physical and social infrastructure.

On the other hand there are others, mainly outsiders, who are firmly opposed to disturbing the flow regime of the holy rivers and to the development of hydropower on the grounds that the mystical properties of the waters and the region will be destroyed, that the rich biodiversity will be seriously damaged and that such projects would cause loss to the local people.

ii. Accrual of Benefits

There has been a feeling that the projects benefit people from other regions at the cost of people around the project site. Compensation, however generous, can never be enough for a person, who is dislodged from his place and profession, or even if not dislodged, goes through a number of difficulties and tensions of temporary and permanent nature. Consequently the people in the area suffer mentally and physically from uncertainty, worry and hardships. Moreover, there are many persons whose property is not acquired and still they have suffered mental agony.

Remedy:

Socio-economic study of the affected area should be conducted to determine whether the economic status of the people and the quality of life in region has improved or deteriorated.

The State gets 12% of the power generated free of charge. It, therefore, stands to reason that a part of the revenue earned by the State from free electricity is spent on the local people on items such as health, education, transport and physical, financial and social infrastructure.

Since a HP creates difficulty for the local people in terms of changed availability of water and its diversion, it will be useful for the developer to enter into an agreement with the affected community for the implementation and operation of the need based schemes even on completion of project so that the community's social, cultural and religeous needs are met. There are some agreements already in operation between the developers and the local communities, based on which other required agreements can be drawn.

11.15.12. Impact On Irrigation

In the area under study, the rivers flow in the narrow valleys and there are hardly any irrigation schemes from the main rivers. Irrigation is mostly from the tributaries and sub- tributaries. As such the impact on irrigation of HPs is assessed as low and localised.

11.15.13. Creation of Settlement Because of Hydropower Projects

The large hydropower projects have attracted outsiders leading to urbanisation near the sites of the dams/barrages and the power houses. It has caused environmental problems, especially the pollution of solid and liquid waste. Similar development will also take place when near the sites of other projects.

Remedy:

It is necessary to plan the human settlements that will arise as a result of the HPs and the growth of service industry such as tourism, banking, business etc. Needless to say that safe disposal of solid and liquid waste should enjoy the highest priority. For temporary shelters needed during the construction phase, arrangements for safe disposal of solid and liquid waste should be made.

11.15.14. Haphazard Development in the vicinity of the Project

It is necessary to regulate the land use near the project site as well in the entire river stretch covering some distance beyond the floodplain of the river.

However, it is clear that the State of Uttarakhand and, indeed the country, are desperately short of electricity and the basin offers excellent sites to harness this clean form of energy. Chapter 8 on Hydropower Development contains a detailed account of the potential of the basin to develop hydropower and status of its development, relationships between electricity generation on the one side and discharge, head, the area under pondage, the length of the tunnel and the stretch of the river bypassed, area submerged, environmental flow requirement, cost, revenue generation, direct and indirect employment generation have been discussed. It comes out that the hydropower is the cleanest form of energy, has by far the best ratio of energy generated to energy consumed and is the most economic of all sources of energy. Needless to say that energy is the prime mover of development and for the State of Uttarakhand this is the only available source.

11.15.15. Public Awareness and Public Participation

There was criticism during the implementation of the project that project affected families were not taken into confidence and not kept informed from time to time about the developments regarding the project and the manner in which any adverse effects on them will be managed. It is well known that on account of deficiencies in the Information Education and Communication (IEC) programme the people developed many misapprehensions about the projects resulting in protests and litigations causing very expensive delays and social tension.

Remedy:

For future projects an effective IEC should be an integral part of the project.

CHAPTER 12

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

The conclusions of this study have been summarised under different aspects and are as follows:

12.1 ENERGY GENERATION ASPECTS

12.1.1 Status of Development of Hydropower in the Basin

The area of the catchment of Alaknanda and Bhagirathi basins up to Devprayag is 19,600 km^2 and has a potential to generate hydropower of 9033 MW, producing 37,103 MU of electricity from 70 allotted sites. Thirteen commissioned hydropower projects with total installed capacity of 1851 MW (7,860 MU), 14 projects of 2,538 MW capacity (10,727 MU) and 42 projects with installed capacity of 4,644 MW (18,516 MU) are at different stages of development. There may be a few more sites (a few large ones and many small ones) in these basins which have not been allotted yet and for which relevant details are not available. Therefore, such sites are excluded in this study.

There are 15 projects (2 commissioned, 2 under advance stage of completion, 2 under construction, and 9 in other stages of development) with storage reservoirs having more than 20 m height (above the river bed level). All these, except the Tehri project, are basically run of river projects with diurnal storage for operating for peak hours during lean flows.

River Bhagirathi and its tributaries have a total length of 456.5 km. The diverted stretch is 130.5 km (28.6%) and the submerged length is 85.4 km (18.7%). Thus, the total affected stretch of the river and its tributaries is 216 km (47.3%).

In the case of Alaknanda basin, the total length of the river and its tributaries is 664.5 km. The diverted stretch is 233.7 km (35.2%) and the submerged length is 58.2 km (8.75%). Thus the total affected length of the river and its tributaries is 292 km (43.9%).

12.1.2 Energy Generation View

An analysis of the data of 70 projects has been carried out and the results that have emerged are as follows:

1. Vishnuprayag RoR project has the highest electricity generation of 32 MU for each cubic m of water against storage based projects like Kotlibhel 1B and Koteshwar which have a low energy generation from diverted unit discharge as 2.5 MU and 1.8 MU, respectively (Fig 8.19(a) & Fig. 8.19(b)).

2. Storage (even diurnal) based schemes have high electricity generation for each m potential head viz. 23 MU for Srinagar and 15 MU for Koteshwar,

respectively. Small scale hydropower projects have low electricity generation for each meter of head available in the river gradient as they carry low discharge.

3. Power plant utilization factor is nearly 1 for some run of the river projects like Jummagad and as low as 0.45 and 0.4 for Kotlibhel 1B and Tehri storage projects, respectively.

4. If Environmental Flow Requirement is met, reduction in potential to generate power in the Bhagirathi Basin is estimated between 4% - 13% (minimum to maximum values of environmental flow) and the Alaknanda Basin between 7%-15% (minimum to maximum values of environmental flow).

As per detailed project reports/feasibility reports of all hydropower projects, an investment of ₹406 Billion is planned. It may be noted that additional investment is also involved in creating appropriate transmission network for power evacuation.

The following analysis has also been carried out using the data of these projects on the following basis:

1. Investment per unit of river water used for power generation,
2. Investment per unit of river stretch used for power generation,
3. Investment made per MW of installed capacity,
4. Revenue that will accrue to the State Government if the allotted potential is harnessed and
5. For each project and for each tributary and for rivers, river stretch diverted, bypassed and submerged has also been worked out.

12.1.3 Revenue to the State Government from Hydropower

As per state policy, power generation from hydropower projects carries a premium on the investment and certain amount of free power is given to the state as royalty. This royalty, at the rate of 12% of power generated, adds to the revenue of the state government, for carrying out development and social welfare activities. The amount estimated is ₹ 3,295 Million from commissioned projects, ₹ 3,482 Million from ongoing projects and ₹ 9644 Million from projects under development at different stages with a total of ₹ 16,421 Million. Investments in projects, especially by the private sector, which are mainly from the outside the state, further strengthen the economy of the state and its people by way of development. With a very rough estimate @ about 10% of investment through various activities on the project, it brings a sum of ₹9,764 Million for ongoing construction projects and ₹26,949 Million for planned projects. Such aspects may be studied in detail in due course for building up database for the country which may be used for decision making pertaining to hydropower development in the country in an overall perspective.

12.2 ENVIRONMENT AND BIODIVERSITY ASPECTS

12.2.1 Water Quality

By comparing the base line water quality data at most upstream points of rivers and tributaries, it was observed that impact of hydropower projects on water quality (9 standard water quality parameters) was insignificant. Water quality in the given basins was found to be of class-A.

12.2.2 Aquatic Biodiversity

The basin is characterized by a rich biodiversity and several unique ecological domains. Biological components can be classified into distinct broad categories, namely terrestrial flora, terrestrial fauna, aquatic flora and aquatic fauna. Riverine habitats generally occupy a small proportion in the total landscape, yet play a critical role as corridors and migration pathways for several faunal and floral species. They also serve as ‘edge’ habitats, facilitate river courses and also assist in prevention of soil erosion. They are often designated as ‘sensitive habitats’. The courses of Bhagirathi and Alaknanda rivers support a number of forest formations which are typically riverine in nature. Among the faunal groups, several species of herpetofauna, riverine birds such as laughing thrushes, red starts, forktails, whistling thrush; and mammals especially, otters and fishing cats, are of high conservation significance. Among fishes, there are several threatened species including golden mahseer, snow trout, etc. that breed in this landscape. Many species of fish require an uninterrupted riverine habitat as well as floodplains for their breeding.

12.2.3 Impact on Aquatic Life

Construction of a dam with a reservoir changes the domain of flowing water (river) to a standing water (lake) domain. This change brings about significant changes in physico-chemical characteristics affecting the ecological parameters. The new standing water body would have its own ecology and biodiversity. So far, we do not have any study of changes in aquatic life from river to reservoir. Thus, at present it is not possible to give any firm assessment on the impact of HP on biodiversity of Alaknanda and Bhagirathi basins.

To understand the impact of HPs on aquatic fauna and flora, it is necessary to have a systematic documentation of various genera and species in different segments of the river system. Moreover, record of temporal changes in aquatic life is also required to assess natural changes and changes due to HP projects. However, this kind of information was not available for the study area.

12.2.4 Assessment of Environmental Flow Requirement (EFR)

A number of methods such as hydrological index method (e.g. Look-up tables, EMC-FDC approach) and hydraulic habitat analysis, e.g., EMC HMD approach, etc were employed to estimate EFR at various representative projects and locations of religious and cultural importance. The minimum flow, given by World Commission of Dam, and 75% of low flow based on Q95 along with the minimum required based on Environmental Management Class (EMC)-Hydraulic Mean Depth (HMD) have been presented. Maximum and minimum values from these methods/approaches have been presented as the range of environmental flows.

A major handicap in this study is that the measured river cross sections and velocity of flows were available at limited locations. These estimated values were used to derive the required parameters such as hydraulic mean depth at different locations. Similar was the case with river flows. EFR were estimated using interpolated values at places of interest. In view of the above, the environmental flow values computed in this study may be considered indicative values as only.

Actually, EFR critically depends upon the development stage of the region and expact action of the society from the river. Methods, such as the Building Block Method, have the provision of consultation among experts and stakeholders which require a much larger time period and resources. However, application of BBM for a large number of sites requires a lot of time, data and human and financial resources.

12.3 VIEW OF STAKEHOLDERS

Interaction with stakeholders has revealed that the Bhagirathi and Alaknanda valleys and its people have not remained unaffected by major changes brought about by the recent spurt in economic growth in the country as a whole, and they have a desire to be part of the growth story and share in the gains. There is no denying that as far as the local people are concerned, the projects do have a positive economic impact in myriad ways. These are in the form of employment opportunities, secondary economic benefits like opportunities for small contractors, transport, hotels and guest houses, spurt in trade and business especially market for local businesses, overall development of the area through roads, schools and hospitals.

For the local people, economic considerations apparently seem to outweigh social, cultural, and religious considerations, but if challenged and presented with feasible alternatives they may not be averse to accept a compromise that assures them a better economic status through assured livelihood opportunities along with preservation of the ecological health of the river.

In Haridwar diversion of the river into a canal has not only been accepted by Hindu society in general and the religious leaders in particular, but it has also been accorded a especially venerated status. The Har-Ki-Pauri bathing ghat at Haridwar is actually located on the Upper Ganga Canal and not on the main river. Over the years everyone, including the Sadhu Samaj, have accepted the changed river course and diversion. The water at Har-ki-Pauri is considered as sacred as that of the main Ganga river. In fact it, and not the main river, is the prime bathing area during the all important *Kumbha Mela,* held after every twelve years. This diversion and construction of the canal was achieved in the year 1847.

Though agriculture in Bhagirathi and Alaknanda basins may not benefit directly from hydropower projects, the indirect benefits by way of better linkages and supply of inputs, access to markets, better prices as a result of increased prosperity and year round demand would definitely prove beneficial. Furthermore, there has been a marked improvement in condition of roads during the last decade. This is a result not only of large investment in road building under various government schemes, but is also due to the necessity for ferrying large machinery to the sites of hydro power projects. Improvements in roads will indirectly benefit the tourism industry.

The local people in the Bhagirathi valley are, by and large, in favour of resuming work on the abandoned hydropower projects, especially the Loharinag Pala project on which substantial work has already been done. The justification was invariably given in terms of economic benefits of the project viz., employment and other secondary activities, and the fact that since the damage had already been done, the people gained nothing from stopping the half-constructed projects.

12.4 ASSESSMENT OF IMPACTS OF HPS ON VARIOUS IDENTIFIED COMPONENTS

The study of impact of these projects has been done in a variety of ways as given below:

- Cumulative impact of each project on all ecosystem components
- Impact of each project on selected components
- Cumulative impact of all projects on each tributary at the point of confluence with Bhagirathi
- Cumulative impact of all projects on each tributary at the point of confluence with Alaknanda
- Cumulative impact of all projects located on Bhagirathi at Devprayag
- Cumulative impact of all projects located on Alaknanda at Devprayag.

Conclusions pertaining to cumulative impact on identified components are summarised below:

i. The impact of HPs on seismicity is nill. It means that a HP will not induce earthquakes. However, the study area is in Seismic Zone IV and V and, therefore, the HPs should be designed to withstand expected earthquakes.
ii. Glaciers are much higher altitudes, upstream and distant to be affected by hydropower projects.
iii. The impact on tourism is generally positive.
iv. Very few places of religious and cultural importance will be affected by HPs. However, in case there is some such place, it can be ensured that the needed water is released whenever required.
v. The impact on irrigation is generally positive.
vi. The impact on economy is positive. However, construction activity leads to migration into the project area and creation of temporary human settlements/urbanizations giving rise to waste generation and other developments associated with urban areas. Analysis of satellite imagery has clearly established changes that have taken place at many project sites. Unless care is taken, the rivers may become polluted.
vii. The impact on water quality is low and in all projects, the quality of water, after it comes out of the power house, is well within the limits of environmental sustainability
viii. There is no significant impact of Hydropower Projects on water quality in run of river projects. Out of 10 parameters, only five, namely, temperature, DO, BOD, FC and conductivity show minor changes in the vicinity of the

hydropower projects. However, in places where habitations have come up because of projects and where waste water flows to the rivers, the parameters change. In most cases habitations do not have very large population and so the impact is also small.

ix. In storage based HPs, stability of slopes could be affected and landslides could take place the rim of the reservoir. However, the slopes stabilize after a few years of operation of the project.

x. During tunneling, ground water or water from springs may enter into the tunnel. This may be mitigated by detailed prior geological investigations so that the tunnel alignment may avoid springs and ground water passages.

xi. Sediment is transported from the catchment and is trapped at the dam/barrage. In RoR projects, the bed is flushed and so sediment does not pose much of a problem. However, in storage based projects, sediments collect at the bottom and sediment concentration in water from the powerhouse is much lower. Silt ejections facility may be provided through low level outlets thereby mitigating the adverse impact.

xii. Unless sites for dumping muck, excavating building material are chosen after careful investigation, there is dust and noise pollution and erosion of slopes and flow of muck into the river during rains during construction.

xiii. In storage based projects, the river is converted into a big and deep reservoir and the migration of fish upstream from downstream and vice versa is obstructed.

xiv. In RoR projects, a considerable length of the river downstream of the barrage is bypassed and water is discharged into the river only after the powerhouse. Thus, this stretch of river becomes dry. This fragmentation, if unattended, can be very harmful for aquatic life and landscape.

12.5. FEASIBILITY OF HARNESSING HYDROPOWER IN THE BASIN

The economics of producing power at each site has been worked out as also the revenue that will accrue to the State if the allotted potential is harnessed. In order to help decision makers for evaluation of HPs, a number of relationships have been worked out and depicted in tables and graphs. These include discharge versus electricity production, fall versus production, length of the river diverted and submergence to power production.

Impacts, localised and cumulative, of hydropower projects on identified components needs to be mitigated. For this purpose, certain recommendations are made. Environmental flow releases will reduce power generation and such reduction may make several schemes unviable, especially small scale hydropower schemes. In addition to the accrued revenue from electricity, investment on power project directly adds to the economy of the region. The area may not have optimal conditions for industrial development due to its physiographic conditions but hydropower development provide an opportunity.

Based on analysis of potential sites, it can be concluded that hydropower at identified sites can be harnessed consistent with environmental sustainability, provided certain measures are taken.

12.6 RECOMMENDATIONS

Recommendations are grouped under relevant categories.

12.6.1 Impact Assessment

1 In view of the fact that the field of cumulative impact assessment (CIA) is new and is being introduced for the first time in India, there are many gaps in the knowledge necessary to undertake CIA with the desired degree of precision, particularly in the Himalayan region where the database is weaker than that in the rest of the country. It is, therefore, necessary that a major programme of research and development should be drawn and implemented as early as possible.

2 In Cumulative Impact Assessment literature, Adaptive Management is a recommended method of ensuring environmental and social sustainability of developmental projects. For applying it, data on Valued Ecosystem Components needs to be collected on a regular basis, and studied for deciding what measures need to be taken in the interest of sustainability.

12.6.2 Geology and Seismology

3 At the planning and execution stages of hydropower projects, detailed geo-scientific studies should be carried out to identify problematic areas of earth mass failure, site-specific, cost effective measures such as plantation on slope, re-grading of slope, shotcreting, grouting, anchoring, retaining and supporting walls, etc. along with proper drainage (surface and subsurface) measures to avoid saturation of earth mass, should be taken up. The studies that should be carried out are mentioned in Chapter 4, 'Geological Studies'.

4 Geotracts 2 and 5 are very fragile zones in the Garhwal Himalayas. In Geotract 2, there have been incidents of infiltration of substantial quantity of water during tunnelling. Projects falling in these Geotracts should be carefully investigated for slope stability, ground water and springs.

5 Geological investigations will also help in avoiding interference with springs and ground water flows and in identifying suitable sites for dumping construction muck and in selecting sites for retaining walls to prevent flow of dumped muck into the river.

6 Tunnelling as well as adit sites be chosen in such a manner that they don't cut through the underground water flow paths and spring.

7 It is recommended that the reservoir based hydro projects of more than 20 m high, especially close to Main Central Thrust zone, may be avoided and if constructed, these should be monitored for geo tectonic activity.

12.6.3 Soil erosion and sedimentation

8 Since hill slopes around reservoir are likely to be affected by discrete, isolated shallow landslides in the initial stages of operation, a no-activity buffer zone above the Maximum Reservoir Level (MRL) along the rim of the reservoir may be created to avoid untoward incidences. The width of this zone may vary from a few meters to about 50m, depending on topography, lithology and

structural attributes of the area. The zone be monitored for change in hill slope of the rim area.

9 Catchment Area Treatment Plans are prepared for all major projects. However, their effective implementation is crucial. Their implementation needs to be monitored and its effectiveness ensured.

10 For all projects, accumulation of sediment upstream of the project should be studied and measures for its stabilisation should be designed and implemented.

12.6.4 Hydrological Aspects

11 Optimum environmental flows should be released from every project keeping in view hydrological requirements of organisms, especially, during the winter dry season and residual flows should be set at a level that is compatible with maintaining integrity of the aquatic environment downstream. This will ensure that the diverted stretch of the river will maintain flows necessary to meet ecological requirements. All projects should have outlets at lower levels in the dam so that EFR can be released.

12 There is a need for a research programme on EFR so that the best methodology for estimation of EFR for Indian basins is evolved. On projects which have been completed, such studies should be carried out to see how the aquatic life is impacted when the flow is diverted for generation of power.

13 Hydrological variability is important for maintaining health of fluvial ecosystems. Natural variation occurs during flooding, fluctuations in water levels during the period of snow melting, which determines biological aspects of the ecosystem, such as habitat and species distribution, fish migration and spawning and various stages of life cycles of benthic aquatic macro-invertebrates. To mimic natural variations in flow regime, recommended variability in environmental flows should be maintained.

14 Modification or manipulation in morphology of stream channel in the form of increasing bed form, roughness, heterogeneity, and channel sinuosity is also recommended to improve habitat structure and induce hyporheic exchange flow in streams and rivers.

15 Regular flushing of the bed should be carried out so that the sediment deposited on the bed at the barrage is removed and benthic condition for fish eggs is improved. Benthic stability of the bed should be regularly monitored.

16 Gap between two consecutive projects along a stream should be sufficient for the river to recuperate itself.

17 In the diverted stretch of the river bed, at suitable intervals, about one meter high check dams may be constructed where water would collect to meet the needs of the local population.

12.6.5 Hydropower Related Aspects

18 No further allotment of HP sites may be made for rives where percentage of river length affected is high. A threshold, say 70%, may be fixed for this purpose.

19 Projects where energy generation per unit of diverted discharge is low may be discouraged and a suitable threshold may be fixed for this purpose.

20 Environmental flow requirement depends on development stage of the area and societal requirement and this shall reduce the hydropower generation

during lean season as well as advantage of peaking. Exact values of EFR for every single project for implementation should be established after carrying out detailed measurements of discharge, river cross sections and assessment of impact on biotic life as a result of reduced discharge on commissioned hydropower projects and consultation with the local community. The installed capacity of a hydropower project should be planned to be in conformity with the water available after satisfying the needs of environmental flow.

12.6.6 Environment and Biodiversity

21 Typically, river restoration focuses on surface system and their longitudinal and lateral connections, whereas the vertical dimensions are largely ignored. Thus, a holistic view to protect surface and sub-surface systems (hyporheic zone) and their fauna is recommended.

22 Fish passes may be made an integral part of hydropower projects.

23 Reforestation or riparian planting in degraded sites of the regulated river should be undertaken for stabilizing banks to reduce peak temperatures and source of particulate organic matter which can be entrained into river bed sediments during bed load movements.

24 Biological Monitoring: Regular biological monitoring should be undertaken at the project level under the guidance of expert environmental biologist, for assessing the level of environmental degradation with the help of potential bioindicators. The potential indicators for assessing the health of ecosystem are recommended as members of macroinvertebrates (Ephemeroptera and Trichoptera), hyporheic organisms (meiofauna), fish (Mahseer and other migratory fish) and a few aquatic periphyton/phytoplankton and macrophytes. This biological monitoring is required for adaptive management. An adaptive management plan based on specific requirements of aquatic organisms and the regulated river and the necessary modification made after thorough management effectiveness evaluation is recommended for effective conservation and management of aquatic biodiversity and integrity of the fluvial ecosystems. Environmental monitoring should be coordinated by a central agency for minimizing the cumulative footprint of these hydropower projects in Alaknanda and Bhagirathi basins.

25 Ecosystems of small streams or tributaries of Alaknanda and Bhagirathi should not be overexploited for hydropower generation as these streams are the main contributors of biological production of the main rivers. These small streams act as hatcheries for biological production at the first and second trophic levels of freshwater ecosystems and are a rich source of aquatic biodiversity. These streams have been identified as Nayar, Birhi Ganga, Bhyunder Ganga, Balganga and Asiganga which should not be exploited further as these are the lifelines of the main ecosystem of Alaknanda and Bhagirathi rivers.

26 The study on “Self-Purification Capacity of River Bhagirathi: Impact of Tehri Dam” conducted by NEERI for THDC in 2004 concluded that the self-purificatory quality of Bhagirathi or Ganga is not likely to be adversely affected by any reservoir or tunnel through which the water of the river is made to pass.

12.6.7 Religious and Social Aspects

27 Though there is a provision for public hearings on environmental issues, more often than not, these turn out to be mere formalities without much advance publicity and with minimal public participation. Public hearings should be given greater importance and conducted in such a manner that the general public feel that they are partners.

28 To ensure that opposition to such projects is minimized, the projects should ensure that a fair deal is offered to the affected areas and inhabitants and that the promises made, such as those relating to jobs, minimum water discharge, etc, are adhered to in 'letter and spirit'.

29 A feeling among local people has been discerned that the projects benefit people from other regions at the cost of people around the project site. Compensation, however generous, can never be enough for a person who is dislodged from his place and profession or even if not dislodged, goes through a number of difficulties and tensions of temporary and permanent nature. Consequently, people in the area suffer mentally and physically from uncertainty, worry and hardships. Moreover, there are many persons whose property is not acquired and still they have suffered mental agony. The cess on power generation and part of income from free power available from developers of projects should be spent on development of affected areas and providing facilities such as health, education, transport and development of physical and social infrastructure.

30 It should be ensured that sites of religious and cultural importance at the local level are clearly identified and efforts are made to minimize adverse effects on them on account of the projects.

31 A view expressed by many stakeholders is that Tehri Dam has affected the Bhagirathi basin much more than all other projects put together, both in size and in the trend it has set. As a result, having accepted the Tehri dam with the displacement and disruption, they feel cheated in being denied the benefits of project construction that promises them jobs and improved economic status without causing any significant displacement or disruption.

32 An issue that has been relatively neglected but which deserves serious attention is that the local people, especially, those likely to face any adverse impact of project construction activities e.g., damage to houses and property, agricultural fields, water sources etc., must be taken into confidence prior to commencement of construction and also informed of rehabilitation and compensation measures that are proposed. This should mitigate, to a large extent, resentment that some projects have generated.

33 Bathing ponds (kunds) may be constructed adjacent to rivers at places of religious and social importance. These should be connected to the river so that there is continuous flow of fresh water and adequate depth of water is present.

34 Regarding water requirement at places of religious importance, their needs on different festivals should be ascertained and the needed quantity of water should be released to meet these needs.

35 It is necessary to plan human settlements that will arise as a result of HPs and the growth of service industry such as tourism, banking, business etc. Needless to say that safe disposal of solid and liquid waste should enjoy the highest priority. For temporary shelters needed during the construction phase, arrangements for safe disposal of solid and liquid waste should be made.

12.6.8 Construction related aspects

36 Suitable dumping sites for disposal of muck generated during construction should be identified well in advance. The dumped muck should be protected by a retaining wall at the toe up to HFL. This is equally necessary for small hydropower projects.

37 Construction gives rise to large quantities of dust. During construction water should be regularly sprinkled on roads so that it does not become airborne. Water should also be sprinkled on crushing and batching plants. The HP at Srinagar is a case in point where dust and noise is a big nuisance. Generators and other equipment used need to conform to prescribed standards of CPCB.

12.6.9 Monitoring

38 Project authorities of large projects are expected to monitor prescribed parameters of the project and send periodical reports to the MoEF. It appears desirable to monitor, among others, the following parameters:

- Aquatic biodiversity in the reservoir and in the river beyond the reservoir,
- Landslides near the rim of the reservoir,
- Water quality at different depths and at different parts of the reservoir,
- Impact on water table and springs in the catchment upstream of the project,
- Landslides downstream of the dam,
- Flow (discharge) downstream of the project in the diverted length of the river,
- Aquatic life in Ganga downstream of Devprayag, and
- Any springs that may have dried up.

39 In addition to monitoring of physico-chemical characteristics of water, regular bio-monitoring should be undertaken under the guidance of an expert environmental biologist for assessing the level of change with the help of potential bio-indicators. Details are given in the Chapter 6 on Water Quality, Biodiversity and River Ecology.

40 There should be a State Environmental Monitoring Mechanism to formulate a monitoring programme for all projects to generate data so that Adaptive Management can be practised. It is only appropriate that monitoring is done with the association of representatives of civil society.

41 There should be a depository where all the data generated in relation to the project should be deposited and it should be available to any interested person and, preferably, be on the internet.

42 It is necessary to regulate land use near the project site as well in the entire river stretch covering some distance beyond the floodplain of the river.