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EXECUTIVE SUMMARY

ENVIRONMENTAL IMPACT ASSESSMENT AND MANAGEMENT PLAN FOR TEESTA STAGE-IV H.E. PROJECT SIKKIM

Prepared for :
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1. INTRODUCTION

Teesta Stage-IV HE project is one of the many HE projects proposed on Teesta river. The project is proposed between Teesta Stage-III HE Project (under construction) and Teesta Stage-V HE project, which has already been commissioned. The project is located in Mangan subdivision of North district of Sikkim (**Fig.1**). The Teesta H.E. Project (Stage-IV) envisages utilization of gross head of 165.50 m by construction of a concrete gravity dam at a location near village Chandey and Hee-Gythang just downstream of the confluence of Runchu and powerhouse near Village Phidang in the north district of Sikkim. This is a run of the river hydropower scheme. Detailed salient features for Teesta Stage-IV are given in Table 1.

Table 1 Salient Features of the Teesta Stage-IV HE Project

LOCATION:		
State	:	Sikkim
District	:	North Sikkim
Dam	:	Lat.-27°28'50" N, Long.-88°31' 23" E
Power House	:	Lat.-27°25'N , Long.- 88°30'35''E
Nearest Town	:	Mangan (Distt. HQ)
Nearest Railway Station	:	New Jalpaiguri / Siliguri (West Bengal)
Nearest Airport	:	Bagdogra (West Bengal)
HYDROLOGY:		
River	:	Teesta
Catchment Area	:	3910 sq km
Average Annual Rainfall	:	2546 mm
Design flood	:	10600 m^3/s
River diversion design flood	:	3800 m^3/s
RESERVOIR:		
Full reservoir level	:	EL 755.00 m
Minimum draw down level	:	EL 740.00 m
Gross storage	:	18.6 MCM
Live storage	:	8.2 MCM
Length of reservoir	:	4.37 Km along Teesta 644 m along Tolungchhu
DIVERSION TUNNELS:		
Number	:	Two

Shape	:	Horse –Shoe type
Diameter (finished)	:	12.5 m
Length of DT	:	681 m (DT-1) & 593 m (DT-2)

DAM:

Location	:	D/s of confluence of Runchu with Teesta
Type	:	Concrete Gravity Dam
Length of dam at Top	:	197.20 m
Max. Height above river bed level	:	65 m
Max. Height above deepest bed level	:	108.50 m

SPILLWAY:

Type	:	Gated Low Level Sluice Spillway
Design flood	:	10600 m³/s
Crest of spillway	:	EL 716.00 m
Number and size of sluices	:	Five nos. 9m x 14.5m
Energy dissipation	:	Flip bucket type

COFFER DAMS

Upstream:

Top Level	:	El. 728.00 m
Height of Coffer Dam	:	32 m
Length at the Top	:	160m

Downstream:

Top Level	:	El. 710.00 m
Height of Coffer Dam	:	18 m
Length at the Top	:	110m

INTAKE:

Number & size of inlets	:	Four Nos. each of size 6.5 m x 6.5 m
Discharge capacity	:	480 m^3/s
Invert level	:	EL 726.00 m

DESILITING CHAMBERS:

Number & type	:	Four Nos., Dufour
Length	:	360 m
Size	:	17 m x 21.5 m
Minimum particle size to be removed	:	90% of 0.2 mm & above
Crown Level	:	El. 736.75 m
Level of GOC	:	El. 756.00 m

HEAD RACE TUNNEL:

Number and Diameter (finished)	:	2 Nos. / 8 m dia
Shape	:	Horse-shoe
Length	:	6581.5 m (HRT-I) & 6476 m (HRT-2)
Total Discharging capacity	:	410.76 m^3/s

SILT FLUSHING TUNNEL:

Outlet Level	:	EL. 704.50 m
Shape & Size of Main Tunnel	:	D-shape, 4.5m X 5.0m
Shape & Size of Branch Tunnel	:	D-shape, 2.0m X 3.0m & 3.0m X 4.0m

Level of GOC	:	El. 715 m

SURGE SHAFT:

Number and Type	:	2 Nos. Underground with restricted orifice
Internal diameter	:	23 m
Height of surge shaft	:	116.50 m (EL. 796.50m- EL. 680.00m)
Maximum upsurge level	:	EL 795.00m
Maximum down surge level	:	EL 685.00m

PRESSURE SHAFTS:

Number and type	:	Four Nos. vertical shafts steel lined
Diameter	:	4.8 m
Height	:	110.2 m approx.
Top Horizontal Length	:	101m to 145m
Bottom Horizontal Length	:	59 m

POWER HOUSE:

Type	:	Underground
Installed capacity	:	520 MW
Number and capacity of units	:	4 nos. of 130 MW each
Size of machine hall	:	166.2 m x 23.5 m x 54 m
Size of transformer cavern	:	123.2m x 16.5 m x 19 m
Length of Service Bay	:	38 m
Elevation of Service bay	:	El. 577.70 m
Length of control room	:	23 m
Spacing of unit axis	:	23.8 m
Maximum Net head	:	159.09 m
Rated net head	:	151.81m (Oct.-May) / 141.81m (June- Sept.)
Main Inlet Valve	:	4m diameter, Butterfly biplane lattice type
Capacity of E.O.T. Cranes in service bay	:	2 x 225 ton (Main)/ 35 ton (Auxiliary)
Capacity of EOT crane in Transformer hall	:	75 ton (Main) / 20 ton

TURBINE, GENERATORS & TRANSFORMERS:

Turbine Type	:	Vertical Francis
Turbine discharge	:	102.69 Cumec (at 141.81m Head)
Discharge diameter of runner	:	3.6 m
Speed of Turbine	:	187.5 RPM
Generation Voltage	:	11 kV
Step up Transformer	:	53 MVA, single phase, 11kV/ 400/ √3 kV
Number of Transformer	:	10
Transmission Voltage	:	400 kV

TAILRACE TUNNELS:

Shape	:	Horse Shoe
Number and Diameter (finished)	:	2 Nos./ 8 m dia
Length	:	622 m (TRT-1) & 627 m (TRT-2)
Branch TRT	:	4 no. 5.5 m dia, HS shape
Max. Tail water level	:	EL 584.52 m
Min. tail water level	:	EL 582.24 m
Outlet Weir Level	:	El. 582.00 m

D/S Surge gallery	:	2nos. 6 m dia D-shape , 360m long each
Max. D/S upsurge Level	:	EL. 604.00 m
Max. D/S downsurge Level	:	EL. 568.60 m
GIS / POTYARD:		
Type	:	Indoor type located outside the caverns
Dimensions of GIS/ Potyard Complex	:	125 m x 40 m
Type of Switchgear	:	400 kV Gas Insulated Type
No. of bays	:	7
Connecting Cable	:	Single phase 400 kV XLPE cables, 13 Nos.
Capacity of GIS Crane	:	1 x 5 ton
POWER BENEFITS:		
Installed capacity	:	520 MW
Firm Power	:	64.3 MW
Annual energy production in a 90% dependable year	:	2373 MU (At 95% machine availability)
Load Factor	:	51.14 % (At 95% machine availability)
LAND REQUIREMENT:		
Total Land	:	324.07 ha
Govt./ Forest Land	:	143.49 ha
Private Land	:	180.58 ha
SUBMERGENCE:		
Total Land under submergence	:	105.37 ha
Govt./ Forest Land	:	68.82 ha
Private Land	:	36.55 ha
PROJECT COST (At July 2009 PL):		
Total Cost	:	Rs. 3594.74 Cr
Civil Works	:	Rs. 2349.21 Cr
E&M Works	:	Rs. 558.69 Cr
IDC & FC	:	Rs. 686.84 Cr
COST OF GENERATION:		
Cost of generation at Bus bar (including 12% free power to state and return of equity)	:	Rs. 2.32 /Unit
Levellised Tariff	:	Rs. 3.65 / Unit

The main objective of the present study is to carry out the Comprehensive Environmental Impact Assessment (EIA) for the proposed Teesta Stage-IV HE project and based on these impacts, to prepare various mitigative plans and also to meet the Environmental clearance criteria of Ministry of Environment and Forests, Government of India.

2. CONCEPTS & METHODOLOGY

Standard methodologies of Environment Impact Assessment were followed in the EIA study of Teesta Stage-IV H.E. Project. The scope of the present study is based on the Terms of Reference (TOR) approved by Ministry of Environment & Forests (MOEF), Govt. of India for preparation of EIA & EMP reports. All the methods were structured for the identification, collection and organization of environmental impact data. The information thus gathered has been analysed and presented in the form of a number of visual formats for an easy interpretation and decision-making. The study was carried out in catchment area, influence zone (10 km radius) and project areas. Spatial database on physiographic features were taken from various sources including Survey of India (SOI) topographic sheets, satellite data and analysed with Geographic Information System (GIS) tools.

The regional geology around the project area highlighting geomorphology, stratigraphy and structural features were based on the existing information on these aspects contained in the Detailed Project Report (NHPC, 2010) of the project and substantiated by primary surveys in the project area. In addition, the important parameters of seismicity of the region was assessed using published literature on seismic history and seismo-tectonic nature of different structural features. On hydro-meteorology the data on 10-daily average water discharge were available at 9 gauge stations. This data set was utilized for calculating monthly and annual water discharge of Teesta Stage-IV HE Project. Flood peaks are also discussed using the instantaneous flood peaks from the discharge data at Teesta IV (NHPC-DPR, 2010).

Forest types and various plant species were recorded during the field visits during 2006 to 2007. Besides the primary surveys in the project areas, the floristic data for the catchment study was procured from the published literature. To understand the community structure, vegetation sampling was carried out at different locations in the project area. For sampling various strata of vegetation, the area was divided into two sites/stands viz., powerhouse site, right bank of Teesta river and Dam site, left bank of Teesta river. Phytosociological studies were carried out at two sites with respect to frequency, density, total basal cover, IVI and diversity index using standard methods. In order to collect the information on the fauna (mammals, birds, herpetofauna, butterflies) in the catchment area of Teesta river, primary as well secondary sources were utilized.

The soils of project sites (proposed dam site to power house site) and catchment are classified by using standard method of National Bureau of Soil Survey (NBSS), 1998. The soil samples were collected from 6 sites, of which, 3 belong to the proposed dam area (S1, S2, S3) and 3 to the power house area (S4, S5, S6) and analysed for physical (moisture content, water holding capacity, bulk density and pore size measurement (soil texture), chemical (pH, conductivity, chloride, phosphate, nitrate and organic matter) and biological characteristics (fungi, bacteria) using standard methodology.

The water sampling was conducted at three different locations including downstream of the dam, the proposed dam site and upstream of the dam site. The sampling was carried out for four seasons (winter, pre-monsoon, monsoon and post-monsoon). A total of 17 physical and chemical parameters and 6 biological parameters were studied to assess the river water quality. The study of fish fauna was carried out in the Teesta and its tributaries.

The ambient air characteristics (SPM, NO_2 and SO_2) were recorded with the help of Respirable Dust Sampler (Envirotech APM 460 BL) with gaseous sampling attachment (APM 411TE). The data was recorded at different locations viz., Mangan, dam site (near Hee Gyathang village) and powerhouse (near Phidang village). In addition, noise level and vehicular movement were also analysed in and around the project areas.

Socio-economic profile includes brief description of Sikkim, North Sikkim district and the Dzongu area in which project components are located. History, cultural aspects, ethnic values and local life of Sikkim and North Sikkim district are mentioned. A detailed account on the demography, education, occupation and other amenities of the villages located in 10 km radius and project affected villages is discussed in EIA report. In order to collect baseline data for preparation of R & R plan a door to door survey for project affected families was carried out for the proposed project.

The vulnerability of an ecosystem to various impacts resulting from an activity or multiple activities was identified and accordingly impacts were predicted.

3. PHYSIOGRAPHY

The physiography of a region refers to geomorphological features of the area like hills, mountains, peaks, drainage network, relief, slopes and aspects. It also includes glacier cover, recent depositional and erosional landforms. In the present study various physiographic parameters were analysed through remote sensing and GIS techniques. A data base of different aspects was formulated for all constituent sub-watersheds of Teesta river catchment.

3.1 Drainage Network

The drainage network in the Teesta basin is complex with rectangular pattern prevalent in the upper part of the catchment. The project area and its catchment lie in the Chhombo Chhu / Teesta river upstream of Zemu Chhu-Teesta confluence, Zemu Chhu, and Teesta river (Lachen Chhu) between Lachen and Chungthang sub-systems. Chhombo Chhu (Teesta River) Sub-system is the source of the main Teesta river system and originating from Khangchung Chho (5,280 m) the Teesta river flows as Chhombo Chhu towards the northwest. The Lasha Chhu, a glacier fed and lake fed tributary of Teesta river (Chhombo Chhu) joins on its left bank. This stream has a large catchment and most part of the catchment is barren rocky land or covered with moraines. This stream confluences with Chombo Chhu at 3840 m. Thangu and Bomcho are two settlement areas nearby its confluence. Kalep Chhu is a lake and glacierfed stream, flowing in sickle shaped channel, whose headwater regions lie above 5000 m. Fairly dense mixed jungle extends on its right bank from its confluence point at 3648 m up to an elevation of 4600 m (**Fig. 2**).

There are a number of glaciers and glacial lakes in the Teesta Stage-IV catchment. The longest glacier in the Sikkim Himalaya is the Zemu Glacier in the Zemu Chhu Catchment in North Sikkim. Other glaciers in the Zemu Chhu catchment are Siniolchu Glacier, Simvo Glacier, Twins Glacier, Nepal Gap Glacier, Hidden Glacier, Chanson Glacier, East Langpo Glacier, Jongsang Glacier, South and North Lhonak Glaciers and Khorakhang Glacier. The glaciers feeding the main channel of Teesta are Teesta Khangse, Yuhle Khangse, Tasha Khangse, Chhuma Khangse and Chento Khangse. The important glacial lakes present in the project catchment are Khangchung Chho, Chho Lhamo, Gurudongmar Chho, Gayum Chhona, Khora Chho, and Lhonak Chhu. Besides there are several small streams feeding the tributaries of Teesta river in the catchment

3.2 Gradient Profile of Teesta River in the Catchment

The entire profile covers a distance up to Dik Chhu confluence of about 117 km. In the initial 28 km stretch Teesta river flows westward in a gently sloping (1:44) plain. Then with the change in the course towards south the gradient increases to 1:17 in the next 43 km stretch up to the downstream of Tarum Chhu confluence. Further 31 km downstream the river flows in a channel with gradient of 1:25. Downstream of this stretch up to the Dikchu confluence the river channel has a gradient of 1:71. In the reservoir area the channel gradient is 1:70. The gradient of the major tributary stream Zemu Chhu (considering the Lhonak Chhu portion) is higher (1:13) compared to that of Teesta Chhu. Other tributary streams flow through channels of higher gradient viz. Lachung Chhu (1:14), Rangyong Chhu (1:10), Chakung Chhu (1:5), and Rangrang Chhu (1:4).

3.3 Slope

The maximum area in the catchment is covered by steep slopes and it amounts to 36.3% of the catchment. Moderately steep slope category also covers large part (27.5%) of the catchment. Strongly sloping category covers 12.1% of the catchment and Very steep slopes also have similar coverage (11.8%). The escarpments cover 0.8% of the catchment (**Fig. 3**).

3.4 Elevation and Aspect

Starting from the bed level (El. 695 m) at the dam site up to the Khangchendzonga peak (8598 m) the catchment area covers 3909.46 sq km. This catchment has been divided into thirteen elevational bands. The lowest elevation band extends from 695 m to 1000 m elevation, whereas the highest band is spread between 7600 to 8598 m.

The area (on catchment area proportionate basis) covered under different aspect categories. Most part of the catchment (41.8%) are flat lands (<30% slope). Slopes with NE-E-SE and SE-S-SW aspects have equal coverage; each of these aspects covers 17% of the catchment. While SW-W-NW facing slopes cover 14.6%, the NW-N-NE slopes cover 10.4% of the catchment (**Fig. 4**).

4. HYDRO-METEOROLOGY

The hydro-meteorological condition of a region is defined by several factors viz. rainfall, temperature, wind speed and direction, evapo-transpiration, drainage network, vegetation, soil and rock cover in the catchment. These factors control water discharge in a river basin. The water

discharge in a river and the sediment input from the catchment are the most important factors that decide the viability of any hydroelectric project proposed on it. The average monthly rainfall calculated from the rain gauge stations at Thangu, Yumthang, Lachen, Lachung, Chungthang, Singhik, Tolung Chu, Sankalang and Dikchu. Singhik station receives highest precipitation. Maximum rainfall is recorded during July particularly below 1500 m elevation. Singhik receives 659 mm in July and 606 mm in September likewise at Tolung Chu receives 590mm in July and 620mm in September. Singhik, Tolung Chu, Sankalang and Lachen receives high rainfall (166 - 336 mm) is received during March compared to February and April.

In the present study, discharge data from the four available sites was used for water discharge analysis. The average discharge in Teesta river during the monsoon months (June to Sept) vary from 148.69 to 263.85 cumec, 351.12 to 595.51 cumec, 416.76 to 729.45 cumec and 537.17 to 843.41 cumec at Teesta-III, Sakalang, Dik Chu and Teesta-VI sites, respectively. The variation of discharge is high in the month of August. During 1984-1985 to 2007-2008 the water discharge during August varied from 265.29 cumec to 937.64 cumec. In the mid of May, 1994-1995 and beginning of October, 2001-2002, the water discharge was 479.97 cumec and 529.21 cumec, respectively. Such high discharge in Teesta river during pre-monsoon (Mar-May) and post-monsoon (Oct-Nov) is due to occasional heavy rain. The winter (Dec-Feb) discharge in the river vary from 42.47 cumec to 146.70 cumec. The mean of average 10-daily discharge pattern shows that, the peak discharge is in the month of August and average discharge in this month is 908.82 cumec, whereas the average winter (Dec-Feb) discharge varied from 45.99 cumec in the month of January to 55.14 cumec in the month of December.

The sediment yield in a catchment area is controlled by several factors including landslide and flooding. Seismically triggered landslide may result in natural damming of tributaries. The breaching of such dam would supply huge sediment load into a reservoir. Maximum silt load in the river is recorded during July. Of the total silt load the proportion of coarse silt is high in all the months and that of medium silt is low. The fine silt fraction has concentration higher than the medium silt during monsoon. The average annual suspended load at Dikchu works out to be 497.2 Ham of which coarse, medium and fine constitute 267.7 Ham (53.8%), 127.3 Ham (25.6%) and 102.1 Ham (20.5%) respectively. Assuming 20% of the sediment load is transported as bed load, the total annual sediment load (suspended + bed load) comes out to be 597.0 Ham.

5. SOIL

The catchment area of the proposed Teesta Stage-IV H.E. project has 41 soil series belonging to 15 soil families. Soil series Thangu-Rockoutcrop is the most predominant in the catchment, covering about 34.27% of the total catchment. This soil series belongs to Typic Dystrocrepts group and moderately shallow, light textured and extremely gravelly in nature (**Fig. 5**).

The area from the dam to various project activity sites and the immediate vicinity are covered with 37 soil series belong to 18 soil families. Soil series Mangjing-Dharamdin, Dikling-Hilley and Rumtek-Tumin are predominant in this area, covering about 23% of total area. These series are associated with 2 families - Typic Endoaquepts and Humic Hapludults. The river Teesta in this stretch flows over the Mangjing-Dharamdin series. Also, the proposed dam and the power house sites are located at the sites, covered by this series. The soils are coarse loamy and mixed thermic. These soil types are good for maize, rice and wheat crops. Other agricultural crops like mustards, vegetables, ginger, millets may be grown effectively through proper soil conservation measures.

Among the different soil texture categories, 'very fine sand' is predominant constituent of soil and accounts for 24.97 to 38.54% of soil composition. The soils at different sites were rich in 'fine silt with clay' (8.11 – 12.53%), which results in the fertility of soils. Moisture contents ranged from 17.44% to 36.16% with maximum at site S2 near the proposed dam site, which had good forest cover. The maximum water holding capacity was recorded at site S2 and the minimum at site S3. The lowest bulk densities were recorded at sites S4 and S5, where quantity of pebbles and cobbles were high. The soils from the proposed dam sites with high silt, moisture contents and water holding capacity support a good forest cover.

6. GEOLOGY AND SEISMICITY

North Sikkim is characterized by sharp crested snow bound mountains. The ridges trend both in E-W and N-S directions and Teesta River flows from north to south in Sikkim. The important tributaries of Teesta are Lachung Chhu, Tolung Chhu (Rangyong Chhu), Chakung Chhu, Rangit Chhu and their numerous tributaries. Most of the river valleys near their source regions are U-shaped and small streams have formed deep gorges. Many lakes and glaciers are present above 3,900 m.

Four distinct tectonic belts are enshrined in Darjeeling-Sikkim Himalaya from lower southern tectonic level to higher northern tectonic level. These are: i) Foot Hill Belt: Composed of Siwalik Group, Gondwana Group and impersistent Buxa Formation of Daling Group; ii) Inner Belt: Comprises the metamorphic rocks of Daling Group and Lingtse Granite Gneiss, containing "tectonic windows" in the areas of deep erosion and structural culminations where the Gondwana and Buxa rocks occur as inliers within the Daling metamorphites; iii) Axial Belt: defined by the high grade metamorphites and gneisses with intrusive tourmaline granite; iv) Trans-Axial Belt: represented by the Tethyan sequence that comprises the Mt. Everest Pelites and Everest limestone.

The lithounits present in Sikkim Himalaya occur in an arcuate regional fold pattern, where the core is occupied by the schistose rocks of the Lesser Himalayan units (Daling Group and other related group of rocks of Inner belt) and the distal parts (axial belt) occupied by the group of medium to high grade crystalline rocks of Higher Himalaya (Gansser, 1964). This axial belt is named as the Central Crystalline Complex of Sikkim and is chiefly comprised of gneissic rocks. The Central Crystalline gneissic complex of Sikkim forms the basement for the fossiliferous metasediments of the Tethyan sedimentary sequence (Trans-Himalaya) further north.

The main lithounits exposed in the vicinity of Teesta Stage-IV hydroelectric project are Daling Group of metavolcanosedimentaries, Lingtse Granite Gneiss and Central Crystalline Complex comprising high grade Central Crystalline (CCG), high grade metasedimentary units and some calc-silicate gneissis rocks with impure marble. The proposed project is located in the area that exposes the Daling Group of metasedimentaries with minor metavolcanoclastics. The Daling Group of rocks comprise metawacke, chlorite-sericite-phyllite intercalated with chlorite-quartzites, quartz-biotite schists and their metamorphic equivalents up to garnet-staurolite kyanite grade. The metawacke units are schistose in nature and are highly sheared. These are found to be associated with Lingtse Gneiss at some places.

On the left bank of Teesta at the dam site, a rocky escarpment extends for 180 m between 699 and 750m elevation. Above 750 m the slope is about 40° and is blanketed with a thick (20 to 30m) cover of slope wash material. The right bank slope is also an escarpment between the elevation 699 and 750 m. Above this elevation the slope is steep (50°) and covered with dense vegetation. The bedrock is medium grade metamorphosed garnetiferous quartz mica schist with thin quartz veins and

lenses of quartz. At powerhouse complex, there are rocky escarpments on both the banks of river Teesta. Between 810 and 960 m elevation the slope is covered by 15-20 m thick pile of slope wash material. Phyllitic quartzite and its variant with persistent bands of micaceous phyllite/ schist belonging to Daling Group are present in the area. Garnetiferous mica schist belonging to Daling Group and Quartz Biotite Gneiss of High Grade Metamorphic Group are exposed in the reservoir area. The former lithounit is present near the dam site, is foliated and jointed and slightly weathered. The latter rock unit is exposed in most part of the reservoir area.

The north dipping E-W nodal plane is comparable with the MBT and is the preferred fault-plane (De, 2000). These observations suggest that the MBT is seismogenic in this part of the Himalaya. The seismicity trend in Sikkim Himalaya and its foredeep shows that the Teesta, Gangtok and Yamuna lineaments and the Goalpara wedge of the Shillong massif are seismically active.

7. LAND USE AND LAND COVER

The land use and land cover of the Teesta stage-IV catchment area includes barren/ rocky, snow, scrub/ alpine scrub, forest lands, settlements/cultivation and water body. In the entire catchment the settlements and cultivation constitute just 0.1% geographical area (385.82 ha) of the total catchment. Cultivation in the region is restricted to the areas around dam site in Mangan, Ligthem, Manu, etc. Forests (dense and open type) comprise 22.4 per cent of the total geographic area of the project catchment. Dense forests in the catchment constitute 5.2 per cent area, restricted mainly to the valleys. The open forests (17.4 %) are located on ridges around Mangan, Chungthang, Lachen-Lachung and Sakkyong Phontong region. Rest of the catchment area is either barren (48.4%) or covered with snow and glaciers (18.5 %) (**Fig. 6**).

Total project area (considering 10 km radius from dam as well powerhouse site) is around 448.90 sq km. The entire project impact area is covered with forests (87.76%) which includes both dense and open type. Dense forests constitute 35.68 % of the area and are either restricted in the valleys or over ridges. The open forests constitute 52.08 % of the area and are interspersed between settlements and agricultural fields (3.31%). The right bank has more dense forest than the left bank. Settlements and cultivation are more prevalent to the downstream of powerhouse site along both banks of river Teesta. A large part of the project area (7.61 %) is degraded with scrubs, particularly

around powerhouse area. Some part in the downstream of the powerhouse around Kamban and Samdong region is barren rocky (0.98 % of the total project area).

Total area of the reservoir (at 755 m FRL) is around 84.04 ha. The maximum submergence area is under dense forest (37.27 %) while 14.98 % (12.59 ha) area is covered with open forest. Around 5.95% of the total area of submergence is presently under cultivation. There are no human settlements in the submergence area.

8. FOREST TYPES & FLORISTICS

Sikkim is reported to have more than 45.97 percent of its geographic area under forest cover which includes very dense, moderately dense and open forest (FSI, 2003). The catchment area of the proposed Teesta-IV HE project covers all the representative forest types of Eastern Himalaya viz., tropical moist deciduous forests, sub-tropical wet hill forests, wet temperate forests, mixed coniferous forests, sub-alpine birch/fir forests and moist and dry alpine scrubs and pastures. The project area covers tropical moist deciduous forest in the lower reaches and its submergence area is approximately 6 km from the buffer zone of Kanchendzonga Biosphere Reserve (KBR). The vegetation in these forests is comprised of tropical moist deciduous forests with some riverine semi-evergreen plant species in lower foothills of project area. In the mid hills sub-tropical wet hill forests occur, while towards higher elevations dense wet temperate, mixed coniferous, sub-alpine and alpine scrub forests are prevalent.

The ecological study in the project area of Teesta stage-IV HEP was undertaken with the objectives of preparing a checklist of flora in the submergence area and locations where project components are proposed and its adjoining areas; listing of rare/endangered, economically important and medicinal plant species; determination of frequency, abundance and density of different vegetation components. In the study area (within 10 km radius), angiosperms are represented by 365 species belonging to belonging to 277 genera and 106 families. The dicotyledons are represented 289 species belonging to 211 genera and 91 families, while the monocotyledons are represented by 15 families, 66 genera and 76 species. Gymnosperms are represented by 2 families, 4 genera and 4 species. Poaceae with 31 genera and 34 species and Asteraceae with 13 genera and 17 species are the largest families of monocots and dicots, respectively. Among Gymnosperms, Pinaceae is the most dominant family represented by 3 genera and 3 species. Among dominant genera represented by 5 or

more species in the project area are *Cyperus* (6), *Impatiens* (5), *Prunus* (5) and *Rubus* (7). A number of monotypic genera distributed over different habitats in the study area include *Bischofia javanica* (Bischofiaceae), *Gynocardia odorata* (Flacourtiaceae), *Houttuynia cordata* (Saururaceae), *Herpetospermum pedunculosum* (Cucubitaceae), *Parochetus communis* (Fabaceae) and *Schima wallichii* (Theaceae).

The project area is largely a degraded ecosystem due to high human pressure, large scale lopping and removal of fodder and timber species, clearing of ground cover for the cultivation of large cardamom, construction of road, etc. Nayar and Sastry (1987-1990) have discussed the rare and endangered plant species from Sikkim, which include *Begonia rubella, Calamus inermis, Cissus spectabilis, Lagerstroemia minuticarpa, Livistona jenkinsiana* and *Ophiorrhiza lurida* from low hills in the altitudinal range of 600-1200 m. However, in spite of several rounds of surveys any of these species in the field could not be recorded.

The diversity of vegetation in Runchu Nala and its adjacent areas was assessed in terms of physiognomy of its floral elements. Herbaceous species formed the bulk of the flora (51.84%), followed by trees (22.63%), shrubs (20.26%), climbers (5.78%) and parasites (0.78%). The vegetation of Sikkim is rich in medicinal plants that are distributed in various climatic zones of the state. Some of the herbs like *Achyranthes aspera, Acorus calamus, Artemisia nilagirica, Bergenia ciliata, Cissampelos pareira, Cyperus rotundus, Hedychium spicatum, Houttuynia cordata, Jatropha curcas, Oroxylum indicum, Viola betonicifolia,* etc. are quite common in tropical and sub-tropical parts of the proposed project. These plants are used internally for treating stomachic diarrhoea, dysentery, cough, cold, fever and asthma and externally for rheumatism, skin diseases, cuts, boils and injuries.

The region is rich in important crop plants such as rice, finger millet, maize, large cardmom, and many wild vegetables and fruits. There are many species of flowering plants found wild in diverse localities which may serve as life saving food products. These include: leaves and young twigs of *Aconogonum molle* (Thotney), leaves of *Fagopyrum esculentum* (Jungaly-Phaper), *Girardinia diversifolia* (Bhangrey Shisnu), tuber of *Dioscorea glabra* (BanTarul), young shoots of *Dendrocalamus hamiltonii* (Tama), roots of *Manihot esculenta* (Semal tarul), flower bud of *Bauhinia variegata* (Koiralo), fruits of *Persea robusta* (Kawla), *Ficus auriculata* (Kabra), *Musa balbisiana* (Ban Kera), *Pandanus nepalensis* (Tarika), *Syzygium formosum* (Jamuna), *Tetradium*

fraxinifolium (Khankapa), etc. The agricultural land is used for cultivation of cereals and millets. The important cereals are Chanwal (*Oryza sativa*), Jau (*Hordeum vulgare*) and Makai (*Zea mays*). Kodo (*Eleusine coracana*), Japanese millet (*Echinochloa frumentacea*), Pearl millet (*Pennisetum americanum*) and Fox tail millet (Setaria italica) are some of the pseudocereals. Among the horticultural crops *Citrus limon* (Nimbu), *C. maxima* (Chakotra), *C. medica* (Bara Nimbu), *C. reticulata* (Suntala), *Mangifera indica* (Aam), *Morus indica* (Mulberry), *Musa balbisiana* (Kaul), *Phyllanthus emblica* (Aonla), *Psidium guajava* (Guava), *Prunus persica* (Peach), *Pyrus sinensis* (Naspati), *Punica granatum* (Pom grante), *Vitis vinifera* (Grape), etc. are some of the fruit yielding cultigens in the area.

9. FAUNA

The proposed Teesta Stage-IV H.E. project is located in the tropical ecozone of Sikkim, which is exposed to the maximum human settlements and human activities, therefore, it has a large catchment area, which includes protected areas like Kanchendzonga Biosphere Reserve. In addition, a large number of species are restricted to high altitudes of the catchment. The important threatened, rare and scheduled species are Himalayan tahr (*Hemitragus jemlahicus*), Serow (*Capricornis sumatraensis*), Argali (*Ovis ammon*), Tibetan Gazelle (*Procapra picticaudata*), Musk deer (*Moschus chrysogaster*), Snow leopard (*Panthera uncia*), Blue sheep (*Pseudois nayaur*), Sloth bear (*Melursus ursinus*), Tibetan fox (Vulpes montanus), Himalayan marmot (*Marmota himalayana*) etc. These species are distributed above 2500 m. in the catchment.

Mammalian fauna in the influence zone (10 km radius) is comprised of macaque, deer, cats, bear, mangoes, hare, wild boar, rats, bats, mouse, shrews, etc. Most of the bat species viz. Naked-rumped tomb bat, Great Himalayan leaf-nosed bat, Fulvous leaf-nosed bat, Asian false vampire bat, Short-nosed fruit bat, Nepalese whiskered bat, Scully's tube nosed bat, Harlequin bat, Bamboo bat, Hairy winged bat etc. inhabit this zone. The deer, Goral and Barking deer are distributed in the upper reaches (around 1000 m) of the project sites. Indian wild boar inhabits open forest area and agricultural lands. Jackal, Wolf, Fishing cat, Marbled cat and Leopard cat, common otter, Mangoes, Himalayan yellow throated marten are common around the project area, while Red panda inhabits dense forests, in the higher elevations. Leopard is not common around the project sites, but the Clouded leopard has been occasionally sighted by the inhabitants. The clouded leopard inhabits dense forests in the mid reaches of the catchment (700 m-1500 m). Black bear occasionally visits lower reaches (up to 1500 m)

and sometimes invades agricultural fields. All the species of macaque, rats, squirrels, mouse, shrews are found commonly near the settlements.

The important species in and around the project components (colony, submergence, dam site to power house site etc) are Fishing cat, Jungle cat, Barking deer, All species of squirrel, bat and rat, Common mongoose, Himalayan Marten and Common otter. Out of the 32 mammalian species in influence zone, 7 are threatened in India (ZSI, 1994). Indian wild boar, Red panda, Clouded leopard and Marbled cat are 'endangered', while Tibetan wolf, Common leopard and Leopard cat are categorized as 'Vulnerable' species. The Himalayan black bear, marbled cat, Indian porcupine and Assamese macaque are globally threatened species (IUCN, 1994) and are known from this area. On the basis of conservation prioritization (WPA, 1972, amended 2003), 8 species known from this area have been categorized as Schedule I species while 5 and 3 species are kept in Schedule II and III. Most of the species belong to order Chiroptera. The species of Rodentia are placed under Schedule V. None of the mammalian species is endemic to Sikkim.

The avifauna of Sikkim comprises about 500 species belonging to 57 families. The catchment area harbors more than 400 species of birds. The important species which are restricted to high altitudes of catchment are Black kite (*Milvus lineatus*), Northern goshawk *(Accipiter gentiles*), Black necked crane (*Grus nigricollis*), Snow partridge *(Lerwa lerwa*), Tibetan Snowcock (*Tetraogallus tibetanus*), Himalayan snowcock (*Tetraogallus himalayensis*), Blood Pheasant (*Ithaginis cruentus*), Satyr Tragopan (*Tragopan satyra*), Himalayan Monal (*Lophophorus impejanus*), Snow Pigeon (*Columba leuconota*), Hume's Short-toed Lark (*Calandrella acutirostris*), Northern House Martin *(Delichon urbica*), Rufuous-throated Wren Babbler (*Spelaeornis caudatus*), White-tailed Rubythroat (*Lucinia pectoralis tschebaiewi*), Eurasian Blackbird (*Turdus merula maximus*), Rosy Pipit (*Anthus roseatus*), Tibetan Snowfinch (*Montifringilla adamsi*), Rufous-necked Snowfinch (*Pyrgilauda ruficollis*), Plain-backed Snowfinch (*P. blanfordi*) etc. Most of the species come for Phasianidae, and Black nacked crane are categorized under Schedule I.

About 170 species of birds are estimated to inhabit the 10 km radius of proposed dam and power house site of the proposed project. Avifauna within this area comprises hawks, partridges, sandpipers, cuckoos, doves, pigeons, parakeets, malkoha, barbets, woodpeckers, owlets, kingfishers, tits, swifts, flycatchers, flower peckers, magpies, treepies, bulbuls, wagtails, forktails, thrushes, laughing thrushes, babblers, warblers, etc

A total of 36 species of birds were recorded from the different sites of proposed activities. The avifauna of the project sites comprises Crested Goshawk, Spotted dove, Oriental Turtle-dove, River lapwing, Asian Barred owlet, Common kingfisher, Common Hoopoe, Great Barbet, Barn Swallow, Himalayan Bulbul, Red-vented Bulbul, Striated Laughingthrush, White-browed Shrike Babbler, White-hooded Babbler, White-naped Yuhina, Yellow-vented Warbler, Grey-hooded Warbler, White-browed Bush Robin, Plumbeous Water Redstart, Blue Whistling Thrush, Brown Dipper, Grey Wagtail, Ashy Drongo, Common crow, Common Myna, Green-backed Tit and House sparrow. None of the species, inhabiting project sites, is threatened and endemic to Sikkim. Except Crested Goshawk and Common crow all the species have been categorised under the Schedule IV. Crested Goshawk and Lammergeir are Schedule I and Common crow is Schedule V species.

The herpetofauna of the catchment area and influence zone comprises 11 species of amphibian and 35 species of reptiles belonging to 5 and 9 families, respectively. Families Ranidae in the amphibia and Colubridae in the reptiles are predominant. Only *Tylototriton verrucosus* among the amphibia is an 'endangered' species (ZSI, 1994) as well as Schedule I species (WPA, 1972). The remaining species have been categorized as Schedule IV. Similarly, in Reptilia most of the species are Schedule IV; only *Xenochrophis piscator* and V*aranus bengalensis* are placed in the Schedule II. *Varanus bengalensis* is a threatened species categorized as 'endangered' species. *Rana annandalii, Bufo himalayana, B. melanostictus, Calotes jerdoni*, *Hemidactylus bowringi, H. garnoti, H. flaviviridi, varanus bengalensis, Vipera russelii* are relatively abundant species of influence zone.

The herpetofauna of the project area comprises amphibian *Rana livida*, *R. alticola* and *Bufo melanostictus* were spotted near the proposed dam site. In Reptiles, species of Agamidae and Geckonoidae were very common in the project area. *Varanus bengalensis* was sighted near the proposed power house. The carcass of *Naja kaouthia* and *Vipera russelli* were observed on the left bank; immediate vicinity of the project. Only *V. bengalensis* is threatened and Schedule I species of the project area.

Butterfly species are more in lower altitude (<900 m), where the proposed project is located. The butterflies of this zone belong to families Papilionidae, Hesperiidae, Pieridae, Lycaenidae and Nymphalidae. Common Dartlet (*Oriens gola pseudolusi),* Purple Red Eye (*Matapa purpurascens*), Common Crow (*Euploea core*), Common Beak (*Libythia lepita lepita*), Club Beak (*L. myrrha myrrha*),

Glassy Tiger (*Parantica aglea melanoides*), Blue Baron (*Euthalia telchinia*), Himalayan Fivering (Y*pthima sakra sacra*), Variegated Fivering (Y. *methora*), Eastern Fivering (*Y. persimilis*), Common Fivering (*Y. baldus*), Common Sailor (*Neptis hylas* vermona), Chocolate Soldier (*Presis iphita iphita*), Blackstripe Crow etc. are common species of the proposed project area.

10. AQUATIC ECOLOGY, WATER QUALITY AND FISH

The present study has been focused on water quality of Teesta river in North Sikkim district of Sikkim. Teesta is a glacier fed river originating from the Teesta Khangse glacier. It drains alpine meadows/pastures, sub alpine zone, temperate coniferous forests and sub tropical dense broadleaved forests. Water samples were taken during winter, pre-monsoon, monsoon and post-monsoon seasons from various locations. All the water samples were analysed for various physical, chemical and biological parameters to get an overview of water quality. Table 2 gives details of physico-chemical parameters of river water. River waters were rich in the suspended algal species. The maximum densities were observed in the winter season, while minimum values were recorded in monsoon season**.** A total of 69 species of algae were recorded from the suspended and benthic forms during 4 seasons. Out of these, 65 species belong to Bacillariophyceae. *Didymosphenia geminata* was the site specific species and was recorded from W3 site in winter season. The maximum phytobenthic densities were observed in the winter season, which decreased gradually during the monsoon season. Details of various biotic components of Teesta river is given in Table 3. The maximum densities and diversities of macro-invertebrates were observed during winter season when water discharge and velocity were low. Heptageniidae was the most abundant and common family, followed by Hydroptilidae and Hydropsychidae. Brachycentridae and Psephanidae were rarely observed taxa. The majority of taxa, viz. Heptageniidae, Ephemerellidae, Hydropsychidae, Hydroptilidae, Leptoceridae and Perlidae in Teesta river are considered to be intolerant to water pollution. However, a few of them like Chironomidae, Psephanidae and Simuliidae are moderately tolerant of polluted waters.

10.1 Fish & Fisheries

The proposed project area lies in the tropical zone, which is inhabited by the maximum number of fish species in Himalaya as compared to the other zones. About 32 species of fish belonging to 6 families inhabit river Teesta around the project area. Family Cyprinidae is the largest, comprising of 13 species, while Channidae is the smallest family, represented by a single species. Fish composition and distribution in the river Teesta is given in Table 4.

Table 2. Physical and chemical characteristics of river Teesta in project area of Teesta Stage-IV H.E. Project

Characteristics	Power house site (W1)				Dam site (W2)				Upstream site (W3)			
	W	PrM	M	Po	W	PrM	M	PoM	W	PrM	M	PoM
Water current velocity (m/s)	2.80	2.18	3.30	1.28	1.83	1.49	2.17	0.90	1.11	1.30	1.50	1.50
Turbidity (ntu)	6.00	51.00	75.00	10.00	7.00	55.00	69.00	4.00	9.00	44.00	62.00	3.00
Water temperature (°C)	11.00	15.67	18.67	13.50	10.00	14.67	15.33	15.00	9.50	12.00	14.50	12.00
pH	7.73	7.98	8.10	6.90	8.00	8.03	8.07	7.00	8.11	7.30	7.00	8.00
BOD (mg/l)	1.23	1.44	0.56	4.10	2.22	1.56	1.12	1.25	1.78	1.36	0.80	1.12
Dissolved oxygen (mg/l)	11.00	10.21	11.00	10.00	11.15	10.50	10.60	10.20	11.20	11.38	11.30	11.50
E. Conductivity (µS/cm)	108.30	47.67	44.33	65.20	78.67	50.33	49.00	48.50	82.10	54.60	52.00	50.00
Salinity (mg/l)	10.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.00	0.00	0.00	0.00
Total dissolved solids (mg/l)	86.67	30.00	27.00	42.00	60.00	40.00	32.00	42.00	72.50	42.00	34.00	45.00
Total alkalinity (mg/l)	32.00	22.00	22.00	26.40	30.00	24.00	24.00	23.20	30.00	32.00	20.40	27.60
Total hardness (mg/l)	60.00	40.00	44.00	56.20	60.00	40.00	44.00	52.00	46.00	38.00	38.00	43.00
Ca++ (mg/l)	20.80	12.80	16.00	18.80	20.80	12.80	16.00	18.40	-	11.20	12.35	15.20
Mg++ (mg/l)	1.94	1.94	0.97	2.10	1.94	1.94	0.97	1.40	-	0.77	0.77	1.21
Chloride (mg/l)	6.00	7.00	8.51	7.37	5.00	6.00	8.51	8.10	4.50	6.10	7.75	6.52
Nitrate (mg/)	0.13	0.08	0.12	0.08	0.19	0.06	0.15	0.13	0.07	0.05	0.13	0.10
Phosphate (mg/l)	0.04	0.02	0.01	0.04	0.04	0.08	0.05	0.12	0.03	0.04	0.03	0.07
Dissolved iron (mg/l)	0.10	0.10	0.05	0.05	0.10	0.05	0.05	0.05	0.10	0.10	0.05	0.10

Table 3. Details of different biotic communities of Teesta river

Biotic communities	Power house site (W1)				Dam site (W2)				Upstream site (W3)			
	W	**PrM**	**M**	**Po**	**W**	**PrM**	**M**	**PoM**	**W**	**PrM**	**M**	**PoM**
E. coli (P/A)	P	A	A	A	A	A	A	A	-	A	A	A
Coliforms (P/A)	P	A	A	A	P	A	A	A	-	A	A	A
Zooplankton (indiv./lit)	62	32	0	12	44	09	08	22	-	0	0	12
Suspended algae (cells/lit)	10107	8148	1639	1495	35378	1225	1509	1557	-	1612	1384	662
Phytobenthos (cells/cm^2)	39606	15753	1142	5225	81848	33757	7217	8610	-	6940	3612	8768
Macro-inverte. (indiv./m^2)	511	422	300	344	844	176	88	377	-	719	243	1220

Table 4. Fish composition and distribution in the river Teesta in Sikkim

Species	Vernacular name	Distribution (m)	Status (CAMP-BCPP)
Family Cyprinidae			
Acrossocheilus hexagonolepis	Catly	up to 850	-
Acrossocheilus spinulosa	Catly	up to 850	-
Schizothorax richardsonii	Asla	up to 1600	VU
Schizothoraicthys curvifrons	Asla	up to 1000	LRnt
Schizothoraicthys progastus	Chuche asla	up to 1600	VU
Tor putitora	Shahar	up to 850	EN
Labeo dero	Gardi	up to 800	VU
Semiplotus semiplotus	Chepti	up to 900	VU
Garra gotyla gotyla	Budhna	up to 900	VU
G. gotyla stenorhynchus	Budhna	up to 900	EN
G. annandalei	Budhna	up to 900	-
G. lamta	Budhna		
G. mcclellandi	Budhna		
G. mullya	Budhna		
Homalopteridae			
Balitora bruccei	Teeta Maccha		LRnt
Family Sisoridae			
Pseudecheneis sulcatus	Kahray		VU
Glyptothorax gracilis	Kahray	up to 800	-
G. sinense manipurensis	Kahray	up to 800	-
G. sinense sikkimensis	Kahray		
G. conirostris	Kahray		
G. trilineatus	Kahray		-
G. dey	Kahray		-
Euchiloglanis hogarti	Loolay machha	up to 1800	VU
Family Balitoridae			
Nemacheilus carletoni	Gadela		EN
N. corica	Gadela		LRnt
N. devdevi	Gadela		EN
N. sikmaiensis	Gadela		EN
N. multifaciatus	Gadela		EN
N. bevani	Gadela		
Acanthophthalmus pangia	Lamo gadela		-
Family Schilbeidae			
Clupisoma montana	Jalkapoor		
Pseudeutropius antherinoides			EN
Family Channidae			
Channa gachua	Hilay		-

EN = endangered; VU = vulnerable; LRnt = Low risk near threatened

11. AIR ENVIRONMENT

The air quality of Sikkim and particularly of North Sikkim, where the present project is proposed, is clean and pristine. There is no point source of air pollutants in the region. However, the diffuse sources like household fuels, road construction, and vehicular movement are main agents of air pollution. The economy of the district is totally agriculture based. Most of the area in the district is covered with forests and vegetation. There are no industries in the project area, therefore, vehicles are the only source of NO_x in the region. In the project area the average NO_2 was nearly negligible when compared to the national standards of MOEF. The level of NO_2 in the Mangan area ranged from 1.7 to 6.41 $\mu g/m^3$. The level of sulphur dioxide in the region is very less. At Mangan the observed level of SO_2 is much lower than the standards given by CPCB.

The ambient levels of RSPM and NRSPM measured at Mangan near project area. The ambient level of the RSPM ranged from a minimum of 10.86 $\mu g/m^3$ to12.08 $\mu g/m^3$. The number of vehicles per hour at Mangan ranged from 43 to 49. At all the locations, the SPM level in the ambient air was quite lower than the national standards given by MOEF. The sources of SPM in the region were mainly moving vehicles on the roads.

The peak traffic is observed during May-August when tourist arrivals are high. During off-season (with respect to tourist flow) only local vehicles and a few trucks (mostly army) ply in the region. Bus traffic on the road is low, which is restricted to the morning and evening hours. The predominant mode of transport in Sikkim comprises light vehicles like jeeps, vans, etc. Army trucks and private trucks carrying heavy loads comprise the heavy vehicle category. Tadong in Gangtok recorded the maximum number of vehicles per hour in the tourist as well as the non-tourist season.

The project area is a noise free zone. Occasional vehicles disturb the silence of the region. Noise levels at the riverbank near dam site which ranged from a minimum of 52.9 to 70.3 dBA (day time observations). In forest area it was recorded to range from 58.2 dBA to the noise levels on the road ranged from 52.9 to 58.2 dBA.

12. SOCIO-ECONOMIC AND & CULTURAL PROFILE

Sikkim is one of the smallest mountainous state of Indian Union located in the Eastern Himalaya with a total geographical area of 7,096 sq km. Administratively, the state is divided into 4 districts namely North, South, East, West and the capital, Gangtok, is located in the East

Sikkim district. Further, the districts are divided into nine sub-divisions *viz*. Gangtok, Pakyong and Rongli in the East District, Namchi and Ravong in the South District, Gyalzing and Soreng in the West District and Mangan and Chungthang in the North District. The total population of Sikkim is 5,40,851 with sex ratio of 875 and a population density of around 76 persons per km^2 (Census, 2001). The rural population accounts for 88.90% of the total population and the Schedule Castes and Schedule Tribes population constitute 5.02% and 20.59%, respectively of the total population. The population is comprised of many ethnic groups like Nepali (70%) Lepchas (8.46%), Bhutias (25%), Chumbipas, Dukpas, Sherpas, Yolmos, etc. Hinduism and Buddhism are the two predominant religions in the state.

The project is located in the North District of Sikkim, which is the largest (4,226 sq km) among the four districts in terms of geographical area, but the smallest in population (41,030 individuals in 2001) with a sex-ratio of 752. The district covers nearly 60% of the total land area of the state. North district, whose headquarters are located at Mangan, consists of two sub-divisions namely, Chungthang and Mangan. There are 45 revenue blocks in the district of which 5 are in Chungthang sub-division and 40 are in Mangan sub-division. About 97% of the total population is rural. Schedule Caste and Schedule Tribe populations account for 2.14% and 51.6% of the total population. Total literacy rate in the North district is 67.2%. The dominant ethnic groups living in the district are the Lepchas and the Bhutias.

The proposed project and its components fall in the Mangan sub-division. Total population of Mangan Tehsil is 30,528 with a sex ratio of 873, belonging to 6,024 households and 40 revenue blocks (Census 2001). Scheduled Tribe (ST) and Scheduled Caste (SC) populations constitute 55.8% and 2.5% of the total population. The literacy rate of Mangan sub-division is about 64.9% which is slightly less than the State (68.3%) and district averages (67.2%).

A total of 34 revenue blocks/villages are located within 10 km radius of the proposed dam site. These revenue blocks belong to Mangan tehsil of North district, Gangtok tehsil of East district and Ravong tehsil of South district. Of the 34 villages within 10 km radius, 19 come under the jurisdiction of Mangan tehsil. Total population of all these villages is 28923 belonging to 1301 households. Scheduled Caste population in these villages ranges from 2.0 – 3.9%. Scheduled Tribe population accounts for 36.4% of total population in these villages. The average literacy rate in the villages located within 10 km radius is 61.80%. The average literacy rate is higher in the blocks

of Gangtok tehsil. A total of 66 primary (PSch), 19 middle (MSch), 7 secondary (SSch) and 2 senior secondary schools (SSSch) provide the educational facilities to these villages.

A total of 14 villages/ blocks are directly affected due to various project activities. Total population of these villages is 14,291 which belong to 2793 households. Revenue block Zimchung is largest block with a total population of 2697. The average sex ratio is 895 with maximum in Lingdong and minimum in 809. Scheduled Caste (SC) population accounts for 3.6% of total population while Scheduled Tribe (ST) population is 46.1%. The maximum ST population resides in Swayem village. Average literacy rate (56.2%) in the affected villages is considerably lower than the state, district and tehsil averages. The male literacy (63.7%) is significantly higher as compared to that in the females (47.8%) in these villages. Government service, small scale business and farming are the main occupation in the affected villages. Large cardamom, maize, rice and orange are the main crops grown in these villages. About 52% of the total population comprises workers of which 35.5% are main workers and 16.2% are marginal workers. The main workers are dominated by the males (67.9%) while the female population dominates the marginal workers category (65.6%).

All the affected villages occupy an area of 9096 ha where forest land is not owned by the villagers. About 54% of the total land is used for agricultural purposes, 48.8% of which is unirrigated.

A total of 256 families comprising 232 landowners/ khatedars and 3 tenants are likely to be affected due to the various project activities. The total population of these affected families is 1678, with an average sex ratio of 1042, which is higher than state, district and tehsil averages. The population within the age group of 0-6 years accounts for 9.48% of the total population. An average family size was calculated to be around 7 persons per family. All families belong to Scheduled Tribe. Village Tingchim has the maximum project affected population of 391 which belong to 39 households, while village Lingthem has the lowest affected persons (5 individuals) belonging to a single household**.** Most of the affected villages/ blocks are located in Dzongu area, where proper educational facilities are largely lacking. Despite poor facilities average literacy rate in the affected families is considerably higher (79.46%) than the State, District and Sub-division averages. About 27.9% of total population of the affected families has got education up to the primary level. Only 18.9% of the total population has got middle school education. There are only a few members of the affected population (10%) that have received higher education.

Agriculture is the main source of livelihood of the project affected persons; about 85.3% of worker's population is employed in agricultural activities. Nearly 46.91% of the total population of the affected families comes under the workers category. The service class (government and non-government) persons account for 14.2% of the population Only 3 persons are engaged in small scale business while there are no individuals with government or old age pension in the affected families The age group 0-18 year accounts for the major part in the non worker category. The livestock population in the affected families comprises of cows, buffaloes, ox, pigs and goats. Total land to be acquired for various components of the project is 324.07 ha of which private land is 180.58 ha (Table 5).

Table 5. Land requirement (in ha) for Teesta Stage-IV H.E. project in Sikkim

Components		Right bank		Left bank		Sub-Total		Total
		Private	Govt.	Private	Govt.	Private	Govt.	
1.	Dam complex	17.95	12.82	8.62	15.98	26.57	28.80	55.37
2.	Power house complex	14.59	12.08	6.66	2.84	21.25	14.92	36.18
3.	Adit-II area	9.19	9.12	24.26	4.18	33.45	13.30	46.76
4.	Colony area	-	-	27.69	0.87	27.69	0.87	28.56
5.	Reservoir area							
	a) Land submergence	22.41	22.08	14.14	15.24	36.55	37.32	73.86
	b) Water course	-	16.42	-	15.10	-	31.51	31.51
6.	Dumping area	11.63	-	20.40	-	32.03	-	32.03
7	Quarry area	-	1.12	3.03	1.25	3.03	2.37	5.40
	Total	**75.78**	**73.63**	**104.81**	**55.46**	**180.58**	**129.09**	**309.67**
8.	Underground (Head race & Tail race tunnel)	-	14.40	-	-	-	14.40	14.40
	Grand Total							**324.07**

13. COST BENEFIT ANALYSIS

As per approved TOR, it was desired by MOEF that *"a detailed environmental cost-benefit analysis shall be carried out for the life of the project (capital and recurring). It should also include cost-benefit analysis with respect to environmental damages and how the same would be compensated."* Accordingly, a separate chapter has been included in the EIA Report.

Cost-benefit analysis (CBA) is a form of economic analysis in which costs and benefits are quantified and compared. Environmental cost-benefit analysis is defined as the evaluation and comparison of capital and environmental costs of a project to estimate its relative merits and demerits.

In the absence of a defined methodology for environmental CBA of hydropower projects in India, the methods used for CBA as per the guidance manual for preparation of forest proposals under FCA, 1980 alongwith methodology given by Federal Energy Regulatory Commission (FERC) of United States was consulted. The cost including all quantifiable environmental costs of the project has been derived. Benefits, taking into account revenue from project and the value of avoided carbon emissions alone was calculated. Cost amounting to Rs. 7418.92 crore whereas benefit was valuated to be Rs.32789 crore. The ratio of cost to benefit was found to be Rs.7418.92 cr : Rs. 32789 cr = 0.22, showing that the quantifiable benefits due to the project far outweigh the quantifiable cost of the project. Thus it is proven that the proposed Teesta-IV HE Project is an environmentally sustainable developmental activity.

14. ENVIRONMENTAL FLOW REQUIREMENT

As per approved TOR, MOEF desired that *"an estimation to be made for environmental flows downstream for sustenance of aquatic environment and for downstream uses, considering details of streams joining the river below the proposed dam site with their approximate distance from the dam site, their nature (whether perennial or seasonal) etc. A detail environmental flow study shall be carried out through the premier institutions such as Central Inland Fisheries Research Institute (CIFRI), Barrackpore and National Institute of Hydrology (NIH), Roorkee for biological and hydrological components".* Accordingly, National Institute of Hydrology (NIH), Roorkee and Central Inland Fisheries Research Institute (CIFRI), Barrackpore were entrusted to carry out the study on environmental flow requirement from the proposed Teesta-IV dam.

On the basis of hydrological and hydraulic analysis, NIH has concluded that total flow volume requirement comes out to be 756790.5 cumec days for river to achieve Class 'C' river specification as per Flow Duration Curve method. This is about 48% of the annual flow volume. It was observed that with the release of about 5 cumec per day as environmental flow and operation of all the four machines the flow volume is about 46% of annual flows. Therefore, NIH concluded that the consideration of releasing about 5 cumec per day as environmental flow satisfies the condition of class 'C' River.

On the basis of ecological assessment in the downstream river stretch between the proposed dam and tail race tunnel outlet, CIFRI has suggested a release of minimum of 10 cumecs of water from proposed Teesta-IV dam during lean season for sustenance of ecological integrity in the 7.3 km stretch of Teesta river.

15. POSSIBILITY OF MICRO HYDEL AT DAM TOE

As per approved TOR, MoEF desired that a study to be conducted to "*explore the possibility of having a micro hydel at dam-toe, if 10 cumecs of water to flow from the dam as environmental flow in the river".* Accordingly, the power potential study has been carried out for environmental flow of 5.2 cumecs as well as for 10 cumecs.

DPR of Teesta-IV HE Project has already been approved by CEA with reference to 520MW as plant capacity and 2373MU as design energy, wherein environmental release of 5.2 cumecs has been considered. Two alternatives have been studied, first a mini power house at d/s of dam with provision of inlet from HRT (Alt-I) and other at dam toe with intake in right non-overflow block (R1) of main dam (Alt-II). On detailed estimation including Civil & HM quantities for development of the mini hydro power plant, it emerged that the cost of ALT-I i.e. mini power house at d/s of dam with provision of inlet from HRT is significantly higher than ALT-II i.e. power house at dam toe with intake in right NOF block (R1) of main dam. Therefore, ALT-II shall be considered for further detailed planning. In first option, single unit of 1.75 MW shall operate with 5.2 cumec discharge however two units of 1.68MW each shall be operated with 10 cumec discharge in another option. The energy output of the project with an installed capacity of 1x 1.75 MW and 2 X 1.68 MW have been estimated at 12.97MU and 24.94 MU at a tentative project cost of Rs.21.02 crores (at Nov.'10 PL) and Rs.36.60 crores (at Nov.'10 PL) respectively. Cost of Power Evacuation, Transmission and financial implication due to loss of generation at main power station has not been taken in the cost analysis. It was also observed that increase in environmental release from proposed 5.2 cumec (as per approved DPR) up to 10 cumec will cause a loss of approximately 46 million units of energy annually. In addition to this, change in environmental flow at this stage may affect peaking capacity, tariff and possibly unit size as well as the layout of the project.

ENVIRONMENT MANAGEMENT PLAN

Environmental Management Plan deals with the management and mitigation measures of the impacts discussed in part one (EIA). There are 15 nos. of management plans on different aspects of environment discussed below. Total cost of the management plan is summarized in last section.

1. RESETTLEMENT AND REHABILITATION PLAN

The objectives of Rehabilitation and Resettlement Plan are to avoid or minimize the negative impacts of the project but if negative impacts of the project are not avoidable, the project affected persons will be assisted in improving or regaining their standard of living. Teesta Stage-IV H.E. Project is located on the Teesta river in North district of Sikkim. The project is located between $27^0$25' – $27^0$30' N latitude and $88^0$30' – $88^0$32' E longitude. The proposed dam site is located downstream of the confluence of Run Chhu with Teesta near Chandey village. Major components of the project are located on the right bank (Dzongu area) while other establishments (project head quarters, store, workshop and colony) will be housed on the left bank to minimize the land requirement in the restricted Dzongu area. The total land required for the various components of the proposed project works is around 324.07 ha. The required land is divided into private (180.58 ha) and government/ forest (143.49 ha) ownership. The project activities confined to the right bank would require a total of 149.41 ha land, in which 75.78 ha land is private and 73.63 ha land belongs to the government. A total of 14 villages/ blocks are getting affected due to acquisition required for various project activities. Total population of these villages is 14,291 which belongs to 2793 households. Revenue block Zimchung is the largest block with a total population of 2697. There are 256 landowners, including 3 tenant tillers, who are going to be affected due to land acquisition. Out of 256 affected landowners, after land acquisition, 67 would become landless, 32 would become marginal farmers, 40 and 114 would become small and large farmers respectively. The package for which project affected families are entitled are described in this section. Since none of the family is losing homestead land and house in the affected zone, as such no family is getting displaced due to the construction of the project. Therefore, package for resettlement colony and houseless families are not relevant to this project.

A rehabilitation package in line with NRRP 2007 and NHPC R&R Policy 2007 has been proposed comprising stamp duty and registration charges for small and large farmers and tenant

tillers, land development assistance, seeds, pesticides and fertilizer subsidy, irrigation support, rehabilitation grant, marriage grant, subsistence grant, etc. Total financial outlay for Rehabilitation package, besides compensation of land is **Rs. 1387.30 lakh.** In addition to the rightful compensation and R & R package for the project affected families**,** the project authorities will undertake a comprehensive community and social development plan (CSDP) in the project affected areas for socio-economic upliftment of the area. The highlights of the plan are Infrastructural Development, Development of a Model Village, Economic Development, Health Facilities, Capacity Building and Contribution for opening up of ITI, etc. Infrastructural Development will mainly comprise construction of footpaths, Bus Stops/ Rain Shelters, Water supply facilities for the villages, Upgradation of existing educational & medical facilities, Community Welfare Centres, Protection of Cultural Heritage and Old Monuments, Improvement of Namprikdang Mela Ground, etc. Implementation of this plan will result in better quality of life for the entire human population of the affected area. The financial outlay for Community and Social Development would be **Rs. 1391 lakh**. Therefore a total of **Rs. 2778.30 lakh** will be spent on Resettlement and Rehabilitation Plan.

2. CATCHMENT AREA TREATMENT PLAN (CAT)

Catchment Area Treatment Plan (CAT) for the free-draining catchment area has been formulated with the main objective of arresting soil erosion in the catchment area up to the dam site. The CAT has been limited to free-draining catchment because of upstream river valley projects, namely Teesta Stage-III H.E. Project on Teesta river, Panan HEP on Rangyong Chhu and Chakung Chhu HEP on Chakung Chhu river. Based on the topographic factors, slope, soil type, climate, land use/vegetation cover in the catchment area, erosion susceptible areas have been identified. Eventually, analysis of these databases to assess the sediment yield index have been undertaken. Various measures, both engineering/mechanical and biological have been proposed to be undertaken with the aim to check the soil erosion, prevent/check siltation of reservoir and to maintain its storage capacity in the long run. The engineering measures will comprise construction of a number of check dams/ walls, retaining walls, wire crates, etc. for gully control, stabilization of flood prone streams, landslides/slopes, river banks, roads, etc. and the biological measures suggested are afforestation, pasture development, NTFP regenerations etc. Those sub-watersheds which are affected due to siltation have been prioritized according to their sediment yield index. Subsequently, biological as well as engineering treatment measures have been discussed to minimize the siltation in the dam reservoir. The total area of free draining catchment of Teesta Stage-IV H.E project from dam site upstream is around 36269.60 ha. The

management plan is prepared for four watersheds Chakung Chhu watershed, Run Chhu watershed, Rangyong Chhu watershed and Teesta river watershed (**Fig. 7**). The total estimated cost of catchment area treatment plan for treatment of 4277.68 ha area of severe and very severe erosion prone areas of free draining catchment, to be spent over a period of six years is **Rs.2157.82 lakhs.**

3. BIODIVERSITY MANAGEMENT PLAN

Biodiversity management plan prepared here is a means to maintain and conserve the biodiversity up to the level that has been lost or is likely to be lost due to developmental activities and over-exploitation. The catchment area of the adjoining upstream tributaries, i.e. Chakung Chhu and Tolung Chhu harbour about 340 species of angiosperms belonging to 254 genera and 99 families. Out of 99 families 87 are dicots, 12 are monocots. Poaceae with 31 genera and 36 species and Asteraceae with 12 genera and 13 species are the largest families of monocots and dicots, respectively. Among Gymnosperms, Pinaceae is the most dominant family represented by 3 genera and 3 species. For the promotion of the conservation and preservation of habitats and ecosystems the several measures are proposed in the Teesta Stage-IV H.E. project area such as setting up of Butterfly Park, Preparation of Peoples Biodiversity Registers (PBR), Identification and management of invasive species and Miscellaneous conservation activities. The total estimated cost of the Biodiversity Management Plan would be **Rs. 498.00 lakhs.**

4. FISHERIES AND DEVELOPMENT

Fish and fisheries are very important component of the river valleys which must receive utmost attention in the management plan of hydroelectric projects with respect to conservation and livelihood of the local inhabitants about 32 species of fish belonging to 6 families are expected to inhabit river Teesta around the project area. Family Cyprinidae is the largest group comprising 13 species, while Channidae is the smallest family, represented by a single species. *Acrossocheilus hexagonolepis* (catli), *Acrossocheilus spinulosa* (catli), *Schizothorax richardsonii* (Snow trout), *Schizothoraicthys progastus* (Snow trout), *Schizothorax curvifrons* and *Semiplotus semiplotus* are important fish species inhabiting the river stretch up to 900 m. A fishery management plan is formulated considering the importance of fish and fisheries in terms of conservation and local economy. In Sikkim, the management plan can be designed either for the conservation of indigenous species or as a compensatory measure, which would help the local fishermen. Because native species are known to have slow growth rate, therefore, are not used as culture fisheries. Generally, fast growing species like *Salmo trutta fario, Cyprinus carpio*, etc. are

introduced in the reservoirs and rivers to achieve economic benefits. This practice has neglected the issues of conservation of native fish species. Considering this fact, the proposed fishery management plan has been formulated in respect to the conservation of native fish species. Fishery Development includes; Hatchery unit, Collection of brooders, Reservoir fishery, Stocking of seeds and Fish farms. About 2 ha of land would be required for the establishment of a hatchery unit and fish farms. The total cost for fisheries development in Teesta-IV HEP is proposed to be **Rs.141.80 lakhs.**

5. PUBLIC HEALTH DELIVERY SYSTEM

A health delivery plan has been formulated to develop, create and augment the medical facilities in the project area and also to meet the demand of increased population in the area due to the influx of migrant labour during the project construction. Within the project area of Teesta IV H.E. Project, there are 34 villages, being called as vicinity villages, falling within the 10 km radius from dam and powerhouse sites. The available medical facility may not be adequate considering that additional population of around 5000-6000 people will inflow into the project region during the construction activity. Looking into all these aspects certain medical facilities are proposed to be created under the environment management plan. The migrant workers for the proposed project are estimated to be around 2000 and the total population will be around 6000. It has been observed that existing medical facilities are not sufficient for this suddenly increased population as there will be additional burden on the existing medical facilities of the region. To meet this increased demand of medical and healthcare facilities of the migrant workers and their dependents, various medical facilities like hospital and primary health centre are proposed in the plan. Health extension services like Provision of Free Medical Camps, Immunization Programme, Ambulance facility have also been proposed. The total cost for setting up of all the above mentioned medical facilities in the project area and the implementation of different mitigation measures would be around **Rs. 362.00 lakhs.**

6. RESTORATION OF MUCK DUMPING SITES

The proposed Teesta Stage-IV HE Project is likely to generate large volumes of muck, of which some quantity will be utilised and the remaining muck needs to be rehabilitated in suitable dumping sites in a technically and ecologically sound manner. The basic aims and objectives of Restoration plan is to utilize excavated material, prevent soil erosion and to rejuvenate the dumping sites into green area. During the construction phase a total of 3756639 cum of muck will be generated from surface and subsurface excavation at different appurtenant structures like diversion tunnel, dam, adits, HRT, and power house complex etc. Four dumping sites (DS-1 to DS-4) have been earmarked at different locations to rehabilitate

the generated muck. Engineering and biological measures conducive to terrain have been suggested to rehabilitate the muck. Retaining walls filled with plum concrete are proposed at the base of the dumping yards. Biological measures would also implemented to stabilize the muck and restore the disposal sites. The total cost requirement for the purpose of rehabilitation of muck is **Rs.707.41 lakh** of which the requirement for engineering measures is Rs. 657.49 lakh, and for biological measures it is Rs. 32.92 lakh.

7. SOLID WASTE MANAGEMENT

The construction as well as maintenance of the proposed Teesta Stage-IV HE Project in Teesta valley would require a number of technical staff and non-technical labour. The estimated peak labour force for the project is around 2000 which will comprise of labourers, technical staff, service providers and other officials. Total floating population may be much higher than the expected due to influx of the labourers and their families and may peak around 6000 persons. Therefore, for about 6000 persons residing in the project area an estimated amount of 931 tonnes of solid waste will be generated annually. Therefore the waste generated would not be allowed to be dumped near any water body or a stream. There is a residential and an office complex proposed in the project. Labour colony is proposed at one location near dam site at Tingchim which is located on the left bank of Teesta River. Office complex is proposed in colony area on the left bank of Teesta River. Several measures will be taken to manage the solid waste generated by floating population such as Water and Sanitary Facilities, Water supply facility, Restroom facilities, Septic tanks, Bathrooms and washing places, Sewage treatment plant, Incinerators, Staff, Dumpers and Wheel barrows. A budget of **Rs. 248.05Lakh** will allocated for the Solid waste management.

8. LANDSCAPING AND RESTORATION OF CONSTRUCTION AREAS & QUARRY SITES

The total project area identified within the direct impacts (project area within 10 km radius from dam site and powerhouse site) is around 44890.49 ha, which is around 11.48 per cent of the total catchment area and 97.38 per cent of the free draining catchment area of the proposed project. Total area likely to have direct impacts of the proposed project is 324.07 ha (309.67 ha land will be acquired for different components of the project and 14.4 ha underground land will be affected due to HRT). After detail geophysical investigations, total of 11 sites were finally chosen for quarrying of construction material viz. coarse aggregate, fine aggregate, rockfill material, impervious soil, etc. Except for soil deposits TR-IV-C-1 (near Dam site), the entire requirement of construction material will be met either from river bed material or from excavated material from underground works like HRT, Powerhouse & TRT. The approximate area that would be disturbed due to quarrying is only

5.40 ha. For restoration and landscaping of Construction areas and quarry site, a management plan has been formulated which involve biological, engineering and bio-engineering measures. An amount of **Rs. 178.25 lakhs** is proposed to be spent on this account.

9. FUEL AND ENERGY CONSERVATION MEASURES

Primary objective of the energy conservation in the project areas is to protect the forest resources of project area as large influx of labour population may exert additional pressure on the surrounding forest resources for fuel wood. The proposed plan is formulated considering not only the project workers but project affected families also. To meet the fuel demand project proponent would establish LPG Depots, Kerosene Depots and Community Kitchen. In addition, other energy conservation measures have also been proposed such as installation of Rooftop Photovoltaic Cells in office complex, guest houses, etc.; distribution of pressure cookers; solar cookers and smokeless chullahs among locals. Total financial outlay for the provision of fuel would be **Rs. 75.00 lakhs**.

10. GREEN BELT DEVELOPMENT PLAN

Green belt development around the project sites of hydro electric power has a special significance as the project construction process emanates lot of dust due to excavation works, crushing of material and batching of aggregates. Some of the aims and objectives for creating a green belt around the project area are to prevent land degradation, to enhance the forest cover, to provide an aesthetic view to the project area, to enhance the ecological equilibrium of the area and to combat soil erosion. Development of green belt around the reservoir will also improve the habitat of birds and other wild animals around the region. The green belt is proposed to be developed within the project area in and around residential colony at Tingchim, Dam Complex, Adit-II area, Powerhouse, Switch Yard & TRT Area and along the periphery of reservoir. A nursery will also be developed under the same plan to produce approximately 1,00,000 saplings every year to meet the demand of green belt development as well as landscaping & restoration of construction areas. A list of indigenous tree, shrubs and herbs was prepared after identification of species suitable for raising in nurseries and for development of green belt around the project area and along the periphery of reservoir. The overall cost of green belt development **Rs. 96.5 lakhs.**

11. RESERVOIR RIM TREATMENT PLAN

On the basis of the EIA conducted, general geology of the area and problem of slope instability resulting in landslides was assessed. The anticipated impact of these potential landslides

on the dwellings/ structures situated along the reservoir rim was also assessed. Based on this assessment, a treatment plan for the reservoir rim area was formulated. The aims and objective of this plan are: i) To prevent the land degradation/ soil erosion in the reservoir rim area, ii) To provide stability to the stream banks, iii) To augment the life of the reservoir by reducing siltation, and iv) To protect the loss of adjacent land of local villagers. Keeping in mind that reservoir area has already been covered under free draining catchment area treatment plan, only specific engineering measures have been suggested here which will be useful for protection of river banks which would be under direct impact of fluctuating water level of the reservoir. All these measures are to be followed as per need of the specific sites at the time of treatment and as per budgetary provisions of the purpose. The overall cost of Reservoir Rim Treatment Plan is **Rs. 329.5 lakhs**.

12. AIR, NOISE & WATER QUALITY MANAGEMENT PLAN

During the construction phase, the activities like site preparation, approach roads, excavation, drilling, blasting, foundation, tunneling, deployment of machinery, erection, transportation, dumping will be taken up. All these activities would be affecting the environment by increased noise level and deteriorated water and air qualities. Suspended Particulate Matter (SPM) is the main pollutant during construction. The major pollutants, which get emitted from diesel vehicles, are hydrocarbons and SO_2. The noise will be generated at the time of construction of powerhouse tunnel boring machine operations, pumps, drilling machines, blasting, dumpers etc. Continuous exposure of workers to high level of noise may result in annoyance, fatigue, and may cause temporary shift of threshold limit of hearing. During the construction of tunnels, shaft and power house installations, surface water (river/ stream water) may get polluted due to the generation of large quantities of suspended particulate matter at the time of transportation of muck and wastewater (sewage) coming from temporary arrangements like offices, labour camps, sheds, etc. Various measures have been suggested for management of air, water and noise quality during the construction of the project. In addition to above management measures, it is proposed that periodic monitoring of air, water and noise quality should be conducted at key points in the project area during construction stage and water quality monitoring should be carried even after commissioning of the project and total budget for environmental monitoring / studies of air, noise and water would be **Rs.50 lakhs** only.

13. COMPENSATORY AFFORESTATION PLAN

The total forest land proposed to be diverted for the project is 143.4928 ha out of which 14.400 ha land is required for underground works like tunnel, adits, etc. The compensatory

afforestation work is proposed to be done in lieu of 143.4928 ha diversion of forest land. Accordingly, a Compensatory Afforestation Scheme on double the degraded forest land i.e on 287 ha of degraded forest land has been formulated to compensate for the loss of Forests due to submergence, construction of different structures for project, etc. A comprehensive plan has been formulated by the Deptt. of Forest, Govt. of Sikkim which will include various afforestation and soil conservation measures with a total cost of **Rs.243.29 lakhs** only.

14. DISASTER MANAGEMENT PLAN

Teesta-IV H.E. project is a run of the river project planned along river Teesta as a part of cascade development of projects in Teesta basin. A number of projects have been proposed in the Teesta basin with a view to exploit the vast hydro potential of river Teesta and its tributaries. The proposed dam site is situated about 200m downstream of confluence of Runchu nallah with river Teesta and about 3.5 km d/s of Sankalang. The project envisages construction of 65 m high concrete dam (above river bed level) on river Teesta with a gross storage capacity of 18.60 Mcum at FRL 755m. The submergence area is 84.04 ha.

The dam break analysis was done using ***HEC-RAS version 4.1.0*** model released by Hydrologic Engineering Center of U.S. Army Corps of Engineers in January 2010. The analysis was carried out considering one scenario of dam break of Teesta-IV and other scenario if dams of upstream projects Panan and Teesta-III also fail along with Teesta-IV HEP.

Because the dambreak flood has the potential to damage the natural landscape, road network and settlements, it is essential that an appropriate disaster management plan be prepared for the reaches of Teesta river where the hazard is likely to take place. The surveillance and monitoring programmes are required to be implemented during design and investigation, construction, first reservoir filling, early operation period and operation & maintenance phases during the life span of dam. The estimated total cost for execution of disaster management plan including the equipment is **Rs. 350.00** lakhs.

15. ENVIRONMENTAL MONITORING PROGRAMME

The proposed project is expected to bring prosperity and improve present environmental condition of the region. Various measures/plans *viz.* Catchment Area Treatment, Biodiversity Conservation & Management, Public Health Delivery System, Fisheries Development, Rehabilitation of Muck and Restoration of Dumping sites, Landscaping and Restoration of

Construction Areas & Quarry Sites, Green Belt Development, Resettlement and Rehabilitation etc. have been proposed/suggested in the Environment Management Plan (EMP). In order to monitor the progress of various environmental plans proposed for Teesta-IV HEP, a two tier monitoring committee has been suggested which will comprise the officials from State Govt., MOEF and Project authorities. It is also proposed to create Environmental Management Cell at the project level. In order to strengthen the monitoring programme and Environmental Management Cell of the Project, a lump sum provision of **Rs. 30.00 lakh** is suggested. A separate budget of **Rs.20 lakh** is also proposed for carrying out post-construction EIA of the project.

16. SUMMARY OF COST ESTIMATES

The environment management plan, proposed for Teesta Stage-IV HE project is useful during and after its development. It embodies 15 different management plans viz. Biodiversity conservation management plan, catchment area treatment plan, resettlement and rehabilitation plan, muck disposal plan, fishery development plan, disaster management plan, solid waste management plan and some other important plans. It is believed that implementation of all these plans would ameliorate the condition of the environment that is likely to be resulted due to adverse impacts anticipated due to the development of the proposed project and also bring in socio-economic development of the region. The total financial layout proposed to meet the measures suggested in various management plans is **Rs. 8265.92 lakh** (Table 6) which is approximately 2.30 per cent of the total project cost (Rs. 3594.74 Cr at July 2009 PL).

Table 6. Cost estimates for the implementation of EMP*

Sl. No.	Plans	Amount (Rs. in lacs)
1.	Resettlement and Rehabilitation Plan	2778.30
2.	Catchment Area Treatment Plan	2157.82
3.	Biodiversity Management Plan	498.00
4.	Fisheries Management Plan	141.80
5.	Public Health Management	362.00
6.	Restoration of Muck Dumping Sites	707.41
7.	Solid Waste Management	248.05
8.	Landscaping and Restoration of Construction Areas & Quarry Sites	178.25
9.	Fuel and Energy Conservation Measures	75.00
10.	Green Belt Development Plan	96.50
11.	Reservoir Rim Treatment Plan	329.50
12.	Air, Noise & Water Quality Management Plan	50.00

13.	Compensatory Afforestation Plan	243.29
14.	Dam Break Analysis and Disaster Management Plan	350.00
15.	Environmental Monitoring Programme	50.00
	Total	**8265.92**

* This does not include the cost of land to be acquired.