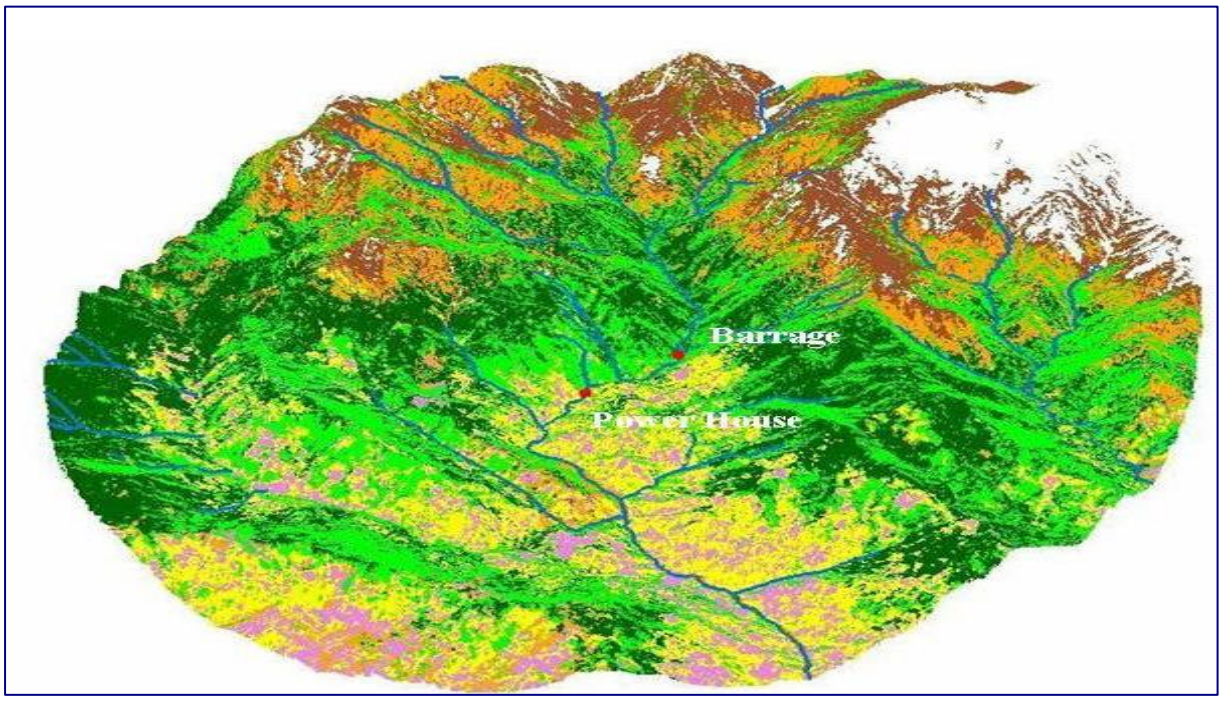
Kalpan Hydro

KHC Lethang Hydro Project Private Limited

Draft CEIA Report for 96 MW Lethang Hydro Electric Project , West Sikkim District, Sikkim



COMPLETE SOLUTIONS
IN WATER & ENVIRONMENT

Asian Consulting Engineers Pvt. Ltd., New Delhi

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INTRODUCTION

1 INTRODUCTION

1.0 Hydropower Potential in Sikkim

Electricity is an essential requirement for every facet of life and also to achieve accelerated economic development as well as growth in our country. Hydropower is perhaps the cleanest, renewable and readily available source of energy with bulk of its potential yet to be harnessed in many developing countries including India. The Ministry of Power has set a target for providing "Power to all by 2012". This will entail electrification to all households by 2012.

The Government of India has decided to focus on Hydro power development as, it is one of the cleanest sources of energy. The intent of the Government is to tap the Hydropower potential of India to meet its goal of power for all by 2012.

In India, hydropower potential is largely available in Himalayan states viz, Himachal Pradesh, Uttarakhand, Sikkim and Arunachal Pradesh. The re-assessment studies of hydro-electric potential of the country, completed by Central Electricity Authority in 1987, have placed the hydro power potential at 84,044 MW at 60% load factor. When fully developed this will result in an installed capacity of 148,701 MW (145320 MW above 25MW installed capacity). At present (as on 31.05.2010), 32,127.8 MW (22.11%) of the potential has been developed and 14,225 MW (9.79%) is under construction in terms of installed capacity. Thus about 98,967.2 MW (68.1%) of the potential is yet to be developed. Similarly in Sikkim, out of 4248 MW, 570 MW (13.42%) has been developed and 2066 MW (48.63%) is under construction.

The foundation stone of power development in Sikkim was laid in 1927 with the commissioning of first hydel power project of 50KW capacity at Lower Sichey Busty on the bank of river Ranikhola near Gangtok. Till the year 1975, the state had a generation capacity of only 3 MW from its small hydel projects (SHP) such as Jali Power House, Rimbi Micro Hydel, Rothak Micro Hydel, and Manul Micro Hydel.

Sikkim has number of streams & rivers flowing down the glaciers, which provide abundant potential for hydro electric projects. It is estimated that Sikkim has a potential of generation of 4286 MW and about 600 MW through projects which are largely "run of river" schemes. This potential resource can be tapped effectively and efficiently for meeting the electricity demands of that region.

To pursue hydro power development, Government of Sikkim has created its own hydro power development nodal agency "Sikkim Power Development Corporation" (SPDC). SPDC is playing a critical role in encouraging independent power producers to invest in hydro power development in Sikkim. This is further supported by a liberalized policy of the Government of Sikkim for hydro power.

The river Teesta is known as the life line of Sikkim. It is one of the major rivers with tremendous potential for planning and implementation of hydro power projects. The river has the potential for over 7046MW of hydro power potential, as it flows from an elevation of about 3600 m to about

300 m over a distance of 175 Km. A number of hydro projects are currently under development on Teesta by the private sector.

The second largest river, which is a tributary of Teesta, is the Rangit River in West Sikkim. A number of hydro projects are also currently under development by the private sector on this river. A large hydro power potential is also available on the smaller rivers and streams of Sikkim. This is also being tapped by the private sector to accelerate hydro power development.

Small to medium size hydro projects require comparatively less time for development and have minimal impact on environment as compared to large dam based hydro power projects.

1.1 Lethang Hydro Electric Project (HEP)

The proposed Lethang Hydro Electric Project (Lethang HEP) is a run-of-the-river scheme with barrage as a diversion structure on River Rathang Chu in West Sikkim. The downstream project is Ting Ting HEP.

The proposed Lethang Hydro Power Project is a medium head scheme with rated design head of 304.5 meters. It has full reservoir level and minimum normal reservoir level at barrage as 1575 meters and 1571.50 meters above mean sea level respectively. The design discharge has been adopted as 34.95 cumecs for generation of power. Accordingly, a 96 MW hydro Power Project has been conceptualized on Rathang Chu River. The diversion site has been planned near village Yuksam. The underground power house will be located near Lethang village on the right bank of the river.

The proposed plan of evacuation of power from Lethang HEP envisages transmission to Melli Substation. Melli is about 50 circuit km from Lethang HEP.

1.2 Identification of the Project

The state of Sikkim has vast hydro power potential. River Rathang Chu is one of the major tributaries of River Rangit in West Sikkim. Along the river Rathang Chu, there is a sharp fall of levels from about 1625 m at some location above the Yuksam village to a level of 1260 m close to Lethang Bridge. The project proponent has visualized a Hydro Electric Project to utilize this head and the flow in the Rathang Chu

The Agreement for the execution of Lethang HEP had been signed between, KHC Lethang Hydro Project Private Limited and Govt. of Sikkim on 5th November 2008.

1.3 Project Proponent

M/s KHC Lethang Hydro Project Private Limited (KHC) proposes to develop the Lethang Hydro Electric Project in west district of Sikkim for harnessing the power potential of Rathang Chu River. Kalpan Hydro Company (Kalpan) is a leading IPP (Independent Power Producer) the parent company of KHC Lethang Hydro Project Private Limited.

Kalpan has already acquired the rights to develop three hydro projects in the State of Punjab. Two of these projects are expected to be operational by March 2011 and one will be operational by September 2011. Kalpan has an experienced team with extensive expertise in successful hydro power projects delivery, carbon credits financing and corporate social responsibility (CSR) initiatives. . The Kalpan team has extensive work experience in across most of the river basins of North and North-East India

Kalpan Hydro Company (Kalpan) is a triple bottom line (financial, social and environmental) focused independent hydro power producer. The strategy of Kalpan is to -

a) Acquire run-of-the-river small to medium size Hydro Projects across the leading hydro power potential states of India. Typically this will involve acquiring rights for projects which are either green field and or post Detailed Project Report (DPR) stages.

b) Deliver significant positive sustainable development impact around the project sites:

   i) Reforestation/ afforestation & other conservation measures around the hydro sites.
   ii) Support local electricity generation using renewable energy sources.
   iii) Improve drinking water and sanitation facilities of local community.
   iv) Facilitate local community in capacity building and support t value addition in farming, and marketing of local agricultural produce.
   v) Support build-up of local infrastructure for education/ health.

c) Implement better cost and time control mechanisms to ensure delivery of project within cost and time through in-house competencies as also in partnerships with leading players in the hydro sector.

d) Allocate a certain percentage of project costs and a percentage of the revenues, for further social and economic development of communities around the acquired projects.

Kalpan is conscious of social and environmental aspects associated with development of hydro power projects and accordingly, have earmarked resources, manpower, and capital for the development of the local area during the project development phase, as also on an ongoing basis.

1.4 DPR Consultants & EIA Consultants

The detailed project report has been prepared by AF Colenco Ltd. while the EIA report has been prepared by Asian Consulting Engineers, New Delhi.

1.5 Purpose of EIA Study

The purpose of Environmental Impact Assessment (EIA) study is to identify the possible impacts on environment and to suggest ways for mitigating & minimizing impacts. The study also identifies possible adverse and beneficial impacts on the environment as a result of implementation of the project. The EMP (Environmental Management Plan) provides a plan meant for reducing the impacts of the project. It also helps in identifying alternatives that will ensure minimize environmental degradation. This may be via modification in project design, implementation of project alternatives, environmental protection measures and other solutions will help in reducing the severity & magnitude of impacts.

1.6 Policy & Legal Framework

The project proponent, KHC Lethang Hydro Project Private Limited will ensure that it conforms to all National and International legislations, regulations, and conventions, relating to various aspects of hydro power development in India. Recognizing that the proposed project is located

close to a protected and environmentally sensitive area namely Kanchendzonga National Park & Biosphere Reserve,; KHC Lethang Hydro Project Private Limited will follow established national standards and practices for environmental protection. Every endeavor has been made to bring the proposed project in compliance with relevant legislation. A list of applicable Acts and Rules is described in **Table 1.1.**

Table 1.1: Applicable Acts and Guidelines

Issues	Applicable Legislation
Water	1) The Water (Prevention and Control of Pollution) Act, 1974, and amendments thereafter.
	2) Water Cess Act, 1977 and amendments thereafter.
Air	3) The Air (Prevention and Control of Pollution) Act, 1981 and amendments thereafter
Hazardous Substances and Wastes	4) Hazardous Wastes (Management, Handling and Transboundary Movement)Rules, 2008. 5) Manufacture Storage and Import of Hazardous Chemicals 1989 and Amendments thereafter.
Other Issues under the Environment (Protection) Act, 1986, and Rules	6) The Public Liability Insurance Act, 1991 and Rules 1991
	7) The National Environment Tribunal Act, 1995
Noise	8) The Environment (Protection) Second Amendment Rules, 2002 (Noise Limits for New Generator Sets)
	9) The Noise (Regulation & Control) Rules, 2000
Forest	10) Forest Conservation Act 1980 and amendments thereafter
Flora & Fauna	11) Wild life Protection Act 1972 and amendments thereafter 12) Convention on Biological Diversity, 1992 and amendments thereafter 13) Biological Diversity Act 2002 and Rules 2004 14) The Indian Fisheries Act, 1897 and amendments thereafter
Ancient Monuments	15) Ancient Monuments and Archaeological Sites and Remains Act, 1958
Other Acts	16) River Boards Act, 1956
	17) The Central Motor Vehicles Act, 1938, amended in 1988 and Rules, 1989
Resettlement and Rehabilitation	18) National Rehabilitation & Resettlement Policy (NRRP – 2007)

The project is also designed so as to abide by the guidelines set out by The Central and State Pollution Control Board (PCB) and Ministry of Environment & Forests (MoEF) on various aspects of environmental management.

1.7 Scope of EIA Study

An EIA study is useful to understand and mitigate the impact of the project on various parameters of environment. Therefore, the scope of the EIA study includes detailed characterization of the existing status of the land, water, air, biological and socio-economic environment in the catchment area. It also includes identification of the potential environmental impacts of the project and formulation of an effective Environmental Management Plan (EMP) to prevent, control & mitigate the adverse environmental impacts to ensure environmental compliance.

The scope of this EIA is according to the TORs (Terms of References) approved by the MoEF (Letter No. J-12011/38/2009-I.A.I dated 11.12.2009 & 23.2.2010). The EIA study includes:

i) Salient Features of the project.

ii) Baseline environmental studies for three seasons - pre-monsoon, monsoon and Winter. The study includes the following areas:

a) Catchment Area
b) Submergence Area
c) Project Area to be acquired and area within 10 km from main project components.

iii) Application of Remote sensing and GIS.

iv) Baseline Data Collection in respect of:

a) Geological and Geophysical Aspect
b) Seismo-tectonics
c) Hydrology of the baseline
d) Land use
e) Soil
f) Biological resources (Flora, Fauna, Avifauna, Aquatic Ecology including Fisheries Conservation areas and endangered texas)
g) Socio Economic aspect
h) Water Environment (Physio-chemical & Biological)
i) Air Environment
j) Noise Environment
k) Construction Methodology and Schedule

v) Identification of potential impacts on :

a) Air Environment
b) Noise Environment
c) Water resources & water quality
d) Land
e) Biological Resources
f) Socio-Economic Aspects downstream impact on hydrological regime/water, land & human environment due to reduction in the river flows in the stretch between Diversion site and Powerhouse site.
g) Identification of potential impacts (positive and negative) during construction phase & operation phase of the project

vi) Environment Management Plan (EMP) including the following action plans on :

a) Catchment Area Treatment Plan (CAT-P) covering directly draining/ or entire Catchment.
b) Creation of Green Belt Plan around periphery of the reservoir
c) Compensatory Afforestation
d) Biodiversity Conservation and Management Plan
e) Reservoir Fisheries Development Conservation/ and Management Plan
f) Muck Disposal Plan
g) Restoration and Landscaping of Working Areas
h) Public Health Delivery System

i) Sanitation and Solid Waste Management Plan
j) Water Quality and Sewage Disposal Plan
k) Reservoir Rim Treatment Plan
l) Air Quality & Noise Environment Management
m) Implementation Mechanism for EMP
n) Environmental Monitoring Plan
o) Summary of Cost Estimate for all the plans

vii) Study on aquatic ecology downstream project area, release of water will be decided on the basis of the scientific studies based on depth and velocity.

viii) Clearance from National Board for Wildlife as proposed project is near to biosphere reserve.

1.8 Approach & Methodology of EIA Study

1.8.1 Approach of the EIA Study

The EIA study includes establishment of the present environmental scenario in the catchment area and project area. EIA report consists of study of the specific activities related to the project and evaluation of the probable environmental impacts, thus, leading to the recommendations of necessary environmental control measures. The entire EIA study has been carried out on the basis of the applicable environmental legislation, regulations and guidelines of the MoEF.

1.8.2 Establishment of Baseline Environmental Status

A comprehensive database on the baseline environmental status/conditions of the study area has been established through review, compilation & analysis of

i) Existing published secondary data/literature/information , and
ii) Primary data generated/collected through field study, surveys and monitoring

1.8.3 Field Study/Monitoring for Generation of Primary Data

The collected secondary data has been supplemented and validated by conducting the necessary primary data generation/collection through field study/monitoring in three seasons study period viz, monsoon, winter and pre-monsoon. The field monitoring has been carried out as per the guidelines of CPCB and requirement of the MoEF. Field study/monitoring has been conducted on:

i) Soil Monitoring: To study the soil characteristics in the study area, seven locations were selected wherefrom the soil samples were collected and analyzed for important relevant physical & chemical parameters.

ii) Water Quality Monitoring: The existing data on water quality has been collected to evaluate surface water quality on upstream and downstream of the project site. The water quality samples were collected in three seasons and analyzed for physico-chemical parameters.

iii) Ambient Air Quality Monitoring: For drawing up the baseline status of ambient air quality in the study area, ambient air quality monitoring in respect of SPM, RSPM, SO_x, NO_x were conducted at four locations in the study area adopting a 24-hours sampling schedule.

iv) Noise Monitoring: To establish the ambient noise scenario in the study area, monitoring of ambient noise level was carried out at representative locations in the study area using a suitable portable sound level meter over a period of twenty-four hours.

v) Geology : The regional geology around the project area highlighting feature were based on the existing information on these aspects as covered in DPR was collected and suitably incorporated in the CEIA Report.

vi) Hydrology: Hydrological data for river Rathang Chu as available in the Detailed Project Report (DPR) was collected and suitably incorporated in the comprehensive EIA study.

vii) Land Use Pattern: Study of Land use pattern in the study area was carried out by standard methods of analysis of remotely sensed data and followed by ground truth verification and interpretation of satellite data. For this purpose digital satellite data was procured from National Remote Sensing Agency, Hyderabad and processed using appropriate software to arrive at land use land cover pattern of the study area

viii) Ecological Aspects

ix) Terrestrial Ecology: The primary survey for this component was carried out using quadrant method for sampling. The primary data on fauna was collected using pug marks, spotting of animals, and locating of the habitats. Secondary data on terrestrial ecology was collected from forest department and department of wild life, Government of Sikkim., local NGO working on the Forests issues, and local people.

x) Aquatic Ecology and Fisheries: Sampling for planktons, benthos was carried out at barrage site, power house site and at a location between the barrage and power house site of the river. The analysed data of planktons was used to calculate Shannon Wiener diversity index. Investigation for fish fauna in the project stretch was conducted by using hook and line and through sample netting. In addition to this secondary data on fish species and fisheries was collected from department of fisheries, government of Sikkim.

xi) Socio- Economic Aspects: Socio-economic survey of villages in the project area was carried out using predesigned questionnaire. This was done to understand people's aspiration and concerns about the project. Data on demography of the area was collected from census department and through primary surveys. This data was analysed to prepare socio-economic impact component of the project.

1.8.4 Environmental Impact Assessment

The environmental assessment has been conducted in accordance with the norms and guidelines of the Govt. of India. The project data/activities has been analyzed & linked with the existing baseline environmental conditions in order to list out the affected environmental parameters and assess the likely impacts on such parameters. Wherever practice, quantitative analysis has been performed. Suitable computer models, wherever applicable, have been used. Compliance of the project with national standards has been duly checked.

1.8.5 Preparation of Environmental Management Plan

Environmental Management Plan (EMP) is the key to ensure a safe and clean environment. The desired results from the environmental mitigation measures proposed in the project may not be obtained without a management plan in order to assure its proper implementation & function. The

EMP envisages the plans for the proper implementation of mitigation measures to reduce the adverse impacts arising out of the project activities. EMP has been prepared addressing issues such as:

i) Details of management plans (solid waste management plan, restoration of construction sites, soil conservation, CAT)
ii) Pollution control/mitigation measures for abatement of the undesirable impacts caused during construction and operational activities
iii) Maintenance of water resources and water quality
iv) Institutional set up identified/recommended for implementation of the EMP
v) Post project environmental monitoring programme

1.9 Structure of the EIA Report

Chapter 1: *Introduction* - provides a background to the project, the project proponent, and the process of environmental impact assessment.

Chapter 2: *The Project Description* - describes the characteristics of the Barrage, tunnel, other underground structures like surge shaft, pressure shaft and power house and operations associated with the construction, and ongoing operations.

Chapter 3: *The Existing Environment* - describes the background environmental characteristics and the other economic activities in the area.

Chapter 4: *Assessment of Impacts* - identifies the potential impacts from the project

Chapter 5: *Environmental Management Plan* - the environmental management plan provides a set of measures for amelioration of anticipated adverse impacts likely to accrue as a result of the proposed project. The approach for formulation of an EMP is to maximize the positive environmental effects and minimize the negatives ones.

Chapter 6: *Environmental Monitoring Program* - describes the mechanism to address the adverse environmental impacts during different phases of the project (construction and operational phases).

Chapter 7: *Catchment Area Treatment Plan* – The CAT plan is based as per the prioritization of sub-watersheds using the Silt Yield Index (SYI) as per AISLUS methodology.

2

PROJECT DESCRIPTION

2 PROJECT DESCRIPTION

2.1 Project Overview

The proposed Lethang Hydro Electric Project of 96 MW capacity is a run of the river scheme (barrage based) on River Rathang Chu near Yuksam and Lethang village in West Sikkim. It is the uppermost Hydro Electric Project proposed on river Rathang Chu.

The proposed project location is shown in **Fig 2.1**. The nearest railway station is New Jalpaiguri (NJP) about 156 km away and the nearest airport is Bagdogra about 155 km from the project site. The nearest district headquarter is in Geyzing, West Sikkim. The barrage site is proposed at four km upstream from Yuksam village, having geographical coordinates as 27° 23' 18? N and 88° 12' 48? E. The Power House site is proposed near Lethang village which is about eight km from Yuksam village by road having geographical coordinates 27° 22' 0.1? N and 88° 12' 22.9? E . The Catchment Area for the proposed project lies between Latitude 27°36'54? N to 27°22'46? N and Longitude 88°07'21? E to 88°13'46? E.

Photo Plate 1 - Lethang HEP - Barrage Site

Photo Plate 2 - Lethang HEP – Tail Race Tunnel

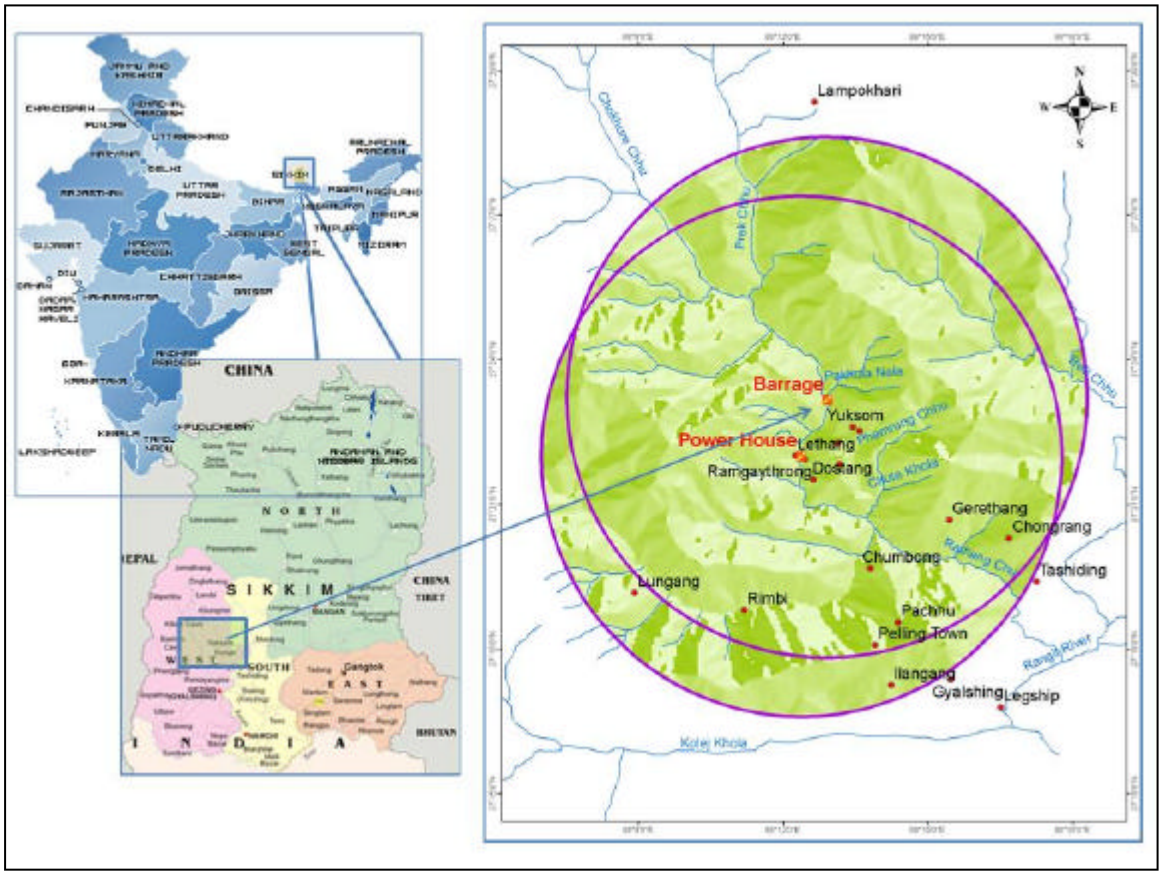


Figure 2.1: Project Location Map

2.2 Justification for Location and Execution of the Project in Relation to Diversion Structure

The project proponent analysed the following two options prior to selection of the Barrage option. –

Alternative 1 (Dam alternative for Peaking Plant) -The dam axis is selected at about 500m downstream of Pau Khola Nallah near Yuksam village and underground powerhouse site at upstream of existing steel bridge at Lethang village. This alternative is ruled out because of many issues involved in the construction of dam as discussed below under the sub paragraph on environmental aspects.

***Alternative 2 (Barrage alternative for run of river Plant*) -**The barrage axis is selected at about 300 m downstream of Pau Khola Nallah and 200 m upstream of dam alternative. The underground power house site is located at upstream of existing steel bridge at Lethang.

Both alternatives were studied and the Barrage alternative is found most suitable with respect to the environmental as well as economical aspects.

Environmental Benefits of the Barrage Alternative – Some of the environmental benefits for the proposed Barrage Alternative are:

1. Most favorable geological conditions
2. Barrage is a smaller diversion structure as compared to high dam, thus minimizing environmental impacts.
3. Minimum submergence area thus ensuring minimum loss to existing environment and land.

4. Comparatively lower coverage of forest and private land to be acquired, thus minimizes any additional impact.
5. Comparatively lower quantities of excavation and concreting required hence resulting in savings of time for construction, thus minimizing environmental and pollution impacts.

2.3 Salient Features of Lethang Hydro Power Project

The Salient Features of the project are as identified below:

a. Project Location	
State	Sikkim
District	West Sikkim
River	Rathang Chu
Nearest Village	Lethang village
Latitude - Diversion Site	27° 23' 18 " N
Longitude – Diversion Site	88° 12' 48 " E
Latitude - Power House Site	27°22'0.1"N
Longitude – Power House Site	88°12'22.9"E
Nearest Railway Station	New Jalpaiguri – 156 km
Nearest Airport	Bagdogra – 155 km
Nearest National Highway Road	National Highway – 31A

b. Hydrology		
Catchment area	km^2	360
Snow fed catchment area	km^2	160
Total annual inflow in 90% dependable year	10^6 m^3	686.20
Average discharge in 90% dependable year	m^3/s	21.69
Minimum ecological water release taken	m^3/s	0.55
Flood discharge for river diversion (~Q_{25}) Non monsoon Flow	m^3/s	100
Design Flood discharge for spillway arrangement (100 yr).	m^3/s	1844
Standard Project Flood (SPF).	m^3/s	2798
Probable Maximum Flood (PMF).	m^3/s	3082

c. Pondage		
Maximum normal reservoir level	m	1575.00
Average normal reservoir level	m	1573.83
Minimum normal reservoir level	m	1571.50
Design flood level (corresponding to 100yr)	m	1575.00
Total storage volume	10^6 m^3	0.074

d. Barrage		
Water Way		
Type		Surface
Design Flood Level	m	1575.00

Average river bed level at Barrage axis	m	1555.00
Bridge Deck Level	m	1578.50
Barrage Crest elevation	m	1555.00
Gate type and size (H XW)	m	Radial, 20 x 9.25
Number	---	3
Width of Bay	m	13.25
Height (from river bed Level)	m	23.50
Height (from foundation level)	m	33.50
Max. Head above crest	m	20
Discharge Capacity (N-1)	m^3/s	1844
Energy Dissipation System		Erosion Protection

e. River Diversion		
Diversion Tunnel (D-Shape) Length, Diameter	m	275, 4.5
Inlet and Outlet Elevations	m	1570, 1552.25
Upstream Cofferdam Elevation	m	1575
Height of Cofferdam	m	12.5
Average Length	m	43
Downstream Cofferdam not required		
Gate		
Gate number	--	1
Type	--	Fixed Wheel
Sill elevation	m	1570
Dimensions (H x W)	m	5 x 4.5
Max. Head	m	5

f. Tunnel Gate		
Number of openings	--	1
Invert sill elevation	m	1563
Nominal discharge	m^3/s	38.43

g. Service Gate		
Number	--	1
Type		Fixed Wheel
Sill elevation	m	1563
Dimensions (H x W) m	m	3.8 x 3.8
Max. Head	m	12
Dimension of trash rack units (H x W)	m	3.5 x 8
Number of trash rack sets		2Nos.
Bulk head gate (H xW)	m	3.8 x 3.8

h. Desilting Basins		
Type		Underground
No. of Desilting basin	nos.	2

Size of Desilting basin (L x W x H)	m	145 x 7.8 x 10.95
Maximum discharge	m^3/s	38.43
Flow through velocity	m/s	0.25
Flushing Tunnel (D-Shape) Length ,Diameter	m	75, 6.4

i. Head Race Tunnel		
Excavated Shape	--	Horse Shoe
Finished Shape	--	Horse Shoe
Length	m	2236
Excavation Diameter	m	4.6
Finished Diameter	m	3.8
Velocity for Nominal Discharge	m/s	2.92
Slope	%	0.97
Nominal discharge	m^3/s	34.94
Lining type		Concrete
Thickness	m	0.30

j. Adits		
Number of Adits		3
Type and Size		D-Shape, 4.5 m
Length of first Adit (after desilting basin)	m	110
Length of second Adit (about mid of HRT)	m	185
Length of third Adit (at valve house)	m	130

k. Surge Shaft		
Vertical Shaft		Underground
Top elevation	m	1595.5
Bottom elevation	m	1546.7
Total height	m	48.8
Max. upsurge level	m	1585.75
Min. down surge level	m	1556.95
Lining	m	0.6
Diameter	m	15
Restricted Orifice Diameter	m	3.80

l. Valve House		
Type and Number		Underground, One
Dimensions (L x H x W)	m	15 x 13.6 x 8
Butterfly valves		
Number	--	One
Diameter	m	2.8

m. Pressure Shaft

Type		Underground
Quality of steel		ASTM A– 537
Thickness of liner	mm	15-35
Number		One
Length	m	495
Internal Diameter	m	2.8
Velocity for nominal discharge	m/s	5.67
Nominal discharge	m^3/s	34.94
Unit Pressure tunnels		
Number		3
Internal diameter	m	1.6
Length (Unit-1)	m	34
Length (Unit-2)	m	23
Length (Unit-3)	m	43

n. Unit Tail Race Tunnels		
Number	m	3
Length	m	95,86,76
Internal Diameter	m	3m, D shape

o. Tail Race Gate Carven		
Elevation	m	1270
Dimensions (L x H x W)	m	33 x 7 x 9

p. Power House		
Access Tunnel		
Diameter, Shape	m	7.0, D-Shape
Length	m	155
Power House		One
Type		Underground
Dimensions (L x H x W)	m	65 X 36.3 X15.0
Turbine type		Francis
Number of units		3
Turbine setting elevation	m	1256.7
Rated discharge per unit	m^3/s	11.65
Rated head	m	304.5
Installed capacity per unit	MW	32
Inlet valve type		Spherical
Number		3

Axis elevation	m	1256.7
Diameter	m	1.38
Generator type		3 phase
Number		3
Nominal speed	Rpm	600
Voltage / Frequency	kV / Hz	11.0/50
Power factor	cos f	0.9

q. Transformer Hall		
Dimensions (L x H x W)	m	48.5 x 16.85 x 13.0
Transformer type	--	3 phase
Location		Underground
Number	--	3 + 1 Spare
Unit capacity	MVA	40
Voltage ratio	kV / kV	11.0/220
Cable Tunnel		
Dimensions, Type	m	3.5, D-Shaped
Total Length		125

r. Main Tail Race Tunnel		
Number	--	1
Length	m	40
Slope	%	16.66%
Nominal discharge	m^3/s	34.94
Outlet sill elevation	m	1259.50

s. Pot Head yard		
Type	--	Outdoor
Area (L x W)	m	60x25
GIS (Underground)		Transformer Hall
GIS Area (LXW)	m	48.5 x 13

2.4 Project Description

The Lethang HEP is envisaged as a run - of - the - river scheme using flow of water from Rathang Chu River. It will harness the head available between the proposed barrage location with FRL of elevation 1575 m and the proposed underground power house. The tail race is located on the right bank of the river with tail water level at elevation 1260.39 m (under normal operating condition). After optimizing the potential at 96MW, barrage location is identified near Yuksam village and Power house near Lethang village.The project layout map is shown in **Figure 2.2.**

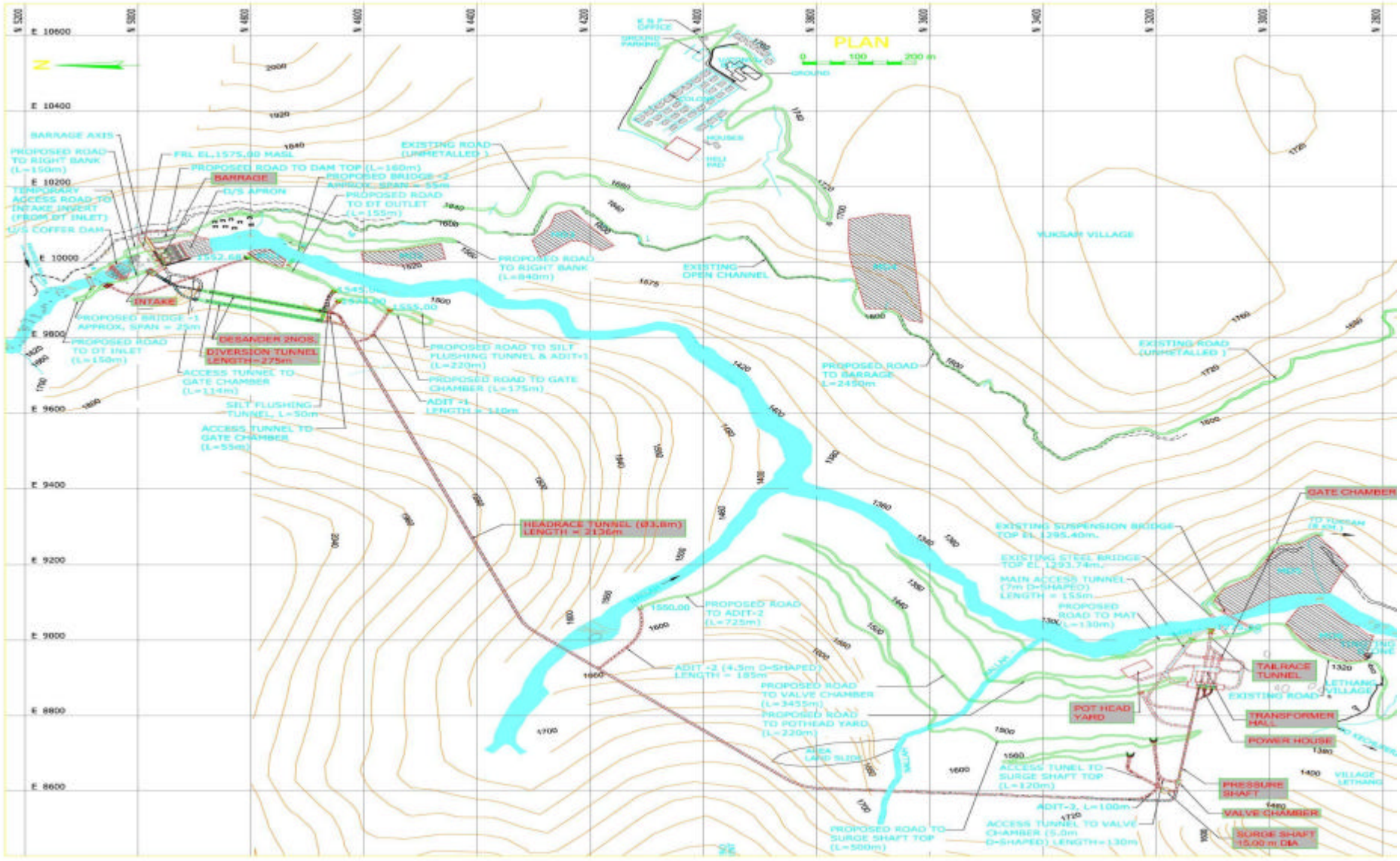


Figure 2.2: Project Layout Plan

2.5 Lethang HEP - Project Costs

The estimated cost of project includes the cost of civil works, Electro-mechanical works and pre-operative works. These estimates of cost are based on the prevailing rates of labour, materials and equipments. The total estimated cost of the project is **Rs 495. 63 Crores.**

2.5.1 Civil Engineering Structures

Civil engineering structures are planned based on natural features and topography/geological condition at site to optimize the power potential of Rathang Chu River. The Lethang HEP is medium head scheme having rated head of 304.5 m after deducting for various losses. The estimated power potential for this scheme is computed as 96 MW. The following major components / structures are proposed:

- Barrage
- River Diversion Works
- Intake structure
- Desilting Basins
- Head race tunnel
- Adits
- Surge Shaft
- Pressure Shaft and Valve Chamber
- Under Ground Powerhouse
- Tailrace tunnel
- Pot Head Yard
- 220 KV transmission line

2.5.2 Brief Description of Civil Engineering Components

2.5.2.1 Barrage

The barrage axis is proposed at about 300 m downstream of Paukhola Nallah. The river has a steep gradient with average slope of 10 – 15 %. The crest of barrage is kept at the same elevation as that of river bed. The width of gorge available at the crest level is 44m and the top of the barrage level is approximately 71 m. The gated section of the barrage consists of three bays 9.25 m X 20 m controlled by radial gates to pass the flood discharges safely without changing the natural regime of river
.

2.5.2.2. Fish Ladder

The fish ladder is planned along the end pier of the barrage on the right bank for fish passage. The inlet of fish passage is planned in front of intake as water will always be in motion in front of intake. The trash rack at intake structure shall be fitted with fish screen. The fish ladder is of pool and weir type and a slot (1m X 1m) shall be kept in each of the baffle walls. The pool size will be considered as 1.5(W) X 3.0(L) and the baffle wall will be of 2.00m height. The ladder will start from the downstream end of the pier at EL 1550.50 m and will have two landings at EL 1557.00m and 1563.50m respectively. The inlet dimensions will be 1.0m (H) X 1.5m (W) and the flow will be controlled by the gate.

2.5.2.3 Intake Structure

The intake structure is proposed about 15 m upstream of the barrage axis on the right bank with an underground gate chamber for gate operation (EL 1578.50 m). The length of approach tunnel will be 35m.The river bed level at the intake inlet level will be 1558 m The intake sill will be kept at 5 m above the river bed level, i.e EL 1563 m with discharge capacity of 38.43 m^3/s.

2.5.2.4 Desilting Basins

Two Underground desilting basins shall be provided to remove suspended particles present in the water. The desilting basin will remove the particle of size 0.20 mm and above under pressurized conditions. The flow through velocity in the desilting basin will be 0.25 m/s. Twin basins are designed for discharge at the rate 19.22 m^3/s (for each basin) which will also includes the silt flushing discharges.

2.5.2.5 Head Race Tunnel

The Head Race Tunnel (HRT) on the right bank of the river with finished diameter of 3.8 m connects the desilting basins to the upper limb of pressure shaft. It will have a total length of 2236 m. The HRT will be concrete lined with a uniform slope of 0.97%.

2.5.2.6 Adits

Three Adits have been planned to facilitate the construction of HRT and will also support inspection and maintenance.

a) One at the upstream end with a length of 110 m
b) Intermediate adit at the middle of the HRT with a length of 185m, and
c) One downstream from the valve chamber access tunnel with a length of 130m.

2.5.2.7 Surge Shaft

An underground restricted orifice type surge shaft with uniform diameter is proposed for the project. The finished diameter of the surge shaft is 15 m will have concrete lining thickness of 600 mm.

2.5.2.8 Pressure Shaft and Valve Chamber

The diameter of the pressure shaft will be 2.8 m and the total length will be 495 m. The valve chamber will comprise of an underground cavern with dimensions of (LxWxH) 15m x 8m x 13.6 m and will be equipped with a monorail crane of 50 tones capacity.

2.5.2.9 Power House Complex

The Power House Complex is underground and it will house machine hall, transformer hall and tail race tunnel. Machine hall will have three Francis Turbine Generators. It will also have provision to accommodate drainage and dewatering sumps at lower elevations and also for staircases to access all the floors.

The Erection Bay is sized to accommodate erection of stator, rotor and for assembling other miscellaneous works such as turbine top cover and generator bottom bracket.

2.5.2.10 Transformer Hall

Transformer Hall will have three phase generator transformers. The transformers will be connected with a bus duct tunnel that opens upstream of the transformer bay. An oil water separator tank is proposed adjacent to transformer near access tunnel. Separate soak pits under each transformer will be provided to collect the oil spillages/leakages.

2.5.2.11Tail Race Structure

The three tail race tunnels each of 3.5 m diameter will have lengths of 95 m, 86 m and 76 m respectively, which will then join with a 3.8 m diameter, common tail race tunnel. The length of common tail race tunnel will be 40 m. A trash rack shall be provided in order to prevent entry of rolling boulders/pebbles inside the tail race tunnel during the floods

2.5.2.12 Pot Head Yard

The surface pot head yard is proposed at EL 1365.00 m. The inclined cable –cum- ventilation and escape tunnel is proposed between the transformer hall and the pot head yard.

2.6 Electro- Mechanical Works

The Electro Mechanical Works will comprise of three 32 MW each, vertical axis Francis turbines, generators, governors, transformer and auxiliary equipments.

2.6.1 Turbine

Some of the main features of the vertical shaft Francis Type Turbine are:

a. Rated Speed of 600 rpm.
b. Runners having composition of 13% Cr and 4% Ni stainless steel with HVOF coating.
c. HVOF Tungsten Carbide coating on parts prone to hydro-abrasion will be required.

2.6.2 Generator

The main features of the generator are as described below.

a. The generator will be vertical shaft synchronous machine with rated continuous output of 35.55 MVA, having rotational speed of 600 rpm to match with turbine.
b. Will have a Generator stator and rotor winding with epoxy insulation of Class F.
c. The generator ventilation system will be of water cooled type and will be provided with a cooling system based on closed circuit air circulation principle.
d. A Carbon Dioxide fire extinguishing system will be provided.

2.6.3 Transmission Lines

Lethang HEP's power is proposed to be transmitted through double circuit line to Melli substation which is 50 circuit km from Lethang HEP. The evacuation arrangement will be finalized in consultation with the State Government.

2.6.4 Control and Protections

An automation control system will be implemented for the Turbine Generator units, water conductor system and the 220 KV GIS. The control system shall be PLC (Programmable Logic Controller) based. The complete power house will be operated from central control room located in the power house building.

The unit protection system shall monitor and perform activities such as -

a. Acquisition of all necessary data (measurement signals, device faults, status and/ or position of equipment.); Detection of faults (electrical, mechanical, hydraulic device failures); Processing of fault signals and elaboration of appropriate tripping orders.
b. The protection equipment will comprise of instantaneous time delay over current relay, over voltage relay, reverse power relay, negative phase sequence relay, loss of excitation relay, and differential protection relay.

2.6.5 D.C Equipments

A 220 Volts DC System will be installed with two sets of DC batteries. It will have main and stand by chargers, other control equipment system and independent DC distribution boards.

2.6.6 Mechanical Auxiliaries

The different components of Mechanical auxiliaries will be:

a. Potable Water System:
b. EOT Crane:
c. Fire Fighting System: Fire fighting system will be designed as per the guidelines of TAC (Traffic Advisory Committee), a subsidiary of General Insurance Corporation of India. The Fire Fighting System (FFS) shall have
   i. High Velocity Water Spray (HVWS) system for generator transformer.
   ii. Low Velocity hydrant system.
   iii. Portable extinguishers

d. Air Conditioning and Ventilation System: Requisite number of Air Handling Units (AHU) will be installed into the identified areas and manually controlled heaters will be provided in the ventilation system to maintain warm temperature, whenever required during cold season.
e. Dewatering and Station Drainage System: Separate set of pumps and independent sumps for dewatering and drainage systems common to all the three units shall be provided. Water shall be drained by gravity. Dewatering is proposed to be through dry pit; therefore special submersible pumps shall be employed for drainage.
f. Cooling Water System : The equipment to be supplied by cooling water systems, will include the following:
   i. Generator air coolers
   ii. Generator thrust cum guide bearing oil coolers
   iii. Generator guide bearing oil coolers
   iv. Governor oil coolers
   v. MIV oil coolers
   vi. Turbine Shaft seal
   vii. Generator transformers

Cooling water required for the above applications and other purposes will be taken from the tail race through draft tube and fed into a common header through centrifugal pumps and the cyclone separator from each unit.

g. **H. P Compressed Air System:** Compressed air requirement is envisaged for governor pressure oil system, the turbine inlet valve (MIV) pressure oil system, Generator braking system. Additionally low pressure air system is planned for different floors for station service.
h. **Oil Handling System:** Oil filtration system of sufficient capacity will be installed for removing the moisture content of oil of the guide bearings and transformers.
i. **Elevator:** Powerhouse shall be equipped with an elevator for access to all the floors of the power house.
j. **Transformers, Station Service and Unit Auxiliary Supply:** Three nos. indoor types, three phases, 40 MVA, 11/220 KV Delta/Star Step up transformers of OFWF type with necessary protective and monitoring devices will be provided. Two nos. 11/.415 KV, 630 KVA, Dry Type Station Auxiliary Transformers (SAT 1 and SAT 2) will also be provided.

2.6.7 Station Grounding System

One grounding mat of Mild Steel bars having suitable cross section will be provided under power house area. Grounding electrodes of suitable sizes will also be installed and connected to grounding mat. The grounding system shall be designed to keep the step and touch potential within safe limits.

2.7 Infrastructure Facilities

2.7.1 Access Roads

The Lethang Power House Site is approachable by National Highway 31A upto Melli, thereafter state highway upto Geyzing. One can reach the project site by major district road connecting the Geyzing to Yuksam via Rimbi. At present, the diversion site is approachable by the major district road upto Yuksam and is reached after about 4 km of trekking partly along the abandoned head race channel. These except the trekking trail are metallic with black top all season roads. The carriageway of the road lies between 3.5 to 4.5 m, with shoulders of 1.0 to 0.5m on both sides.

It is proposed to use exisiting un-metalled road (trekking trail) from Lethang and Yuksam village up to proposed power house as well as barrage site which will be modified in to road up to barrage top.

a) Proposed Roads in Barrage Area

It is proposed to use existing unmetalled road from Yuksam village upto abandoned water channel and there after the abandoned water channel will be modified in to a road upto the barrage site. Brief details for proposed road construction for accessibility upto the barrage site are tabulated in **Table 2.1** and road construction layout plan near barrage is also given in **Figure 2.3**.

Table 2.1: Details of the proposed road near barrage site (Reference Fig: 2.3)

S.No.	Description	Length	Unit
1.	Left Bank high level road to top of barrage (Modification of existing channel to Road)	2.445	Km
2.	Left bank road from top of barrage to bridge-1	0.160	Km
3.	Right bank road from Bridge-1 to DT Inlet	0.150	Km
4.	Left bank road to Bridge-2	0.840	Km
5.	Right bank road from Bridge-2 to silt flushing tunnel, Adit-1 and d/s desilting gate operation chamber	0.450	Km
6.	Road to DT outlet	0.155	Km

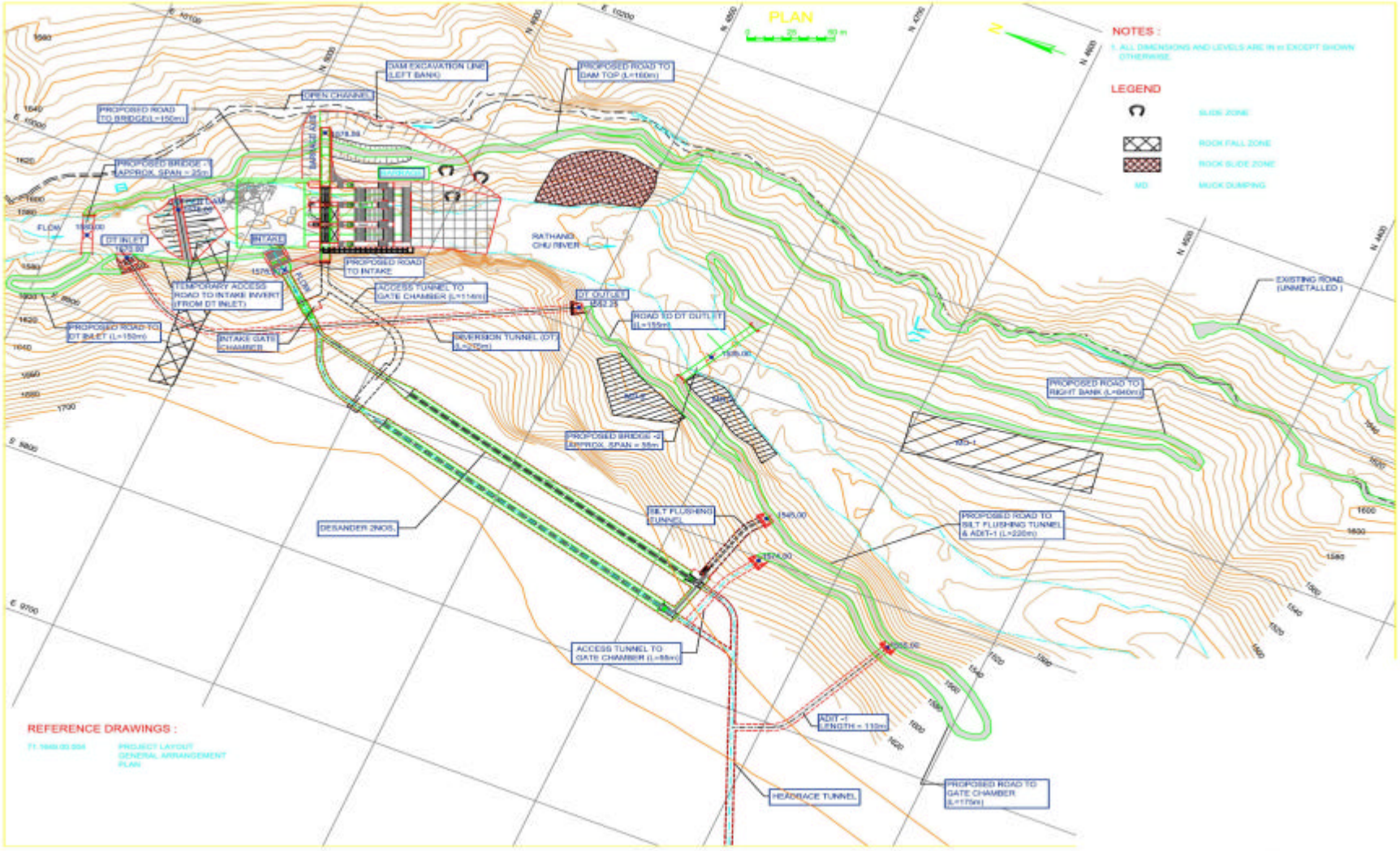


Figure 2.3: Proposed Roads Network near Barrage Site

b) Proposed road network to the power house, surge shaft and HRT

The proposed road network to the power house**,** surge shaft and HRT areas is planned from near the existing PWD steel bridge near Lethang village. The proposed road will provide access to power house main access tunnel, all the adit portals in powerhouse and surge shaft areas, valve house, top of surge shaft and adits to HRT. Details are as given below in **Table 2.2** and the proposed road network is shown in **Figure 2.4** below.

Table 2.2: Details of the proposed road network to the power house, surge shaft and HRT (Reference: Figure 2.4)

S.No.	Description	Length	Unit	Remarks
1.	From existing steel bridge to point 'S'	0.210	Km	.
2.	From point 'S' to Main Access Tunnel	0.130	Km	
3.	From point 'S' to point 'T'	0.935	Km	'T' is off taking point on road to adit-6, about 1.145 km from steel bridge.
4.	From point 'T' to Pothead yard	0.220	Km	
5.	From point 'T' to Adit-6 portal	0.410	Km	
6.	From adit-6 portal to point 'U'	1.320	Km	'U' is off taking point on road to Adit-2. 'N' is portal to valve chamber access tunnel.
7.	From point 'U' to Adit-2 portal	-0.725	Km	
8.	From point 'U' to Valve chamber adit portal (Point 'N')	-0.575	Km	
9.	From point 'N' to surge shaft top adit portal (Point 'Q')	0.500	Km	'Q' is portal to surge shaft top.

2.7.2 Project Colony

The permanent colony for the operation and maintenance staff for the power station is proposed to be constructed near power house site on the left bank of river Rathang Chu. Sufficient land is available for construction of permanent colony. Suitable environmental safeguard measures will be implemented for disposal of the solid waste and all other effluents.

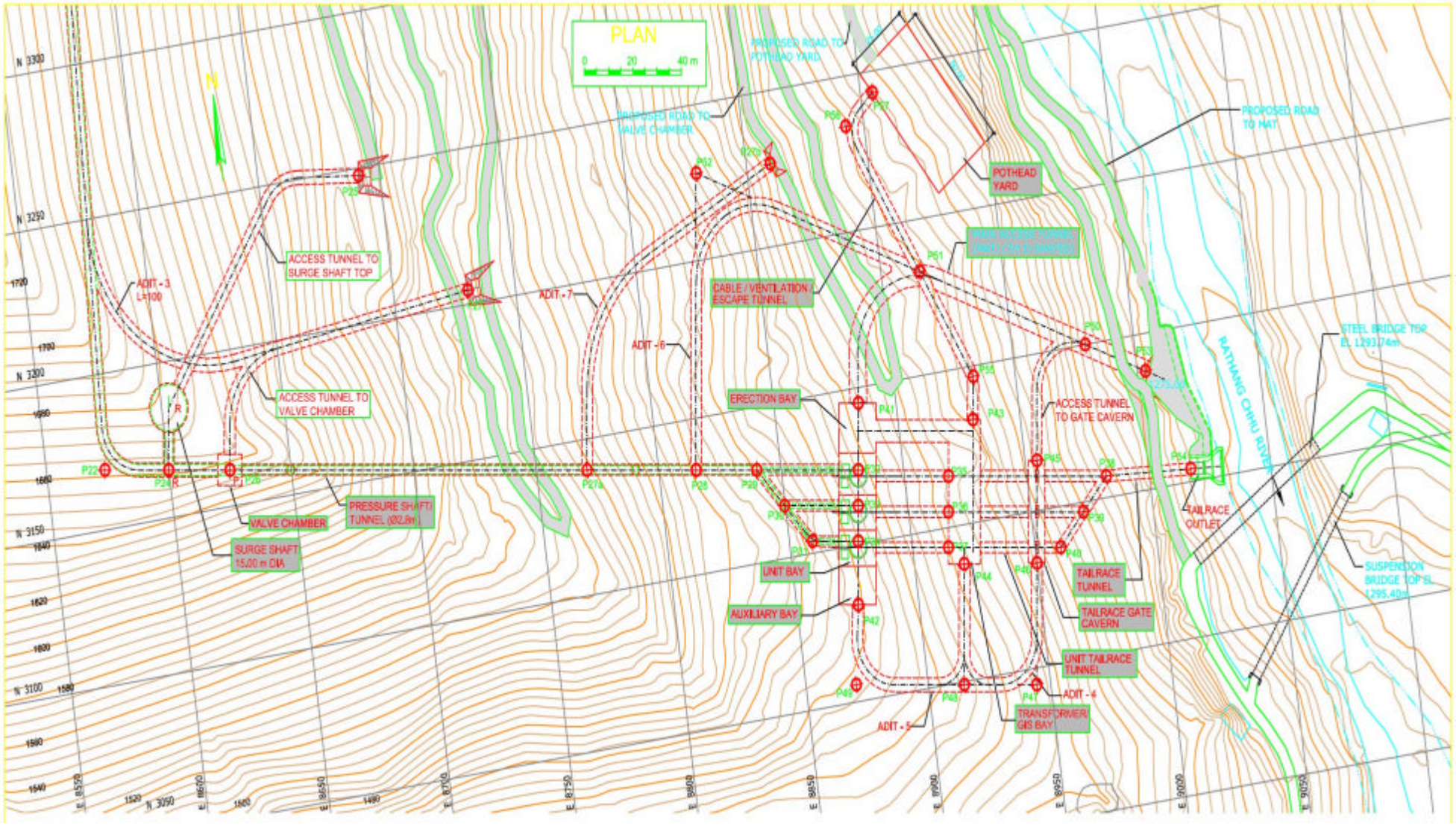


Figure 2.4: Proposed Roads network near Power House Site

2.7.3 Construction Facilities and Dumping Areas

Construction Plant Areas will have the crushing plant, batching and mixing plant, compressor house and field workshop on the left bank of the river.

2.7.4 Power Requirement

a) During construction period:

The construction power is required for following works:

1. Main works at, Barrage, Desilting Basins, HRT, Valve House and Power House Complex
2. Infrastructure works.

Peak Load power requirement for Lethang HEP during construction period is around 2 MW. The nearest existing 11 KV substation is at Yuksam which is just uphill of the barrage site. Power back up facilities will be provided through 4 diesel generator sets of capacity 500 KVA each.

b) During operation period:

Power requirement during operation phase of the project will be for infrastructure facilities comprising of offices, residential blocks, health care center, guest house, transit camp, recreation center and other facilities.

2.7.5 Telephone Facilities

It is planned to acquire additional 2-3 lines from Yuksam Exchange to power house and barrage site. A proposal for 100 line automatic exchange for project works is made. This exchange will be located at Yuksam itself and lines will be extended to all camp sites and work sites.

2.8 Land Acquisition

a) Land for Project Components:

The Lethang HEP (96 MW) will require majority of land from the Government (Forest Department.). Private land is also required at some locations. The total land to be acquired for the proposed project is around 24.63 Ha (including private and Government. /Forest land) and details of land requirement for different components is summarized below in **Table 2.3** -

Table 2.3: Details of Land Requirement for the Project:

S.No.	Land Requirement	Type of Land	Area (Ha)
Land for Surface Components			
1.	Road to Barrage Area	Forest Land	0.555
		Private Land	4.091
2.	Upstream Works	Forest Land	4.380
		Private Land	0.402
3.	Road to Power House Area	Forest Land	3.066
		Private Land	5.224
Land for Underground Components			
4.	For Underground Components	Forest Land	1.628
Land for Muck Dumping			
5.	Muck Dumping (On Lease)	Private Land	5.283
A) Total Forest Land			9.629
B) Total Private Land			15.00
** Total Land Required (A+B)			24.629
** In addition, 20 Ha of Land to be taken on lease for residential area, construction facilties like crushing and batching plant.			

b) Permanent Colony:

Approximately two hectares of land will be required for permanent residential colony.

c) Construction Facilities:

Construction facilities like batching plants, stores, workshops, temporary labour hutments, crushing plant and other miscellaneous facilities shall be constructed on the leased land near the project area but sufficiently away from the barrage site.

2.9 Construction Materials

The main construction materials required are cement, coarse aggregates, fine aggregates, and stone for masonry. It is proposed to generate coarse and fine aggregates from usable muck. The total quantity of muck to be generated from open excavation including roads is 3.87 lakh m^3 and from underground excavation is 2.31 lakh m^3. Total quantity of muck to be generated with 40% swelling factor will be 8.65 lakh m^3. Approximately 2.93 lakh m^3 of generated muck (approximately 1/3 of the total muck generated) will be used as construction material and rest of the muck is planned to dispose safely at the selected muck dumping site as shown in **Fig 2.4.** The remaining quantity of construction material will be quarried from the pondage area. The initial quantity of the construction material for the project is envisaged to be procured from the exisiting quarry at the tip of Rangit III reservoir near Legship (approx. 40-45 km downstream of Yuksam). The requirement of construction material is estimated as per **Table 2.4.**

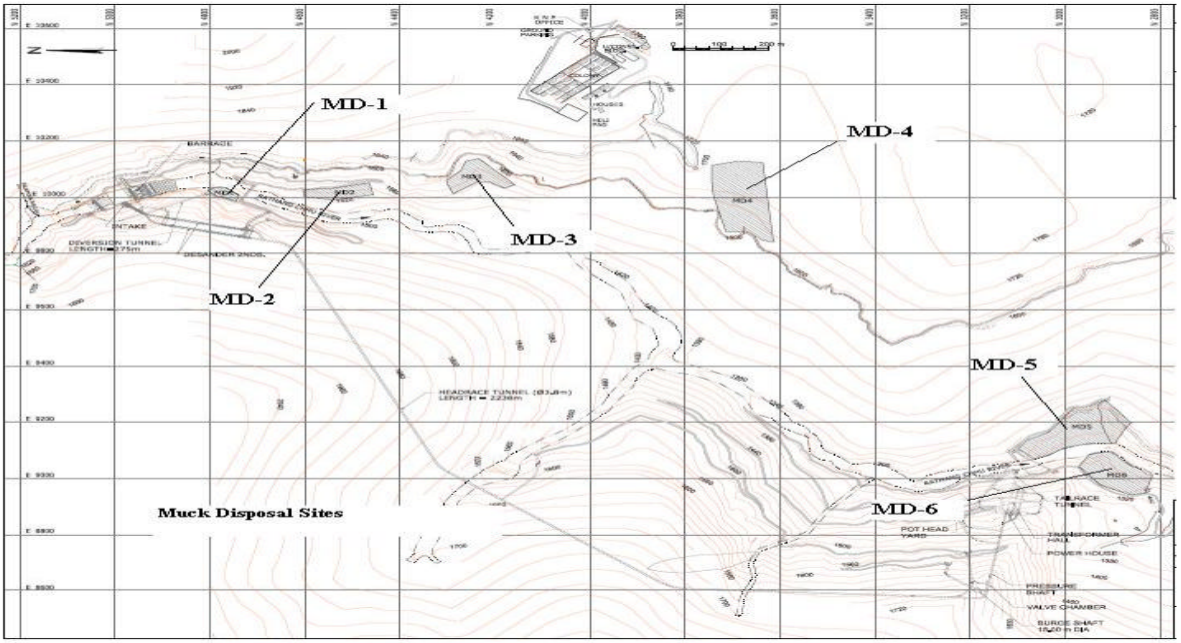


Figure 2.5: Identified Muck Disposal Site

Table 2.4: Approximate quantities of major construction material

Construction Materials	Quantity	Units
Reinforcement Steel	5	Thousand Tonne
Structural Steel	0.5	Thousand Tonne
Cement	120	Thousand Tonne
Coarse Aggregates	2.1	Lakh Cubic meter
Fine Aggregates	1.05	Lakh Cubic meter

2.10 Muck Generation and Disposal

All the muck dumping sites have been planned on private land (wasteland), as further away from the river as possible. This shall be reclaimed by adopting suitable engineering and vegetative measures leading to creation of green cover.

Table 2.5: Average Sectional Area in square meters

Muck Dumping Area	Sectional Area (sq.m)			Average Sectional Area (sq.m)
	1	2	3	
MD-1	150	260	130	180
MD-2	110	140	125	125
MD-3	304	1206	290	600
MD-4	1600			1600
MD-5	490	890	1470	950
MD-6	350	635	710	565

2.11 Construction Methodology and Schedule

2.11.1 Main Construction Methodology

a) Diversion Tunnel

Diversion tunnel construction is the first activity planned in the schedule for upstream works and it will be constructed from the downstream side towards upstream side. Post this activity, river diversion will be undertaken. Diversion tunnel construction is proposed to be completed during the month of October 2011.

b) River Diversion

Once the diversion tunnel (DT) is ready for water passage the river diversion operation will take place. It is expected that river diversion will start during the month of November 2011 with a river discharge below100 m^3/s and will need to be completed in the shortest possible time.

The river will be diverted through the DT by means of an upstream earthen-rock fill closure cofferdam whose top elevation is 1575 m. The closure cofferdam will be executed by dumping earthen rocky material directly into the river.

c) Barrage Excavation and Concreting

The barrage foundation is in sound gneiss at about elevation 1545 m.. Once the river is diverted through the diversion tunnel the excavation of left and right banks can be carried out. Rock support and protection works will be undertaken as the excavation progresses from top to bottom. Controlled blasting techniques including pre splitting shall be used during excavation.

When the desired foundation level is reached the construction of the barrage structure will be undertaken in suitable number of lifts from foundation level to the top.

d) Desilting Basins

A construction adit (Adit -1) will be constructed to approach the HRT. Then excavation will be started and downstream side of the desilting basin will be approached. After that the crown of the desilting basin will be excavated and supported by suitable techniques and then benching will be done by control blasting methods.

e) Head Race Tunnel Construction

The Headrace Tunnel (HRT) connects the desilting basins at its upper end and to valve house at its lower end. It will be concrete lined and finished diameter will be 3.8 m

For construction purpose three (3) adits is planned , one at the downstream of the desilting basins, the second adit is an intermediate adit at approximately the middle of the HRT and third adit is at the downstream end of the HRT i.e. at Valve House.

The excavation of the HRT will be undertaken from all the four faces with controlled drilling and blasting techniques and the excavated crown will be supported by suitable supporting system designed according to the rock conditions.

f) Surge Shaft Construction

Once the access road reaches the portal of adit to the surge shaft, excavation of the adit will be started. After completing the adit, a winch of suitable capacity will be erected at the top of surge shaft and downward excavation will be started and completed to the invert of HRT.

Shotcreting anchors and ribs installation will be executed layer by layer during excavation according to the rock quality.

g) Pressure Shaft and Tunnels

Penstock excavation is envisaged by raise climber method. Once the horizontal portion of the lower limb of penstock is achieved raise climber installation is foreseen. Upon completion of lower penstock the raise climber will be moved and assembled for upper penstock construction.

Steel lining ferrules will be prefabricated and transported to the upper part of the shaft. A hoisting equipment will be installed to handle the piece. After welding is completed, tested and approved the 5 m of steel lining is ready for concrete backfilling which will be carried out using a concrete pump. The same operation will be repeated to complete the other components.

h) Power House Construction

A Main Access Tunnel will be constructed to reach the crown of the power house. After that, the central drift will be excavated and widening will be done by using the control blasting techniques to minimize the vibrations.

Once the excavation and supporting of the crown portion of the power house is completed, benching excavation will be taken up to lower the power house and reach to the service bay and pressure shaft levels.

During benching excavation, pre splitting and line drilling methods will be used and in one go; only 1.5 m depth of bench will be taken up. By repeating this process, we will achieve the level of the pressure shaft entering the power house.

TRT excavation is scheduled in such a way so as to allow for the bottom part of Power house excavation being removed through TRT. The sequence and the links are shown in the construction schedule. Remaining structures of Power house complex i.e. transformer hall cavern, tail race gate cavern, Pot head yard and cable tunnel are not critical activities and they are scheduled during the leveling activities for excavation and concrete works in Power house complex area.

i) Transformer Hall Construction

The excavation of the transformer hall is proposed to be carried out with a ramp. The access to bottom of the transformer hall is available from service bay through access tunnel to transformer hall.

Shotcrete and rock supports will be executed as soon as possible after bench excavation according to the construction drawings and rock quality

j) Tail Race Gate Cavern Construction

The tailrace gate cavern will be constructed by enlarging the adit-4 to desired size. The Adit-4 will provide access to the top of powerhouse from main access tunnel via gate cavern. After completion of gate cavern, three vertical shafts will be excavated from gate cavern to TRT and later they will be lined.

k) Pot Head Yard Construction

The inclined cable cum ventilation and escape tunnel is proposed to be excavated from Pot head yard to transformer hall. Cable tunnel excavation is proposed to be carried out from the pothead end. Equipment for drilling and mucking will be lowered and raised to the front by means of a steel platform operated through a hoist installed at Pothead end. Rails will be laid down on the floor of cable tunnel for the working platform approach and they will be extended following the front advancement. Drilling will be carried out with crawler track drill and mucking will be done with 0.5 m^3 bucket hydraulic excavator. Concrete lining will be done with the same methodology described for diversion tunnel.

2.12. Summary of Total Project Costs

The Summary of the Total Project Costs for Lethang HEP project is as presented below in **Table 2.6**:

Table 2.6: Summary of Costs for Lethang HEP

Civil Works including pre-operative works	INR in crores	Rs. 312.00
E and M Works	INR in crores	Rs. 138.97
Total basic cost (excl. transmission line cost)	INR in crores	Rs. 450. 97
Interest during construction and financing charges	INR in crores	Rs. 44.66
Total Project Cost	**INR in crores**	**Rs. 495. 63**

3

THE EXISTING ENVIRONMENT

3 EXISTING ENVIRONMENT

3.1 Introduction

Clear understandings of both the physical and biological characteristics of the existing local environment are imperative in planning of any developmental project. Therefore, a study was conducted to enumerate the status of existing environment within 10 km radius around barrage and power house for the Lethang HEP project.

3.1.1 Project Components and the Site

The project facilities will be constructed near Yuksam village of Geyzing sub-division in West Sikkim district. The project envisages construction of 23.5 m high barrage from river bed level across Rathang Chu River. The HRT (Head Race Tunnel) will be constructed on the right bank of the Rathang Chu River and will have a total length of 2.236 km with a finished diameter of 3.8 m. The underground power house will be constructed near Lethang village on the right bank of Rathang Chu River and houses three generator units each having capacity of 32 MW.

3.1.2 Study Area

Study area for baseline environmental condition is delineated as:

a) Direct impact study area within 10 km radius of the barrage axis and power house.
b) Catchment area up to the barrage site.

A map of the study area is presented in **Fig 3.1**. Information was gathered both from primary and secondary sources. The field surveys were conducted in different seasons of the year, i.e., pre-monsoon, monsoon and winter to collect data/ information on flora, fauna, forest types and ecological parameters as well as social aspects.

3.1.3 Sampling Locations

To assess the anticipated impacts on the surrounding environment due to the proposed project sampling was conducted for ambient air, soil, surface water and ambient noise levels. Sampling for aquatic ecology (fish fauna, planktons and benthos) was also conducted in the study area. The sampling locations of various parameters are presented in **Fig 3.2.**

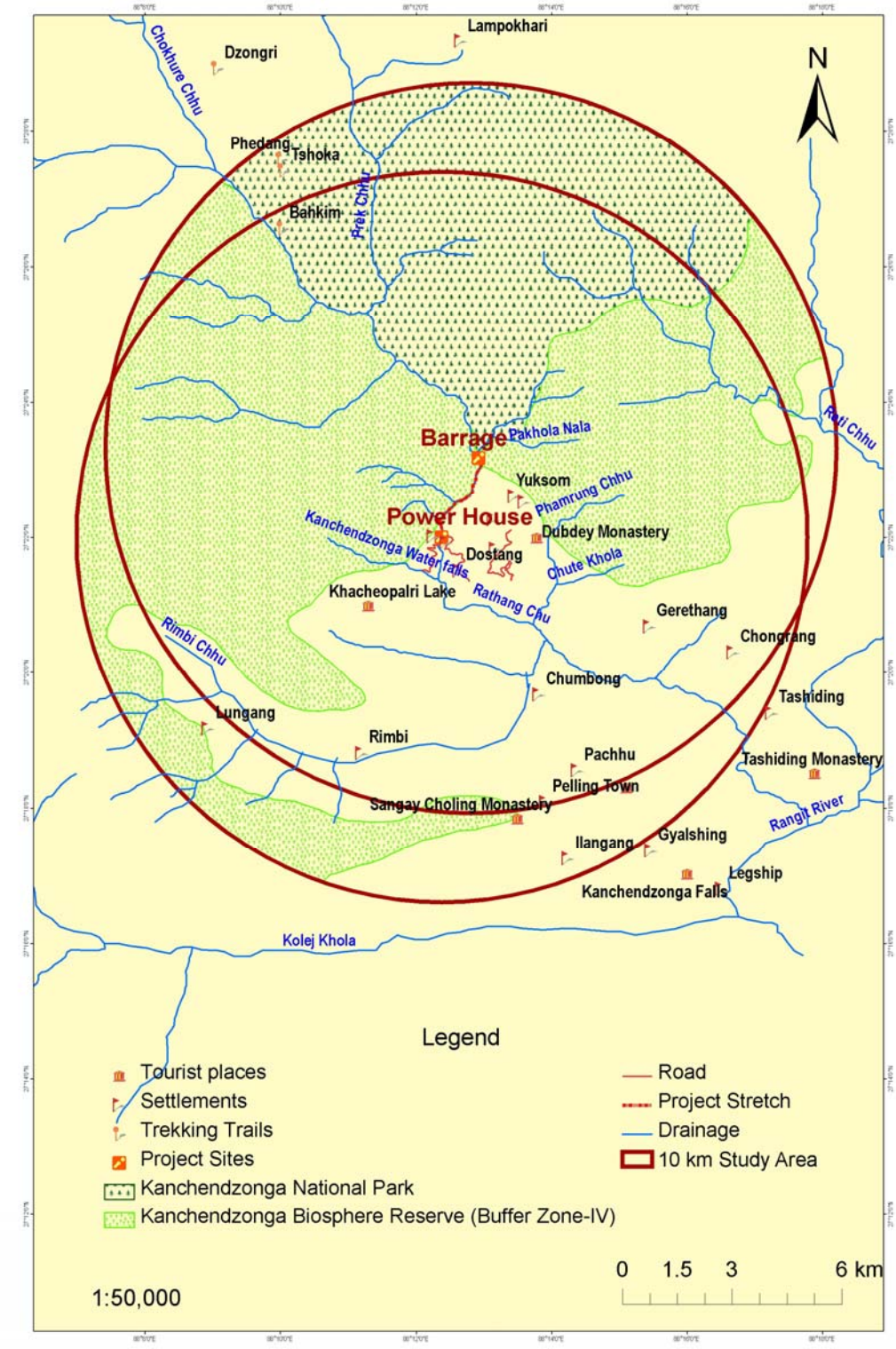


Figure 3.1: Lethang Hydro Power Project Study Area Map (10 Km Radius)

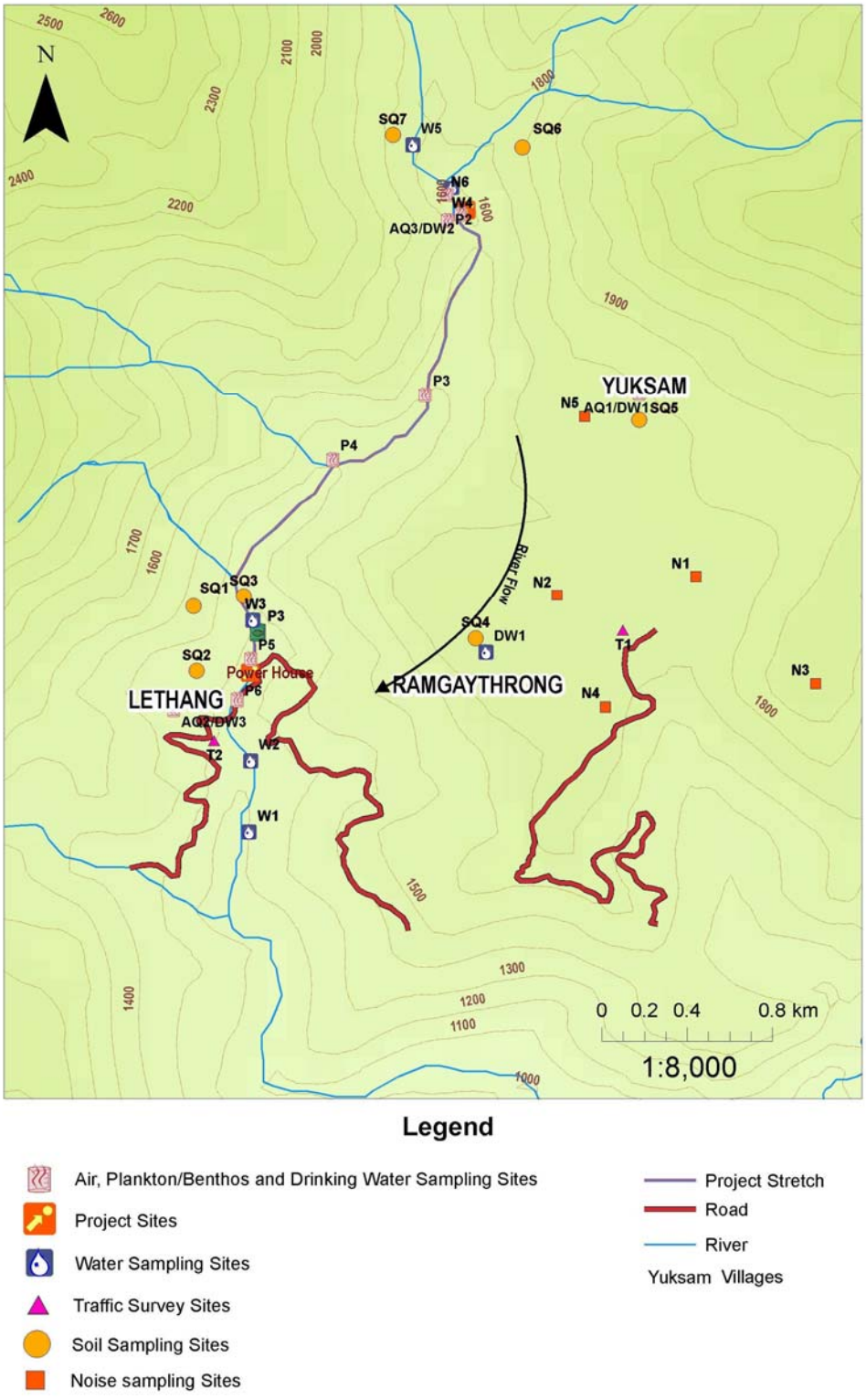


Figure 3.2: Sampling Locations Map for Various Parameters

3.2 Land Environment

The landscape is entirely hilly. The area is drained by the Rathang Chu and its tributaries. More than 54.88 % of the area is covered by vegetation. Study area encompasses diverse terrain. The topography of the area has steep (near the ridges) to gentle slops. The ridges mostly run from West to East direction and most of the rivulets and streams flow from West to East, except Pau Khola and its associated nallas, which flows from East to West to drain in Rathang-Chu. The altitude of the area varies from as low as 743 m. to as high as 4050 m. (west). Seven hamlets are present within the study area in scattered manner in which Yuksam and Lethang are the most important settlements.

The land environment is discussed under the following headings i.e., physiography, geology, seismicity, land use-land cover, soil and mineral resources.

3.2.1 Physiography

The mountain terrain of the study area consist of the tangled series of interlacing ridges, rising one above the other, from south to the foot of the high peaks, which mark the abode of snow in the north. National bureau of soil survey and land use planning have divided the terrain into nine categories viz. Summits the Ridges, Escarpment, Very Steep Slope (>50%), Steep Slope (30-50%), Moderately Steep Slopes (15-30%), Narrow Valleys (<15%), Cliff and Precipitous Slopes, Zone of Glacial Drifts/Moraines/Boulders, Perpetual Snow. The slope map of the study area is given in Figure 3.3 Based on the degree of slope, vegetation and geology these nine categories are grouped into five major physiographical division viz. Summit and Ridges, Side Slope of the Hills, Valleys, Rocky Cliff and Glacial Zone.

The proposed barrage area is located in 40-60 % of slopes as per NBSS & LUP criteria as categorized under very steep slopes and steep slopes. The trend of the mountain system is viewed as a whole in a general East-West Direction. Physiography map of the study area is presented in Figure 3.4

The study area has high ranges in the northern and north western corner moving south the ranges drop in height. The Rathang Chu and its tributaries form V shaped valleys. In the southern most part of the study area elevation is the lowest, at about 700 m. This trend continues in the north south direction. The western part of the study area ranges of medium height and it drops to 700 m in the east direction to form the Rathang Chu Valley. In the eastern part the topography again rises to about 2000 m. The relief map of the study area is given in Figure 3.5 and Figure 3.6 delineates the relief profile of the study area. The district comes under the watershed of the River Rangit and its tributaries.

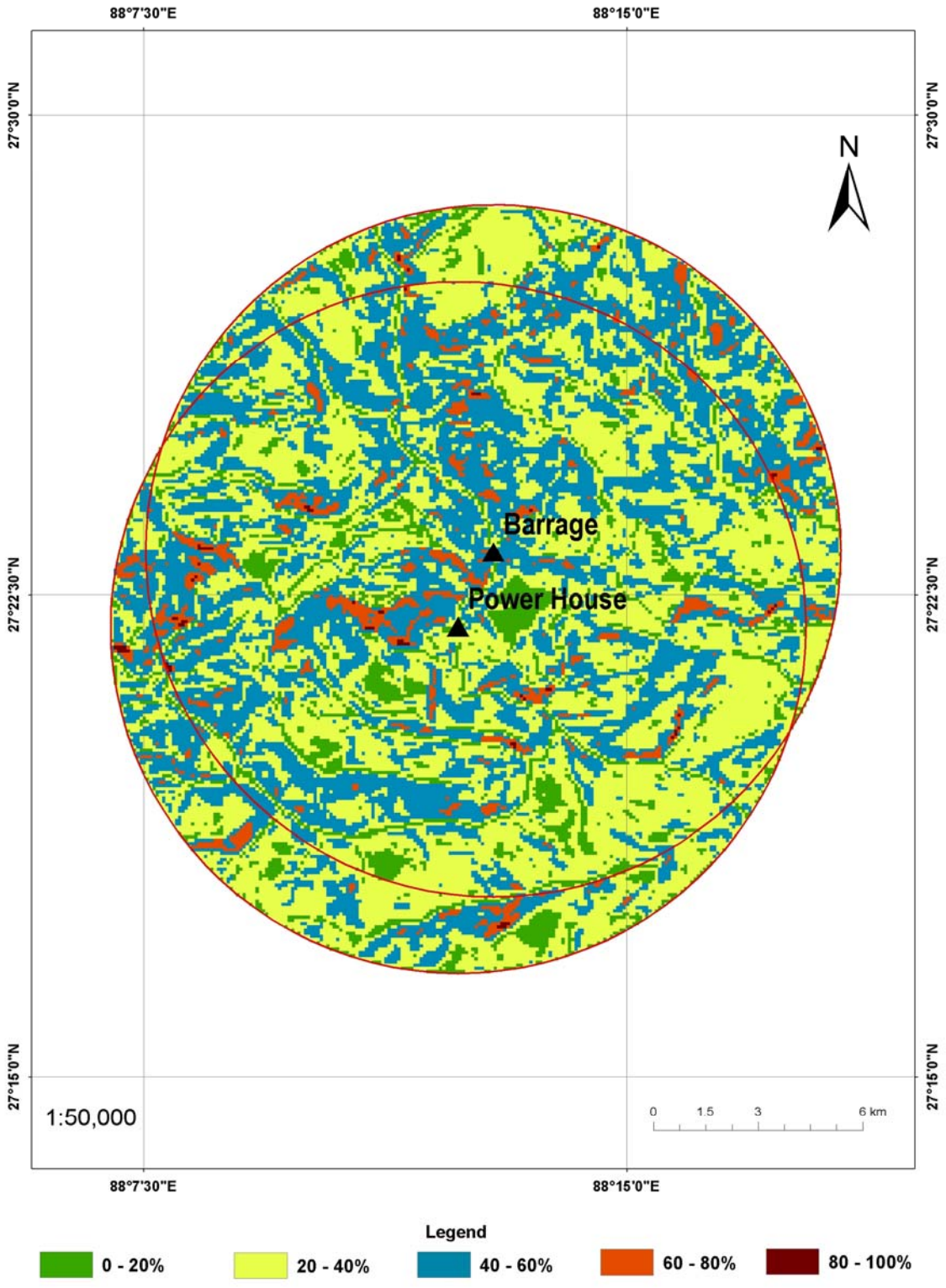


Figure 3.3: Slope Map of the Study Area

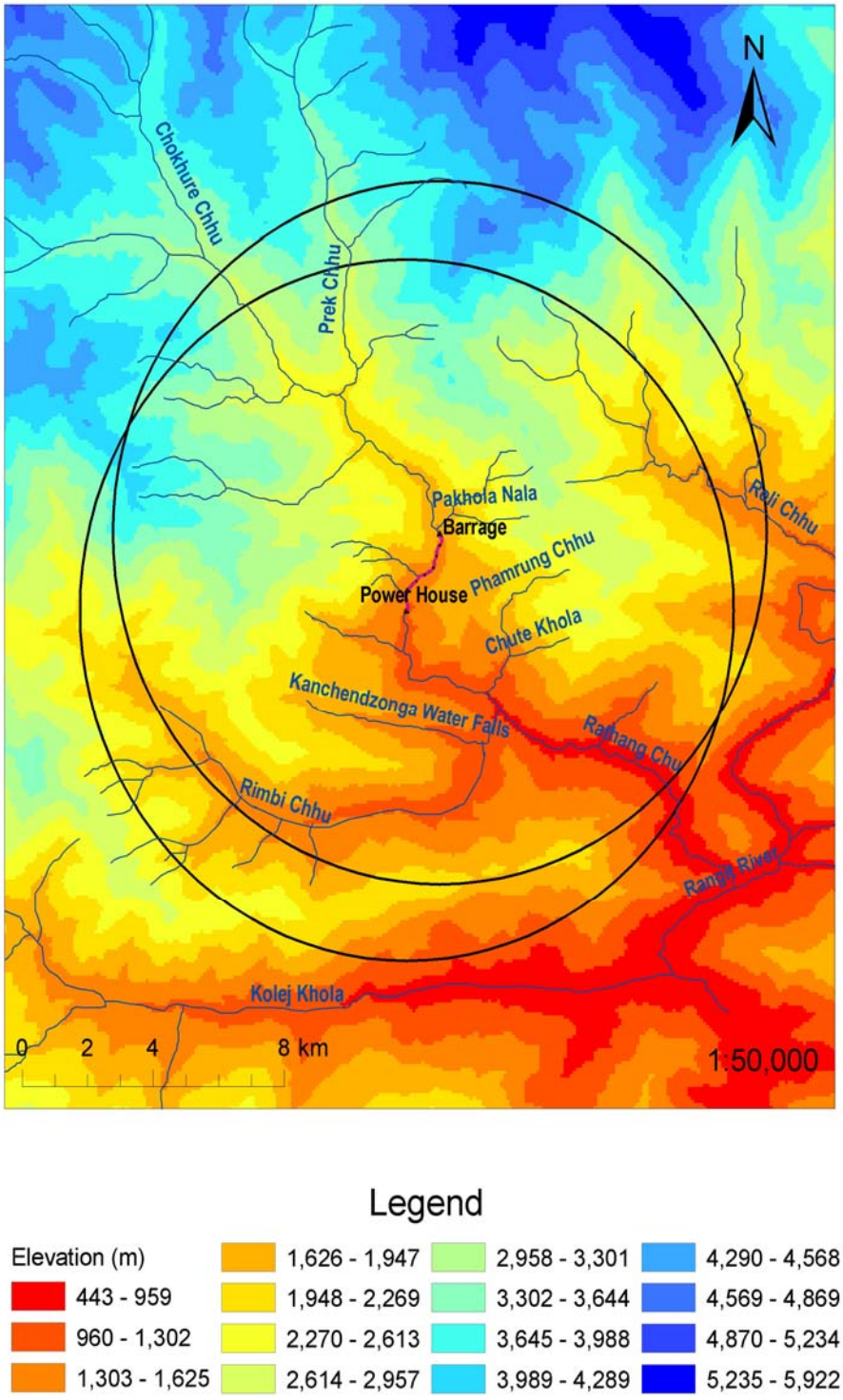


Figure 3.4: Physiography Map (DEM) of the Study Area

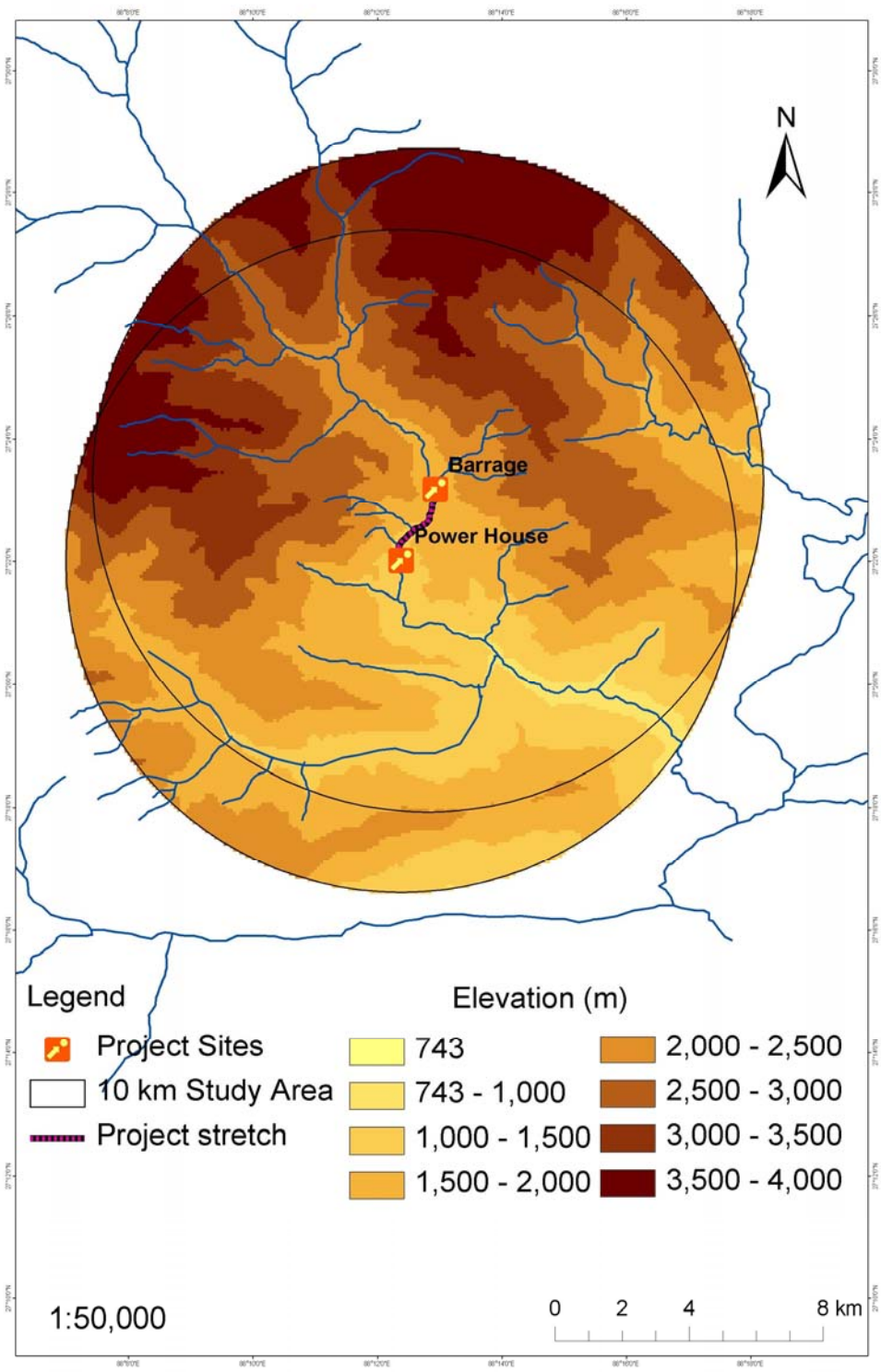


Figure 3.5: Relief Map of the Study Area

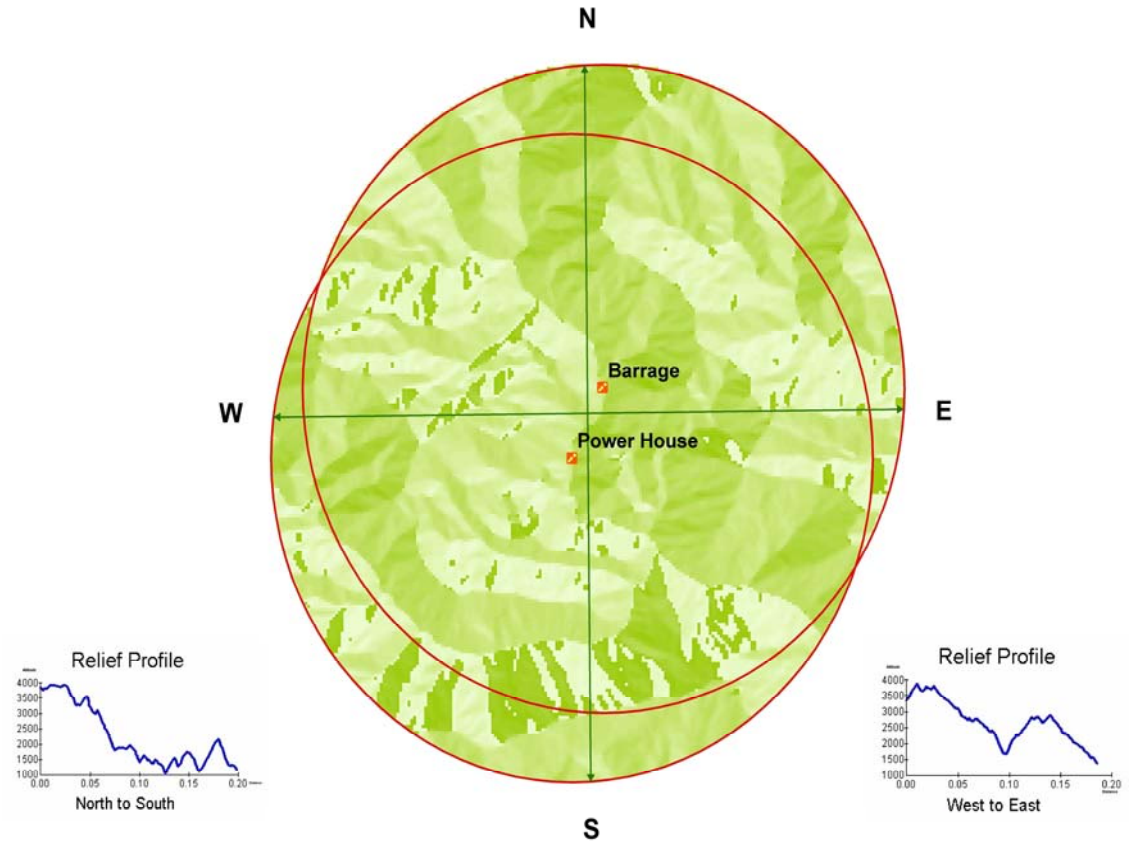


Figure 3.6: Relief Profile Map of the Study Area

3.2.2 Geology

3.2.2.1 Project Area Geology

The project area is located northwest of the Rangit tectonic window of the Sikkim Himalayas and comprises of medium to high grade metamorphic domain of the Central Himalayan Crystalline. The sedimentary rocks in the Rangit Window belong to Precambrian Daling and Buxa with overlaying Permian Gondwanas, which are terminated by the Tedong Thrust, which has brought the Daling rocks in juxtaposition with gondwanas. The daling metasediments displaying low grade metamorphism are exposed in a wide zone along the Rangit valley but in Rathang Chu River Valley these rocks are terminated by the Main Central Thrust, which has brought higher grade metamorphic rocks of Darjeeling Group/ Lingste gneisses in juxtaposition with the daling group of rocks. Stratigraphically, the Lethang HEP placed in the high grade gneisses of the Higher Himalayan Crystalline Sequences (HHCS).

The predominant lithologies are well foliated quartzitic gneiss with biotite streak along with migmatites and band of quartzites are also observed. At places garnetiferous /tourmaline gneisses are common.

Pondage Area Geology

Lethang HEP has a very small pondage area extends along Rathang Chu River and just above the head of the pondage/reservoir area, the boundary of the Kanchendzonga National Park begins and this is considered as the upper boundary limit of the project.The total extent of reservoir is just 190 m from the barrage. The pondage/reservoir displays gorge-like rugged topography with a high gradient having significant discharge and bed load. The principal lithological units consist of augen gneisses, quartzitic and granitic gneisses and migmatites.

The right bank has rock exposure in a high sub vertical gorge side all along the pondage and appears to be stable. The right bank has rock exposure all along which are characterized with stress joints. At some places, there are signs of minor toppling failures along sub-vertical tress joints. There are three joint sets present in the area including the most prominent foliation joint. One active rock slide area is present just upstream of the proposed barrage axis on the right bank. On the left bank there are numerous slide/rock fall zone and reservoir stability will be required.

One major nallah, the Pau-Khola, with significant discharge, drains the Rathang Chu near the project upstream boundary (Kanchendzonga National Park). There are few other nallah also present but with limited discharge on the left bank of the river towards the direction of flow.

Barrage Area

The barrage site of Lethang HEP is located 4 km. upstream of Yuksam village on the right bank of Rathang Chu and can be accessed via trekking trail along the abandoned head race channel of earlier proposed Rathang HEP. The trail reaches close to the barrage site above the level of the reservoir.

The barrage site is located in a natural gorge with widely jointed strong to very strong gneiss rock in the abutments and in the foundation. There is bouldery river alluvium in the center of the river bed. The river section is suitable for a concrete dam or barrage founded on rock. Approximately 35 m. upstream of the barrage axis the river widens to approximately 70 m. probably arisen from historical impacts due to rock slides from the right bank onto the left bank. The river bed near proposed axis is narrow and flows from the NNW to the SSE direction and the barrage here is oriented in the North 72 degrees East-South 72 degrees West direction.

On the right bank the gneiss forms a strong and generally stable semi vertical gorge side. The right bank exposes two prominent sets of joint plane with the foliation joint dipping 30 degrees to 35 degrees in the North, 40 degrees in East direction. The joint plane dips in the upstream direction. The second set of joint has a dip of 40 to 45 degrees in the South, 10 degrees West Direction. A third random set is also visible at some places along the right abutment.

The conditions of the rocks are moderately to slightly weathered along the surface and joints with iron staining seen at few places. However these staining appear to be superficial and fresh surfaces are expected to be encountered at depth. The joint planes show rough and undulating surfaces.

The left bank of the river in general has rock exposures to about 5-10 m. above the river bed. At certain sections colluvial material is also noted where the slopes become moderate to steep. The left bank of the barrage site exposes gneissic rock and the orientations of the joint sets are consistent with the right bank.

Here the foliation along with the foliation joint is dipping upstream into the hill. About 70 m. downstream of the barrage axis, slide zone is seen consisting predominantly of colluvium material resting at high angle, which probably may be responsible for the slide. This slide zone is followed by highly destressed jointed blocks of gneissic rock near the river bend about 180 m. upstream of the axis. The exposure is weak and fractured and is slight to moderately weathered.

The river bed consists of angular and sub-rounded boulders, partly brought by fluvial processes and some other appears as dislodged bodies from the banks of Rathang Chu river. The deposits of coarse sand and pebbles with moderate to high permeability are locally available.

Diversion Tunnel

The river diversion during construction is proposed through diversion tunnel. The right bank appears to be the more suitable for the diversion tunnel owing to the sliding nature of the left bank with reduced rock cover for diversion tunnel and an outlet portal is also expected to be in colluvium. On the right bank good rock cover is expected along the entire length of the tunnel. Both the inlet and the outlet portal of the diversion tunnel are expected to be in rock. Strong to moderately strong gneissic rock is exposed all along the tunnel. It is envisaged to construct the most of diversion tunnel from outlet end. The construction of tunnel from outlet end on left bank will be in colluvium. Hydraulically also outlet of diversion tunnel on right is more suitably placed as compared to left bank.

Intake Structure

The Intake structure is proposed approximately 25 m upstream of the barrage axis on the right bank at an invert elevation of 1563 m a.s.l. The intake structure (**Photo Plate – 1**) will be founded in the same strong to moderately strong gneissic rock as exposed all along the right bank. The initial portal will be moderately to slightly weathered, however fresh rock is expected to be encountered at depth. Also to avoid steep cutting, the gates are proposed underground. The gate chamber is approached through access tunnel from barrage at El 1578.50 m asl. The portal for this access tunnel will be in strong gneissic rock.

Photo Plate - 1 Intake Site

Desilting Basins

The two underground desilting basins will encounter the same rock as that of the barrage site. The maximum & minimum covers above the desilting basins are 100m and 75m respectively. The rock is massively jointed gneiss with the excavation intersecting joints at generally favourable angles. No significant shear or crush zones are detected from surface observations and the outlet portals of the flushing tunnel will be located in the same gneissic rock as observed along the right bank of the barrage site. Rocks exposed are gneisses with two sets of joints. Foliation joint is the most prominent one dipping 30° to 35° towards N40°E.

Based on exposure available on around right bank of the Rathang Chu River, desilting basin area is assumed to have similar rock mass condition.

Tunnel

The proposed headrace tunnel alignment passes under a rough and rugged terrain constituting the right bank of the Rathang Chu. It is 2,236 m long with a finished diameter of 3.8 m and has a uniform gradient of 0.97%. To facilitate the construction of the HRT and consequent inspection and maintenance, three Adits are conceptualized. The tunnel has four Kink points named as T1, T2, T3 and T4 provided for the requirement of the construction adits and optimal cover on the HRT alignment. The maximum cover reaches to 346m between T1 and T2 however, more then 50% of the tunnel length will encounter less then 200m. The two nallah will crosses the tunnel span where cover will be 41m and 92m respectively.

The 3.8 m finished diameter HRT will pass through generally strong to very strong jointed and foliated gneissic rock for its entire length.

There are two main sets of joints present in the initial portion of HRT. The foliation joint (S1/J1), being the most prominent dips 35 degrees towards N35°E. J2 dips 35° to 45° dipping towards S10° W. Whereas towards the end part near the surge shaft three sets of joints are visible, S1/J1 dipping 20° to 25° towards N20°W, J2 dipping 60° to 70° towards S15°E and J3 dipping 55° to 60° towards W. The tunnel will generally follow the strike of the prominent foliation, which is favorable for the excavation and support.

The slopes above the tunnel are partially vegetated, steep, and typical for this region. Two nallahs cross the alignment. The quality of the rock will be largely fair but some weak zones may be expected. Rock may also be deteriorated close to or in the nallah crossings. The cover above the tunnel is expected to be generally high along the major parts of its length except along the two nallahs where low cover is expected.

Surge Shaft and Pressure Shaft Area

The under ground surge shaft is located beneath a ridge of strong jointed gneissic rock. The ridge is present from about elevation 1700m down to river elevation at 1269m. The rock cover above the surge shaft is 60.5m. The minimum lateral cover of 95m is near top of surge shaft increase to 141m till the bottom of surge shaft. The south side of the ridge exposes strong jointed gneiss running with the dip of the foliation whilst the northern side of the ridge comprises bouldery colluviums and some outcrops along the strike of the foliation. The rock at depth is strong jointed gneiss with generally fair to good RQD, clean rough and curvy-linear or stepped joint surfaces, no infillings, surface generally fresh at depth or iron stained towards the surface. There is no sign of significant crush or shear zones the vicinity of the shaft.

The butter fly valve chamber is also under ground having minimum cover of 90m. There are two vertical pressure shafts upper & lower parts. There are also horizontal stretches in middle and lower parts. These pressure tunnels & shafts will be located in a hill on the right bank of the Rathang Chu. The rock covers above upper & middle bend are 96.5 and 89m respectively. Similar geological situation as encountered along the surge shaft area with similar structural details is expected along the pressure shaft.

Power House Area

The proposed power house site is located near the steel bridge on the river Rathang Chu and on the road connecting to Yuksam. The underground powerhouse complex is in the same strata strong gneissic rock as exposed throughout the area. The power house complex consists of power house cavern, transformer cavern, gate cavern, main access tunnel and allied tunnels. The rock is strong to very strong, widely jointed; with generally clean rough joints, occasionally stepped. No infillings or coatings and some iron staining. The minimum cover above power house cavern is 124 m. The rock conditions are very suitable for the underground complex, allowing traditional powerhouse construction with appropriate rock support and monitoring systems.

Tail Race Tunnel

The proposed tailrace tunnel (**Photo Plate -2)** will be in the same gneissic rock as encountered along the powerhouse area. The foliation and joint planes are consistent with the data observed near the powerhouse site.

PhotoPlate 2 - TRT Site

3.2.3 Seismicity

The proposed project falls under the Seismic Zone IV, which is susceptible to major earthquakes as per the seismic zone map of India (IS 1893 - Part I: 2002), shown below in **Figure 3.7**.

The northward movement of the Indian plate against the Tibet block of the Eurasian plate has made the Himalaya prone to the tectonic activity. The tectonic framework and the seismicity of the North Eastern States including Sikkim are considered as a result of collision tectonics in the Himalayan arc and subduction tectonics below the Myanmarese arc. Studies have indicated a very complex tectonic setting of the region due to constant movement of the Indian plate from South to North and the Myanmarese from East to West. The two major structural elements in the eastern Himalaya are the Main Central Thrust (MCT) and the Main Boundary Thrust (MBT).

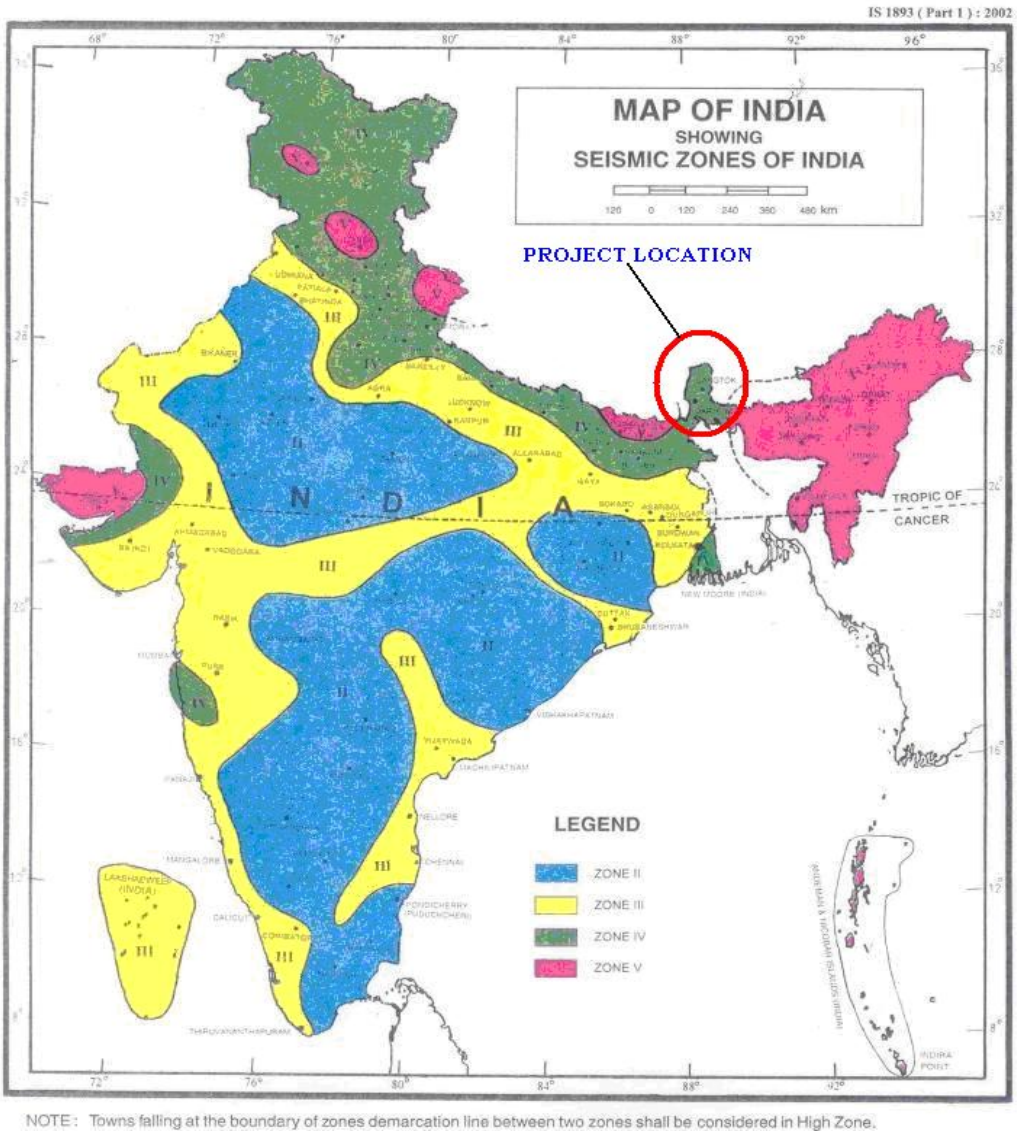


Fig 3.7: Seismic Map of India (IS 1893 - Part 1: 2002)

Rangpur Ridge is a prominent tectonic future in the east, which is bounded on all sides by major fault and Kathiar – Nailphamari fault several subsidiary faults, Parallel to Teesta fault forming grabens are reported from this ridge (Narula et al., 1998). There are also a large number of prominent lineaments in this region, some of which are reported to extend for several kilometers beneath the Himalayan fore deep. The project area lies in below the Kanchendzonga Lineament on the eastern side of the Teesta Lineament **(Figure 3.8).**

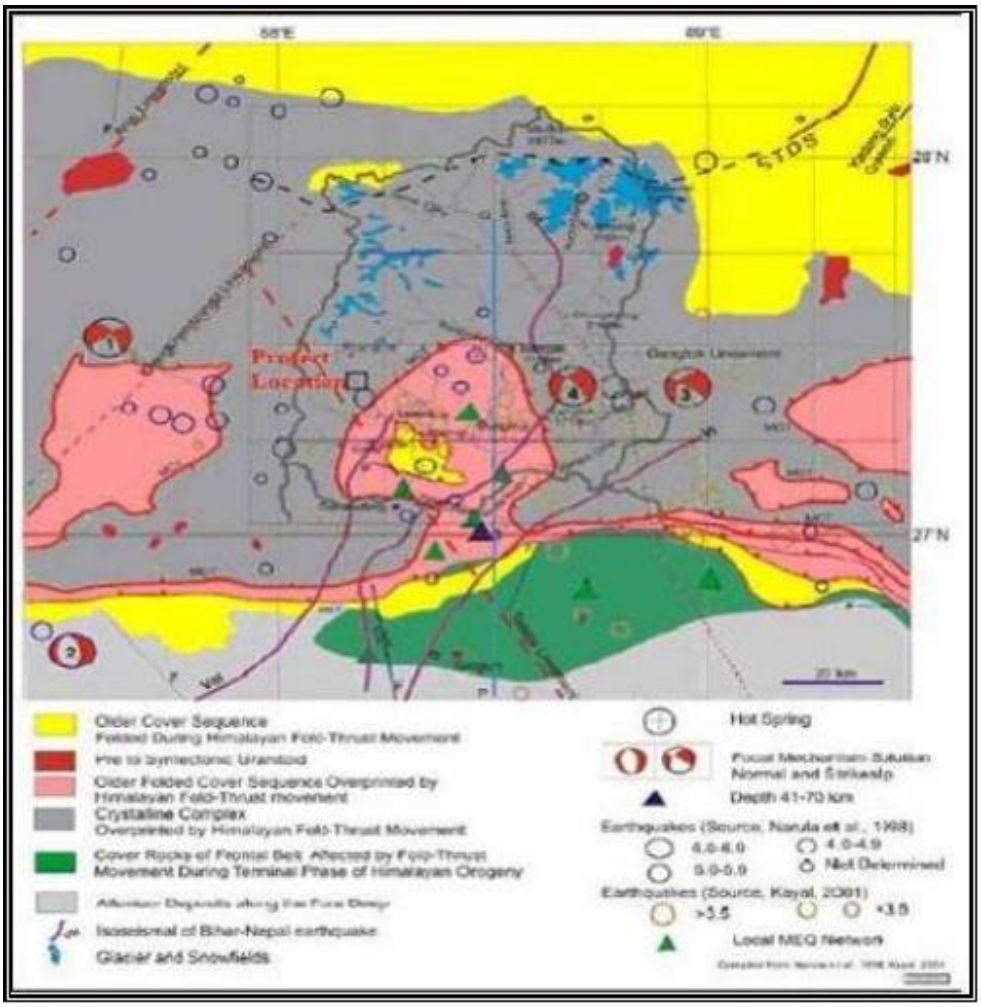


Figure 3.8: Seismo Tectonic Map of Sikkim (Narula et. al, 1998; Kayal 2001)

Review of the past earthquake history shows that in the region, most of the earthquakes are of shallow focus (< 40 km) and are commonly in the range of 4.5 – 5.5 magnitude. **Table 3.2** shows the history of past earthquakes recorded in Sikkim.

3.2.3.1 Possible Seismic Source and Peak Ground Acceleration

Based on the seismo tectonic evaluation, the following possible earthquake sources are considered for evaluating seismic hazard and computation of peak ground acceleration for the Lethang hydroelectric project in the west district of the Sikkim Himalayas.

Recent studies have shown that, the great earthquake of magnitude +8 are related to the under thrusting of the upper crust of the Indian plate, below the sedimentary wedge along a low angle northerly dipping decollement surface located south of the Basement Thrust Front (Seber and Armbruster, 1981). This source of large magnitude earthquakes in the Sikkim Himalayas, is located south of Rangit Fault, that run parallel to Rangit River tectonic Flux Fault, as inferred by Pande and Guptasharma (2005). As a most conservative consideration the focus of this event could be at a distance of 40 km, even if it is considered that the source of great magnitude earthquake is at the same location as the Basement Thrust Front. There is a concentration of moderate magnitude in a 35 Km wide E-W domain located north of the Rangit River. Majority of the events of magnitude > 4.5 magnitude are allocated within this domain.

Table 3.1: History of Past Earthquakes in Sikkim

S.No.	Location		Magnitude	Focal Depth (km)	Date
	Latitude	Longitude			
1.	27.36 N	88.21 E	5.1	21	30 Aug 1964
2.	27.33 N	88.01 E	4.5	33	21 Aug 1972
3.	27.23 N	88.02 E	5.1	33	21 Aug 1972
4.	27.44 N	88.37 E	4.5	33	23 Jan 1975
5.	27.90 N	88.70 E	4.6	39	16 Nov 1979
6.	27.90 N	88.80 E	6.0	47	19 Nov 1980
7.	27.38 N	88.83 E	5.0	09	05 Apr 1982
8.	27.04 N	89.26 E	4.6	51	18 Aug 1982
9.	27.60 N	88.48 E	4.6	33	25 May 1985
10.	27.40 N	88.43 E	4.7	41	07 Jan 1986
11.	27.45 N	88.61 E	4.6	42	26 May 1988
12.	27.19 N	88.37 E	5.0	23	27 Sept 1988
13.	27.35 N	88.35 E	5.7	30	14 Feb 2006
14	27.70 N	88.80 E	5.7	33	14 Feb 2006

Source: Indian Meteorological Department Website

The maximum magnitude recorded is 6.3 and a few events are recorded from this region. The Maximum magnitude assigned to this source is 7.0, the epicentral distance of zero and hypo-central distance of 20 km based on the focal depth of majority of the event in this domain.

The Main Central Thrust in the Sikkim Himalayas has two arms are disposed in the NNE-SSW direction and the other disposed NNW-SSE. The former with steep dips in the westerly direction and is interpreted that the arms of the entrant of MCT is because of existence of transverse strike slip faults and a few focal mechanism solutions have proved so. These transverse features are capable of generating 6.5 to 7 magnitude earthquakes. Hence, these are assigned the status of possible earthquake faults. The NNW-SSE trending other arm is located at a distance of 40 Km as such because of larger distance the Peak Ground Acceleration values for the same will be much less than the NNE-SSW.

The neo-tectonic activity along the Teesta Fault has observed in recent times. This feature, continuing for a length of 250 Km, is capable of generating a 6.5 -7 magnitude earthquake passes close to the Lethang hydroelectric project area.

Other likely sources such as Kanchendzonga Fault, the Gangtok lineament, the Arun lineament and the Chungthang Fault are located at quite large distance with possible 6.5 to 7 magnitude. Earthquakes originating from these sources will give much less PGA values than the sources considered. The computed motions for four sources considered for the project are presented in **Table 3.2** below:

Table 3.2: Computed Motions for Four Sources Considered for the Project

Seismic Sources	Hypo Central Distance (km)	Type	Magnitude	Peak Ground Acceleration Values		
				Boore et. al	Campbell 1997	Sadigh et. al
Main Himalayan Seismic Source, the detachment surface	15	Thrust	8	0.40 g	0.39 g	0.45 g
Baseline thrust Front	20	Do	7	0.18 g	0.22 g	0.26 g
NNE-SSW trending area of MCT	15	Strike Slip	7	0.22 g	0.28 g	0.26 g
Teesta Lineament	20	Do	7	0.18 g	0.22 g	0.26 g

Proper seismic co-efficient shall have to be derived for different structures. However, there is no immediate threat perception to human life due to occurrence of an earthquake specifically by the project itself as no large reservoir is involved.

The micro-zonation identification of seismic area map of Sikkim was studied and prepared by IIT Kharagpur delineated in **Figure 3.9.** Various sectors such as geology, bedrock topography, sub-soil condition, and geomorphology and earthquake ground motion amplification were considered while preparing this map. Six major hazard zones namely, very low, low, moderate, high, very high and severe are identified. Based on the seismic map the Lethang HEP site lies in Hazard Scale ($0.2 < H <= 0.3$) & ($0.3 < H <= 0.4$) very near to epicenter of earthquake having low magnitude ranging from 4 – 5 on Richter scale.

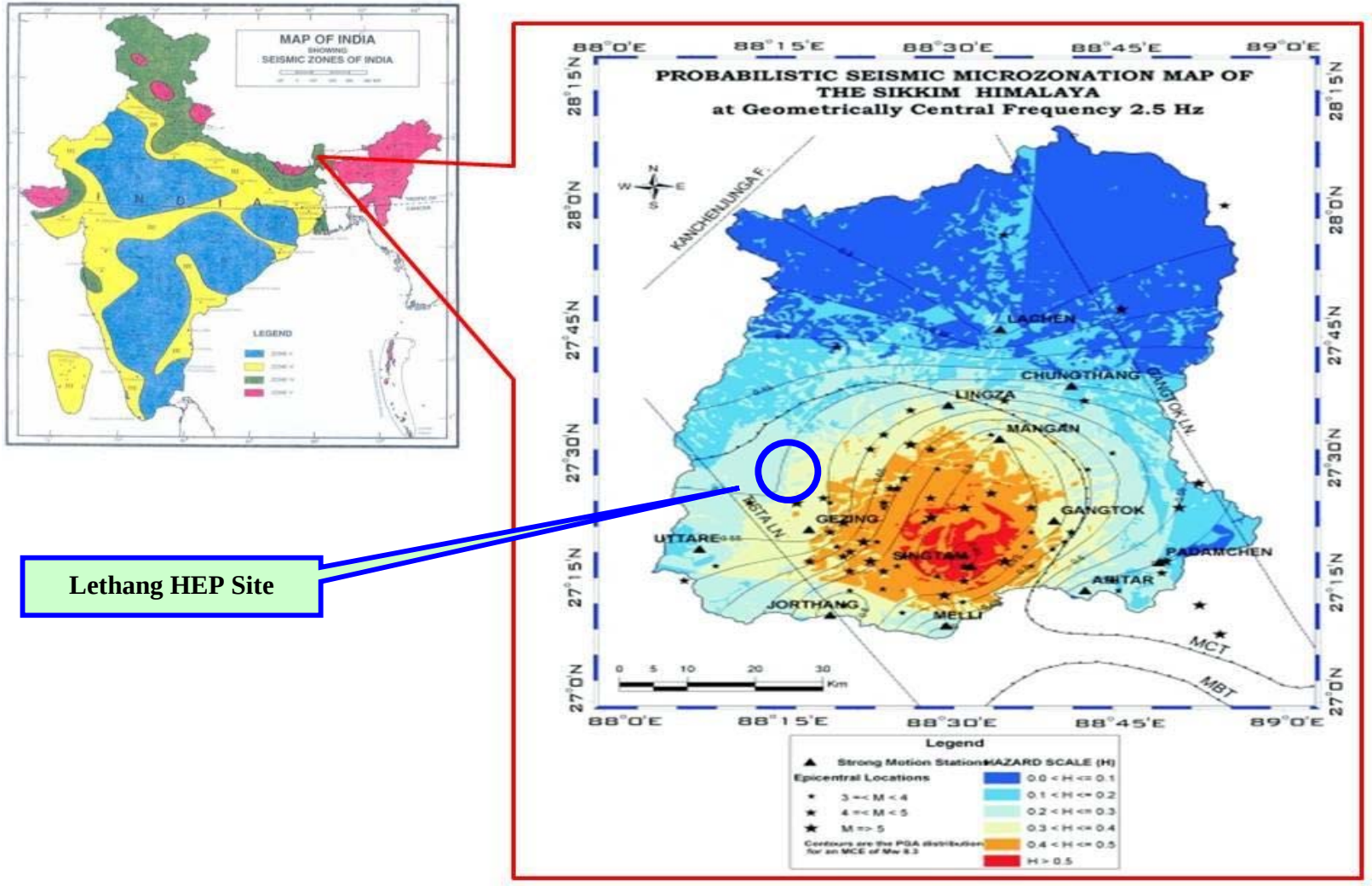


Figure 3.9: Probabilistic Micro-Zonation of Seismic Areas in Sikkim

3.2.4 Landslide Zonation

There are total six minor landslide areas existing in the project stretch. Detailed investigations were carried out along the periphery of the proposed barrage in order to delineate the active and potential landslide areas. No landslide prone area is identified while surveying along the periphery to the barrage. The location wise details on these landslides prone spots are presented in **Table 3.3**. Topographically the area is constituted by steep slopes with a narrow V shape valley beyond power house site in lethang village. The landslide map is given in **Figure 3.10**

PhotoPlate-3 :Landslide area near TRT

Table 3.3: Landslide Prone Areas Details

Land Slide No.	L/R Bank of the river	Location Details	Longitude/ Latitude	Aerial Distance from Barrage Axis	Average Elevation (m a.s.l.)
L1	Right	On the right bank, approx 1 km away from the barrage along the western slope near nallah -1.	N 27 22.522 E 88 12.126	1.04 km.	1930 m.
L2	Right	On the right bank, near nallah 2, 0.8 km approx from the power house	N 27 22. 266 E 88 11.978	1.86 km.	1706 m.
L3	Right	On the right bank, upstream nallah 2, 1 km. approx from the power house.	N 27 22.162 E 88 11.984	2.14 km.	2084 m.
L4	Right	On the right bank of the river 0.5 km. from power house.	N 27 22.122 E 88 12.043	2.57 km.	1537 m.
L5	Left	On the left bank of the river 0.5 km. from power house.	N 27.22.284 E 88 12.448	2.11 km.	1366 m.
L6	Left	On the left bank of the river, 1.5 km. from barrage, along the eastern slope of the left bank near BDO Colony.	N 27 22.984 E 88 13.573	1.46 km.	2000 m.

Figure 3.10: Google Satellite Image (2010) showing Landslide Prone Areas around Proposed Project Site

3.2.5 Soil (Physico-Chemical Characterization)

As a part of field studies, soil samples from various locations in the study area were collected and analyzed for pre-monsoon, monsoon and winter seasons. Soil sampling locations are described in **Table 3.4** and shown in **Figure 3.2.** The results of the analysis of soil samples are given in **Annexure – I.**

Table 3.4: Location of the Soil Sampling

Station	Location of Soil Sampling	Elevation
SQ1	Near Lethang Village	1410 m
SQ2	Dosthang Village	1260 m
SQ3	Upstream power house	1350 m
SQ4	Ramgaythrong Village	1740 m
SQ5	Yuksam village	1860 m
SQ6	Near Paukhola Nallah	1790 m
SQ 7	Near KNP bridge	1795 m

Observations:

a) There was not much variation in characteristic of soil sample collected in different seasons except moisture content. The moisture content for the seven samples was between 1.30% and 2.44 %.
b) The soil samples were Grey Black to Black in colour.
c) Soil pH varied in the range of 6.79 to 7.24 with an average value of 7.07, which indicates neutral nature of it.
d) The value of percent organic matter was found in the range of 0.37 to 1.74 and percentage of organic carbon was in the range of 0.288 to 0.502.
e) Minimum TKN percentage was found 0.0028 while maximum was observed 0.017. This indicates moderate productivity of the soil.
f) Phosphorus, Chloride, Potassium, Sodium, Calcium and Magnesium contents were varied within the range of 0.34-9.20 mg/100g, 5.01-15.02 mg/100gm, 6.7-49.3 mg/100gm, 2.9-21.8 mg/100gm, 10.42-73.35 mg/100gm and 4.39-39.47mg/100gm, respectively.

Above results indicate that the soil in the study area possess fewer amounts of the nutrient elements like nitrogen, phosphorus, potassium etc. and contain relatively less water retaining capacity, a property very essential for rising of crops. This indicate that the soil within the study area is moderately productive for agricultural and forest crops. As per National Bureau of Soil Survey and Land Use Planning mapping units the study area has following types of soils:

a) Fine loamy typic haplumbrepts Fine loamy umbric dystrochrepts.
b) Coarse loamy pachic haplumbrepts fine loamy umbric dystrochrepts.
c) Coarse loamy typic haplumbrepts coarse loamy over fragmented typic udorthents.
d) Coarse loamy typic undorthents loamy skeletal pachic haplumbrepts.
e) Coarse loamy lithic haplumbrepts coarse loamy typic undorthents

A soil map was prepared on the bases of NBSS and LUP mapping units for the entire study area. The area wise distribution details of soil types existing in the area are delineated below in **Table 3.5.** The soil map of the study area is shown in **Fig 3.11** .

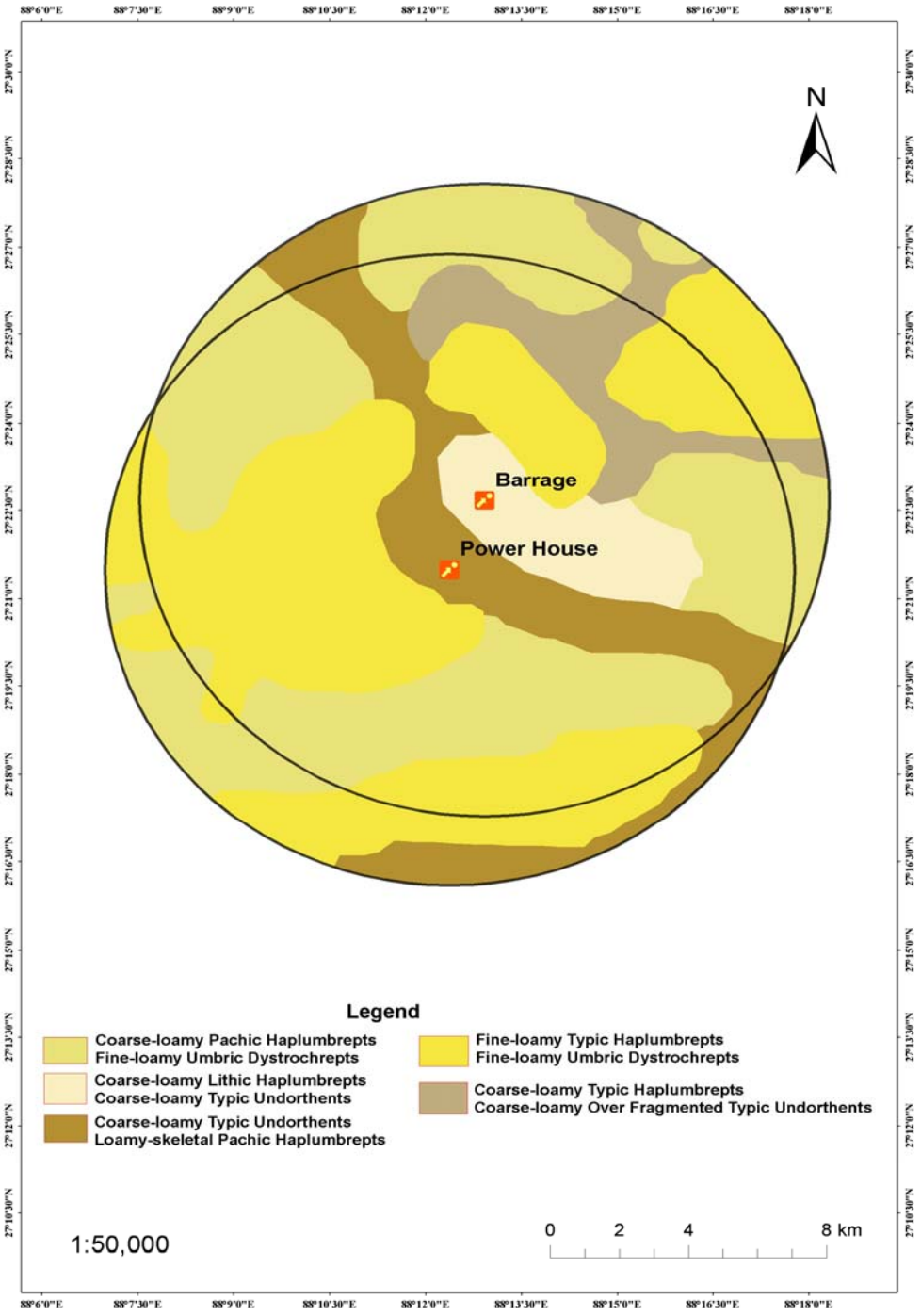


Figure 3.11: Soil Map of Study Area

Table 3.5 Soil Types Existing in the Area

S.No.	Soil Types	Area (in sq.Km.)
1.	Fine loamy typic haplumbrepts Fine loamy umbric dystrochrepts	119.68
2.	Coarse loamy pachic haplumbrepts Fine loamy umbric dystrochrepts	113.61
3.	Coarse loamy typic haplumbrepts Coarse loamy over fragmented typic undorthents	240.29
4.	Coarse loamy typic undorthents Loamy skeletal pachic haplumbrepts	448.47
5.	Coarse loamy lithic haplumbrepts Coarse loamy typic undorthents	185.03

3.2.6 Land Use

The land use details of Yuksam village are obtained from secondary sources, like ADM office and Agricultural office, the details are shown in the **Table 3.6. Photo plate 4 and 5** depict the land use of the area.

Table 3.6: Landuse Details of Yuksam Village

S.No.	Classes	Area (Hectares)	Area (Sq.Km)	Percentage (%)
1.	Cultivable Area	732.062	7.320	57.34
2.	Uncultivable Area	14.7480	0.147	1.15
3.	Barren Land	14.7480	0.147	1.15
4.	Dry Field	515.0440	5.150	40.34
Total Geographical Land		**1276.602**	**12.76**	**100**

Source: ADM Office and Agriculture Office, West Sikkim.

Photo Plate 4 -Landscape of Yuksam Village

Photo Plate 5 - Landscape of BDO Colony

3.2.6.1 Landuse/Land cover Study

Land cover of the 10 km radius study area with reference to the barrage site and powerhouse site is derived using latest satellite imageries. The satellite imagery used for the study is procured from Indian Remote Sensing (IRS) Satellite 1D/P6, LISS III sensor from National Remote Sensing Agency for October (2009) month. The imagery from LISS III sensor is of 23.5m resolution. The accuracy of the interpretation of the satellite imagery is enhanced using reference data from ground truthing. The Land cover is categorized based on the density of crown cover and also on the type of vegetation. This categorization are based on the density of crown cover of >40 %, 10-40 % and <10 %, respectively. Land use/ Land cover map of the study area, as derived from the satellite imagery is depicted in **Figure 3.13** and digital elevation model for land use and land cover **Fig 3.14** whereas the satellite imagery of this area is presented as **Figure 3.12.**

Detail of land cover of the study area indicates that approximately 65% is covered by vegetation of various density, i.e. dense forest (22.37 %), open forest (32.51%) and alpine scrub (9.37 %), which refers to the crown cover density of >40%, 10-40% and <10%, respectively. The other four important land covers, which are alpine barren that is transitional area between the snow cover and vegetation about 14.23%, cultivated area is about 10.17%, settlements are about 5.74 % and snow covered area is about 5.61%.

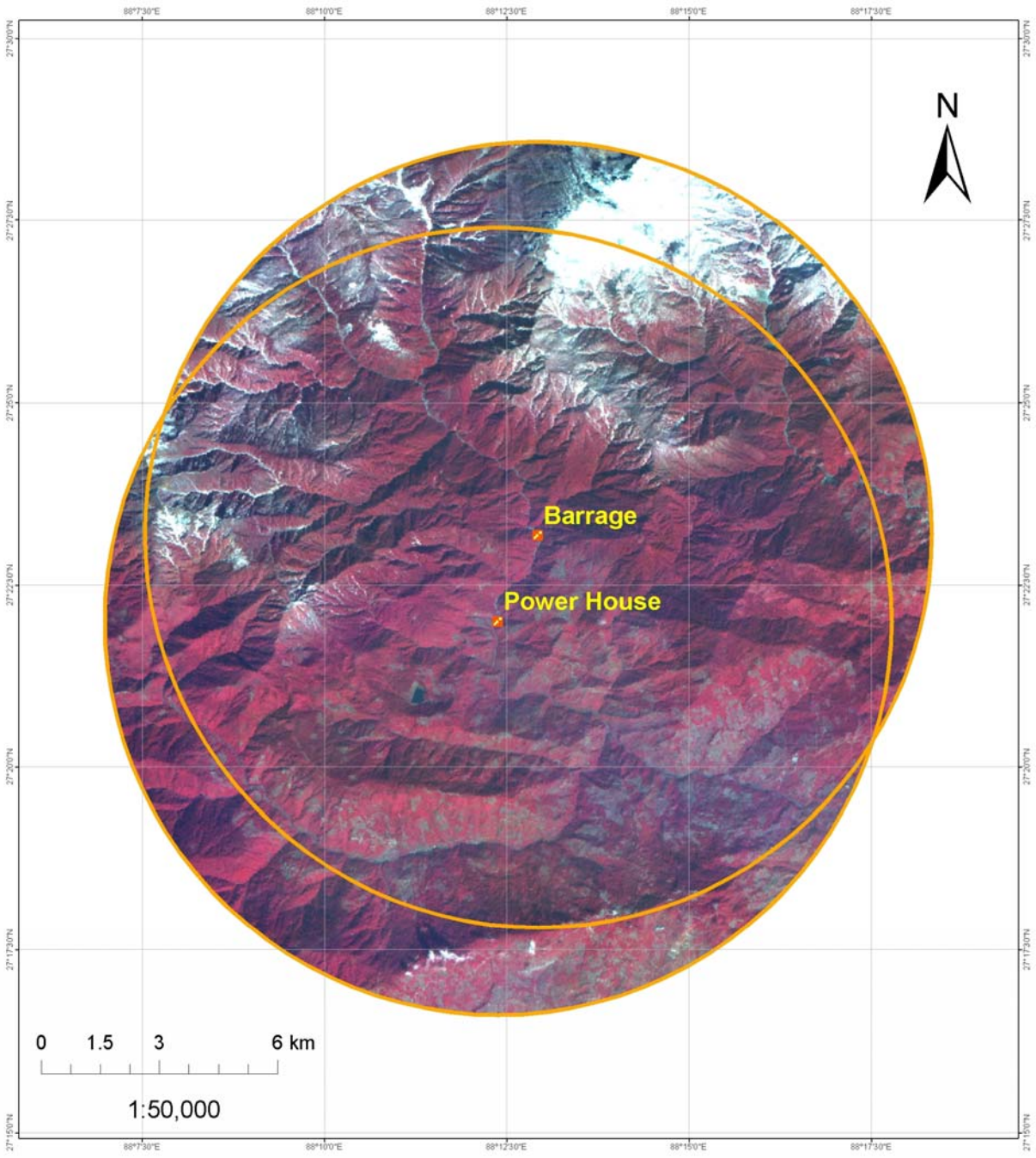
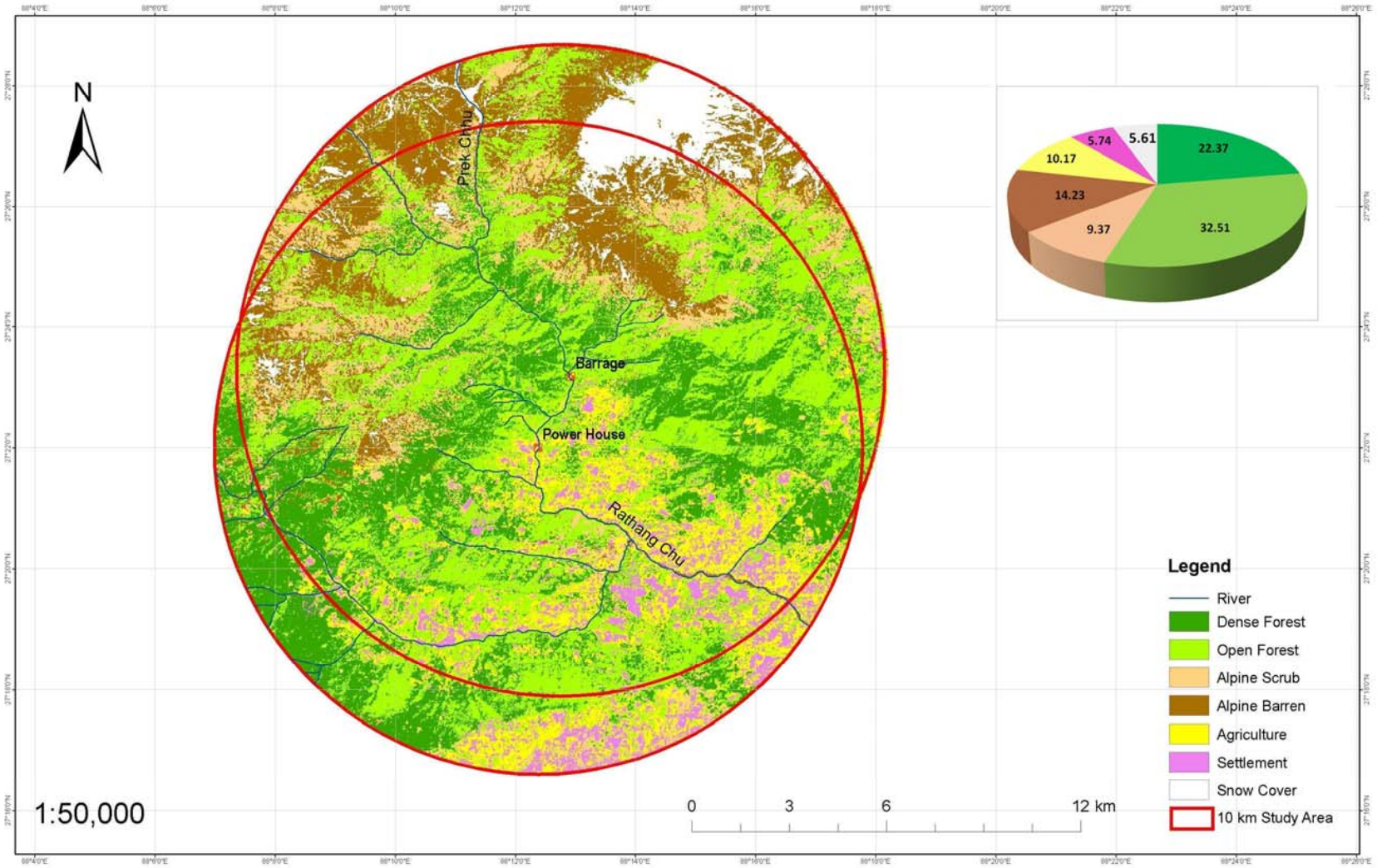


Figure 3.12 : False Colour Composite LISS III image (October 2009)



3.13: Land Use / Land Cover Map of the Study Area

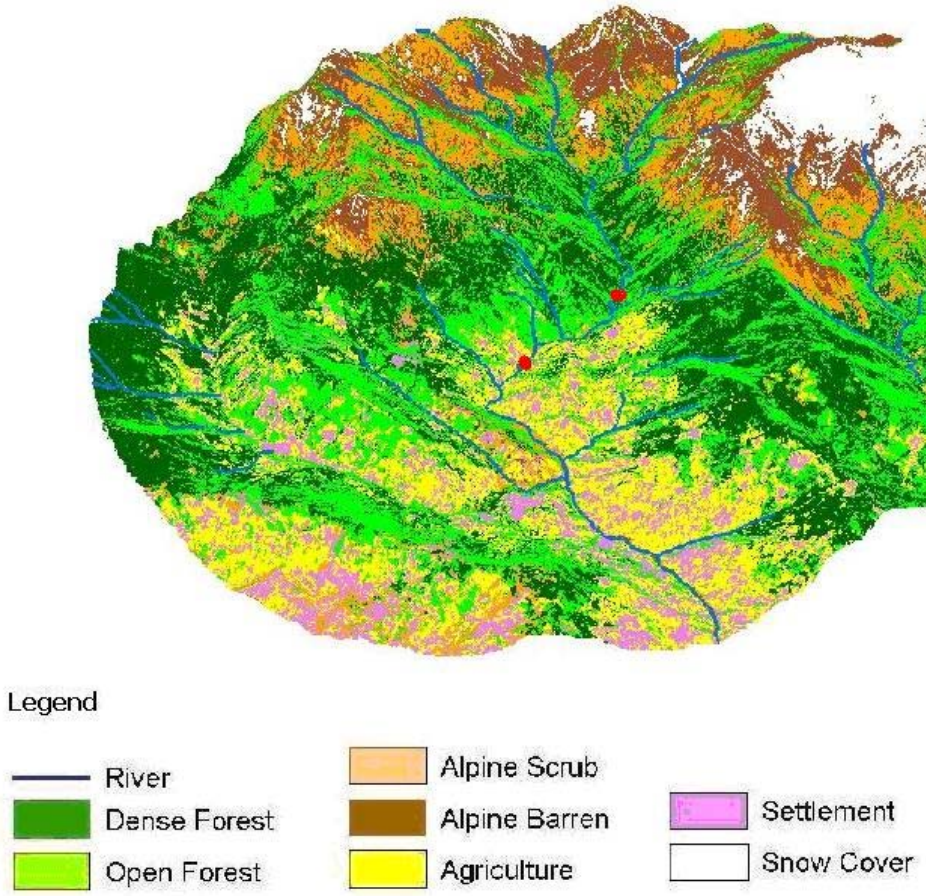


Figure 3.14: Digital Elevation Model for Land Use Land Cover of the Study Area

3.2.6.2 Land Requirement

The land required for the project is delineated in **Table 3.7.**

Table 3.7: Land Requirement for the Proposed Project

S.No.	Land Requirement	Type of Land	Area (Ha)
Land for Surface Components			
1.	Road to Barrage Area	Forest Land	0.555
		Private Land	4.091
2.	Upstream Works	Forest Land	4.380
		Private Land	0.402
3.	Road to Power House Area	Forest Land	3.066
		Private Land	5.224
Land for Underground Components			
4.	For Underground Components	Forest Land	1.628
Land for Muck Dumping			
5.	Muck Dumping (On Lease)	Private Land	5.283
A) Total Forest Land			9.629
B) Total Private Land			15.00
** Total Land Required (A+B)			24.629
** In addition, 20 Ha of Land to be taken on lease for residential area, construction facilties like crushing and batching plant.			

3. 3 Climate and Meteorology

3.3.1 Climate

The climate of the district varies from sub-tropical to alpine depending upon the elevation of the place. The tropical climate is observed at the lower elevation while temperate climate prevails in the higher elevation. Climatologically there are four seasons viz. summer (pre-monsoon), monsoon, post-monsoon and winter in the region.

Summer	:	April, May
Monsoon	:	June, July, August, September
Post-monsoon	:	October, November
Winter	:	December, January, February. March

Monsoon Season: In this region the southwest monsoon is the principal rainy season. Normally, the Bay of Bengal branch of the monsoon current reaches the Sikkim Himalayas towards the beginning of June. The monsoon normally starts withdrawing from the region towards the end of the last week

of September. The relative humidity is high during the monsoon season generally exceeding 70% on the average.

Post Monsoon Season: In September the influence of the summer-monsoon begins to decrease. During the post-monsoon season the temperatures decline noticeably. The precipitation activity also declines perceptibly. This time of the year is generally the most pleasant season due to the stable weather condition and the warm climate.

Winter Season: Severe winter is the chief climatic feature of the area with a significant amount of snowfall in high altitude. It lasts from December to March. January is the coldest month, the mean minimum temperature recorded by KHC meteorological station was of the order of 5 ° C, however the mean minimum temperature is generally 8°C at 1800 m, -12°C at 6000 m in the northern altitudes. Precipitation during this season only occurs in conjunction with that of western disturbances (flat low-pressure areas).

Summer Season: The driest part of the year is the summer, when humidity may become as low as 35% during the afternoons. Owing to nature of terrain, local effects are pronounced and when the general prevailing winds are not too strong to mask these effects, there is a tendency for diurnal reversal of winds, blowing up the slopes during the day (anabatic flow) and down the slopes at night (catabolic flow).

3.3.2 Meteorology

A meteorological station is established at Yuksam village by the project developer to record daily meteorological data. The monthly average temperature, humidity and rainfall as observed from meteorological station is given in **Table 3.8.** The calculation sheets for meteorological data are given in **Annexure-II** for reference**.**

Table 3.8: Average Monthly Temperature and Relative Humidity

S.No.	Year	Month	Rainfall (mm)	Temperature ˚ C		Relative Humidity	
			Avg.Montly	Maximum	Minimum	Maximum	Minimum
1.	2009	August	15.77	21.92	16.26	95	90
2.	2009	September	15.10	18.45	12.12	90	82
3.	2009	October	5.32	20.55	11.76	82	72
4.	2009	November	0.26	16.75	7.91	76	68
5.	2009	December	0.39	12.85	5.19	81	74
6.	2010	January	0.33	14.98	4.60	64	56
7.	2010	February	1.13	14.46	5.14	74	66
8.	2010	March	1.48	10.53	5.09	75	66

Source: Kalpan meteorological station, Yuksam

The Windrose Models for Lethang Hydro Power Project are developed using Lakes Environmental WRPLOT View (freeware) a fully operational windrose programme, depicting the frequency & occurrence of winds in each of the specified wind direction sectors and wind direction classes for a given location and time period. The Windrose models were prepared on the basis of primary data obtained from KHC meteorological station. The **Table 3.9** delineates the output of WRPLOT View model for different seasons.

Table 3.9: Lakes Environmental WR Plot View Analysis Results

S.No.	Season	Calm Winds	Avg. Wind Speed
1.	Monsoon Season	54.80 %	2.39 m /sec
2.	Post Monsoon Season	15.14 %	6.35 m / sec
3.	Winter Season	22.15 %	5.70 m/ sec
4.	Pre-Monsoon Season	15.44 %	7.39 m / sec

3.3.3 Cloud Cover

During the monsoon months, particularly June to September, the sky is heavily clouded (mean monthly total cloud between 6 – 7 Octas as per IMD data). The cloudiness decreases since post monsoon and summer months. The sky is generally clear (mean monthly cloud between 1- 2 Octas) during summer season except occasional short spells of cloudy weather. There is an increase in cloudiness from June onwards and medium clouds cover exists during the month of October and November.

3.3.4 Snow Cover

The permanent snowline for the planning of Lethang Hydro Power Project is taken as 4500 m. The permanent snow cover area calculated using GIS and RS on LISS III October imagery is about 65.26 km^2.Only 18 % of the catchment area (Approx 360 Sq.km) is permanently snow covered, the snow appears beyond the study area. The snow cover map of the catchment area is shown in **Figure 3.15.**

3.3.5 Cloud Burst

No past records of cloud burst were found in the study area.

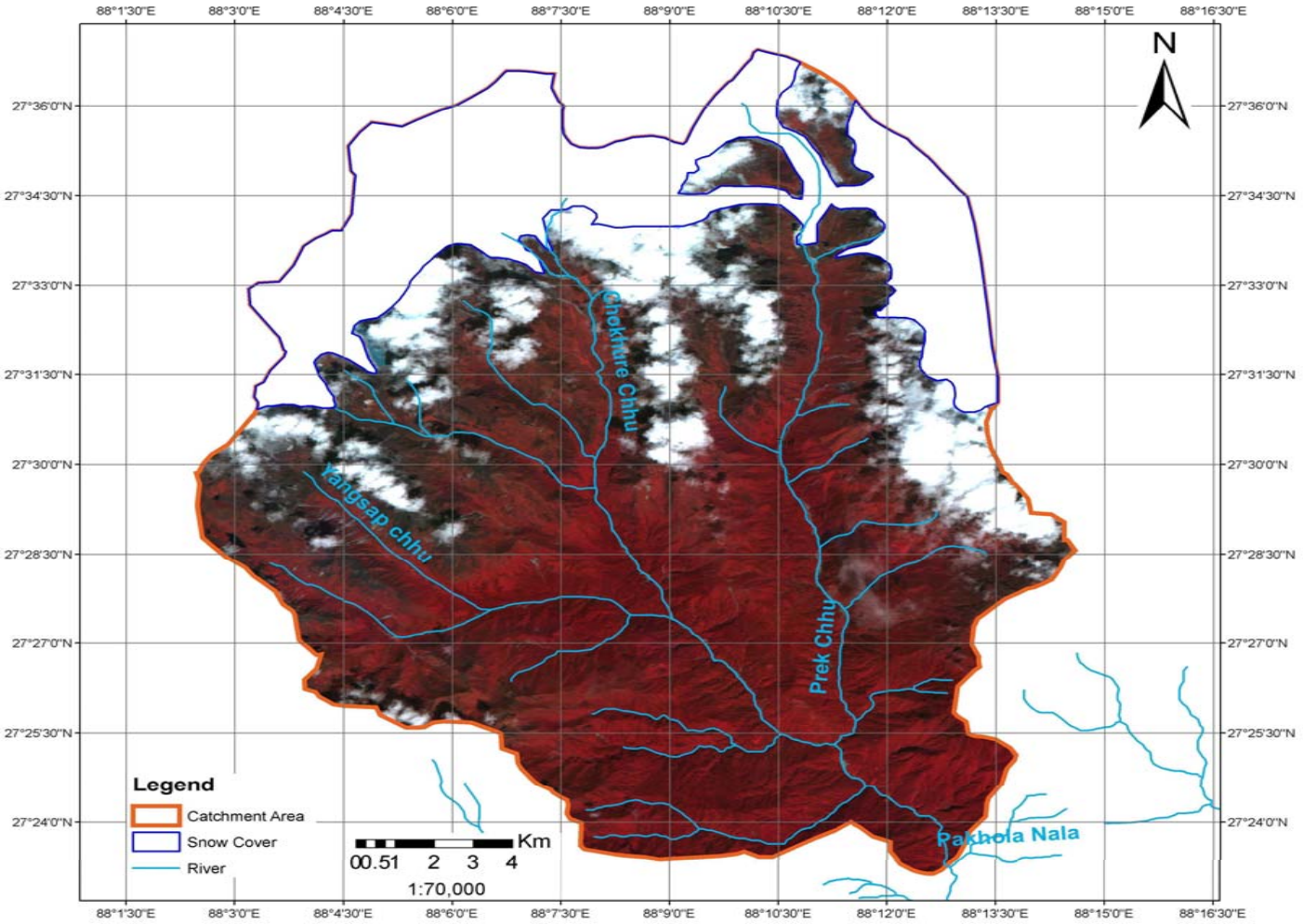


Figure 3.15: Snow Cover Map of Catchment Area

3.4 Air Environment

3.4.1 Ambient Air Quality

The proposed Lethang HEP on Rathang Chu River lies in a clean area free from harmful air pollutants. There is not a single factory or industry operating near by the proposed project. Moreover, the area from barrage to power house site is covered with mixed broad leave type of forests on both the banks of river consequently resulting in absorption of any pollutant resulting due to human interferences.

3.4.1.1 Ambient Air Monitoring

In a water resource project, impacts on air quality are marginal and limited only during construction phase. In order to assess the existing status of air quality, the data on ambient air quality in the area as monitored by the Sikkim Pollution Control Board are used. The locations of Ambient Air Quality Stations are delineated in **Table 3.10**

Table 3.10: Ambient Air Quality Monitoring Stations

S.No.	Location Code	Monitoring Stations
1.	AQ 1	Yuksam Village
2.	AQ 2	Lethang Village
3.	AQ 3	Ramgaythrong Village

3.4.1.2 Air Monitoring Results

The ambient air quality data as provided by the State PCB are given in **Annexure III** The prevailing air quality graphs are depicted in **Figure 3.16**. The national ambient air quality standards and the observed emission levels are given in **Annexure III**. There is no industrial activity in the study area, the main sources of air pollution is fuel wood burning. The dense forests in the area act as a natural sink for air pollutants.

Observations

Suspended Particulate Matter (SPM)

The 24 hours average SPM levels recorded during premonsoon, and winter seasons at AQ1 were 61.1µg/m^3, and 86.2 µg/m^3, respectively; at AQ2 are 59.8µg/m^3, and 72.6 µg/m^3, respectively; at AQ3 are 66.3 µg/m^3, and 84.1 µg/m^3, respectively. The SPM levels recorded were below the stipulated standards (100 µg/m^3) for ecosensitive areas as well as industrial, rural and residential areas as prescribed by CPCB in the year 2009.

Respirable Particulate Matter (RSPM)

The 24 hours average RSPM levels recorded during pre-monsoon and winter seasons at AQ1 are 23.0µg/m^3, and 25.2 µg/m^3, respectively; at AQ2 are 23.4 µg/m^3, and 25.2 µg/m^3 respectively; at AQ 3 are 22.6 µg/m^3, and 26 µg/m^3. The RSPM levels recorded were below the stipulated standards (60 µg/m^3) for ecosensitive areas as well as industrial, rural and residential areas as prescribed by CPCB in the year 2009.

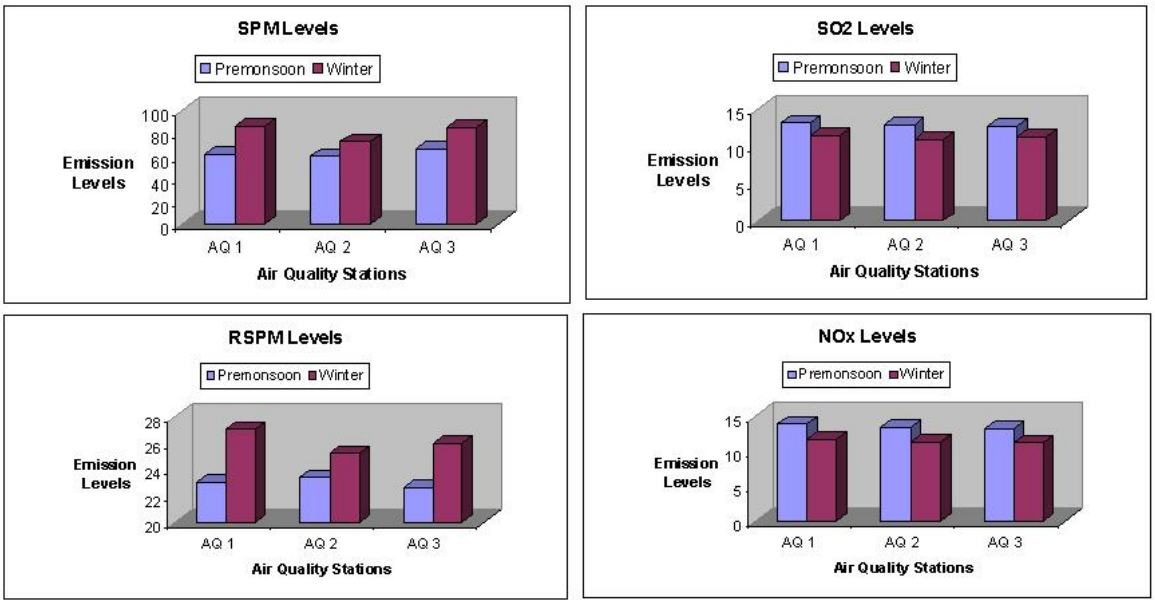
Sulphur Dioxide (SO_2)

The 24 hours average SO_2 levels recorded during premonsoon, and winter seasons at AQ1 are 13.1 µg/m^3, 11.4 µg/m^3 ; at AQ2 are 12.9 µg/m^3, and 10.9 µg/m^3 , at AQ3 are 12.7 µg/m^3, and 11.2 µg/m^3 respectively. The SO_2 levels recorded were below the stipulated standards (80 µg/m^3) for ecosensitive areas as well as industrial, rural and residential areas as prescribed by CPCB in the year 2009.

Oxides of Nitrogen (NOx)

The 24 hours average NOx levels recorded during premonsoon, and winter seasons at AQ1 are 13.8, 12.3 and 11.6 µg/m^3 ; at AQ2 are 13.4, 12.1 and 11.3 respectively; at AQ3 are 13.2, and 11.2 µg/m^3 , respectively. The NOx levels recorded were below the stipulated standards (80 µg/m^3) for ecosensitive areas as well as industrial, rural and residential areas as prescribed by CPCB in the year 2009.

Figure 3.16 : Prevailing Ambient Air Quality



3.4.2 Traffic Density

The project site is about 40 km from Geyzing, the district headquarter of West Sikkim district. The nearest village is Yuksam, about 4 km upstream of project site. Yuksam village is approachable through major district road connecting the Geyzing to Yuksam via Pelling and Rimbi. The traffic data was collected on hourly basis for various types of vehicles on the district road near Yuksam Bazar and Lethang Bridge during winter season (February 2010) and pre monsoon season (April 2010). No traffic studies were conducted during the monsoon season. The traffic density as observed on the district road is given in **Figure 3.17** and **Figure 3.18.** The detailed traffic survey is given in **Annexure–IV .** The traffic as observed during the pre monsoon period i.e., in the month of April is high due to peak tourist season compared to the low density of the traffic in the lean season. The LMV accounts to maximum traffic density (both – Yuksam and Lethang) i.e more than 50 % followed by Cars, HMV, 2-Wheelers and cycles.

Photo Plate-6 -Lethang TRT Bridge Road connecting Yuksam

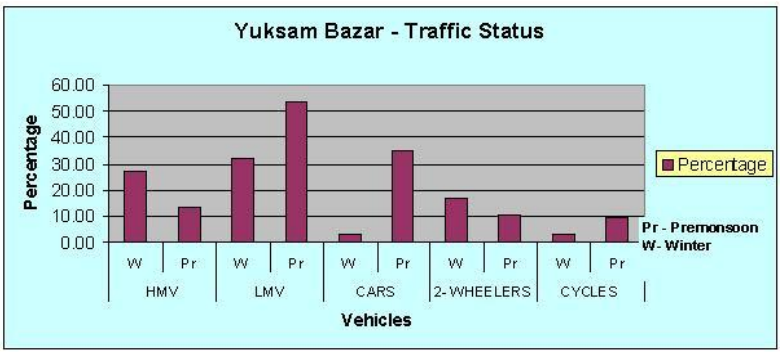


Figure 3.17: Traffic Status of Yuksam Bazar

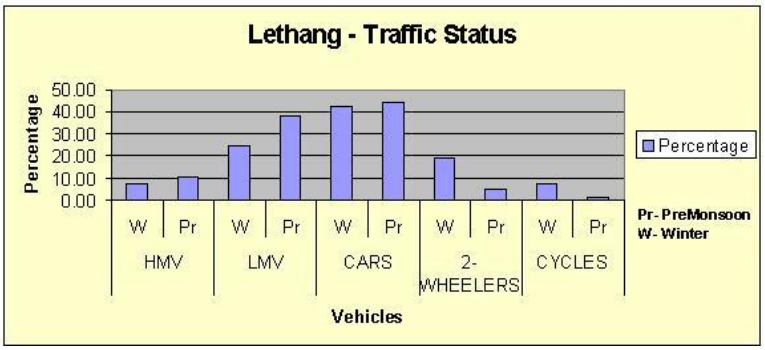


Figure 3.18: Traffic Status of Lethang

3.5 Noise Environment

Noise levels monitoring was conducted for three seasons. The noise levels were monitored continuously for day time for 6 AM to 9 PM at each location and hourly equivalent noise level was measured. The locations selected for the study area are given in **Table 3.11.**The summary results of ambient noise level monitoring during the field survey in monsoon (September 2009), winter (December 2009) and pre-monsoon (April 2010) for the study area are presented in **Tables-3.12** .The noise calculations (Leq.(Day) and Leq (Night)) for three seasons is given in **Annexure-V**.

Table 3.11: Location of the Noise Monitoring Stations

S.No	Name of the Location	Location code	Category
1.	Primary Health Care Centre	N1	Silence /
2.	Yuksam Bazar	N2	Commercial
3.	Dubbdi Monastery	N3	Silence
4.	Yuksam School	N4	Silence
5.	Helipad Point, Yuksam	N5	Residential

Table 3.12: Summary of Ambient Noise Levels

(Monsoon 2009)										
Loc. Code	Station Location	Area Cat.	Day				Night			
			Lmin	Lmax	Leq	Limit	Lmin	Lmax	Leq	Limit
N1	Primary Health Care Center	S	34.4	48.9	41.65	**50**	29.4	33.7	31.55	**40**
N2	Yuksam Bazar	R	39.3	50.9	45.1	**55**	32.1	35.6	33.85	**45**
N3	Dubbdi Monastery	S	38.7	49.9	44.3	**50**	34.3	38.9	36.6	**40**
N4	Yuksam School	S	41.2	44.8	43.0	**50**	35.6	37.5	36.55	**40**
N5	Helipad Point, Yuksam	R	44.9	59.8	52.35	**55**	38.5	43.4	40.95	**45**
(Winter 2009-2010)										
Loc. Code	Station Location	Area Cat.	Day				Night			
			Lmin	Lmax	Leq	Limit	Lmin	Lmax	Leq	Limit
N1	Primary Health Care Center	S	31.8	59.3	45.55	**50**	28.4	40.7	34.55	**40**
N2	Yuksam Bazar	R	45.4	52.7	49.05	**55**	38.6	46.7	42.65	**45**
N3	Dubbdi Monastery	S	29.7	67.7	48.70	**50**	28.3	35.6	31.95	**40**
N4	Yuksam School	S	41.4	45.6	43.50	**50**	31.5	36.2	33.85	**40**
N5	Helipad Point, Colony, Yuksam	R	31.2	72.6	51.90	**55**	32.2	39.6	35.90	**45**

(Pre Monsoon 2010)										
Loc. Code	Station Location	Area Cat.	Day				Night			
			Lmin	Lmax	Leq	Limit	Lmin	Lmax	Leq	Limit
N1	Primary Health Care Center	S	32.7	63.3	48.00	**50**	38.4	41.5	39.95	**40**
N2	Yaksum Bazar	R	42.4	62.7	52.55	**55**	41.5	46.7	44.1	**45**
N3	Dubbdi Monastry	S	39.7	59.9	49.8	**50**	32.3	39.6	35.95	**40**
N4	Yuksam School	S	39.2	58.8	49	**50**	35.8	39.4	37.6	**40**
N5	Helipad Point, Colony,Yuksam	R	41.2	68.6	54.9	**55**	39.2	48.8	44	**45**

Residential Area: The population density in the residential area is very thin. The values of noise level during monsoon season were observed between 45.10-52.35 dB (A) at day time and 33.85-40.95 dB (A) at night time. The values of noise level during winter season were observed between 49.05-51.90 dB (A) at day time and 42.65 - 35.90 dB (A) at night time. During, the Pre – monsoon season the noise values as observed for day time were between 52.55 dB (A) – 54.9 dB (A) and during the night it was 44.0 dB (A). The noise levels in residential areas increases slightly during day time due to commercial activities and vehicular movements. On the other hand the noise levels in the night time are well within the permissible limit.

Sensitive Area: The sensitive zone is the one of the important area in respect to noise. The proposed project area is mostly covered by Mixed Dense Forests. The noise level in various sensitive areas during Monsoon Season were observed between 41.65- 44.30 dB (A) at day time and 31.5 to 36.60 dB (A) at night time. During winter season, the noise equivalent values were observed between 43.55 – 45.55 dB (A) at day time and 33.85 – 39.55 dB (A). During pre monsoon season, the noise equivalent values were observed between 48 – 49.8 dB (A) at day time and 35.95 – 39.95 dB (A). In silence zone the ambient noise levels monitored at day and night times are well within the permissible limit.

3.6 Water Environment

3.6.1 Hydrology

Lethang HEP is run of the river scheme proposed on the Rathang Chu River, one of the major tributaries of river Rangit in West Sikkim. The Rangit basin is one of the most important river basin in Teesta River the state of Sikkim, India. The geographical limits of the basin lie between the latitudes 27° 32″N to 27° 37″N and longitudes 88° 00″E to 88°15″E. The drainage map of the study area is presented in **Figure 3.19.**

River System and its Characteristics

Combination of three tributaries namely, Chokchurang Chu, Prek Chu and Yangsa Chu forms the Rathang Chu river. It meets with Rangit River and after confluence with tributary Kalej Khola, in further downstream of Geyzing flows as Rangit River. The Rangit basin is bounded on the north by Tibetan plateau, on the west by Singalila Range of Nepal and Darjeeling district of West Bengal in the South, and south east is Teesta basin. The highest point in the Rathang Chu catchment is having an elevation of 6780 m.

The Rathang Chu is joined by Rimbi Chu at the downstream of Lethang village and by Relli Chu at Tashiding. The total drainage area of Rathang Chu up to diversion site is 360 sq.Km, whereas its catchment area upto Rangit Stage-III HE Project is 979 sq. km. The total length of the Rathang Chu from the origin up to the proposed barrage site is 28 km. The average slope of the river up to the barrage site is evaluated as 1 in 8 i.e. 135 m/km.

3.6.2 Precipitation Characteristics

The average annual rainfall value of Rangit Catchment is 2414 mm approximated as 2400 mm. There are seven Rain Gauges (RG) whose data is presently available. These RG station are located in Rangit Basin. The key rain gauge stations located very near to project site are Dentam, Yuksam and Geyzing. Dentam is located comparatively at higher altitude as compared to Geyzing. Both of these RG stations are located in the adjoining Kalej Khola Catchment. Dentam is having good rainfall record almost for 20 years. The Rangit Basin is comparatively small i.e., total catchment area is of the order of 2000 square km. All these stations are located in the villages close to the valleys for practicability; no rainfall information is available on the higher parts of the mountainous regions. Based on the rainfall observed at meteorological stations in the area are analyzed and presented below in **Table 3.13:**

Table 3.13: Average Annual Rainfall Data from various RG Stations

S.No.	Rain Gauge Station	Elevation	Avg. Annual Rainfall
1.	Damthang	1981	2640
2.	Yuksam	1780	2540
3.	Geyzing	1524	2100
4.	Dentam	1793	2480
5.	Rangit Dam	677	2400
6.	Rimbi	1480	2310
7.	Pelling	1470	2430

Yuksam village is located very near to the project area, the barrage site is just four kilometers upstream from Yuksam Village. Therefore, the rainfall data collected from this station is used for the prediction of consequences of precipitation on the flow / discharge of the River Rathang Chu. From the above graphical data, it can be inferred that the highest rainfall recorded ever was in the year 2000 with annual rainfall of about 3500 mm & the lowest rainfall recorded was in the year 1973 of about 1200 mm.The intensity of rainfall increased significantly between years 1975 – 1978.Rainfall pattern in Yuksum village over past 12 years is depicted in **Fig. 3.20**.

3.6.3 Inflow at Diversion Site

The 10 - daily flow series for 30 years (1977 – 78 to 2006 – 2007) are finalized for Lethang diversion site. Based on these derived flows, the detailed summary of dependable years based on total annual inflow volume at diversion site is given in **Table 3.14**. The pattern of flows in 90 %, 75 % & 50 % dependable flows are given in **Table 3.15.**

Table 3.14: Flow Detail based on Annual Volume, Lethang Site

Parameter	90 % dependable years	75 % dependable years	50 % dependable years
Year	1987 – 88	1977 – 78	1984 – 85
Minimum Flow	5.22	7.32	9.23
Maximum Flow	72.18	78.51	113.11
Average	24.45	26.50	27.75
Annual Flow	**772**	**839**	**881**

As per the flow duration curve, the slope near 90 % exceedance probability is almost flat which indicates sufficient natural flow in the stream corresponding to the dependability. But the slope of the curve at 50 % exceedance probability is steep, i.e. the corresponding value is somewhat less reliable than that evaluated for 90 % exceedance probability. The flow pattern in 50 %, 75 % & 90 % dependable years are given in **Fig. 3.21.** The flow duration curve based on final 10 – Daily flows is shown in **Fig. 3.22**. The mean discharge based on 10 – daily flow estimated for 30 years at Lethang Diversion site is 24.45 cubic meter per second, which corresponds to an annual specific runoff of 2144 mm.

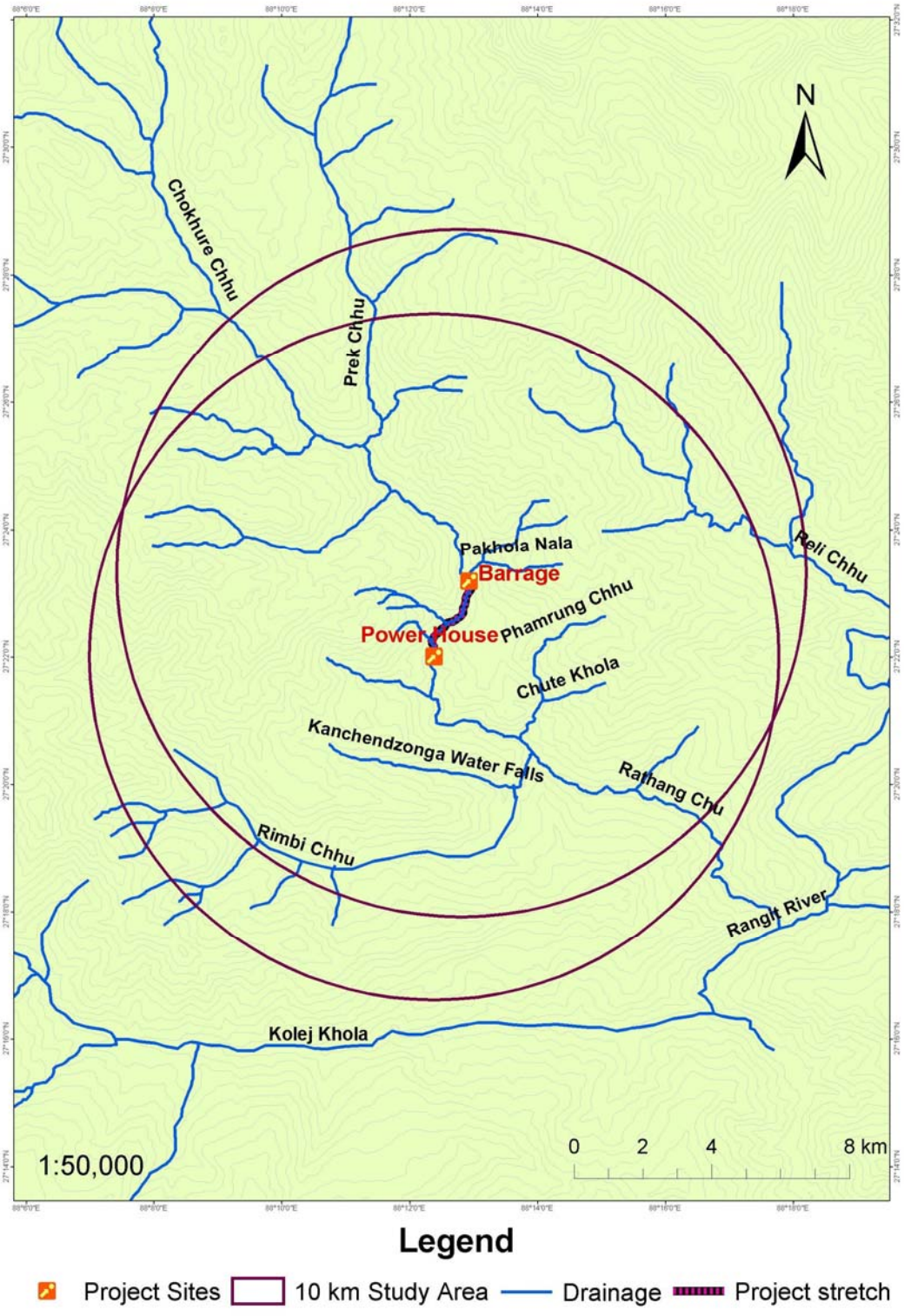


Figure 3.19: Drainage Map of the Study Area

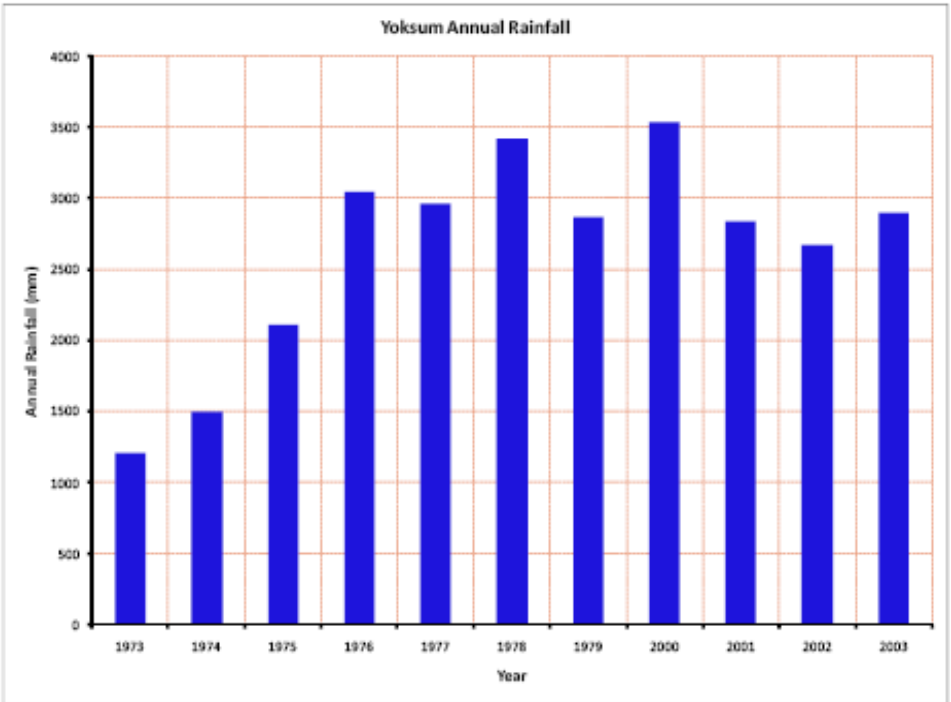


Figure 3.20: The 12 Years Rainfall Pattern in Yuksam village

Table 3.15: Pattern of 50 % 75 % & 90 % dependable year discharge

Month	Period	Pattern of Flow			Compensatory Flow Deducted		
		50 %	75 %	90 %	50 %	75 %	90 %
		2001 – 02	1977-78	1987 – 88	2001 – 02	1977 -78	1987 - 88
Jun	I	53.81	29.31	15.89	52.95	28.45	15.02
	II	51.36	31.84	25.89	50.50	30.98	25.03
	III	56.06	29.71	54.61	55.20	28.85	53.75
July	I	33.44	36.51	63.40	32.58	35.65	62.53
	II	39.82	49.31	50.41	38.56	48.27	49.55
	III	78.19	48.06	47.22	77.33	47.20	46.35
Aug	I	56.36	58.61	69.43	55.50	57.75	68.56
	II	55.10	69.54	72.18	54.24	68.68	71.32
	III	72.05	78.51	41.52	71.19	77.65	40.65
Sept	I	70.00	60.86	67.26	69.14	60.00	66.40
	II	60.38	52.44	41.63	59.52	51.58	40.77
	III	40.90	78.51	47.25	40.04	77.65	46.39
Oct	I	69.50	52.03	30.85	68.64	51.17	29.99
	II	44.26	27.54	18.06	43.39	26.68	17.19
	III	28.42	23.50	14.01	27.56	22.64	13.15
Nov	I	18.15	21.84	12.58	17.29	20.98	11.72
	II	14.33	15.08	9.93	13.47	14.22	9.07
	III	12.30	12.21	9.82	11.44	11.35	8.96
Dec	I	10.90	11.11	9.63	10.04	10.24	8.77
	II	9.62	9.52	9.52	8.75	8.66	8.66
	III	8.46	9.05	8.38	7.60	8.19	7.52

Month	Period	Pattern of Flow			Compensatory Flow Deducted		
		50 %	75 %	90 %	50 %	75 %	90 %
		2001 – 02	1977-78	1987 – 88	2001 – 02	1977 -78	1987 - 88
Jan	I	7.58	8.75	8.02	6.72	7.89	7.16
	II	7.95	7.54	8.09	7.09	6.68	7.23
	III	7.11	7.54	8.05	6.25	6.68	7.19
Feb	I	6.17	7.32	7.43	5.31	6.46	6.57
	II	5.70	8.02	7.34	4.84	7.16	6.48
	III	5.67	7.58	7.13	4.81	6.71	6.27
Mar	I	6.19	7.76	5.22	5.33	6.90	4.36
	II	6.60	7.61	12.06	5.74	6.75	11.20
	III	7.41	7.76	12.43	6.55	6.90	11.57
Apr	I	11.19	7.87	12.43	10.33	7.01	11.57
	II	11.27	11.14	12.17	10.41	10.28	11.31
	III	13.11	12.21	13.02	12.25	11.35	12.16
May	I	14.79	11.99	14.49	13.93	11.13	13.63
	II	16.89	17.06	16.00	16.03	16.20	15.13
	III	10.99	19.08	16.84	10.13	18.22	15.98
Annual Inflow ($10^6 m^3$)		**900.4**	**833.2**	**772.1**	**873.3**	**806.8**	**744.9**
Average Annual Discharge (m^3/sec)		**28.39**	**26.50**	**24.45**	**27.53**	**25.64**	**23.59**

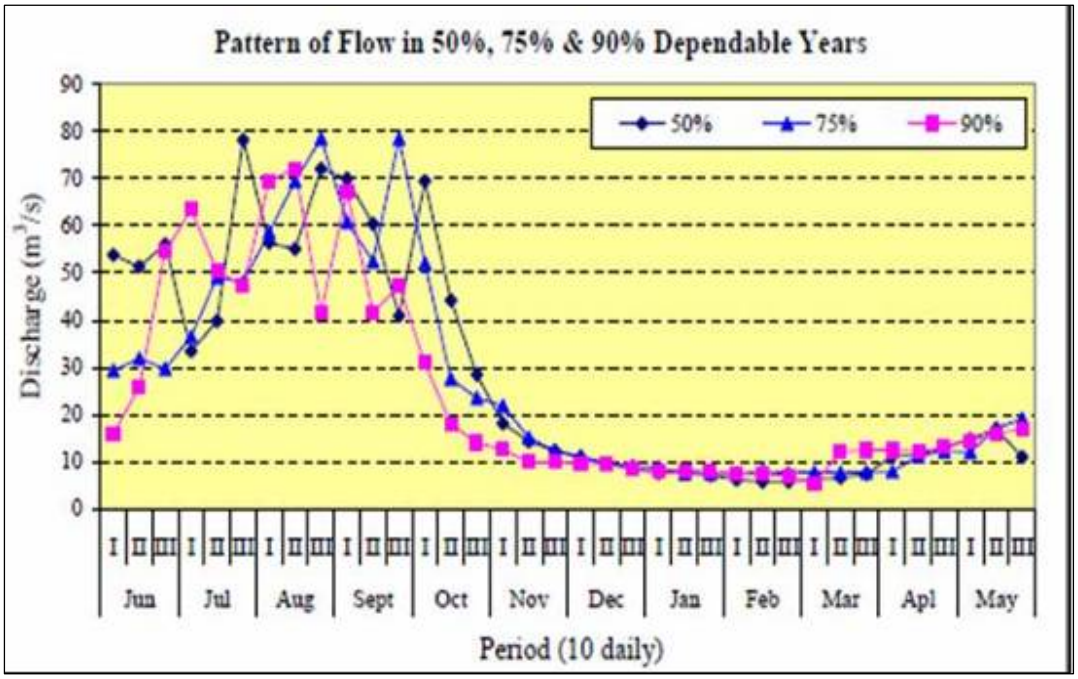


Fig 3.21: Pattern of flow in 50%, 75 % & 90 % Dependable Years

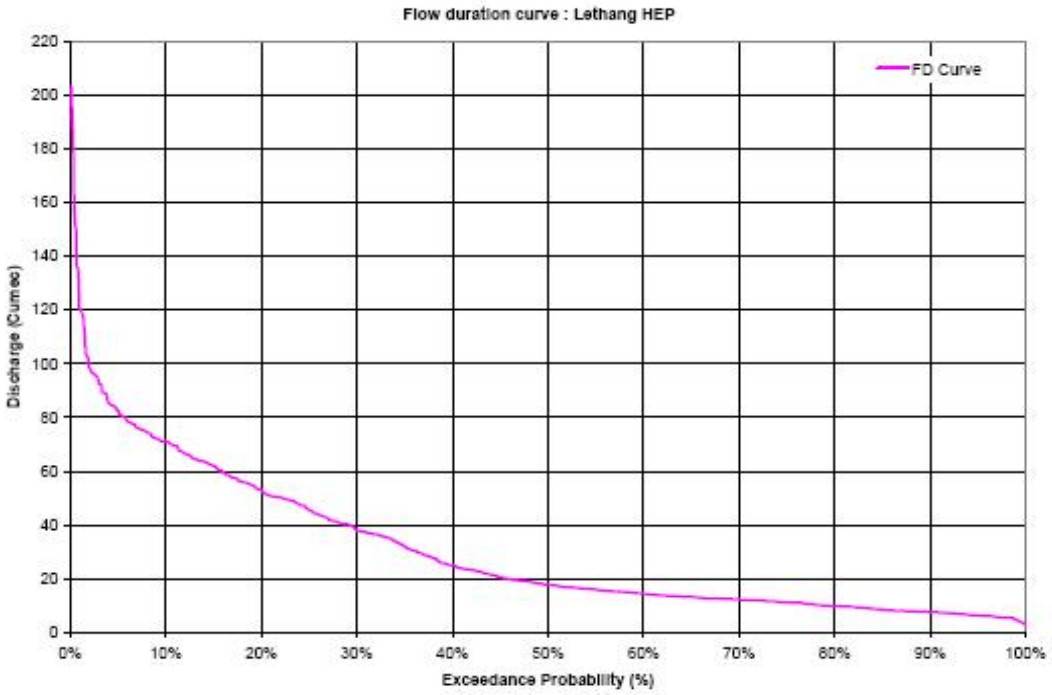


Fig 3.22: Flow duration curve based on final – 10 Daily Flows

3.6.3.1 Hydro Meteorology Approach

This method is used for estimation of design flood for intermediate and large dams, especially when storage has significance effect in modifying the design flood hydrograph as it flows through reservoir. This method gives a realistic picture of its moderating effect while passing through a reservoir or a river reach.

The unit hydrograph is plotted and tabulated below in **Table 3.16**. The run off volume is computed and the ordinates of the unit hydrograph were adjusted to give a run off depth of 1.0 cm over the catchment. The figure of unit hydrograph for Lethang diversion site is shown in **Figure 3.23**

Table 3.16 Unit Hydrograph Ordinates

Time (Hr)	Discharge
0.0	0
1.0	50
2.0	375
3.0	126
4.0	20
5.0	5
6.0	3
7.0	0

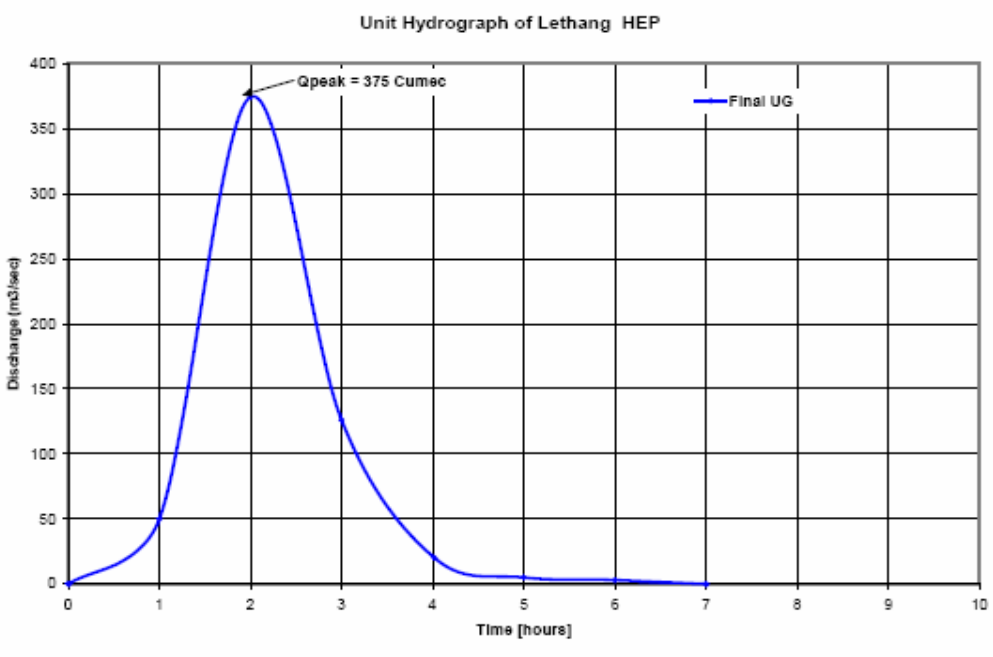


Fig 3.23: Unit Hydrograph, Lethang Diversion Site

3.6.4 Flood Hydrograph

The flood hydrograph is obtained by adding a uniform base flow of 10.4 m^3/s and snowmelt contribution of 26m^3/s to the ordinates of the surface flow hydrograph. The Standard Project Flood (SPF) comes out to be 2420 m^3/s. The details of SPF ordinates are given in **Table 3.17**

Table 3.17: Details of SPF Ordinates

Time (hr)	SPF Ordinate (m^3/sec)	Time (hr)	SPF Ordinate (m^3/sec)
0	36	13	350
1	111	14	506
2	683	15	659
3	970	16	480
4	1150	17	238
5	1384	18	88
6	1914	19	48
7	2423	20	40
8	1830	21	37
9	1013	22	0
10	415	-	-
11	280	-	-
12	292	-	-

3.6.4.1 Flood Recurrence Interval

The surface flow hydrograph peak is computed by convoluting one – hour rainfall excess increments with the ordinates of the one – hour unit hydrograph. For this purpose, the rainfall excess increments are arranged in a critical sequence. The flood hydrograph peak is obtained by adding a uniform base flow of 10.4m³/s and snow melt contribution of 18.99m³/s and 20.19 m³/s to the ordinate of the surface flow hydrographs. The flood hydrograph peaks corresponding to 50 year and 100 year return periods are 1693 m³/s and 1844 m³/s.

3.6.4.2 Frequency Analysis

Different Return Period Floods, Lethang diversion site are tabulated in **Table 3.18**

Table 3.18: Different Years Flood Return Period

SNo.	Return Period (Year)	Log Normal (m³/s)	Gumbel (m³/s)
1.	25	653	654
2.	50	725	728
3.	100	797	801
4.	500	965	971
5.	10000	1292	1286

3.6.4.3 Frequency Analysis Comparison of Frequency Analysis and Hydro–Meteorology Approach

Finally, the design flood by both the approaches i.e frequency as well as hydro meteorological is estimated. The following final values at diversion site are proposed for planning purpose is tabulated below in **Table 3.19**.

Table 3.19: Final Flood Values, Diversion Site

SNo	Return Flood Period (Year)	Frequency Approach, Flood Peak (m³/s)	Hydro – Meteorological Approach		
			Flood Peak (m³/s)	SPF (m³/s)	PMF (m³/s)
1	25	654	-	2798	3082
2	50	728	1693		
3	100	801	1844		
4	500	971	-		
5	10,000	1286	-		

The flood peak value corresponding to 100 year return period is 1844 (m³/s) and SPF of 2798 (m³/s) are being used for planning purpose.

3.6.4.4 Design Flood for River Diversion Work

The non monsoon season for this project is taken from October to May which can be used for construction activities at project site. To estimate the flood discharges in the dry season at diversion site, the non monsoon discharges at Nayabazar, Manjhitar, Reshi, and Raothok are being used on the basis of a probabilistic approach and than transposed to the diversion site giving due weightage to catchment area ratio only.The catchment area ratio for diversion site is 0.27; which is used for transposition of flow peaks estimated by frequency analysis at the diversion site. The criteria value of 89 m^3/s is the diversion flood value. Thus 100 m^3/s is adopted as non monsoon flood for river diversion works.

3.6.4.5 Sedimentation

The sedimentation of the storage reservoir, with small reservoir volume will be rapidly filled with sediment and provision must be made to flush the sediment and ensure the intakes are well clear of the sediment in the dam. In order to carry out sedimentation, a project specific silt measurement is a very important part of project planning. The impact of suspended silt on the design life of the turbines, particle size analysis of silt load and studies for control of entry of particle size larger than a certain size are important from the point of view of turbine maintenance. It is proposed to exclude silt particles of a size of 0.20 mm and above from water before it enters the power house. Since the project is run of river scheme having storage requirements only to meet diurnal variation, there is less scope for sedimentation/ siltation, as it will be required in case of a storage type water resource project.

In order to have some idea about daily silt concentration, the daily silt data available for the site Sanklang on river Teesta for the period Jan 1999 to May 2005 is being analyzed. The available silt data is analyzed for different concentrations and is presented in **Table 3.20**. It is obvious that each year the silt concentration exceeds 2000 ppm. Even the frequency can be higher than these numbers. Because these silt observations are taken at fixed time once a day. There is a very high probability that high floods have occurred during night times as well as during other times of the day. Therefore the figures are only indicative.

However, it can be said that for the majority of the time the concentration is between 150 to 500 ppm. This information is very useful for the planning of the present hydroelectric project. Yet, the information is very limited, considering that it covers only 6 (six) years of silt data.

The detail hydrological studies will be carried at all stages of project development starting from the design stage (pre-feasibility stage) and are continued even till the operation of the project.

Table 3.20: Available Silt Data

Year	No of Days (Silt Concentration Range)		
	> 150 ppm & < 500 ppm	> 500 ppm & < 1000 ppm	> 2000 ppm
1999	63	63	1
2000	93	28	11
2001	88	35	3
2002	78	28	2
2003	65	11	1
2004	60	22	3

3.7 Water Environment

3.7.1 Surface Water bodies

The area is mainly drained by the Rathang Chu river and its tributary streams. The water environment of the study area comprises of Rathang-Chu River, which is formed by confluence of three main rivulets namely, Prek Chu, Chokhure Chu and Yangsap Chu. The Rathang Chu River traverses the study area from North (from middle part) to South-East and drains in Rangit River at further south between Tashiding and Legship town. Another important stream is Rimbi-chu, which flows through the southern part of the area from west to east and meet with Rathang-chu near chumbong. Some of the springs and small streams existing in the study area are Pau Khola Nallah, Chute Khola, Rimbi Khola, Phamrung Chu and Kanchendzonga water falls. The other water bodies existing in the study area are Khecheopalri Lake and Kathog-Bla-TshoLake.

3.7.2 Water Quality Monitoring

To know the existing status of Rathang Chu River, seasonal samples were collected to determine its physico-chemical status. The sampling was conducted for winter, pre-monsoon and monsoon seasons. No source of groundwater was present in the study area. However, samples from drinking water sources, which are mainly natural spring water channelised through pipeline for domestic use under the Water Supply Scheme of Rural Management and Development Department, were collected from outlet point. The locations of monitoring stations are given in **Table 3.21.** The locations of drinking water samples are given in **Table 3.22.**

Table 3.21: Surface Water Quality Monitoring Locations

S.No.	Location Code	Location of Sampling Sites
1	SW1	1 km downstream of Lethang Bridge
2	SW2	½ km downstream Lethang Bridge
3	SW3	17 Miles Lethang Bridge
4	SW4	100 m Upstream of Barrage
5	SW5	500 m Upstream of Barrage

Table 3.22: Drinking Water Sampling Locations

S.No.	Location Code	Source of Drinking Water	Location of Sampling Sites
1	DW1	RMDD Supply Tank, Khyongtey	Yuksam Village
2	DW2	RMDD	Ramgaythrong Village
3	DW3	RMDD	Lethang Village

3.7.2.1 Surface Water Quality

The Surface Water Quality Results of River Rathang Chu for three different seasons are given in **Table 3.23.** The parameters that were analysed are – pH, Dissolved Oxygen, Color, Chloride, Total Dissolved Solids (TDS), Calcium and Magnesium Salts, Total Hardness, Alkalinity, Nitrate and Potassium. The river is the fastest flowing devoid of any industrial pollutants and chemicals, the dissolved oxygen concentration was found very high (ranging between 18.0 mg/l – 21.0 mg/l), which is more than sufficient for the sustenance of aquatic life including fish species found in fast flowing Himalayan streams. The pH varies along the river from barrage site to power house site (6.5 – 8.0). A large number of inorganic salts and small amount of organic matter (constituting the Total Dissolved Solids) were recorded. Level of these constituents were found high during monsoon seasons as compared with other seasons; the inorganic salts were added to the stream flow due to weathering of rocks and organic matter due to runoff flow in rainy seasons. Similarly, the alkalinity was observed high during monsoon season and winter season. The fluctuation in alkalinity depends upon nature of bottom deposits, rainfall in the region and autotrophy of water. The alkalinity in Rathang Chu River recorded maximum upto 140 mg/l during monsoon seasons, which is beneficial for higher productivity of aquatic life.

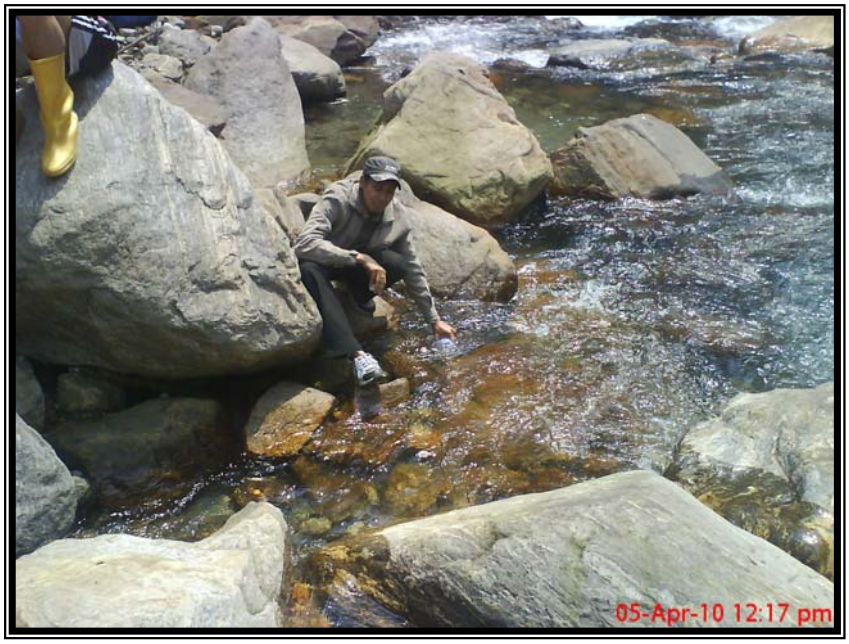


Photo Plate-7 Surface Water Sampling

Table 3.23: Surface Water Quality Results

S.No.	Parameters	SW1			SW2			SW3			SW4			SW5		
Seasons		P	M	W	P	M	W	P	M	W	P	M	W	P	M	W
1.	pH	7.21	7.12	6.83	7.13	7.06	6.91	7.21	7.13	6.89	7.13	7.07	7.13	8.3	7.09	6.85
2.	Dissolved Oxygen (Mg/l)	21.31	20.86	18.90	21.10	18.35	20.93	21.10	18.20	20.60	20.73	19.85	20.62	22.12	20.35	20.65
3.	Color (Hazen)	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
4.	TDS	98.0	448	5.83	92.0	432.0	4.86	98.0	426.0	4.97	58.0	436	1.94	110.0	441.0	1.46
5.	Calcium	10.4	49.7	37.7	6.41	44.89	24.89	10.4	45.09	0.15	6.41	42.0	0.048	16.03	43.01	33.65
6.	Magnesium	4.86	16.04	86.0	1.94	17.98	82.0	4.86	18.23	84.0	1.94	17.2	56.0	5.35	18.06	60.0
7.	Total Hardness	46.0	190.0	46.0	48.0	186.0	48.0	46.0	187.5	39.0	24.0	192	33.0	62.0	189.0	36.0
8.	Alkalinity	22.5	142.0	102	18.0	138.0	121	22.5	136.0	124	18.0	135	115	36.0	139.0	122
9.	Nitrate	2.8	1.28	1.41	2.1	1.31	1.20	2.8	1.26	1.39	2.1	1.20	0.97	3.3	1.16	1.15
10.	Potassium	8.7	11.12	8.39	7.2	12.68	6.89	8.7	14.61	6.15	4.8	13.3	4.81	12.9	12.91	4.90
11.	Chloride	13.7	29.78	5.93	10.2	30.77	5.96	13.7	32.76	7.94	10.2	21.2	8.68	35.6	23.45	9.93

3.7.2.2 Drinking Water Quality

Table 3.24 and Table 3.25 delineate analytical results of drinking water samples collected from the study area. It was observed that all the physico-chemical parameters were well within the desirable limit and acceptable for drinking as per IS: 10500 standards. Hardness was low, which means water was favorable for drinking and cooking. The other parameter like Total Dissolved Solids (TDS), cations like Iron (Fe_3^+), Lead (Pb_2^+) and anions like Sulphate (SO_4^-), Chloride (Cl^-) etc. were well within the desirable limit. However, total coliform count (MPN/100ml) found more than the recommended limit, which indicates all sources had bacteriological contaminations. **Photo Plate 8** and **Photo Plate 9** drinking water taps for Khyongtey and Lethang Village.

Table 3.24: Bacteriological Quality of Drinking Water as per IS 10500: 1991

Parameters	DW1			DW2			DW3			IS 10500 Norms	
	M	PM	W	M	PM	W	M	PM	W	Desirable Limit	Permissible Limit
Total Coliform (MPN/100ml	80	70	40	90	80	30	80	60	30	≤ 10 organism/100ml	
Fecal Coliform (MPN/100ml	0	0	0	0	0	0	0	0		0	--

Photo Plate 8- Drinking Water Tap at Khyongtey Village

Photo Plate 9- Drinking Water Tap at Lethang Village

Table 3.25: Analytical Results of Drinking Water Samples: Physico-chemical Parameters (as per IS 10500: 1991 Standards)

Parameters	DW1			DW2			DW3			IS 10500 Norms	
	M	PM	W	M	PM	W	M	PM	W	Desirable Limit	Permissible Limit
pH	6.8	7.2	7.4	6.9	6.8	7.3	7.3	6.9	7.3	6.5 - 8.5	No Relaxation
Taste	-	-	-	-	-	-	-	-	-	--	--
Colour (Hazen Units), Max.	2.0	1.0	<1.0	2.0	<1.0	<1.0	2.0	1.0	<1.0	5	25
Temperature°C	12.3	11	7	13.1	11.6	7.8	13.2	12	8		
Turbidity, NTU, Max	4.1	2.6	3	3.9	3.1	3.7	3.8	2.9	4.0	5	10
Phosphate PO_4^{3-} mg/l	0.2	0.4	0.16	0.2	0.31	.17	0.22	0.35	0.19	-	-
Total Hardness($CaCO_3$,mg/l)	40.2	28.3	37	42	27.1	38	43	29	36	300	600
Iron, as Fe(mg/l)	0.52	0.41	0.22	0.5	0.46	0.2	0.59	0.49	0.23	0.3	1.0
Chlorides Cl(mg/l)	19	10.3	8.2	21.1	18.3	14.5	38.2	34.0	19.3	250	1000
Residual Chlorine, mg/l	0.09	0.16	0.15	0.1	0.18	0.16	0.09	0.17	0.17	0.2	--
Mercury (as Hg)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.001	No Relaxation
Calcium, Ca(mg/l)	15.2	6.25	8.1	15.7	6.55	7.8	16.1	5.93	8.2	75	200
Magnesium Mg(mg/l)	5.7	2.43	3.01	5.5	3.04	3.13	5.6	2.92	3.21	30	100

Parameters	DW1			DW2			DW3			IS 10500 Norms	
	M	PM	W	M	PM	W	M	PM	W	Desirable Limit	Permissible Limit
Sulphates SO_4(mg/l)	3.9	3.6	3.4	4.0	3.8	3.6	4.2	4.0	3.9	200	400
Nitrateas NO_3(mg/l)	0.9	0.6	0.34	0.92	0.51	0.39	0.88	0.58	0.37	45	100
Fluoride,mg/l	0.14	0.09	0.05	0.15	0.1	0.03	0.12	0.07	0.04	1.0	1.5
Alkalinity (mg/l)	26	28	40	27	29	38	28	31	42	200	600
Sodium mg/l	5.33	8.5	6.8	5.32	9.1	7.1	5.41	8.2	6.2	-	-
Potassium mg/l	1.96	1.58	1.98	1.98	1.79	1.95	1.85	1.65	1.94	-	-
Phenolic Compounds	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.001	0.002
Lead as Pb(mg/l)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.05	No Relaxation
TDS(mg/l)	86	46	74	84	51	70	88	49	78	-	-
TSS(mg/l)	7.3	8.5	6.8	7.4	7.9	6.5	7.2	7.6	6.7	-	-
BOD 5day at 20°C	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	-	-
DO(mg/l)	5.5	4.9	5.8	5.7	5.1	6.1	5.9	5.3	6.3	-	-

3.8 Biotic Environment

3.8.1 Terrestrial Ecology

3.8.1.1 Flora :

General Setting

The landscape is entirely hilly with mostly steep slopes. The area is drained by the Rathang Chu river and its tributary streams. Approximately 55% of the area is covered by the forests (**Photo Plate 10)**. The study area consists core zone of Kanchendzonga National Park (KNP)/Biosphere reserve in north part of the buffer zone IV in North-East corner and west and south-west part **(Fig 3.24).** Rest of the area falls under Geyzing and Pelling blocks of Geyzing Range and Yuksum and Khecheopalri blocks of Yuksam range and part of the Tashiding range of West Territorial Division of Forests in West Sikkim. Study area encompasses diverse terrain.

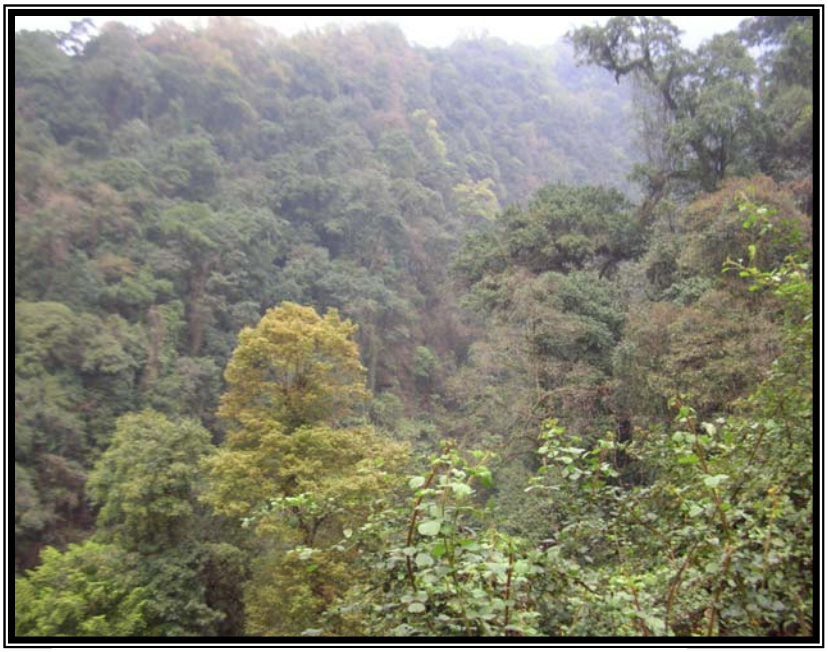


Photo Plate 10 : Forests Cover

The ridges are mostly running from West to East direction and most of the rivulets and streams flow from West to East, except Pau Khola and its associated nallas, which flows from East to West to drain in Rathang-Chu. The diversion site (the most upstream component the project on Rathang Chu river) is approximately 300 m. from the Pau Khola nallah **(**Photo Plate 11), which is the border line of 'V' shaped southern (SSE) tip of KNP core area. Approximately about 1.5 km. stretch of Rathang Chu River is making the boundary with the western part of KBR buffer zone-IV. Rest of the project stretch run through the West Territory Forests Division.

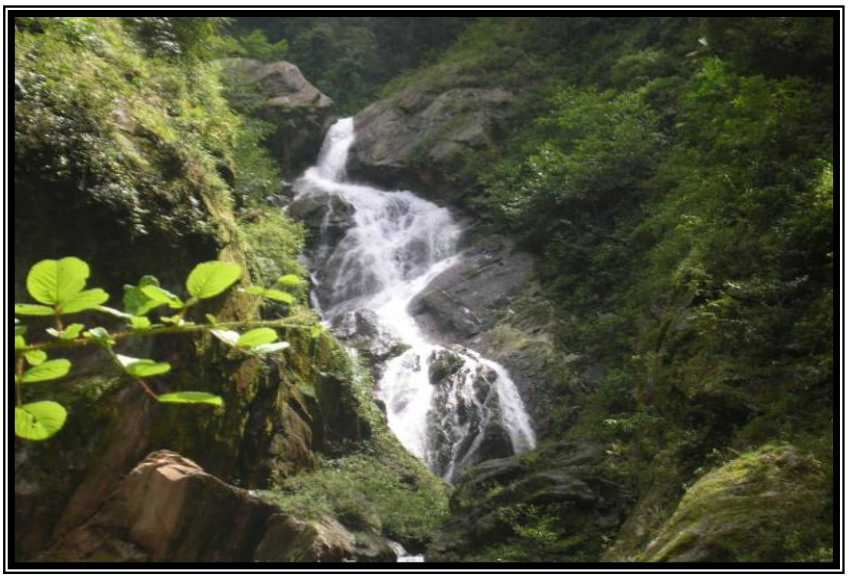


Photo Plate 11: **View from Pau Khola Bridge**

Rathang Chu traverses the study area from North (from middle part) to South-East and drains to Rangit River at further south near Legship. The other important stream the Rimbi-chu flows through the southern part of the area from west to east and meet with Rathang-Chu near Chumbong. The altitude in the part of KNP core Zone varies from 2100 m (at the boundary of the river and rivulets) to 4500m at the peak of the ridge (NNE corner), 2550 m. to 3300 m. in the eastern part of the buffer zone IV and as lowest as 2550 m. to highest 4050 m. towards west. Altitude of the rest of the part of study area, which falls under West Territorial division, varies from as low as 743 m. to as high as 4050 m. The study area (10 km radii) surrounding the Rathang-Chu River was divided into different influence Zone **(Figure 3.24)** on the basis of four divisions, described as below in **Table 3.26**:

Table 3.26: Description of Different Influence Zones in Survey Area

Zone	Description of the Survey Area
A	Central part of the study area towards north, which falls in KNP core Zone
B	The North - East part of study area, which falls in KNP buffer zone IV.
C	Part of the West Territorial Division of West Sikkim Geyzing (forests block Geyzing and Pelling), Yuksum (Yuksum and Khecheopalri forests block) and Tashiding forests ranges
D	North West to South-South –West of study area, which falls in KNP buffer zone IV.

Vegetation Cover

The part of study area (Zone A, part of the KNP core Zone) is having dense forests of mixed vegetation **(photo plate 12 and 13)**. This patch of forests harbor mixed vegetation of coniferous and broad leaf species of trees. Type of vegetation varies depending on the altitude. The altitude varies from 2100 m to 3100 m. Height increases towards North-East direction. The forests here can be categorized as 'East Himalayan Mixed Temperate Forests'. The canopy is formed both by Coniferous and broad leaf trees. Coniferous species like *Larix griffithii, Cupressus corneyana, Abies spectabillis, Tsuga dumosa, Taxus wallichinana* and broad leaf trees such as Acer campbellii, Exbucklandia populnea, Alnus nepalensis, Betula utilis, Malus sikkimensis, Lithocarpus pachyphylla, Engelhardtia spicata, Quercus spp., Enkianthus deflexus, Pieris formosa, Lyonia ovalifolia, Rhododendron grande, Magnolia campbellii* are major constitutes of the upper story of forests cover at the altitude of 2000 m. to 3500 m. Exotic coniferous species i.e., Cryptomeria sp. is also present here.

Photo Plate 12 – Dense Mixed Forests of KNP (KNP Core)

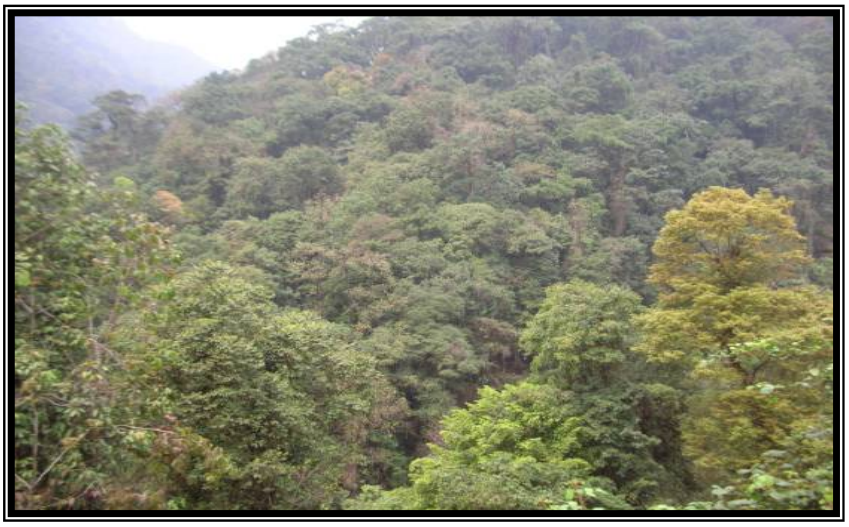


Photo Plate 13 – Dense Mixed Forests (KNP Buffer Zone)

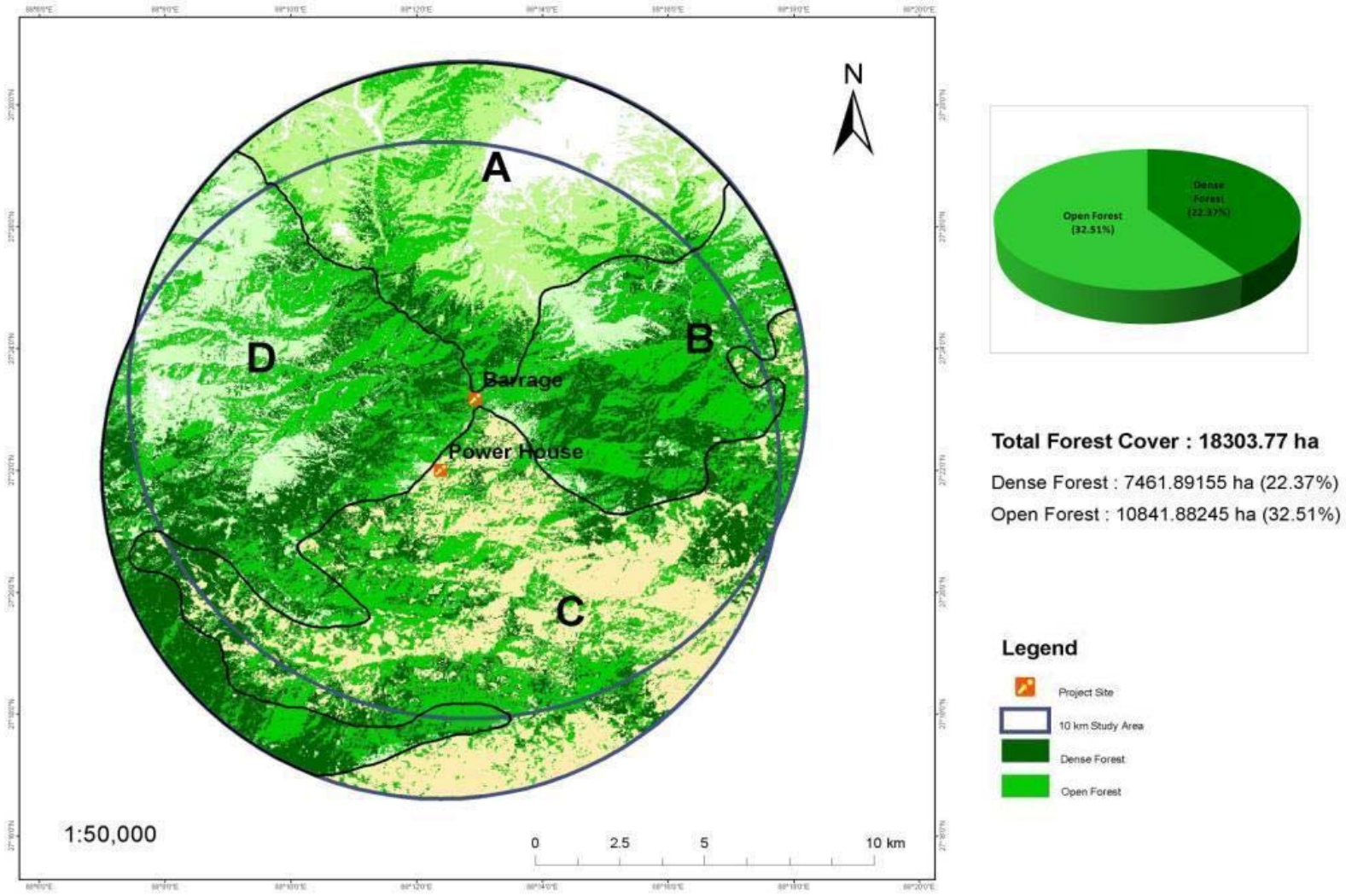


Figure 3.24: Zone wise Forest Coverage

Under story is also dense and diverse, consists both shrubs and herbs. Major shrubby vegetation is *Berberis aristata, Berberis insignis, Buddleha colvilei, Gaultheria spp, Hypericum hookerianum, Philadelphus tomentosus, Mahonia nepaulenes, and Sambucus adnata* etc.

The ground covers are also rich in diversity. Dominated herbaceous species are *Aconogonum molle, Bistorta vaccinifolia, Koenigia nepalensis, Euphorbia sikkimensis, Pilea anisophylla, Gaultheria trichophylla, Agapetes incurvata, Panax pseudo-ginseng, Rubus fragaroides, Arisaema nepenthoides, A. griffithii, A. jacquemontii, A. propinquum, Hedychium spp. Silacina oleracea, Roscoea purpurea* etc.

Species like *Impetiens bicolor, I. ongipes, I. spirifer, I. sulacata, and Begonia flaviflora, B. josephii* mainly found along the banks of rivers, streams and nallas. Presence of various creepers is also prominent. Common creepers grow here are *Ceropegia pubescens, Aristolochia griffithii, Clematis montana, C.acuminata, C. buchananiana, Dicentra scandens, Holboellia latifolia etc.*

Insectivorus plants, *Drosera peltata, Utricularia brachiata, U. wallichiana, U. multicaulis* **(Photo plate 14 and 15)** also grow with the under growth in moist sheddy part of this forests .

Photo Plate 14 –Grass Cover on Rock

Photo Plate 15- Insectivorous Plant

NW corner of the Zone-A, where altitude is above 4350 m no tree was found, only dense clumps of bushy vegetation intermingled with pastures lands are seen.

Predominated species are *Rheum acuminatum, Rheum nobile, Primula capitata. P. oblique, P. minutissima, P. sikkimensis, Rhododendron ciliatum, R. anthopogon, R. lepidotum, Cassiope fastigiata, Parnassia nubicola, Rhodiola himalensis, R. imbricate, Corydalis juncea, Nardostachys grandiflora, Saussurea gossypiphora, Meconopsis paniculata, Potentilla coriandrifolia, P. penduncularis, Caltha palustris, Cypripedium himalaicum, Pododphyllum hexandrum* and species of *Aconitum bryocarpum, Cassiope corydalis, Gentiana gentiana, Saxifraga sedum* etc. In this part of forests *Juniperus sp*. (Gymnosperms) is also present.

Common species found here are *Juniperous recurva* and *J.squamata*.

The North East (Zone B) and North West to South-South –West (Zone D) part comes under buffer zone-IV of Kanchendzonga National Park, where altitude varies from 2500 to 3450 m, which gradually goes down to 1800 m. towards Rathang Chu bank in the East (right bank of river, nearest point of project component) is Power house and its down stream stretch up to river Rimbi, which forms the south boundary of KNP Buffer IV as well as (Zone D). The altitude rises up to 4050 m. at the central part of west boundary of Zone D.

Forests of 2500 m. to 3400 m. of both Zone-B and Zone-C having similar kind of vegetation cover. Except the south and south-east boundary of Zone -D, having lower altitude (1800 m) covered with mixed type of forests. The forests of this part may be categorized as 'East Himalayan Wet Hill Forests'.

Crown canopy comprises tree species like *Macaranga denticulate, Alnus nepalensis, Castanopsis tribuloides, C. indica, Rhododendron arboretum, Alangium chinese, Maesa chisis, Malus sikkimensis, Ficus semicordata, Toricellia tiliifolia, Schima wallichii, Sauruia nepalensis, Betula cylindro stachys, Lithocarpus and Quersuc sp. etc.*

Under growth mainly contributed by shrubby species like *Dichroa febrifuga, Oxysprora paniculata, Melastoma malabathricum, Buddleja asiatica, Edgeworthia gardneri, Rubus ellipticus, Mussaenda roxburghii etc.*

Ground cover is diverse and dense comprising of *Persicaria capitata, Houttuynia cordata, Gnaphalium affine, Eupatorium odoratum, Gynura pseudo-china, Ranunculus diffusus, Notochaete hamosa, Drymaria villosa, Sagina japonica, Elatastema lineolatum, Plantago erosa, Crassocephalum crepidioides, Hydrocotyle asiatica, Achyranthes bidentata, Oxalis corniculata, Oxalis griffithii, Galinsoga parviflora, Bidens pilosa* etc.

Commonly found creepers are *Peper, Smilax, Tetrastigma, Rhaphidophora* etc.

The rest of the part of study area designated as Zone-C, comes under the Geyzing (includes forests block Geyzing and Pelling), Yuksam (includes Yuksam and Khecheopalri forests block) and Tashiding forests ranges of West Territorial Division of West Sikkim.

The Rathang Chu traverses the Zone-C from north-west to south-east direction and Rimbi Chu flows from West to East to meet Rathang-Chu. These two rivers form the main physio-graphic feature of this zone. The altitude along the river banks of both the rivers varies from 750 m. to 1650 m. Where it ranges between 1640 m. to 2240 m. In rest of the part of Zone-C, except the middle portion (which gradually merges with the left lower part of KNP buffer zone IV) and south –south west corner of Zone-C, where altitude varies from 2240 m. to 2850 m.

Hills at the height of 1000 m to 1500 m. is covered by the dense jungle of mixed vegetation , key species are *Castanopsis tribuloides, Castanopsis hystrix, Castanopsis indicia, Betula cylindrostachys, Engelhardtia spicata, Bucklandia populnea, Alnus epilepsies, Machilus spp., Juglans regia, Sapindus detergens, Terminalia bellerica, Albezzia procera, S. wallichiana, Phoeba sp., Cinnamomum spp., Cedrela toona, Ostoides panniculata etc..*

Middle storey consist species like *Ostoides paniculatus, Symplocos sp., Macaranga indica, M. pustulata, Eurya japonica, Meliesma thomsonii, Boehmeria rugulosa, Ficus cunia, Grewelia nudiflora, Dendrocalamus Sikkimensis.*

Herbaceous plants and creepers make dense ground cover, which is rich in diversity. Major species of this height are *Artemisia vulgaris, Dichorrea febrifuga, Strobilanthes coloratus, Girardiana heterophylla, Eupatorium odoratum, Polygonum molle etc.*

Near the streams and rivers where altitude is lower (avg. 750m) found Sal dominated mixed forests. Key stone species is *Shorea robusta.* The major associate species found here are *Terminalia tomentosa, Mallotus philippensis, Bombax malabarica, Albezzia procera, Ailanthus grandis, and Duabang sonneratioides.*

Prominent middle story formed by *Terminalia chebula, Terminalia Bellerica, Dendrocalamus hemiltonii, Pinus roxburghii.*

Like other Sal dominated forests the under growth is very dense and diverse, constituted by species like *Wrightia-tomentosa, Dichorrea, Clerodendron serratum, Piper spp., Mucuna spp, Fabrifuga, Bauhinia vahlii, Buddleia spp., Parthenocissus himaliana, smilex moringe etc.*

The higher altitude above 2000 m is also having dense mixed jungle similar to the rest of the part of study area that falls under KNP, intermingled with clear patches where terrace cultivation take place. The tree varieties are mixed type coniferous and broad leaf. Dominant species are *Abies, Larix, Juglans, Lyonia, Pyrus, Prunus, Rhododendron, Alnus, Cryptomeria, Engelhardtia and Quercus.* The under storey is also very dense at many places. The shrubs observed in the area are *Dichroa febrifuga, Edgeworthia gardeneri, Aconogonum molle, Bistorta vaccinifolia, Koenigia nepalensis, Euphorbia sikkimensis, Pilea anisophylla, Gaultheria trichophylla, Agapetes incurvat etc.*

Bryophytic and Pteridophytic plants, as well as both, epiphytic and parasitic, angiosperms were observed growing on trunks and branches of old-wood trees. *Equisetum* sp., an aquatic pteridophyte, was also observed in a pool of water along the Pau Khola stream. Crustose and foliose lichens were seen on rocks, tree-trunks and fallen wood.
Some of the coomon flowering species found in the study are shown in (**Photo 16 to 20**).

Photo Plate 16 - Rhododendron Spp.

Photo Plate 17 – Koirala *(Bauhinia variegate Linn.)*

Photo Plate 19 - Allium Wallichiana

Medicinal Plants

Some of the medicinal plants associated with the study area are: -
Aconitum heterophyllum, Angelica sikkimensis, Artemisia nilagirica, Aloe vera, Amomum subulatum, Aristolochia sp., Asparagus racemosa, Bassia butyracea, Bergenia ciliata, Betula utilis, Buddleia asiatica, Camellia sinensis, Cannabis sativa, Centella asiatica, Cissampelos pareira, Curcuma longa, Dioscorea bulbifera, Gloriosa superba, Hedychium spicatum, Kaempfera rotunda, Nardostachys grandiflora, Nasturtium officinale, Ocimum sanctum, Piper longum, Rhododendron arboreum, Rumex nepalensis, Viscum articulatum. Zone wise detailed list of plants present in the study area are delineated below in **Table3.27**.

Table 3.27: List of Plant Species (Zone Wise)

Zone A (Part of Kanchendzonga National Park Core Zone)			
Altitude above 4350 m (Bushy ground cover)			
Rheum acuminatum, Rheum nobile, Primula capitata. P. oblique, P. minutissima, P. sikkimensis, Rhododendron ciliatum, R. anthopogon, R. lepidotum, Cassiope fastigiata, Parnassia nubicola, Rhodiola himalensis, R. imbricate, Corydalis juncea, Nardostachys grandiflora, Saussurea gossypiphora, Meconopsis paniculata, Potentilla coriandrifolia, P. penduncularis, Caltha palustris, Cypripedium himalaicum, Pododphyllum hexandrum and species of Aconitum, Bryocarpum, Cassiope, Corydalis, Gentiana, Gentiana, Saxifraga, Sedum, Juniperous recurva and *J.squamata.*			
Altitude: 2100 m. to 3100 m.			
Tree species	**Shrubs**	**Herbs**	**Creepers**
Coniferous species			
Cupressus corneyana	*Berberis insignis*	*Aconogonum molle*	*Ceropegia pubescens*
Abies spectabillis	*Buddleha colvilei*	*Bistorta vaccinifolia*	*Aristolochia griffithii*
Tsuga dumosa	*Gaultheria sp*	*Koenigia nepalensis*	*Clematis montana*
Taxus wallichinana	*Hypericum hookerianum*	*Euphorbia sikkimensis*	*C.acuminata*
Larix griffithii	*Philadelphus tomentosus*	*Pilea anisophylla*	*C. Buchananiana,*
Broad leaf Species			
Alnus nepalensis	*Mahonia nepaulenes*	*Gaultheria trichophylla*	*Dicentra scandens*
Betula utilis	*Sambucus adnata*	*Agapetes incurvata*	*Holboellia latifolia*

Malus sikkimensis	*Berberis aristata*	*Panax pseudo-ginseng*	
Quercus spp		*Rubus fragaroides*	
Enkianthus deflexus		*Arisaema nepenthoides*	
Pieris formosa		*A. Griffithii*	
Lithocarpus pachyphylla		*A. Jacquemontii*	
Engelhardtia spicata		*A. Propinquum*	
Lyonia ovalifolia		*Hedychium spp*	
Rhododendron grande		*Silacina oleracea*	
Magnolia campbellii		*Roscoea purpurea*	
Exbucklandia populnea		*Begonia flaviflora*	
Acer campbellii		*I. Sulacata*	
		I. ongipes	
Zone B and D (Part of KNP Buffer Zone-IV)			
Altitude : 2500 m to 3450 m.			
Tree Species	**Shrubs**	**Herbs**	**Creepers**
Macaranga denticulate	*Dichroa febrifuga*	Persicaria *capitata*	*Peper*
Alnus nepalensis	*Oxysprora paniculata*	*Houttuynia cordata*	*Smilax*
Castanopsis tribuloides	*Melastoma malabathricum*	*Houttuynia cordata*	*Tetrastigma*
C. indica	*Buddleja asiatica*	*Eupatorium odoratum*	*Rhaphidophora*
Rhododendron arboretum	*Edgeworthia gardneri*	*Gynura pseudo-china*	
Alangium Chinese	*Rubus ellipticus*	*Ranunculus diffusus*	
Maesa chisis,	*Mussaenda roxburghii*	*Notochaete hamosa*	
Tree Species	**Shrubs**	**Herbs**	**Creepers**
Malus sikkimensis		*Drymaria villosa*	
Ficus semicordata		*Sagina japonica*	
Toricellia tiliifolia		*Elatastema lineolatum*	
Schima wallichii		*Plantago erosa*	
Sauruia nepalensis		*Crassocephalum crepidioides*	
Betula cylindro stachys		*Hydrocotyle asiatica*	
Lithocarpus sp.		*Achyranthes bidentata*	
Quersuc sp.		*Oxalis corniculata*	
		Oxalis griffithii	
		Galinsoga parviflora	
		Bidens pilosa	

Zone C (Part of West Territorial Division)		
Altitude : 1000 m to 1500 m		
Upper Storey	**Middle Storey**	**Ground cover (Herbs and Creepers)**
Castanopsis tribuloides	*Symplocos Spp.*	*Strobilanthes coloratus,*
Castanopsis hystrix	*Ostoides paniculatus,*	*Girardiana heterophylla*
Castanopsis indicia	*Macaranga indica*	*Eupatorium odoratum*
Betula cylindrostachys	*M. pustulata*	*Polygonum molle*
Engelhardtia spicata	*Eurya japonica*	*Dichorrea febrifuga,*
Bucklandia populnea	*Meliesma thomsonii*	*Artemisia vulgaris*
Alnus epilepsies	*Boehmeria rugulosa*	

Machilus spp.	*Ficus cunia*	
Juglans regia	*Grewelia nudiflora*	
Sapindus detergens	*Dendrocalamus Sikkimensis*	
Terminalia bellerica		
S. Wallichi		
Phoeba sp.		
Cinnamomum spp.		
Cedrela toona		
Ostoides panniculata		
Altitude : 700m to 1000m		
Shorea robusta	*Terminalia Chebula*	*Clerodendron serratum*
Terminlia tomentosa	*Terminalia Bellerica*	*piper spp.*
Mallotus philippensis	*Dendrocalamus hemiltonii*	*Mucuna spp.*
Bombax malabarica	*Pinus roxburghii*	*Wrightia-tomentosa*
Albezzia procera		*Dichorrea*
Ailanthus grandis		*Fabrifuga*
Duabanga sonneratioides		*Bauhinia vahlii*
		Buddleia spp.
		Parthenocissus himaliana
		smilex moringe

Field Survey

Fifteen accessible sites were surveyed within the direct impact zone i.e., proximity with barrage and power house along the project stretch of Rathang-chu river so that the type of ecosystem and land use are well represented. Sites are selected primarily based on its vegetation cover and accessibility.At each site study of floral diversity was carried out by laying down quadrate **(Photo Plate 19)**, approximately 20 m. x 20 m. for trees shrubs and large climbers, 5 m. x 5 m. for number of species of herbs, both grasses and herbs, as well as the number of individuals of each species and 1m. x 1m. for more prolifically growing larger herbs, and also 10 cm x 10 cm for minute herbs. The detailed quadrat sampling data with Shannon index calculation is given in **Annexure – VI a) and VI b).** The ecological sampling locations are shown in **Figure 3.25.** **Table 3.28** provides the species diversity index and species richness of surveyed Quadrates.

Photo Plate 19: Quadrate Sampling of Minute Herbs

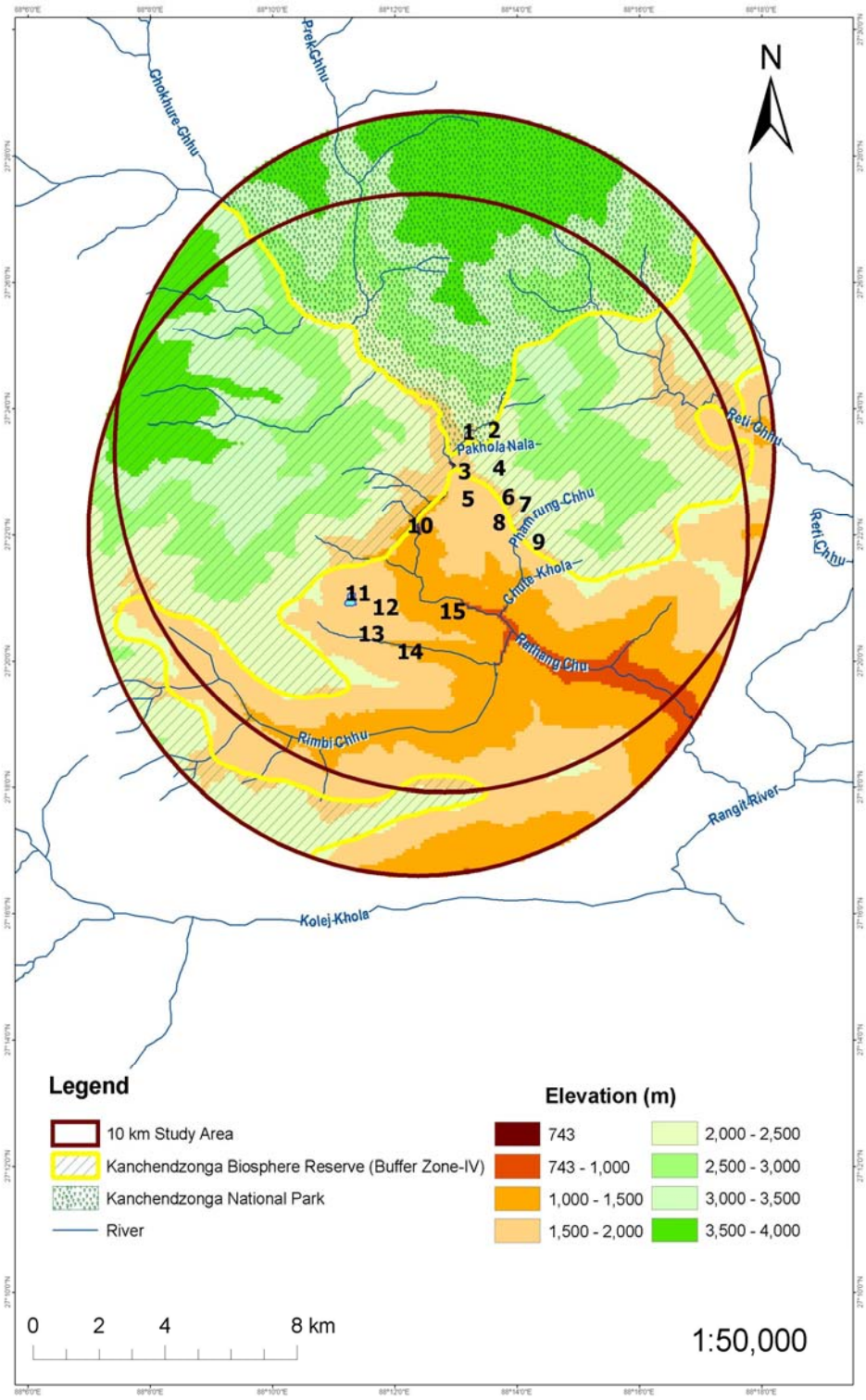


Figure 3.25: Ecological Sampling Site

Table 3.28: Ecological Sampling Results

Quadrat Number	Location	Altitude (m)	Zone	Site Description	SDI (Woody)	SDI (Non - Woody)	SR (Woody)	SR (Non – Woody)
1	N 27° 23′ 33.9″ E 88° 13′ 13.02″	1900	KNP Buffer IV	Upstream of Pau-Khola bridge, Near bank of the nallah	1.834	0.562	13	3
2	N 27° 23′ 21.36″ E 88° 13′ 4.62″	2210	KNP Buffer IV	West slope of Pau-Khola, along KNP trek route	2.245	0.501	10	2
3	N 27° 22′ 46.7″ E 88° 13′ 8.1″	1805	KNP Buffer IV	East slope of Rathang-Chu valley, south-east of barrage site, along path to open channel	2.275	0.501	12	2
4	N 27° 23′ 06″ E 88° 13′ 30″	2400	KNP Buffer IV	East slope of Rathang-Chu, above barrage site, along KNP trek route	1.039	1.233	3	4
5	N 27° 22′ 46.08″ E 88° 13′ 13.62″	1735	West Territorial Division	Plateau to east of Rathang-Chu, near KNP check post	2.181	1.767	16	7
6	N 22° 22′13.8″ E 88° 13′47.6″	1925	KNP Buffer IV	Forest near Dubbdi Gompa	2.246	0	12	0
7	N 27° 22′16.3″ E 88° 14′8.2″	2090	KNP Buffer IV	Terraced slope along bank of Phamrong- Chu	1.828	0.562	10	2
8	N 27° 22′12.6″ E 88° 13′43″	1820	West Territorial Division	Fenced slope along Yuksam-Dubbdi Gompa paved path	2.335	0.562	12	8
9	N 27° 21′54.3″ E 88° 13′50.8″	2060	KNP Buffer IV	Forest along Yuksam-Tshong route	2.415	0	12	1
10	N 27° 22′ 9.6″ E 88° 12′ 25.2″	1310	West Territorial Division	East slope of Rathang-Chu, under Lethang bridge	2.259	1.662	12	6

Quadrat Number	Location	Altitude (m)	Zone	Site Description	SDI (Woody)	SDI (Non - Woody)	SR (Woody)	SR (Non – Woody)
11	N 27° 21′ 5.0″ E 88° 11′ 24.3″	1810	West Territorial Division	Forest near Khechuperi lake	2.458	1.329	13	4
12	N 27° 20′ 48.2″ E 88° 11′ 51.1″	1820	West Territorial Division	West slope of Rathang-Chu, near Khechuperi	2.047	0	9	1
13	N 27° 20′ 27.0″ E 88° 11′ 37.1″	1670	West Territorial Division	Light forest below Khechuperi-Lethang road	2.775	1.708	17	6
14	N 27° 20′ 10.0″ E 88° 12′ 15.3″	1480	West Territorial Division	Dense forest along Khechuperi-Lethang road	2.858	1.054	20	3
15	N 27° 20′ 48.4″ E 88° 12′ 56.8″	1235	West Territorial Division	Outskirts of Choudmal village, on Khechuperi-Lethang road	2.609	0	16	1

***SDI: Species Diversity Index**
***SR: Species Richness**

Altitudinal Variation in Species Diversity and Richness

Species diversity and richness are studied for various altitude ranges.

1. Below 1500 m.
2. 1500-2000 m.
3. 2000-2500 m.

It is observed that the maximum richness and diversity is found in the intermediate ranges i.e. 1500-2000 m. compare to higher (2000-2500 m.) and lower altitudes (below 1500 m.) for both woody and non-woody flora. Altitude wise variation of species diversity and richness for woody and non-woody flora as observed in the study area is shown in **Figure 3.26** and **3.27**, respectively.

Figure 3.26: Species Diversity and Richness of Woody Flora

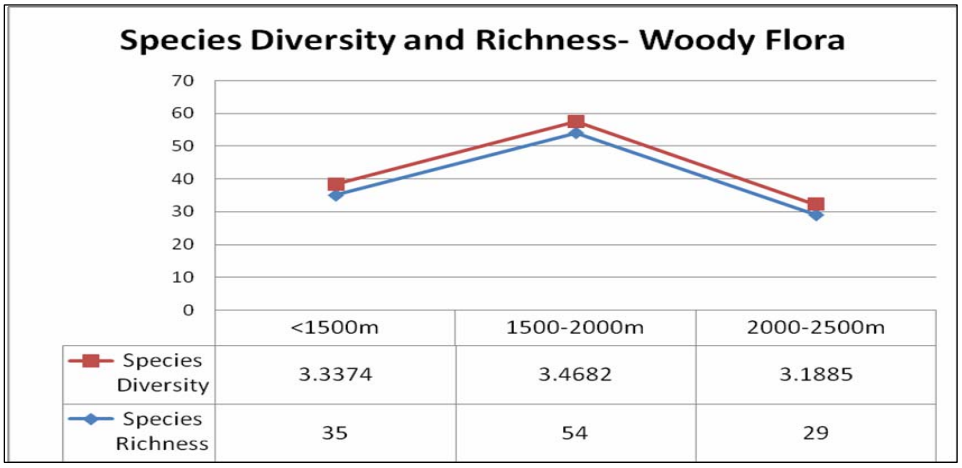
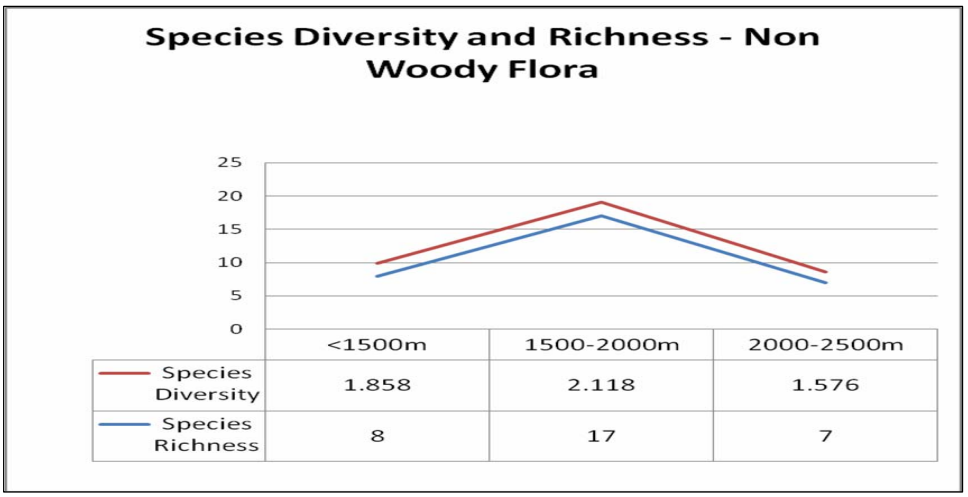


Figure 3.27 : Species Diversity and Richness of Non – Woody Flora



3.8.1.2 Fauna

An exhaustive list of wild animals that are either present or visit the forests in and around the study area were prepared by collecting information from various sources and their conservation status as per 'Wildlife Protection Act, 1972 and amendments thereto' were also noted. The information on wild fauna of the area were mainly gathered from forest officials like Asst. Conservator of Forests, West Sikkim District; Range Officers, Yuksam range; forests guards; villagers; trekking guide; and volunteers of Kanchendzonga Conservation Committee (an NGO working on conservation of wild animals of the area). The list was also verified using KNP management plan and preliminary forest working plan and from the concern forest officials. Total 140 species of wild animals were listed, in which 33 were mammals, 74 species were of birds, 11 species of reptiles and 22 were of Butterflies. In these, 17 were categorized under scheduled- I species, 21 were as scheduled- II, 2 were categorized under schedule III, 19 were as scheduled- IV and 5 species under Schedule –V. The WPA status of the species reported from the study area is tabulated below in **Table 3.29**

Table 3.29 List of Species Reported from Study Area and Their Conservation Status

Species	Total No.	WPA Schedule No. *				
		I	II	III	IV	V
Mammals	33	10	16	2	--	4
Reptiles	11	1	5	--	--	--
Birds	74	1	--	--	19	1
Insects(Butterfly)	22	5	--	--	--	--
Total	140	17	21	2	19	5

* ***WPA schedule number as per Wildlife Protection Act, 1972 and amendments thereto.***

During the field study no direct evidence was found like visual sightings, but indirect evidence such as calls, nests, burrows, droppings, scats, moults, tracks, etc. were also observed. Few evidences for the presence of faunal species in the study area are shown in **Photo Plate 23 to 26**.

At each site, faunal diversity was also studied through direct evidence, in the form of visual sightings, and indirect evidence such as calls, nests, burrows, droppings, scats, molts, tracks, etc.

At each of the fifteen sites of quadrate (for floral diversity study), faunal assortment was also noted through direct evidence, in the form of visual sightings, and indirect evidence such as calls, nests, burrows, droppings, scats, moults, tracks, etc.

A Pallas's Squirrel (Callosciurus erythraeus) was sighted at one survey-site. A quill of a Himalayan Crestless Porcupine (Hystrix brachyura) was recovered from another site. Scats of a small carnivorous mammal were found in another survey site.
Villagers report the existence of bats and flying squirrels throughout the survey area. The records (years 2005 through 2008) of the Khangchendzonga National Park show that Blue Sheep (Pseudois nayaur), Wild Pig (Sus scrofa), Red Panda (Ailurus fulgens), Asiatic Black Bear (Ursus thibetanus) and Himalayan Marmot (Marmota himalayana) are sighted in the forests presenting the study area. While droppings of Wild Dog (Cuon alpinus) and Red Fox (Vulpes vulpes montana), pugmarks of Common Leopard (Panthera pardus) and Snow Leopard (Uncia uncia) have also been found. Invertebrate fauna observed included butterflies, bees, wasps and ants. Nests of wasps and ants were sighted on some trees. Hives of Rock Bees were observed under overhangs of cliffs along the Rathang-Chu gorge.

The Details of the wild animals recorded in the study area are given below:

Mammals: Key species of mammals, which inhabitat the forests in and around the study area were Snow Leopard, Clouded Leopard, Himalayan Musk Deer, Himalayan Brown Bear, Asiatic Black Bear, Wolf, Mainland Serow, Himalayan Thar, Blue Sheep, Bear cat, Marbled Cat, Yak, Monkey, Red Fox, Jackal, Ghoral, Barking Deer etc.

Aviafauna: About 74 species of birds were recorded from the study area. Frequently seen aviafauna in the study area were Great Barbet, Rock Pigeon, Crested serpent Eagle, Grey Treepie, White-throated Fantail, Blue Whistling Thrush, Grey-headed Canary Flycatcher, White-capped Water Redstart, Plumbeous Water Redstart, Green-backed Tit, Wire-tailed Swallow, Golden-spectacled Warbler, White-spectacled Warbler, and Red-billed Leiothrix. None of the bird species are of Schedule-I as per Wild Life Protection Act, 1972. Birds of prey, especially Aquila eagles, have also been seen to use this part of Himalayan forests as an east-west pathway in autumn. The frequency of avifauna observed during the ecological survey are given in **Annexure VII a)**

Butterfly: Butterfly Species listed in the study area were the Golden Birdwing, Common Birdwing, Brown Gorgon, Yellow Gorgon, Spectacle Swordtail, Chain Swordtail, Great Zebra, Veined Jay, Great Mormon, Dark Blue Tiger, Chestnut tiger, Hill Jezebel, Redbase Jezebel, Tree Yellow, Chocolate Grass Yellow, Forest Pierrot, Metallic Green Hairstreak, Striped Punch, Tailed Red Forester, French Duke, Northern Jungle Queen, Jungle Glory and Kohinoor.

The Detailed list of the animals recoded from the study area along with their conservation status as per IUCN and WPA Schedule number are given in **Annexure VII b).**

Photo Plate 23: Chameleon

Photo Plate 24: Eggs of Reptile

Photo Plate 25: Scats of Carnivorous Mammal

Photo Plate 26: Quill of Porcuppine

3.8.1.3 Eco Sensitive Areas

The study area falls within the boundary of **Kanchendzonga Biosphere Reserve** (KBR). KBR is located between 27º 25´ to 27º 55´ N latitude and 88º03´ to 88º38´ E longitude and cover 2619.92 sq km of area. The barrage axis of the proposed HEP is located 300 m downstream of Pau Khola Nallah, which form is of left axis of the Core Zone of the **Kanchendzonga National Park** (KNP).

KBR is comprised of two cores zone covering an area of 1784.00 sq. km. and four buffer zones covering an area of **835.92 sq. km.** The elevation in the biosphere varies from 1220 m. to 8598 m. and encompasses the Kangchendzonga National Park and Reserved Forests of North, South and West Sikkim districts of Sikkim. The project location with respect to Kanchendzonga (Core and Buffer Zone) is given in **Figure 3.28.**

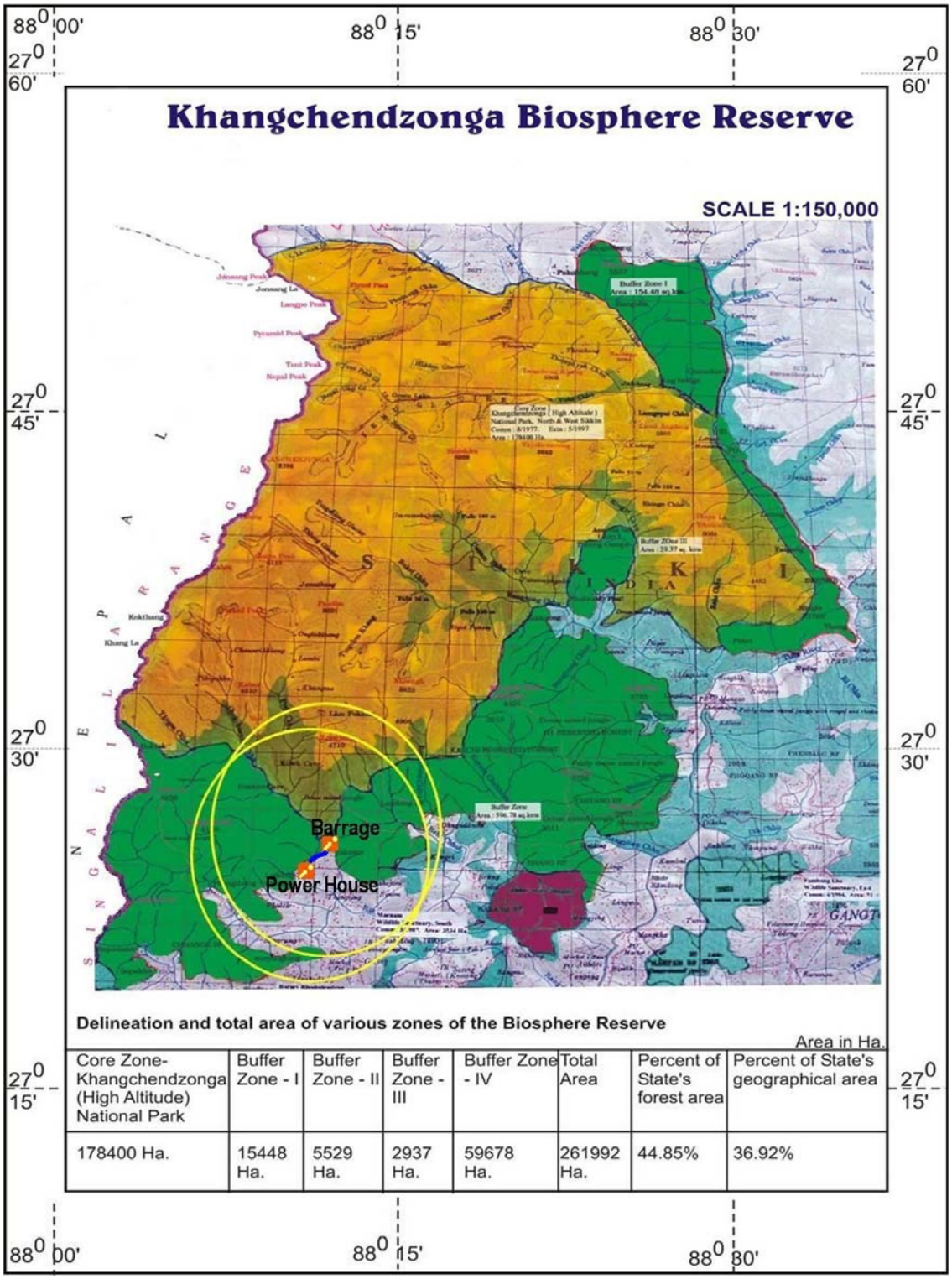


Figure 3.28: Project Location with Respect to Kanchendzonga (Core and Buffer Zone)

It was notified on August 26, 1977 covering an area of 1784.00 sq km with elevation ranging from 1,829 m to 8,598 m. It is home to some of the rare and endangered plant species such as *Saussurea lappa, Paphiopedilum spp*., *Nepenthes, khasiana*, etc. Almost 32% of park area is under permanent snow cover and glaciers, while 16% of the park area is occupied by Moraines. 20.40% of the total area is under forest cover, 5.7% is under dense category and rest is under open category. KBR has varied ecosystems ranging from sub-tropical to alpine to arctic ecosystems.

The park ranks as one of the most important protected areas in the Himalayas. It is the highest altitude protected wildlife area in India and is designated as an Important Bird Area, the largest such in Sikkim. Due to its size and altitudinal range, it is home to birds recorded from at least 4 biomes, with 127 bird species of conservation concern, 7 of which are globally threatened or restricted range species. The high altitude lakes within the park are important staging sites for migratory waterfowl. At least 19 mammals protected under Schedule I of the Wildlife (Protection) Act Schedule I of the Wildlife (Protection) Act (1972), as also protected species of beetles and butterflies, are also reported from here.

3.8.2 Aquatic Ecology

3.8.2.1 Fish Fauna

Information on fish and fisheries of the project stretch and its immediate up and down stream were collected through primary survey and from secondary sources. Sample netting was made in the project stretch in all approachable points in different seasons (monsoon, post monsoon, winter of 2009 and pre monsoon of 2010) but no fish could be caught.

The information on the availability of fish species and presence of breeding or feeding g ground in 10 km (down stream of KNP) stretch of Rathang Chu was obtained from the Department of Fisheries, Geyzing, West Sikkim, which is also verified from the local licensed fishermen and villagers; List of the fish are tabulated in the **Table 3.30.**

Seventeen fish species of five families namely – Cyprinidae, Rasborinae, Cobitidae, Sisoridae and Salmonidae are reported from Rathang Chu River. The snow trouts like Schizopyge *progastus* and (Chuchay Asala) *Schizothorax richardisonni* (Dothay Asala) are reported from the project stretch, which are most common fishes in the Rathang Chu. Investigation revealed that these species travel upstream mainly for breeding purposes, however, no breeding grounds were found in the project stretch. Catch of *Garra annandalei* (Budune) is also seen commonly in downstream near Dosthang village, where river take turn towards east near Ting Ting village. Other indigenous species are *Danio aequipinnatus*, *Danio naganensis* (Bhitti), *Barilius vagra* (Chirkey), *Semiplotus semiplotus* (Chefiti), *Garra annandalei* (Budune) etc.

Table 3.30: Fish Species of the Rathang Chu River

Family	Scientific Name	Local Name	Indigenous or Migratory Species
Salmonidae	*Salmo trutta fario*	Trout	Indigenous
Cyprinidae	*Schizopyge progastus***	Chuchay Asala	Migratory(in stream)
	*Schizothorax richardsoni***	Dothay Asala	Migratory(in stream)
Rasborinae	*Danio aequipinnatus*	Bhitti	Indigenous
	Danio naganensis	Bhitti	Indigenous
	Barilius vagra	Chirkey	Indigenous
	Semiplotus semiplotus	Chefiti	Indigenous

Family	Scientific Name	Local Name	Indigenous or Migratory Species
	Acrossocheilus hexagonolepsis	Katlay	Migratory
	Crossocheilus latius latius	Lohori Budine	Indigenous
	*Garra annandalei***	Budune	Indigenous
Cobitidae	*Noemachellius beavani*	Gadele	Indigenous
	Noumeacheilus carletoni	Gadale	Indigenous
	Noemacheilus devdevi	Gadale	Indigenous
	Noemacheilus corica	Gadale	Indigenous
Sisoridae	*Glyplothorax basnetti*	Dodray	Indigenous
	Glyptothorax bhutai	Kanray	Indigenous
	Pseudechenesis sulcatus	Kabray	Indigenous

**** Highlighted species were recorded from the project stretch**

The habit and habitat requirement for these fish species is given below in **Table 3.31**

Table 3.31: Habit and Habitat Requirement of Fish Species

Fishes Species	Local Name	Vernacular Name	Feeding Habit	Breeding habits
Species Reported from Project Stretch				
Schizothorax richardsoni	Dothay Asala	Alawan snowtrout	Herbivorous feeding mainly algae, aquatic plants and detritus	Winter when the temperature in the Greater Himalayan waters reaches the near-freezing point. Spawning temperatures: 18-21.5°C
Schizopyge progastus	Chuchay Asala	Dinnawah snowtrout	Mainly Carnivorous	Breeds in the upper reaches of river and travels down after breeding
Acrossocheilus hexagonolepsis	Katlay		Omnivorous, eating not only algae, crustaceans, insects, frogs, and other fish, but also fruits that fall from trees overhead	August-September. Breeds naturally on stones ans gravel at 18-23°C.
Garra annandalei	Budune	Annandale Garra	Algae, plankton, and small invertebrates.	August to October, generally goes upstream into the river to spawn
Salmo trutta fario	Trout	River Trout	Feed on benthic invertebrates, insect larvae,	From November to January. Water temperatures:

Fishes Species	Local Name	Vernacular Name	Feeding Habit	Breeding habits
Species Reported from Project Stretch				
			aerial insects (in rivers) and algae. In addition, adults consume fish and frogs.	5-12°C Spawning under gravels
Danio aequipinnatus	Bhitti	Malabaricus, Giant danio	Omnivorous Diet consists predominantly of exogenous insects, but is also supplemented by worms and crustaceans	Native substrate: small gravels
Danio naganensis	Bhitti	Naga danio	-	-
Barilius vagra	Chirkey	Vagra baril, Korang	Carni-Omnivorous Insect Algae, crustaceous prdominant but aquatic weeds and □lgae also. Browses stone & rock substrate to feed periphyton, chlorophyceae & lesser zooplankton	gravelly and rocky bottom
Semiplotus semiplotus	Chefiti	Assamese kingfish	-	-
Crossocheilus latius latius	Lohori Budine	Gangetic latia	Algae, diatoms and other Phytoplankton	Undergo seasonal reproductive migration moving upstream during dryer months and in the opposite direction when water levels rise
Noemachellius beavani	Gadale	-	Omnivorous Aquatic crustacean, insects, small invertebrates and organic detritus	-
Noemachellius carletoni	Gadale	-		-
Noemachellius devdevi	Gadale	-		-
Noemachellius corica	Gadale	-		-
Glyplothorax basnetti	Dodray	-	-	-

Fishes Species	Local Name	Vernacular Name	Feeding Habit	Breeding habits
Species Reported from Project Stretch				
Glyplothorax bhutai	Kanray	-	-	-
Pseudechenesis sulcatus	Kabray	-	Carnivorous (aquatic insects, their larvea an mymphs)	-

The fishing season in the Rathang Chu starts from mid of March and continues till May depending on the weather condition. The sample netting was done in the study stretch. It was observed and also verified from local people and fisheries department that no large scale fishing activities are being practiced in this stretch. Moreover, no spawning/feeding ground is recorded from this stretch or it's immediate up stream and down stream.

Fisheries department issues licenses to the local fishermen for Rod-Line and Cast Net. The department has fisheries guard for patrolling to keep watch on non licensed fishing. As per the Fisheries Department, a total of 14 licenses issued for the Yuksam Block in 2010 fishing season. No family is fully dependent on fishing for earning its livelihood.

There is a fisheries department has a fish farm in Yuksam village where breeding and culture of indigenous species **(Photo plate 27 to 30)** take place. Main activity in this fish farm is breeding of trout (rain bow trout) and Indian major carp. Exotic carp like common carp (*Cyprinus carpio)* is also raised here.

Photo Plate 27: Fisheries Deptt. in Yuksam

Photo Plate 28: Fish Farms

Photo Plate 29: Fish Pond (Common carp)

Photo Plate 30: Rainbow Trout

3.8.2.2 Fish Food Organisms: Planktons and Benthos

The sampling of planktons and benthos was carried out in three different seasons – pre monsoon, monsoon and winter. The sampling for planktons and benthos was carried out at various locations that are given in **Table 3.32.** The diversity and density index of planktons and benthos as observed from the study area are given in **Annexure VIII.**

Table 3.32: Sampling Locations Planktons and Benthos

S.No.	Sampling Station Code(Plankton & Benthos)	Latitude	Longitude
1	P1	88°12’52.30”E	27°23’12.94”N
2	P2	88°12’51.06”E	27°23’8.60”N
3	P3	88°12’9.59”E	27°22’42.47”N
4	P4	88°12’35.54”E	27°22’32.57”N
5	P5	88°12’23.05”E	27°22’2.15”N
6	P6	88°12’22.9”E	27°22’0.1”N

For plankton, 50 litres composite water samples were collected from the river surface about 50-60 cm. depth and were filtered through a 20 µm net and concentrated in a 200 ml bottle and preserved in 4 % formalin solution. Samples were brought for laboratory analysis and further concentrated to 20 ml. The qualitative and quantitative analysis was done using one drop of sample under a light microscope following the APHA et.al. (1998).

The total number of planktons present in a liter of water sample was calculated using the following formula:

P=A x 1/v x n/N

Where, P = Av. no of plankton present /lt,

A= average no of organism per drop

V=volume of drop (ml)

N=volume of water filtered (l)

n=total no of concentrated sample (ml).

Analytical Results:

The dominant species of phytoplanktons as observed were *Acharanthes Affinis, Cyclotella sp., Cymbella Sp., Syndera tabulata, Pinnularia braunii, Gyrosigma sp., Nitzchia gracilis.* The zooplanktons observed in the study stretch were *Ceriodaphnia reticulata, Arcella Sp, Daphnia Sp., Actimophyros Sp., Brachirous caudotus, Keratella monospina.*

The dominant species of Benthic organisms were *Cymbella lanceolata, Diatoma vulgaris, Baetis Sp, Stenonema sp., Cyclotella comta, Gyrosigma Sp., Melosira undulate, Nitzchia gracilis, Psehpnus Sp., Cymbella proxima, Nevicula Sp., Gomphonema Sp., Achnanthes clevel, Melosira gracilis. Acronuria Sp., Stenonema Sp., Amphora Sp, Gyrosigma accuminatus, Cyclotella meneghiana etc.*

The season wise and altitudinal variation was found in the diversity index of phytoplanktons, zooplanktons and benthos (Figure 3.22 -3.23). The planktons (phytoplanktons and zooplanktons) community diversity as observed in the river stretch increased gradually from upper to lower stretches in pre-monsoon and winter seasons. However, different trend was observed in monsoon season due to variation in physical and chemical characteristics of river like water current velocity and turbidity, which increased during monsoon because of runoff resulting into siltation and weathering of rocks from steep slopes from both the banks.

The Density of Phytoplanktons varied widely from upper to lower stretches, with the onset of monsoon season, the phytoplankton's density gradually declined in the lower stretches in due to high water current and turbidity. The peak density of phytoplankton's (Figure was observed during pre-monsoon seasons i.e., April; as the spring season sets it flourishes the growth of phytoplanktons, also the optimum level of alkalinity in water tends to support high productivity for aquatic fauna. Same trend was observed for the benthic population in the river stretch.

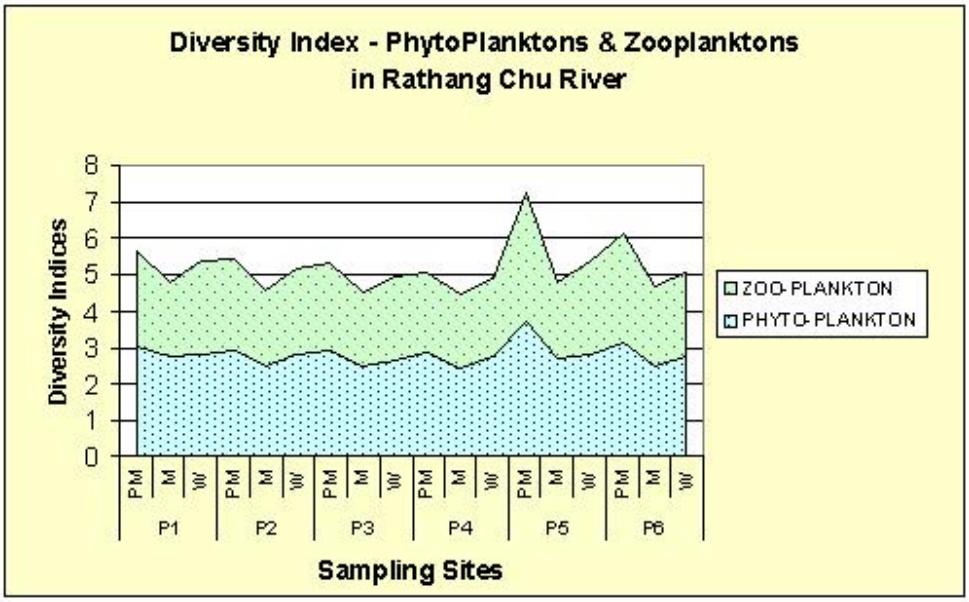


Figure 3.29: Diversity Index of Phytoplanktons and Zooplanktons

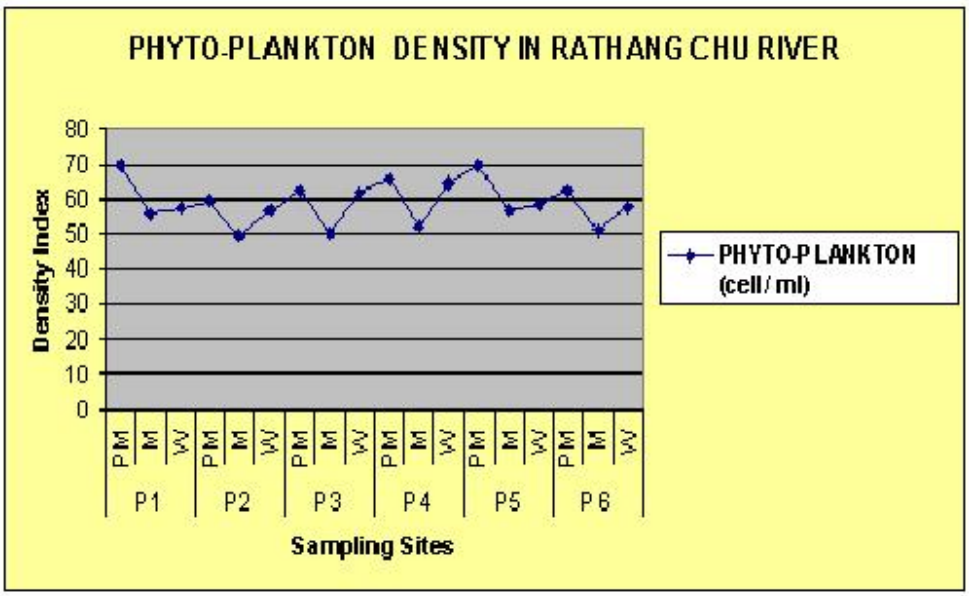


Figure 3.30: Density Index of Phyto Planktons in Rathang Chu

On the other hand, Zooplanktons density declined gradually as observed at each sampling site with the onset of monsoon seasons and it gradually increases during transition period. This trend is due to altitudinal and seasonal variation in the region consequently varying in the physico – chemical characteristics of river water such as TDS and Alkalinity.

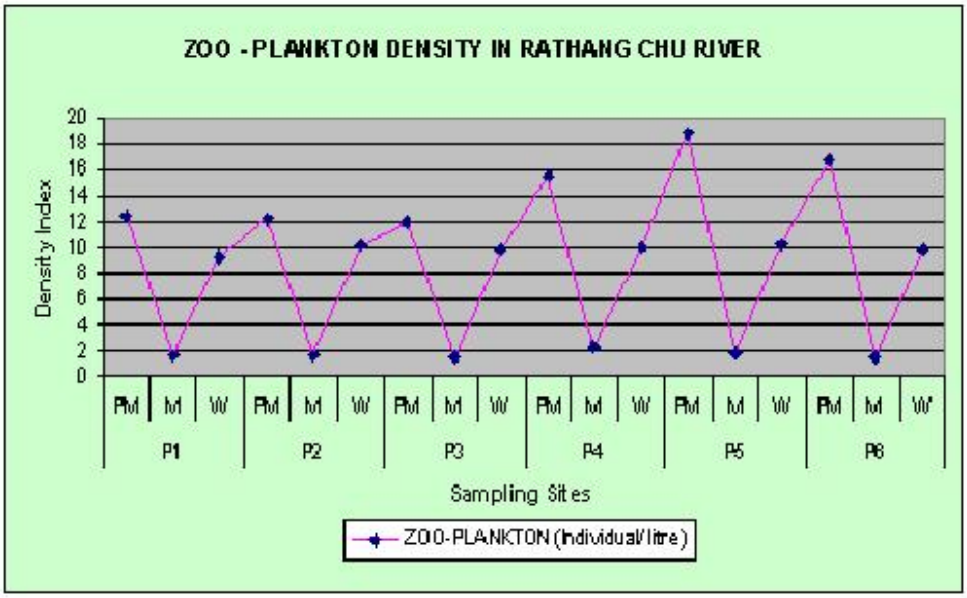


Figure 3.31: Density Index of Zoo Planktons in Rathang Chu

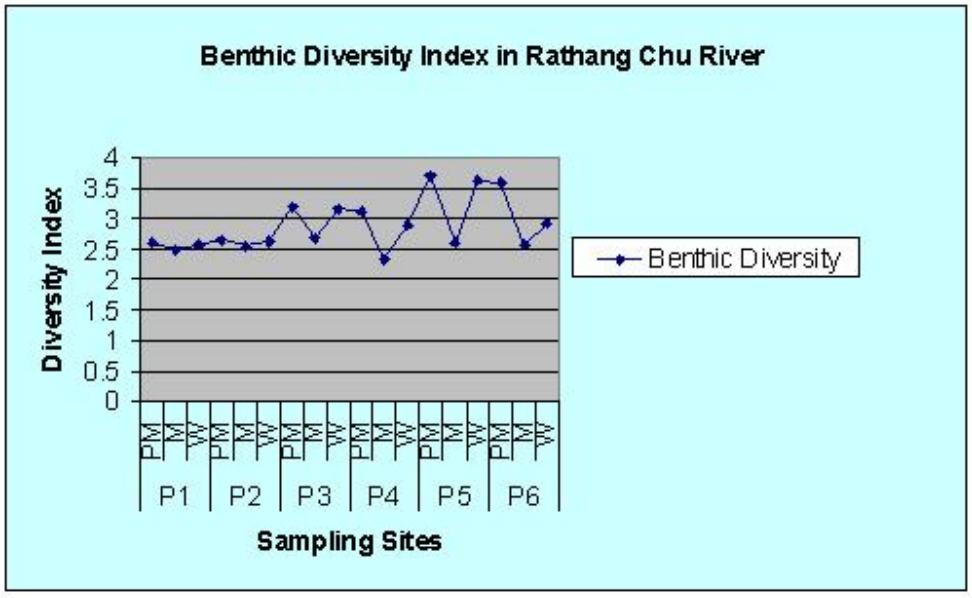


Figure 3.32: Diversity Index of Benthic Community

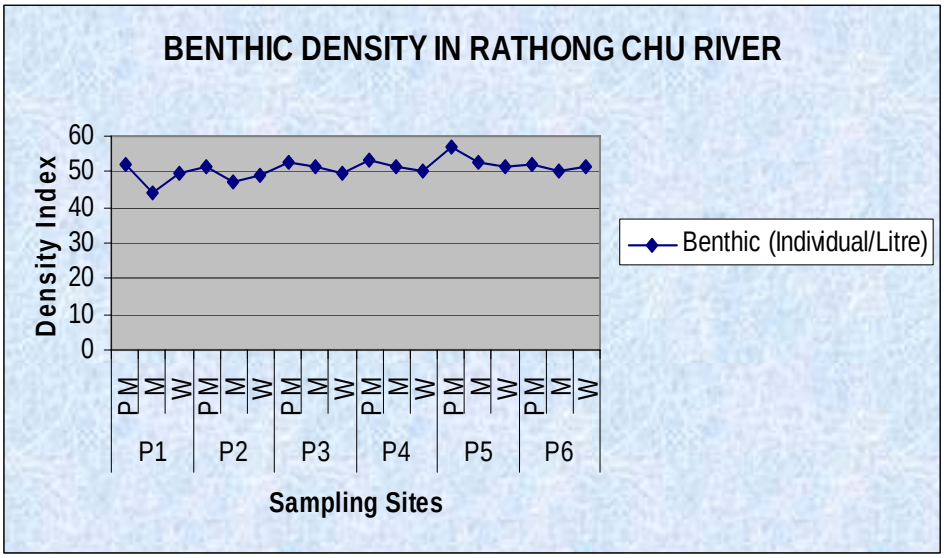


Figure 3.33: Density Index of Benthos in Rathang Chu River

3.9 Socio – Economic Environment

The socio-economic studies were carried out in subsequent chapters to assess the social impact and people's perception about the Lethang HEP. The proposed underground Power House located near Lethang village.

3.9.1 Land Holding Details and Project Affected Families

As per the socio-economic survey of affected villages, the project shall involve construction activities for various components of the project like weir, intake channel, power channel, desilting basin, headrace tunnel, powerhouse etc. Total land requirement for the project is 24.629 ha out of which 15 ha is private land and 9.629 ha is forests land. In addition, about 5.283 ha of private land will be taken on lease basis for muck dumping purposes. The Land area to be acquired from PAF (Project Affected Families) in Yuksam (Yuksam Revenue Block) accounts for about 4.4926 ha and in Lethang (Chojjo Block) accounts for about 5.2240 ha. The project does not require acquisition of any built-up or homestead land. Acquisition of lands from current owners/users (private owners) may lead to some extent of loss of livelihood and economic loss for the project-affected families/people (PAFs/ PAPs). This land acquisition needs to be handled with utmost care and fore thought for issues relating to Resettlement and Rehabilitation of Project Affected Families. Such approach is more sensitive since the project area is remote, where all segments of the society are concerned such as SC, OBC and General. The PAPs include marginal farmers in the project area. The entire list of Project Affected Families/Peoples (PAF/PAPs) is given in Annexure A.

3.9.2 Survey Area and Population Covered

The Socio – Economic survey was conducted in seven villages Norbugang, Khyongtey, Khopchey, Ramgaythrong, Lethang, Yuksam Bazar and BDO Colony. About 168 Household having the population 923 is covered under the study. The village wise details are given the **Table 3.33.**

Photo Plate 31 : SGD with Respondents at Khopchey

Photo Plate 32: SGD with Respondents at Lethang

Photo Plate 34: Discussion with Panchayat Office

Photo Plate 33: Interview at Ramgaythrong Village

Table 3.33: Village wise Details of Population Covered under the Study

Hamlet	Total Households	Total No. of Family Members	Total No. of Adult Males	Total No. of Adult Females	Total No. of girl child	Total No. of boys
BDO colony	26	129	36	43	19	18
Khyongtey	23	125	49	46	12	15
Khopchey	14	91	25	31	18	9
Lethang	36	191	73	60	15	26
Norbugang	24	165	64	69	18	11
Ramgaythrong	14	57	22	24	3	4
Yuksam	31	165	55	54	27	20
Grand Total	**168**	**923**	**324**	**327**	**112**	**103**

3.10 Socio - Economic Profile of Villages

As per the primary data collected from 168 households existing in the project zone, the socio- economic profile of the surveyed villages is given **Table 3.34** and **Figure 3.34**.

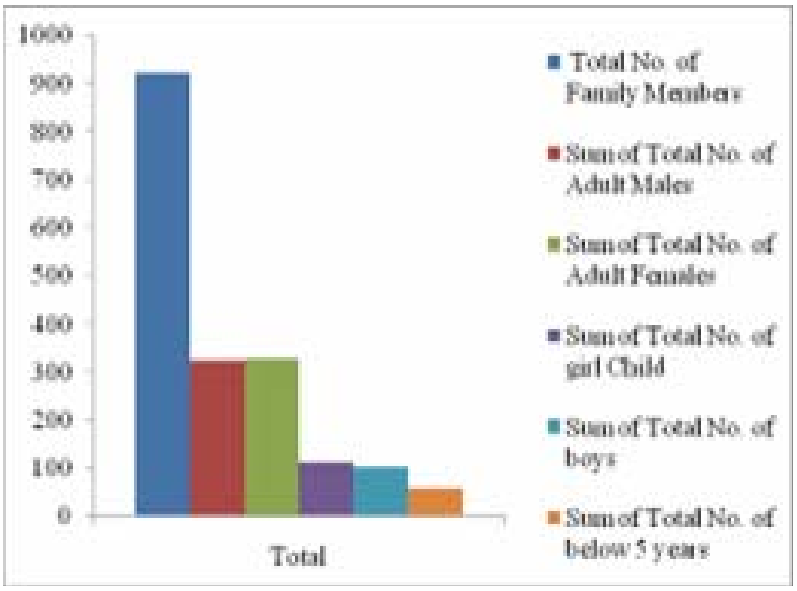


Figure 3.34: Age wise Classification of Population

Table 3.34: Households Surveyed

Villages	Total Nos. of Households covered
BDO colony	26
Khyongtey	23
Khopchey	14
Lethang	36
Nupgang	24
Ramgaythrong	14
Yuksam	31
Grand Total	**168**

3.11 Religion

The entire region is predominantly having faith in Buddhist religion and follows the Buddhist way of life. As per the data 85.20 % of the House Holds (HH) is having faith in Buddhism, 13.60% of HH is having faith in Hinduism and 1.20 % of the HH is having faith in Christianity.

3.12 Social Stratification

The state of Sikkim is having significant population of person belonging to schedule tribes as identified in Schedule IV and V of the constitution of India. The proposed project location is also having significant concentration of tribal population within the vicinity of project zone. However project is not affecting cultural and religious value system. The population of the area comprises of 90 % schedule tribes, 5 % OBC, 2 % each belonging to schedule caste and general category, 1 % belonging to major backward classes. **Table 3.35** given below shows village wise social stratification details.

Table 3.35: Village wise Social Stratification

Hamlet	GEN	MBC	OBC	SC	ST	Grand Total
BDO colony	1		1		24	26
Khyongtey				1	22	23
Khopchey	1	1	5	1	6	14
Lethang					36	36
Norbugang					24	24
Ramgaythrong					14	14
Yuksam	1	1	2	1	26	31
Grand Total	**3**	**2**	**8**	**3**	**152**	**168**

3.13 Family Type and Size

Type of family typically defines the characteristic of the community. The data from the field survey shows that 52% of the HH in the project zone lives in Nuclear Families which is a typical to urban phenomenon. However, it is also common to places where resources are scarce. The Village wise details of family are given in **Table 3.37** and **Figure 3.35** showing percentage of respondents living in various types of families.

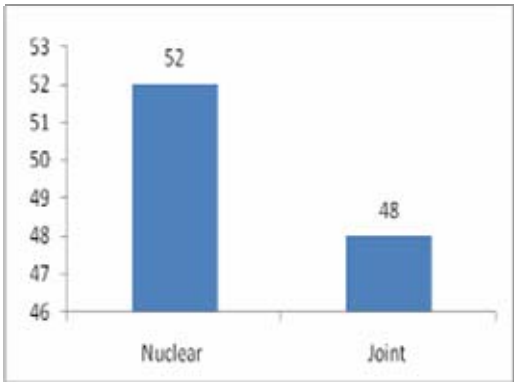


Figure 3.35: Family Type Size – Nuclear & Joint Family Status

Table 3.37: Village wise Family Type Details

Hamlet	Joint	Nuclear	Grand Total
BDO colony	2	24	26
Khyongtey	22	1	23
Khopchey	5	9	14
Lethang	17	19	36
Nupgang	20	4	24
Ramgaythrong	6	8	14
Yuksam	9	22	31
Grand Total	81	87	168

3.14 Literacy Level

The overall literacy level of the villages under study is seemed to be good. Out of total surveyed HH total number of who are literate is 599 out which 241 Adult males, 166 are Adult females and 177 are school going children between the age group of 5 to 14 years. Overall percentage of literates is 64.90%. The **Table 3.36** given below enlists the village wise details of number of literates.

Photo Plate 35: Yuksam Govt. Sec School

Table 3.36: Village Wise Literacy Rate

Hamlet	Total No. of Literates	Total Male	Total Female	Total School going children
BDO colony	78	16	26	46
Khyongtey	71	30	23	11
Khopchey	83	24	14	34
Lethang	126	69	35	20
Nupgang	76	36	24	15
Ramgaythrong	39	18	13	12
Yuksam	126	48	31	39
Grand Total	**599**	**241**	**166**	**177**

3.14.1 Economic Status

While undertaking field investigations it is revealed that most of the people living in the study area belong to BPL Category as defined by State Government of Sikkim. The region is generally underdeveloped and with very less availability employment opportunities and inadequate infrastructural growth. Although most of the people under the study area are literates but due to less educationally qualified mostly people are engaged as unskilled workers. In a nut shell the people under the project are not having good economic status. Tourism industry is the biggest industry which provides employment to the people directly or indirectly. About 55 % are below poverty line and 42 % category above poverty line, remaining two percent category no information was available. The average annual income of the families ranges between Rs. 25000 per to 140000. Out of 168 HH families 82% of the families are having annual income less than 25000, 15% of the families are having annual income ranging between Rs. 25000 to Rs. 1,40,000 , no information was available for remaining 3 % HH.

3.14.2 Occupation Details

Field investigation shows that main occupation of the persons living under the project is labor other than doing unskilled jobs people are also engaged in the cultivation of crops such as Millet, Maize, Cardamom etc and animal rearing. But mostly agriculture and animal rearing is done for their own to domestic consumption purposes. The **Table 3.37** given below provides the occupation details of surveyed households.

Photo Plate 36: Domestic Yak

Photo Plate 37: Local Farming

Photo Plate 38: Cardamom Production

Table 3.37: Occupation of Villagers House Hold Wise

Sl.No	Occupation	Nos. of HH Engaged
1	Farming	130
2	Animal Rearing	118
3	Dairy	1
4	Artisan	0
5	Labour	139
6	Business	10
7	Hotel	3
8	Tour& Travels	3
9	Cottage Industry	0
10	Service	11

3.14.3 Annual Income

The major portion of income of the families comes from job as labor. Farming is mostly done for domestic consumption purposes and very less number of respondents receives income from agriculture and animal rearing. Agriculture and animal rearing is considered to be a part time activity. The income from agriculture allied fields is in terms of kind which provides marginal support to the families. People are mostly dependent on non - farming activities for their livelihoods. The average annual income of the families ranges between Rs. 25000 per to 140000. Out of 168 HH families 82% of the families are having annual income less than 25000, 15% of the families are having annual income ranging between Rs. 25000 to Rs. 140000. Information on 4% of HH is not available because either their houses were locked or there was no one in their houses who can respond to this question. The **Figure 3.36** is showing the percentage wise distribution of annual income of the households

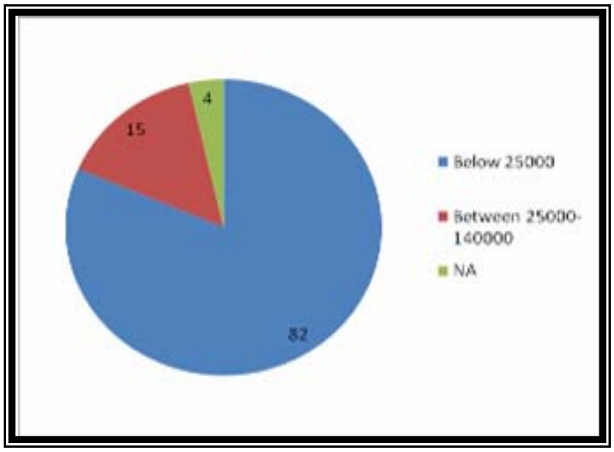


Figure 3.36: Annual Income of Villagers

3.14.4 Schemes for Livelihood Promotion

In order to promote livelihood several government initiative are undertaken in the region. In order provide gainful employment to the villagers' government is also running programme under National Rural Employment Guarantee Act (NREGA). As per the data 15% of the population is engaged under the scheme for employment.

3.15 Archaeological Monuments, Religious Structure and Sacred Lakes

Dubbdi Monastery: Dubbdi Monastery is the oldest Monastery of Sikkim established in 1701 AD near Yuksam Village. This ancient monastery is belonging to the Nyingmapa of Buddhist Lamaism at the time of Chakdor Namgyal. This is not only considered an ancient monument but worship place for Buddhist religious people. The monastery is approximately 7 – 6 Km away from the project site and is elevated at around 2200 meters.

Photo Plate 39: Dubbdi Monastery

Khecheopalri Lake

Khecheopalri Lake is situated between 27º22′24″ N latitude and 88º12′30″ E longitude at a distance of 25 km from Pelling and having an altitude 1828 m. The lake is considered to be one of the sacred lakes of the state both by the Buddhist and the Hindus. The lake is regarded as 'wish fulfilling' lake by the people of Sikkim. The local inhabitants visit this lake in perspective of pilgrimage while people from different parts of India and abroad come here for tourism. The lake remains hidden under the rich forest cover. The lake watershed is covered with some agriculture land with two villages and broad leaved mixed forest, comprises Arundo donax, Shagnum sp., Acorus calamus, Rhododendron sp. etc. Lake is fed by two perennial and five seasonal inlets while drained by a major outlet. It supports trans-Himalayan migratory birds and highly disturbed with commercial and recreational tourism.

Photo Plate 40 -Khecheopalri Lake

Kathok Bla T-Sho Lake

Kathok Lake is non drainage types of lake, situated between 27º22′20″ N latitude and 88º13′26″ E longitude in the West Sikkim district near Yuksam at an altitude 1,780 m. The lake covers an area of 0.0125 sq km. It is a permanent eutrophic temperate lake. The lake is under high stress by anthropogenic activities. The lake surroundings comprised of dense mixed trees. The Alnus nepalensis, Quercus linata, Engelhardia spicata, Lyonia ovalifolia, etc. Also, the surroundings are inhabited by a sparse human population.

Photo Plate 41- Kathok Bla T-Sho Lake

3.16 Existing Facilities

Yuksam being the first capital of Sikkim (Norbugang Throne), seat of Dubbdi Monastry and a tourist destination for trekking the area is relatively well developed. In respect to the quality of life, an account of existing facilities and amenities is described below.

Road Communication Network

The barrage site of Lethang HEP is located 3 km upstream of Yuksam village on the Rathang Chu river and can be accessed via trekking along the abandoned head race channel of earlier proposed Rathong HEP. The proposed power house site is located near Lethang village upstream of steel bridge on the river Rathang Chu on the road connecting to Yuksam (Geyzing-Pelling-Yuksam). The nearest township to the barrage as well as the power house is Geyzing which is connected with Gangtok and Melli, by a highway maintained by Sikkim Public Works Department. Melli is located at a distance of 65 km from Siliguri and also from Geyzing. The proposed barrage site and power house site are 49 km and 41 km away from Geyzing respectively.

Post Office and Bank

There is a post office in Khopchey hamlet of village Yuksam which is 3.0 km away from proposed barrage site. Hamlet BDO Colony of Yuksam village has a branch of State Bank of Sikkim.

Community information Centre (CIC)

Community Information Centre is established near Kathok Lake to provide computer and internet facilities. The Centre also facilitates to provide tourist information and village level information.

Photo Plate 42: Community Information Centre

All the villages in the project area have water supply either with tap or natural springs. Villagers use spring water for drinking purpose while river water for irrigation purposes. The inhabitants along the road have developed their own sanitation system but in villages it is not well developed.

Medical Facilities

Yuksam Village has a well established Primary Health Care Center for providing medical facilties in case of emergencies and epidemics, for awaring and imparting training to locals on health and hygiene, polio, vaccination and AIDS control.

Market Places

Due to tourism, only townships like Geyzing, Pelling and Legship are well developed and are the only important markets in the area.

Police Outpost

To maintain proper law and order a police outpost is there in Yuksam.

Telecommunication

Hamlets like Khopchey, Yuksam Bazar, Norbugang, and BDO Colony in village Yuksam have telecommunication facilities.

4

ASSESSMENT OF IMPACTS

4 ASSESSMENT OF IMPACTS

4.1 Assessment of Impacts on the Environment

The methodology used for environmental impact assessment follows the sequence summarized in **Fig 4.1.**

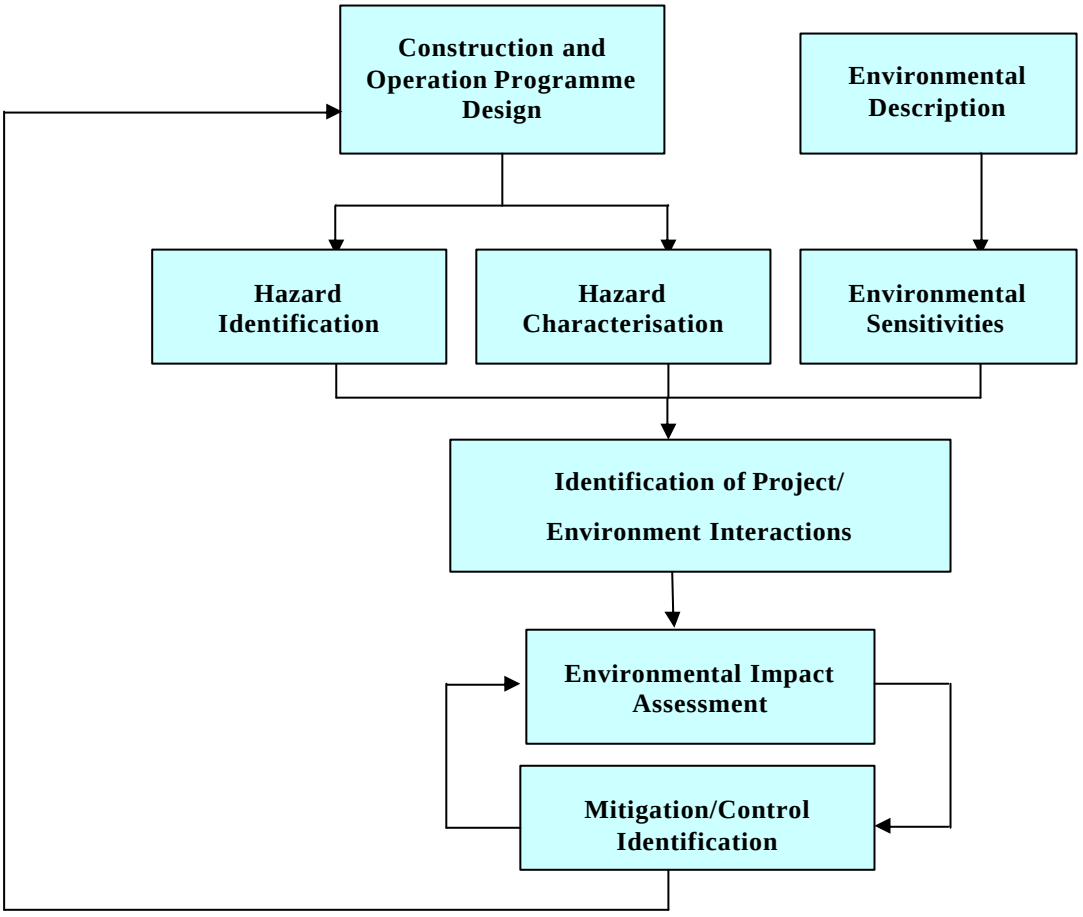


Fig 4.1: Methodology for Environmental Impact Assessment

The main supporting information required for an assessment includes a description of both the project **(Chapter 2)** and the environment in which it is proposed **(Chapter 3).** The information presented in these two chapters allows identification of the interactions between the planned construction and operation phase with the environment.

In this section, the interactions between the project and the environment are identified, impacts on environmental components due to project activities are assessed and key mitigation measures are suggested.

4.2 Identification of Interactions

Matrix methodology is adopted for the impact assessment. In this process, impacting activities and their likely environmental impacts are listed as horizontal and vertical axes in the matrix. Thereafter, the cause-effect relationships between specific activities and impacts are identified. **Table 4.1** summarizes the interactions between the proposed activities and the sensitivities of the local and regional environment.

Table 4.1: Interactions between Project Operations and Environmental Sensitivities

Impacts due to Project Activities	Environmental Sensitivities											
	Physical				Biological		Socio-Economic					
	Soil and sediment	Water Quality	Air Quality	Noise	Flora	Fauna	Living conditions of local people	Economy	Personnel/support crews	Archaeology	Tourism/Leisure	Land Use
1.Construction Phase:												
Immigration of labour	X	X	X	X	X	X		X				
Clearing Ground Cover	X		X	X	X	X						X
Hauling / Quarrying for construction material	X	X	X	X	X	X		X				
Operation of construction equipment		X	X	X	X	X	X					
Soil Erosion / Siltation	X	X	X									
Road Construction	X		X	X	X	X	X				X	X
Muck Disposal	X	X	X		X							X
Sewage		X				X						
Noise and Vibration				X	X	X	X		X		X	
Atmospheric Air Emissions			X				X		X			

Impacts due to Project Activities	Environmental Sensitivities											
	Physical				Biological		Socio-Economic					
	Soil and sediment	Water Quality	Air Quality	Noise	Flora	Fauna	Living conditions of local people	Economy	Personnel/support crews	Archaeology	Tourism/Leisure	Land Use
Waste Water Generation		X			X	X	X					
Solid /Hazardous Waste Disposal	X						X		X			X
Fuel Combustion			X									
Socio-economic Impacts							X	X				
Water related diseases		X					X		X		X	
2. Operation Phase:												
Reservoir submergence	X	X			X	X						
Change in hydrological regime	X	X			X	X						
Water related diseases		X					X		X			
Sewage		X				X	X					

4.3 The Major Activities that may have Impact on Environment

Physical Presence: The project involves construction of barrage, power house and other supporting infrastructures. These are permanent structures.

Atmospheric Emissions: Atmospheric Emissions is mainly during construction phase due to construction activities and fuel combustion.

Noise and Vibration: Noise and vibration is expected to be generated during construction phase.

Reduced Water Flow: The flow of the river is expected to be reduced between barrage and tail race outlet on a length of about 2.5 km aerial distance. This change is permanent.

Waste Water Generation: Waste water is expected to be generated from the construction activity and also from the labour colonies during construction phase and from project colonies through out the operation phase**.**

Quarrying Operation: Loss of top soil and soil compaction due to mining equipment transport and movement of vehicles results in decrease in soil productivity: These effects are restricted only in the construction phase.

Impacts on Land Environment

a) Construction Phase

During the construction period, topography of construction area will change due to erection of buildings, fills and cuts for tunnel, surface components of underground powerhouse, desilting basin, penstock and other associated structures. The most prominent impact on the surface topography will be the construction of impoundment upstream of the barrage. Construction of access road and widening of existing roads also will change the topography. Mainly the following activities are liable for the changes in existing topography :

i) Immigration of construction labour
ii) Quarrying of construction materials
iii) Movement and operation of construction machinery
iv) Runoff from construction site / increased siltation
v) Muck disposal
vi) Construction/widening of access roads.

Impact of Influx of Immigrant Population during Construction Phase

The involvement of large labour population and technical staff is likely to put significant pressure as a result of increase in discharge of sewage, quantity of solid wastes generated and other pollutants. The construction activity will engage different categories of manpower like officials, service providers, technical and non-technical workers. The phase-wise manpower required by the project is given in **Table 4.2.**

Table 4.2: Phase-wise Manpower Requirement for project

Phases (of 6 months)	Civil (25% skilled/ supervision category)	Mechanical (25% skilled/ supervision category)	Electrical (25% skilled/ supervision category)
Construction Phase			
Ist	200	--	--
IInd	300	10	10
IIIrd	500	50	50
IVth	600	200	100
Vth	600	250	150
VIth	600	250	150

Phases (of 6 months)	Civil (25% skilled/ supervision category)	Mechanical (25% skilled/ supervision category)	Electrical (25% skilled/ supervision category)
VIIth	200	250	150
Operation Phase			
	75	35	50

During the peak construction phase, the total population is estimated around 1000 workers most of them will be from nearby villages, out of which assuming 25 % (250) are categorised under skilled workers and remaining under unskilled workers (750). Following assumptions are considered for estimating the migrant population stress **Table 4.3** during the peak construction phases of this project:

- Family size is assumed as 5 and 80% of labours and technical staff is married,
- 50% of labours where both husband and wife will work,
- 50% of technical staff will come with their families and only husband will work,
- 2% of total migrating population are assumed as service providers, and
- 50% of service providers will have families.

Table 4.3: Estimation of Migrant Population & Service Providers

S.No.	Workers	Population
I . Migrant Workers		
a)	Married Families (80 % of 750)	600
b)	Single (20 % of 750)	150
c)	Husband & Wife Working (80 % of 600)	480
d)	No. of Families where both husband and wife work (600/2)	300
e)	Families where only husband is working (300/2)	150
Total of 'I' { 300 x 5 (Avg. no. of family members + 150 x 5 (Av. no. of family members) + 150 } =		**2400**
II. Migrant Technical Staff		
a)	Married Families (50 % of 250)	125
b)	Single (50 % of 250)	125
Total of II (125 x 5 +125)		**250**
III. Service Providers		
a)	2 % of Total Population (2650)	530
b)	No. of service providers with families (50 % 530)	265
Total III		**795**
Peak Migrant Population (I+II+III)		**3445**

During peak construction phase, a population of about 3445 has been estimated to interfere based on the above assumptions. This additional population is likely to affect the existing infrastructure. Thus

adequate provisions will be made to maintain and improve the quality of life in labour camps as well as the people residing in the nearby areas.

The major impacts of immigration of labour population in the project site are increase in demand of resources like potable water, fuel, food materials and other daily commodities. Deterioration of air quality and increase in noise level due to increase in vehicular movement, generation of waste water and solid wastes, vulnerability of decease outbreak and social conflict among outsider and locals, threat on illegal tree cutting and poaching.

Quarrying of Construction Materials

There will be demand of 0.120 million tonnes of cement, 2.1 million cumecs of coarse aggregates, 0.105 million cumecs of fine aggregates and stones for masonry work. The initial requirement of construction materials for the project is envisaged from the existing quarry at the tip of Rangit III reservoir near Legship. The remaining quantity of construction material will be procured from the materials excavated from the under ground structures.

Major impact of quarrying from the project area is increase siltation of the river water. At the time of quarrying from these pondage area sand and other fine particles are likely to enter into the river water, which will increase turbidity and may affect the primary productivity of the river by reducing sunlight penetration. However, this impact will be limited only in the time of quarrying. The turbidity is likely to return to its original level after cessation of excavation of the sandy materials. The depression so created after excavation is likely to be filled up by the sediments/silts brought down by Rathang Chu. Therefore, no specific management measures are suggested for stabilization of borrow sites.

Movement and Operation of Construction Machinery

Various types of equipments, i.e., batching plants, mixing plants, crushers, earth movers, bulldozers, rollers etc. will be brought to the site during construction phase. The sitting of these construction equipments will require significant amount of space. In addition, space will be required for the storage of the construction materials. For this purpose, land will be temporarily acquired on lease basis for construction phase (3 years).

The site for storage of construction materials and equipments will be so selected that it does not acquire any forests land or agricultural land, away from water body and any human habitation so that causes minimum adverse impacts on surrounding environment.

Runoff from Construction Site / Increased Siltation

The runoff from the various construction sites will have a natural tendency to flow towards the natural drainage. The construction effluent with high turbidity from the barrage site during construction phase will flow towards Rathang Chu. This will increase turbidity level of river water. Increased turbidity level will reduce light penetration thus hamper the photosynthetic activity, which may results in reduction of primary productivity of the river water especially in winter season (October to March) when the discharge of Rathang Chu is low.

Muck Disposal

The total quantity of muck generated from open excavation is 3.87 lakhs cubic meters and from underground excavation is 2.31 lakhs cubic meter. Total quantity of muck generated with 40 % swelling factor worked out as 8.65 lakh cubic meters. Approximately 2.93 Lakh cubic meters of generated muck (1/3 rd of total muck generated) can be used for construction and the rest of the

muck is planned to be dumped in a pre-identified dumping sites, which are proposed to be rehabilitated subsequently in an environmentally sound manner.

Total six muck disposal sites are identified namely – MD1, MD2, MD3, MD4, MD5 and MD6. The MD Site - 1 is located near barrage area on the right bank of Rathang Chu, other two disposal sites namely MD–2 and MD- 3 are upstream from Yuksam village near the right bank of Rathang Chu, MD–4 is located on the left bank downstream Yuksam village near confluence of Nallah -1 meeting River Rathang Chu. Muck Disposal Sites – 5 and 6 are near downstream TRT (MD-5 on left bank and MD-6 on right bank.) Total 5.283 ha private land area is envisaged to be taken on lease bases for muck disposal facilities. The identified Muck Dumping facilities are provided with adequate retention walls and slopes for preventing any subsidence due to runoff as a result of heavy rains, which can adversely affect the river flow pattern and also riverine ecology. The Muck Dumping Sites Layout Plan is shown in Environmental Management Plan (Chapter – 5).

The increased vehicular movements near muck disposal sites may have adverse impacts on ambient air quality; however, the impact is not significant to cause major change in air quality of the area. Moreover, all the muck disposal sites are surrounded by vegetation cover, which will work as sink of vehicular emissions.

A detailed muck disposal plan is recommended for amelioration of above referred impacts and presented in chapter 5 (Environmental Management Plan).

Construction/Widening of Access Roads

The construction of new access road or widening of existing road can lead to the following impacts:

i) Removal of trees on slopes and re-working of the slopes in the immediate vicinity of the roads can induce landslides, because, with the removal of vegetal cover, erosive action of water gets pronounced and accelerates the process of soil erosion and formation of deep gullies.
ii) Soil and water contamination by oil, grease, fuel, etc. in equipment yards and asphalts plants.
iii) Air pollution by asphalt plants.
iv) Destruction of vegetation in the right of way occupied by the roads.
v) Contamination of the area due to unorganized disposal of construction wastes and solid wastes generated by construction worker.

Appropriate management measures for amelioration of adverse impacts are outlined in **Chapter 5** of this report.

b) Operation Phase

The Operation period, is likely to envisage impacts on the land use pattern due to diversion of forest land for non – forest purposes i.e., for construction and widening of roads, installation of surface components both upstream and downstream stretch of the river.

Diversion of Land/Change in Land Use Pattern

The project area will lead to permanent change in the land use pattern. The total land requirement for this project is 24.63 ha in which 9.63 ha is forest land and 15.00 ha is private land including muck disposal area. In addition, 20 ha.of land will be taken on lease, which is required for construction facilities like crushing, batching operations, material storing, workshop etc. The details of various category of land required are given below in **Table 4.4.**

Table 4.4: Details of Land Required for the Project

Sl. No	Type of Land	Village Yuksam (ha)	Village Lethang (ha)	Total Area (ha)
1.	Forests	-	-	9.63
2.	Dry Field	2.0156	5.224	7.24
3.	Cardamom Field	2.325	-	2.325
4.	Barren Land	0.152	-	0.152
5.	Scrub Land	-	-	5.283
Total:		**4.4926**	**5.224**	**24.63**

4.4 Impacts on Ecology

The impacts on the biodiversity of the area will be very low as it is a "Run of the River" project and only a 23.5 m. high (from river bed) barrage will be constructed across the river. Three radial gates will control the flood discharge. An environmental flow, which will be work out based on the requirement of the fish species reported from the project of stretch through (a separate study is conduced by IIT Delhi and will be maintained through out the year; moreover a fish ladder will be constructed to facilitate to and fro movement of fish through the barrage stretch. Only 0.8441 ha.of forest land will be inundated because of impoundment, which will have negligible loss of floral diversity or habitat of the wild animalof the area as entire area harbours similar kind of vegetation cover and provide habitat for the wild animals . These features of the project pose minimum threat to the biodiversity of the area.

Direct negative impacts will be mainly due to the construction site clearance /gradation or levelling of the site, excavation and blasting. Indirect impacts envisage due to influx of population and improved access. Details are depicted below.

4.4.1 Terrestrial Flora

4.4.1.1 Loss of Green Cover

The construction of the project facilities involves feeling of trees for the barrage site, access roads, submergence area and the construction of power house, colony etc. Total 597 numbers of trees are identified to cut from the project site. Details of the trees required to cut are presented in **Table 4.5.**

Table 4.5: Details of Trees Identified to Cut

Details	Tree Girth	Total Counts	Total No.
Conifers pp.	0-1	175	462
	1-2	198	
	2-3	89	
Broad Leaf Trees	3-4	39	70
	4-5	21	
	5-6	9	
	6-7	1	
	7-8	0	
	8-9	0	
Bamboo and Others	Clumps	65	65
Total			**597**

The species identified to cut are *Alnus nepalensis, Macaranga pustulata, Schima wallichiana, Albizzia stipulate, Maesa chisia, Castonopsis Tribuloides, Bauhinia veriegata, Cinnamomum cadatum , Engelhardtia spicata, Cedrala toona, Englehardtia spicata, Machilus odoratissima, Kharanay, Swer, Kholmaay, Jungunee.*

4.4.1.2 Increased Human Interferences

The direct impact of construction activity will be limited only in the vicinity of the construction sites. Approximately 3435 people including technical staff, workers and service providers are likely to congregate in the area during peak construction phase of the project. Such influx may have pressure on forests mainly for fuel wood. It can be assumed that the technical staff (aprx. 150 no.) will be of higher economic status and will live in a more urbanized environment, and will not use wood as fuel, if alternate sources of fuel are provided. However during construction time, some labourers are likely to have habit of using wood as fuel. In absence of alternative source of fuel, labour population will resort to cutting of trees and vegetation in areas close to various construction sites. Hence, to minimize such impacts, construction contractor will ensure alternate fuel (kerosene / LPG) to the construction workers. Assuming, 15 litres of kerosene requirement per family per month, for 1000 families the total demand will be around 1,80,000 litres per year. Assuming, annual demand of 1 cylinder per family per month, for 100 employees the total demand will escalate to around 1200 cylinders per year. The cost estimates for the same are covered in Environmental Management Plan outlined in Chapter -5 .

The other major impact on the surrounding vegetation will be increased level of human interferences. The workers may also cut trees to meet their other requirements like construction of houses, furniture etc. in such situation, indiscriminate use or wastage of wood is also may happen. Hence, it is necessary to implement adequate surveillance to ameliorate the adverse impacts on surrounding forests during project construction phase.

4.4.2 Terrestrial Fauna

4.4.2.1 Disturbance to Wildlife

During construction phase, a large number of machinery and construction labour will be active in the construction sites. The sittings of construction equipments, stores, labour camps, the operation of various construction equipments and construction work itself is likely to generate significant noise. The noise may scare the wild animals of near by forests patches and force them to migrate to other areas. For ensuring the safety of wild animals and birds, a comprehensive Biodiversity Conservation and Management Plan is presented in Chapter 5.

4.4.3 Aquatic Ecology

a) Construction Phase

The construction of the barrage will involve large-scale extraction of sand from the river bed at site located proximity to the barrage site. Extraction of gravel and sand may cause considerable damage to aquatic life by destabilizing the sub-stratum, increasing the turbidity of water, silting of the channel bottom and modifying the flow. These alterations may change the composition and balance of existing aquatic system of the immediate down stream of barrage of Rathang Chu. The stones and pebbles at the river substratum, which are now serving as anchorage and habitat to the invertebrates will get disturbed, thus, the ecology of the river may adversely affected.

b) Operation Phase

Construction of 23.5 m high barrage and diversion of river water through a tunnel up to the TRT outlet will lead to modification in the immediate downstream of barrage. Following are some of the likely impacts, which are envisaged to alter the habitat:

General Impact on Habitat:

- Reduction in river flow between barrage and TRT about 2.5 km long project stretch will eventually change the hydrological regime of the stretch.

- Frequent water level fluctuations and reduced flow may change the physical, chemical and biological characteristics of the river water.

- The Dissolved Oxygen (DO) levels may deplete in the immediate downstream of TRT, due to diversion of river water through tunnels, which may have stress on aquatic ecosystem. The DO level of project stretch is around is observed around 18 mg/l. which is very high, therefore, it is expected that river water will regain the DO level within a small run and have minimum impact.

- Increase in turbidity and the reduction of flow in the project stretch may increase sedimentation, which may alter characteristic of river bottom and its nutrient cycle. This may lead to change in prevailing habitat condition.

- The change in habitat conditions may alter the food chain organism specifically the benthic community, which are the main food component of the fish species reported from the project stretch.

Creation of Additional Habitat for Aquatic Life and Birds

The construction of barrage, and consequently the formation of impoundments increases the area covered with water surface. This will create additional habitat for aquatic life, especially for water birds. Receding water outlines will create drying mudflats that provide suitable feeding sites for migratory birds and resident species, which will enhance the biodiversity of the area.

Impacts on Fishes

Construction Phase:

1. No major impacts are anticipated fish fauna of the river by restriction to and fro movement across the barrage structure and reduction of flow in its immediate down stream till TRT. To minimize these hindrances, a 'pool and riffle' kind fish ladder is proposed to be installed. Moreover, an environmental flow of one cumec is designed to maintained through out the year in the project stretch. Detail is given in Chapter 5

2. No major fisheries are present in this stretch of river. Whatever aquatic life are present in this stretch of river are not localized in any certain point. It is expected that during the construction period the fish fauna will be migrated to other undisturbed stretches. Therefore, impact will not be significant.

The mitigation measures of fish and fisheries is delineated separately in Chapter 5 under Fisheries Conservation and Management Plan.

4.5 Noise and Vibration

Source and Types of Impacts

Sources of noise are mainly from the movement and operation of construction vehicles and equipments. Other sources of noise will be the blasting , quarrying and crushing activities. Details are described below.

Impacts Due to Ground Vibrations

Blasting activity will generate vibrations and instantaneous noise. The explosive energy generated during blasting sets up a seismic wave within the surface, which may affect the structures and cause discomfort to local inhabitants. When an explosive is fired in a hole, stress waves traverse in various directions, also causes the rock particles to oscillate. Such noise and vibration will likely affect the wildlife and nearby human population. Such impact will not be severe and will be restricted only in and around the construction site. Moreover, no human habitation is present in the close proximity of any construction site. It is expected that wildlife of the near by forests patches will likely move away from the source of noise and eventually will returns to the area when construction is complete. Therefore, the impact due to construction noise will be restricted only in the noisy construction phase of the project (about two and half years).

Impacts on Labour:

The effect of high noise levels on the operating personnel /and who ever are on the direct exposure may have adverse impact i.e., may develop hearing problem. (It is known that a continuous exposure to high noise levels above 90dB (A) affects the hearing acuity of the workers/operators.) To prevent these effects, the exposure period of affected persons will be limited as per the recommendation of Occupational Safety and Health Administration (OSHA). Detail management plan of noisy construction is presented in Chapter 5.

4.6 Air Environment

a) Construction Phase

The major sources of air pollution during construction phase are:

1. Pollution due to fuel combustion in construction equipments.
2. Emission from stone crushers.
3. Fugitive emissions from other miscellaneous sources.

Pollution due to Fuel Combustion

The operation of various construction equipments requires combustion of fuel mainly diesel. The major pollutants, which gets emitted as a result of diesel combustion is SO_2. The SPM (Suspended Particulate Matter) emissions are minimal due to low ash content in diesel.

Emissions from Crushers

Crusher will be used to utilize existing stone as construction material; the operation of the crusher is likely to generate fugitive emissions, which can move even up to one kilometer in predominant wind direction. No major adverse impacts on this account are anticipated since, there are no major settlements close to the Barrage site, and Yuksam village is also at a distance of three kilometer from barrage site. However, during the layout design, care will be taken to ensure that the labour

camp, project colonies are located on the leeward direction and outside the impact zone (say about two kilometer on the wind direction) of crushers. Wet Crushers will be used instead of dry crushers to reduce and minimize fugitive dust emissions.

Fugitive Emissions from Various Sources

During construction phase, vehicular movement will increase. Moreover, construction materials like sand, fine aggregate etc. also will be stored at various sites of construction. Normally, due to winds, especially when in the dry months, some of the stored material can get entrained in the atmosphere. However, such impacts are visible only in and around the storage sites. The impacts on this account are generally, insignificant and temporary in nature.

b) Operation Phase

Since the project does not involve any air emissions during operation, it will not have any negative impact on the air quality of the region.

4.7 Water Environment

a) Construction Phase

Effluent from Project Colony

The major sources of water pollution during project construction are the sewage generated from the labour camps/colonies. The project construction is likely to last for a period of three years (36 months). As mentioned earlier, about 1000 workers will be required for construction work. Among these workers many will be from surrounding area as the employment opportunities in the area are limited so many will be interested to get work in the proposed activity. Generally, in any such construction work, the contractor brings their own skilled labour from outside. However, it is only in the unskilled category, that locals get employment. The labour and technical staff population is likely to be congregated in two colonies one at Barrage site and other one near Power house site.

The peak water requirement during the construction phase of the project is estimated to as 465 KLD by taking 135 lpcd (as per CPHEEO norms for piped water supply) into account for 3435 i.e peak population as estimated above. It is assumed that about 80 % of the water supplied will be generated as sewage. The total sewage generation will be 80 % of 465 KLD, which is about 372 KLD . The disposal of sewage without treatment may lead to adverse impacts on the receiving water bodies or on land (in case of land disposal). Moreover, in such project construction also leads to mushrooming of various allied activities to meet the demands of the immigrant labour population in the project area, which also generate waste water.

It is recommended to treat the sewage prior to disposal. During construction phase, normally large-scale secondary treatment facilities are not commissioned, because they are rendered useless, once the construction activities are over. In the present project, it is proposed to commission adequate number of septic tanks for treatment of sewage. The details are covered in Chapter 5 of this Report.
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Impacts due to Runoff from Construction Sites

Substantial quantities of water will be used in the construction activities. With regards to water quality, waste water from construction activities will mostly contain suspended impurities. Adequate measures will be adopted to remove the suspended solids from the wastewater before discharge it into water body.

Similarly, effluents due to washing from vehicle parking area, workshop, etc. will have high concentration of oil and grease. Though the effluent quality is too small to cause any adverse impact. However, it is still recommended to treat the effluent from these units/areas by oil and separator unit, to ameliorate even the marginal adverse impacts likely to accrue on this account.

b) Operation Phase

Effluent from Project Colony

During operation phase, only source of liquid waste is sewage, generated from staff colony and office premises. In the operation phase expected number of project staff is 160. The peak water demand is estimated to be 22,000 liters per day (i.e.,160 persons x 135 liters per capita per day). The sewage generated will be 80 percent of the amount of water consumed per day. The total sewage produced will be 80 percent of 22,000 liters per day, which is 17,600 liters per day. The expected BOD load will be four kilogram per day. The disposal of sewage without treatment may lead to adverse impacts on the receiving water bodies or land. Thus, it is recommended to treat the sewage prior to disposal and therefore, a sewage treatment plant is proposed to be installed.

Impacts Due to Change in Hydrological Regime

The total catchments area of the proposed project is 360 sq km. The minimum flow during March reduces to 0.86 m^3/sec; maximum flow during August and October month increases to 80.00 m^3/sec. General flow of the river is close to 28.39 m^3/sec for 50 percent of the year. The flow of the river is about 24.45 m^3/sec. for 90 percent of the year; however, for a small duration, the flow averages to 26.50 m^3/sec.

No major fisheries or localized fish or any other aquatic species are present in the project stretch or its immediate up-down stream stretch of Rathang Chu. Therefore, impact of proposed project on the aquatic ecology of the river is considered to be insignificant. Furthermore, the proposed mitigation measures will also alleviate the adverse impacts on aquatic ecosystem of the project foreseen.

The quality of water is regarded as far an important issue, not only for aquatic life but also for the multi-use of water by riverine and residents. Though, the people residing near to the Lethang Hydro project do not depend on river water. Moreover, a downstream arrangement will be made to release a minimum environmental flow through out the year by considering the ecological and riparian demand.

4.8 Socio-Economic Environment

a) Construction Phase

The construction phase will last about three years. Main adverse impact due to congregation of about 3435 people during the construction phase is detailed in various sections of this report , the basic problem relates to management this large population. However, the construction phase is a temporary phase. The benefits of the project outrage the temporary discomfort. However, the project will have a large number of jobs opportunities to the local population, will provide improve facilities of basic amenities and infrastructures like tele-communication, accessibility, education and health facilities. Job opportunities will drastically improve in this area.

The availability of infrastructure is generally a problem during the initial construction phase. Though the construction workers can be subsidized by providing health, education etc. The facilities of desired quality are often not made available in the initial stage. Therefore, adequate measures will

be taken at the very start of the project to provide basic amenities like water supply, sewage treatment, housing, fuel, medical and educational facilities etc.

Increased Incidence of Water-Related Diseases

There is a close relationship between water and public health. The commissioning of project can have both beneficial and adverse impacts on the health of the people in and around the project area.

The negative impacts envisaged are increase certain vector-borne diseases like malaria. The following factors are likely to responsible for vector-borne diseases:

a) Aggregation of labour population.
b) Excavations and water accumulation.

Aggregation of Labour Population

The health risks due to congregation of imported labour of heterogeneous health status at the construction sites. During the construction phase, new groups come and go constantly keeping the human population in a flux. These people, if housed in temporary dwelling without proper sanitary conditions and water supply may pose health hazard, if precautions are not taken the vector-borne disease epidemiology may show sudden or long lasting change. Many of the immigrant population may be the carrier and reservoir of infection for various communicable diseases. Once they settle in labour camps/colonies, increased incidence of various diseases may occur. Population migration increase by actual or possible opportunities for work can aggravate problems as a result of housing difficulties, over crowding, rise in cost of living and some unpredicted social problem, as well as the introduction of new sources of diseases or new diseases or immigrants immunologically susceptible to the endemic diseases prevalent in the areas of development. The overcrowding may lead to increased incidence of respiratory infection and tuberculosis. The scarcity of water in the houses and the absence of sanitary facilities in labour camps may be responsible for increased prevalence of gastro-enteritis and other diarrhea diseases. This aspect needs to be looked into with precaution, and effort must be made to ensure that a thorough check up of the labour population congregating in the area is conducted. Those affected by any aliments need to be properly quarantined depending on the aliment with which they are suffering.

Excavations

The excavation of earth from borrow pits etc. is one of the major factor for the increase in prevalence of malaria. After the excavation of sand/earth the borrow areas if left without treatment, water will be collected. These pools of water then will serve as breeding grounds for mosquitoes. However, the borrow areas are mainly in the river bed, in close proximity to the barrage site. These depressions are likely to be filled up during the subsequent floods. But, till the time, these borrow sites do not get filled up with the silt and clay being carried by the river because they may serve as a potential breeding habitats for mosquitoes.

b) Operation Phase

The proposed project is for development of a reliable power network; therefore, all communities of the society rural and urban will be benefited. Beneficial impacts of the project are envision on socioeconomic conditions are rural and urban electrification. Industrial development may take place, which will trigger the economic growth in this backward region of the state. These industrial activities will create employment for local people, boosting their economic status. However, health and safety impacts such as accidents due to electrocution, fires, and explosions, as well as exposure to electromagnetic fields along the power evacuation line alignment and at the power house, may occur.