DRAFT CATCHMENT AREA TREATMENT PLAN

OF

RAHI KYOUNG HYDRO ELECTRIC PROJECT

January, 2016

Prepared for:

Sikkim Engineering Private Limited

Prepared by:

R. S. Envirolink Technologies Pvt. Ltd.

402, RADISSON SUITES COMMERCIAL PLAZA,

B-BLOCK, SUSHANT LOK-I, GURGAON

Ph: +91-124-4295383: www.rstechnologies.co.in

Table of Content **Page No.**

1 INTRODUCTION
- 1.1 General 1
- 1.2 Salient Features 2
- 1.3 Catchment Area 6

2 NEED FOR CATCHMENT AREA TREATMENT 6

3 METHODOLOGY ADOPTED FOR THE STUDY 7
- 3.1 Defining Data Requirement 7
- 3.2 Data Acquistion and Preparation 8
  - 3.2.1 Delineation of Sub-Watershed 8
  - 3.2.2 Slope Map 11
  - 3.2.3 Soil Map 13
  - 3.2.4 Land Use/ Land Cover Map 14
- 3.3 Modeling 15
- 3.4 Output Presentation 15

4 PRIORTIZATION USING SILT YIELD INDEX (SYI) METHOD 17
- 4.1 Erosion Intensity Mapping Unit 17
- 4.2 Weightage Value 17
- 4.3 Delivery Ratio 18
- 4.4 Silt Yield Index 18
- 4.5 Prioritization of Sub-Watersheds 18

5 TREATMENT PLAN
- 5.1 Area to be taken up for treatment 19
- 5.2 Treatment Measures 20
  - 5.2.1 Biological Measures 20
    - 5.2.1.1 Afforestation 21
    - 5.2.1.2 Assisted Natural Regeneration 21
  - 5.2.2 Engineering Measures 21
    - 5.2.2.1 Brushwood Check Dams 21
    - 5.2.2.2 Dry Stone Masonry Check Dams 22
    - 5.2.2.3 Contour Bunding 22
    - 5.2.2.4 Gabion Check Dams 23

6 OTHER COMPONENTS OF CAT PLAN 23
- 6.1 Administrative Charges 23
- 6.2 Provision for Micro Planing 23
- 6.3 Monitoring & Evaluation 24
- 6.4 Contingencies 24

7 COST ESTIMATE 24

LIST OF TABLES

Table 1 : Salient Features of Rahi Chu HEP 2
Table 2 : Names and codes of Sub-watersheds delineated for the Catchment Area of Rahi Chu HEP 8
Table 3 : Area falling under different slope categories in Rahi Chu HEP Catchment Area 11
Table 4 : Description of Soil Units in Rahi Chu HEP Catchment Area 12
Table 5 : Sub-Watershed wise areas falling under different soil units in Rahi Chu HEP Catchment Area 13
Table 6 : Sub-Watershed wise area falling under different land use/ land cover categories in Rahi Chu HEP Catchment Area 16
Table 7 : Soil loss ranges in Rahi Chu HEP Catchment Area 17
Table 8 : Sub-watershed wise area under each EIMU class in Rahi Chu HEP Catchment Area 18
Table 9 : SYI Classification of Sub-Watersheds in Rahi Chu HEP Catchment Area 18
Table 10 : Criteria for Priority 18
Table 11 : Priority Number as per SYI Classification in Rahi Chu HEP Catchment Area 19
Table 12 : Basis for selection of catchment area treatment measures 21
Table 13 : Summary of treatment measures and their cost for CAT Plan 23
Table 14 : Estimated cost of CAT Plan Implementation 24
Table 15 : Year wise physical & financial targets of treatment measures for CAT Plan 26

LIST OF FIGURES

Figure 1 : Location Map of Rahi Chu HEP 1
Figure 2 : General Layout of Rahi Chu HEP 5
Figure 3 : Drainage Map of Rahi Chu HEP Catchment Area showing Sub-Watersheds 9
Figure 4 : Slope Map of Rahi Chu HEP Catchment Area 10
Figure 5 : Soil Map of Rahi Chu HEP Catchment Area 11
Figure 6 : Satellite Imagery of Rahi Chu HEP Catchment Area 13
Figure 7 : Land Use/ Land Cover Map of Rahi Chu HEP Catchment Area 14
Figure 8 : Soil Erosion Intensity Map of Rahi Chu HEP Catchment Area 16
Figure 9 : Priority Classification Map of Rahi Chu HEP Catchment Area 19
Figure 10 : Location of Khangchendzonga National Park in the Catchment Area of Rahi Chu HEP 20

ANNEXURE

CATCHMENT AREA TREATMENT PLAN

1 INTRODUCTION

1.1 General

The proposed Rahi Kyooung Hydro Electric Project (HEP), a run-of-river scheme is proposed to be developed on Rahi Kyoung, a left bank tributary of Tolung Chu in North Sikkim district in the state of Sikkim. The development rights of the project have been accorded to Sikkim Engineering Private Limited.

The 25 MW Rahi Kyoung HEP envisages the construction of a Trench Weir on Rahi Kyoung, around 3.3 km upstream of its confluence with Tolung Chu and the underground powerhouse is situated on the left bank of Tolung Chu, around 840 m just upstream of its confluence with Teesta river. The project also involves the construction of the headrace tunnel, forebay, underground penstock and a powerhouse-tailrace channel.

Scope of the present study is to prepare Catchment Area Treatment Plan for the catchment area of Rahi Kyoung HEP. Hence, the catchment area has been delineated from the source of Rahi Chu to the diversion site of the proposed Rahi Kyoung HEP. The project location map is enclosed as **Figure 1.**

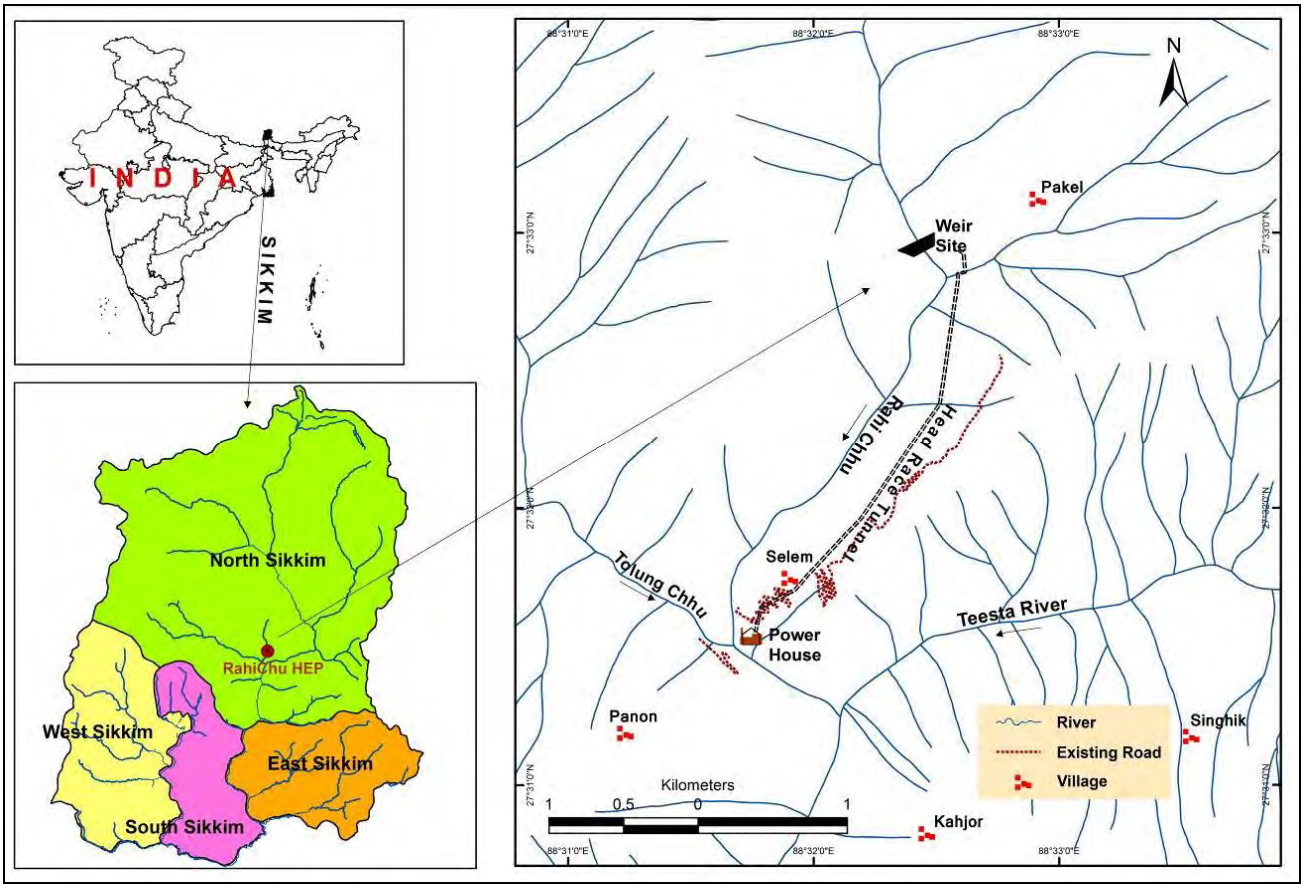


Figure 1: Location map of Rahi Kyoung HEP

1.2 Salient Features

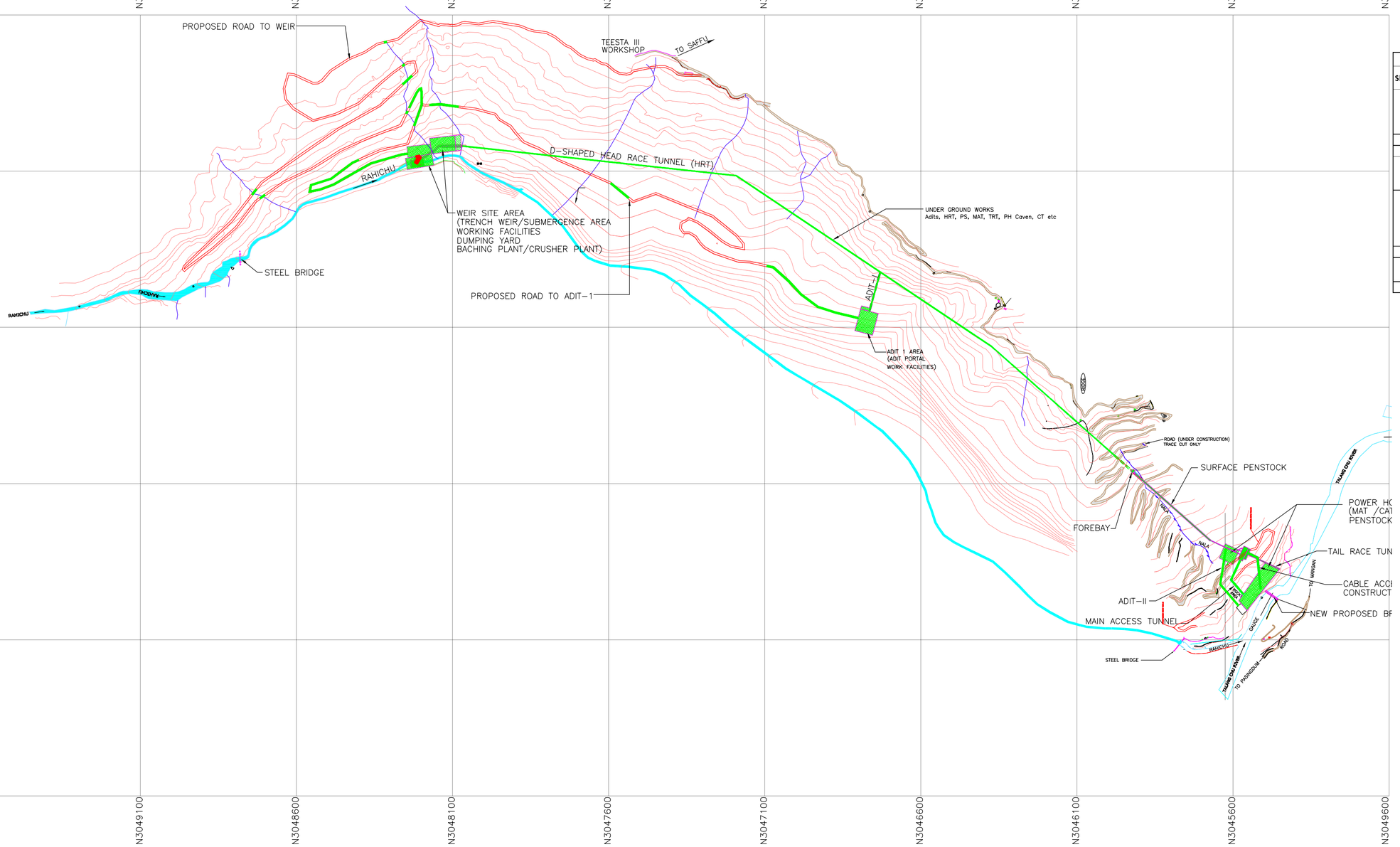
The salient features of the proposed Rahi Kyoung HEP are given in **Table 1**. A general layout plan of the project is given at **Figure 2**.

Table 1: Salient Features of Rahi Kyoung HEP

1	**Location**	
	State	Sikkim
	District	North Sikkim
	Village	Near Saffu
	Access	
	Major Airport	Bagdogra
	Rail Head	New Jalpaiguri and Siliguri
	Road Head	42 km from Mangan via Tung Bridge on the Teesta River and Saffu village that would include a road of about 7 km length from Saffu village on the Saffu-Sangkalan road being construction by the Border Roads Organisation (BRO).
	Geographical co-ordinates of the diversion site	
	Latitude (N)	27 32 53.65
	Longitude (E)	88 32 24.20
	Map reference	Survey of India topo-sheets: 78-A-10-2, 78-A-10-3
2	**Meteorology**	
	Average Rainfall	About 2830 mm
	Atmospheric Temperature	
	Maximum Temp.	Up to about 23^0 C
	Minimum Temp.	Up to about 4.3^0 C
3	**Hydrology**	
	Catchment Area	53.5 km^2
	Design Flood	300 m^3s^{-1}
	90% dependable year and corresponding flow in MCM	161.22 MCM (1997-98)
	75% dependable year and corresponding flow in MCM	171.70 MCM (2003-04)
	50% dependable year and corresponding flow in MCM	181.77 MCM (2001-02)
4	**Power potential**	
	Gross head (m)	375m
	Rated head (m)	367.73
	Design discharge (m^3s^{-1})	7.69
	Installed capacity (MW)	25
	75% Dependable Energy (MU) with 95% machine availability	103.55
	Plant load factor	47.28%
5	**Diversion Structure (Head works)**	
	Type of structure	Trench weir
	Length of weir (m)	20
	Width of trench weir(m)	2
	Average bed level at weir(m)	1154
	Full Supply Level (m)	1153
	Maximum Water Level (m)	1155.24
6	**Feeder channel**	
	Length of feeder channel (m)	31
	Shape	Trapezoidal
	Bed slope / Side Slope	1 in 850 / 1:0.5
	Bed Width (m)	2.5
	Full Supply Depth (m)	1.39 m
7	**De silting Basin**	
	Type	Surface with central flushing conduit
	Incoming/outgoing discharges (m^3s^{-1})	9.23 / 7.69
	Length without transition (m)	57

	Width (m)	6.5
	Height above hoppers up to FSL (m)	7
8	**Head Race Tunnel**	
	Shape	D-Shaped
	Length (m)	2462
	Slope	1:50000
	Size (m)	3.0 (W) X 3.50 (H)
	Adit-I	D-Shaped, 3.0 (W) X 3.50 (H), 73m long
9	**Fore bay**	
	Length (m)	20
	Width (m)	10.7
	Shape / Side Slope	Trapezoidal / 1:8
	Depth (m) from FSL	7.58 m
10	**Spillway & Escape channel**	
	Location	Provided in fore bay on valley side
	Crest length and its Elevation	6 m ; EL 1153.10
	Discharging capacity (m^3s^{-1})	7.69
	Width of escape channel (m)	6
11	**Underground Penstock**	
	Number	
	Main penstock	1 no.
	Unit penstock	3 nos.
	Diameter of main penstock (m) / unit penstock (m)	1.65 / 0.970
	Thickness of steel liner (mm)	8 to 30
	Grade of Steel	IS 2002, Gr.-II
	Length of main penstock	443 m (horizontal), 367 m (vertical)
	Adit-II	D-Shaped, 5.0 (W) X 5.0 (H), 44 m long
	Adit-III	D-Shaped, 5.0 (W) X 5.0 (H), 155 m long
12	**Underground Power House**	
	Size of machine hall cavern (m)	45.0 (L) X 14.0 (W) X 24.0 (H)
	Installed capacity (MW)	3 X 8.33
	Main Access Tunnel (MAT)	D-shaped,6.0m (W) X5.5 m(H) and 66 m long
	Cable Tunnel (Vertical)	Circular, 2 m diameter and 76 m long
	Construction adit to top of	D-shaped, 5m(W) X 5m(H) and 135m long
	powerhouse cavern	
	Maximum Tail water level (m)	775
13	**Electro-mechanical**	
	Turbine	
	No. and Type	3 Nos., Horizontal Pelton with Three Jets
	Efficiency	92%
	Maximum available gross head(m)	370
	Rated head(m)	367.73
	Design discharge(m3s-1)	7.69
	Speed	600 rpm
	Inlet Valve	Spherical Valve
	Generator	
	Type	Synchronous type
	Rated Out put	3 x 8.33 MW
	Efficiency	98%
	Power factor	0.9
	Speed	600 rpm
	Voltage	11 kV ± 10%
14	**Tailrace Tunnel**	
	Shape	D-Shaped
	Length (m)	117
	Slope	1.083333333
	Size (m)	3.0 (W) X 3.50 (H)
15	**Costs**	
	Price level	Oct-15
	Basic Project Cost (INR)	177.00 Cr.

	Escalation (INR) & FC	25.05 Cr.
	Interest During Construction and Front	16.15 Cr.
	End Fees (INR)	
	Completed project cost (INR)	218.15 Cr.
16	**Generation, Cost and Tariff**	
	Annual generation (75% dependable	103.55 MU
	year)-Without overload	
	First year Tariff (in Rs./Unit)	5.17
	Levellised Tariff (in Rs./Unit)	4.72



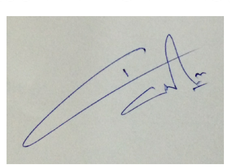
TOTAL FOREST LAND REQUIRED FOR THE PROJECT

SL. No	COMPONENT	PURPOSE	FOREST LAND (Ha)
1	POWER HOUSE AREA	MAT /CAT	0.424
		MUCK DUMPING YARD -1	0.286
		PENSTOCK/VPS JUNCTION	0.250
		TOTAL	**0.960**
2	FOREBAY AREA	**TOTAL**	**0.008**
3	SURFACE PENSTOCK	**TOTAL**	**0.144**
4	ADIT 1 AREA	ADIT PORTAL	0.0400
		WORK FACILITIES	0.3625
		TOTAL	**0.4025**
5	WEIR SITE AREA	TRENCH WEIR/SUBMERGENCE AREA	0.320
		WORKING FACILITIES	0.260
		DUMPING YARD	0.400
		BACHING PLANT/CRUSHER PLANT	0.090
		TOTAL	**1.0700**
6	ACCESS ROADS		**0.9950**
7	UNDER GROUND WORKS	Adits, HRT, PS, MAT, TRT, PH Caven, CT etc	**1.189**
	TOTAL		**4.7685**

Scale 1:10000

Dimensions in m 0 100m 500m

M/S SIKKIM ENGINEERING (P) LTD.



Authorized Signature

Client: M/S SIKKIM ENGINEERING (P) LTD.

TATA CONSULTING ENGINEERS LIMITED MUMBAI

Project: RAHI KYOUNG HYDRO ELECTRIC PROJECT

Title: GENERAL LAYOUT PLAN

Drawing no (Customer)

Drawing no TCE-6944A-200-GA-6003

A3 420 x 297

1.3 Catchment Area

The catchment area has been delineated as catchment area falling between the source of Rahi Chu to the diversion site of the proposed Rahi Kyoung HEP on Rahi Chu. The Rahi Chu, is a tributary of Tolung Chu, which in turn is a major tributary of the Teesta. The Rahi River has its origin in the glaciers of Sikkim at an elevation of over 5000m above mean sea level. The Rahi Chu in general flows in a south-west direction meeting the Tolung Chu almost perpendicularly. The terrain hosts a rich growth of vegetation. Numerous valleys with cultivated terraces are seen in the catchment area. The catchment area of the proposed Rahi Kyoung HEP is 53.50 km^2 and the total length of the Rahi Chu in the catchment area is around 14 km with a very steep gradient. The elevation of the catchment varies from El. 1154.0m to El. 5022.0m. The catchment area map is shown in **Figure 3**.

2 NEED FOR CATCHMENT AREA TREATMENT

Increasing competition for land to meet the requirement of rapidly increasing population has resulted in over exploitation of natural resources leading to widespread damage to soil environment. A large number of hydropower projects are coming up in Basin to meet the peak power demand of the country, which consists of construction of diversion structures on various rivers. The development of these hydropower projects aggravates the problem of soil erosion.

Soil erosion can be defined as detachment, transportation and deposition of soil particles from one place to other by means of transporting agent like air, water or animals. Soil erosion is mainly affected by rainfall intensity and runoff, slope gradient and length, soil erodibility and vegetation cover (landuse pattern). In a hilly catchment area, as in the present case, erosion due to water is a common phenomenon. Therefore study of erosion and sediment yield from catchments are of great importance. Soil erosion leads to:

- loss in production potential
- reduction in infiltration rates
- reduction in water-holding capacity
- loss of nutrients
- increase in tillage operation costs
- reduction in water supply

To control the rate of soil erosion in the catchment, Catchment Area Treatment (CAT) is an ineluctable part of any hydropower project. The CAT plan pertains to preparation of a management plan for treatment of erosion prone areas through adequate preventive measures. An effective CAT plan of a hydropower project is a key factor to make the project eco-friendly and sustainable. Thus, a well-designed Catchment Area Treatment (CAT) Plan is essential to ameliorate the above mentioned adverse process of soil erosion. CAT plan essentially consist of following steps.

1. Identification of highly erodible areas within the catchment by calculation of Silt Yield Index (SYI) and sediment load for sub watersheds using Geographical Information System (GIS).
2. Prioritizing the areas for treatment.
3. Planning of suitable erosion control measures.
4. Cost estimation for CAT plan.

3 METHODOLOGY ADOPTED FOR THE STUDY

In the present study `Silt Yield Index' (SYI), method has been used. In this method, the terrain is subdivided into various sub-watersheds and the erodibility is determined on relative basis. SYI provides a comparative erodibility criteria of catchment (low, moderate, high, etc.) and does not provide the absolute silt yield. SYI method is widely used mainly because of the fact that it is easy to use and has lesser data requirement. Moreover, it can be applied to larger areas like sub-watersheds, etc. The application of SYI model for prioritization of sub-watersheds in the catchment areas involves the evaluation of:

- Climatic factors comprising total precipitation, its frequency and intensity,
- Geo-morphic factors comprising land forms, physiography, slope and drainage characteristics,
- Surface cover factors governing the flow hydraulics and
- Management factors.

The various steps involved in the application of model are:

- Preparation of a framework of sub-watersheds through systematic delineation
- Rapid reconnaissance surveys on 1:50,000 scale leading to the generation of a map indicating erosion-intensity mapping units.
- Assignment of weightage values to various mapping units based on relative silt-yield potential.
- Computing Silt Yield Index for individual sub-watersheds.
- Grading of sub-watersheds into very high, high, medium, low and very low priority categories.

A detailed database on natural resources, terrain conditions, soil type of the catchment area, etc. is a pre-requisite to prepare treatment plan keeping in view the concept of sustainable development. Various thematic maps have been used in preparation of the CAT plan. All the thematic maps thus prepared were processed in Geographic Information System (GIS) domain. The GIS has a capacity to perform numerous functions and operations on the various spatial data because of its special hardware and software characteristics. In order to ensure that latest and accurate data is used for the analysis, Survey of India (SoI) topographical sheets on 1:50,000 scale, satellite data (LANDSAT) and digital elevation model derived from Shuttle Radar Topography Mission (SRTM) data have been used for deriving data for drainage, land use, slope, and elevation. Various steps, covered in the study, are as follows:

- Defining data requirement
- Data acquisition and preparation
- Modeling
- Output presentation

The above mentioned steps are briefly described in the following paragraphs:

3.1 Defining Data Requirement

The requirements of the study were defined and the expected outputs were finalized. The various data layers of the catchment area to be used for the study are as follows:

- Catchment Area/ Sub-Watershed Map

- Slope Map
- Soil Map
- Land use Classification Map
- Rainfall Intensity

3.2 Data Acquisition and Preparation

The data available from various sources were collected. The ground maps, topographical maps etc. were scanned, geo-referenced and digitized as per the requirement. Data was prepared depending on the level of accuracy required and any corrections required were made. All the layers were geo-referenced and brought to a common scale (real co-ordinates), so that overlay could be performed. A computer program using standard modeling techniques was used to estimate the soil loss. The formats of outputs from each layer were formed to match the formats of inputs in the program.

3.2.1 Delineation of Sub-Watershed

Soil and Land Use Survey of India (SLUSI) has Watershed Atlas of India under digital environment using GIS and produced a Digital Watershed Atlas (DWA) where the delineation and codification of watersheds in the country has been undertaken in GIS environment. The delineation for DWS has been done in seven stages starting with Water Resource Regions and their subsequent division and subdivisions into Basins, Catchments, Sub-catchments, Watershed, Sub watershed and Micro-watersheds in decreasing size of the delineated hydrologic unit.

As per Watershed Atlas of India, the catchment area of Rahi Kyoung HEP falls in Watershed '3A1B3' (Tolung), Sub-Catchment '3A1B' (Teesta), Catchment '3A1' (Teesta to Manas Confluence) and Basin '3A' (Right bank of Brahmaputra up to Lohit Confluence) of Region '3' (Brahmaputra). So far, SLUSI has delineated upto Watershed level only. In order to plan watershed management and to formulate action plans it requires sub-watershed delineation. Therefore, the Watershed 3A1B3 is further divided into sub-watersheds on 1:50,000 scale (SoI topographical maps) in which main tributaries and streams are taken up for delineation of sub-watersheds. The detail of Watersheds delineated by SLUSI and further sub-watersheds delineated is given below (**Table 2 and Figure 3**).

Table 2: Names and codes of Sub-watersheds delineated for the Catchment of Rahi Kyoung HEP

S. No	Water Resource Region	Basin	Catchment	Sub-Catchment	Watershed	Sub-Watershed Code	Sub-Watershed Area (Sq km)
1.	Brahmaputra (3)	Right bank of Brahmaputra up to Lohit Confluence (3A)	Teesta to Manas Confluence (3A1)	Teesta (3A1B)	Tolung (3A1B3)	3A1B3a	25.88
2.						3A1B3b	27.62
TOTAL							**53.50**

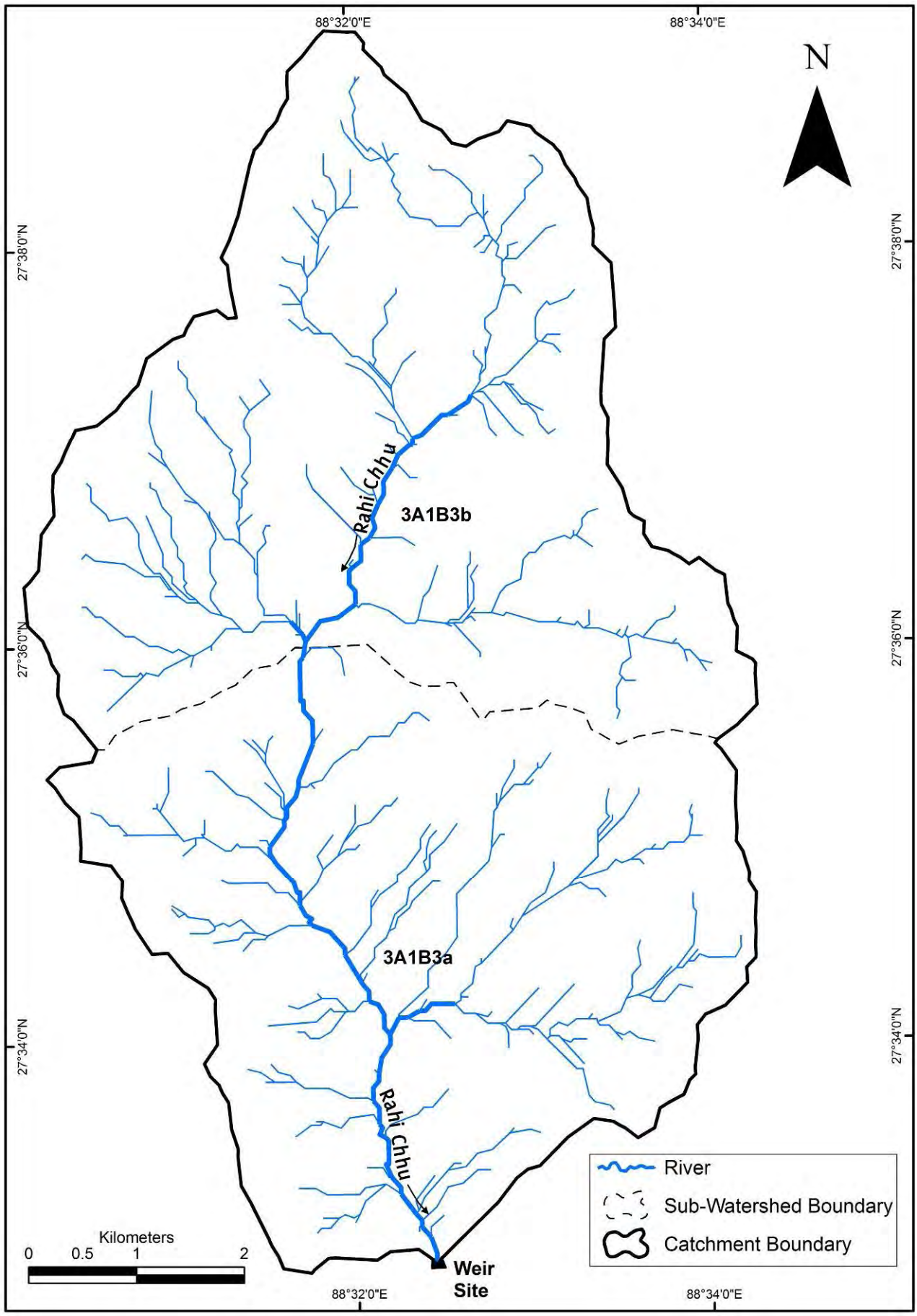


Figure 3: Drainage Map of Rahi Kyoung HEP Catchment Area showing Sub-Watersheds

3.2.1 Slope Map

The slope has a great influence on the soil and water loss from the area and thereby influences the landuse capability. The degree slope determines the erosion susceptibility of the soil depending on its nature. This helps in classifying various lands in suitable capability classes which enables us to formulate suitable conservation measures for the prevention of soil erosion. ASTER Global Digital Elevation Data (GDEM) was used for preparation of slope map. The data was downloaded in Georeferenced Tagged Image File Format (GeoTIFF) format and using ArcGIS software a slope (in degrees) map was prepared. The degree slope was divided into different slope classes as per SLUSI. The areas falling under various standard slope categories in the Rahi Kyoung HEP catchment as well as Sub-Watersheds have been tabulated below in **Table 3**. The slope map is enclosed as **Figure 4**. As seen from the table (**highlighted cells**) and map, maximum of the catchment area as well as sub-watershed area falls under Steep sloping category. The other dominant sloping category is Moderately Steep. In case of sub-watersheds also maximum area falls under Steep sloping category however, in sub-watershed 3A1B3b Moderately Steep sloping category also covers almost equal area as covered by Steep sloping category.

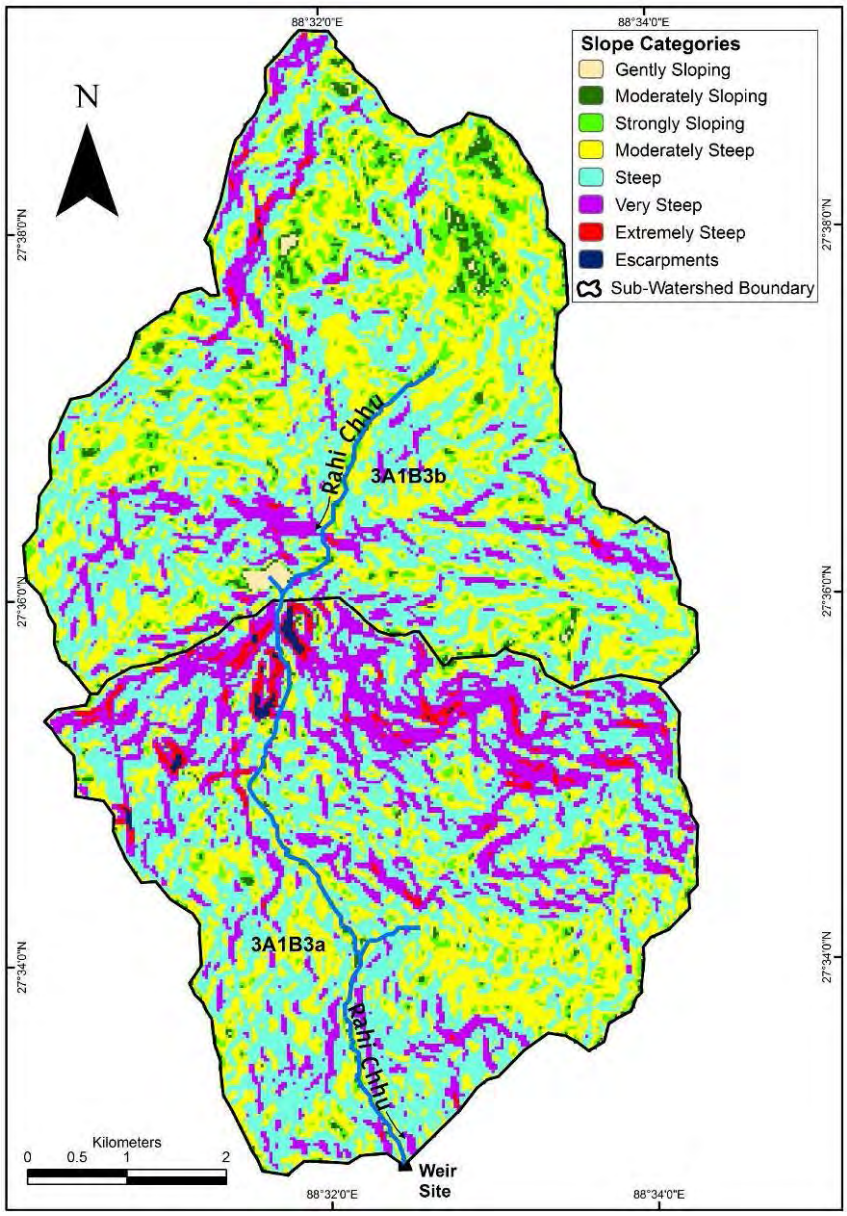


Figure 4: Slope Map of Rahi Kyoung HEP Catchment Area

Table 3: Areas falling under different slope categories in Rahi Kyoung HEP Catchment Area

Slope Category (Degree)	Sub Watersheds				Total	
	3A1B3a		3A1B3b			
	Area (sq km)	Area (%)	Area (sq km)	Area (%)	Area (sq km)	Area (%)
Gently Sloping (Upto 2)	0.03	0.11	0.18	0.64	**0.21**	**0.39**
Moderately Sloping (2-8)	0.24	0.93	0.87	3.16	**1.11**	**2.08**
Strongly Sloping (8-15)	0.71	2.74	2.25	8.16	**2.96**	**5.54**
Moderately Steep (15-30)	6.66	25.73	10.52	38.08	**17.18**	**32.11**
Steep (30-45)	11.76	45.45	10.82	39.16	**22.58**	**42.20**
Very Steep (45-60)	5.75	22.21	2.86	10.35	**8.61**	**16.09**
Extremely Steep (60 – 70)	0.61	2.38	0.12	0.44	**0.74**	**1.37**
Escarpments (above 70)	0.11	0.44	0.00	0.01	**0.12**	**0.22**
Total	**25.88**	**100**	**27.62**	**100**	**53.50**	**100**

3.2.2 Soil Map

Soil map has been digitized and produced using soils map of Sikkim, prepared and published by National Bureau of Soil Survey & Land Use Planning (NBSS&LUP), Nagpur. The above said map has been collected from the Regional Centre of National Bureau of Soil Survey & Land Use Planning (NBSS&LUP), New Delhi. Soil map has been shown in **Figure 5**. The legend for soil classes has been given in **Table 4**. There are 10 types of soil found in the catchment area. As can be seen from the table and map that maximum area is covered by soil unit 55 i.e. 24.31%. 4 types of soil i.e. soil unit 10, 21, 24 and 66 covers the area in the order of 10%. The rest soil types i.e. soil unit 02, 07, 08, 25 and 68, each covers the area less than 10%. The areas falling under different soil units in the Rahi Kyoung HEP catchment as well as Sub-Watersheds have been tabulated below in **Table 5**.

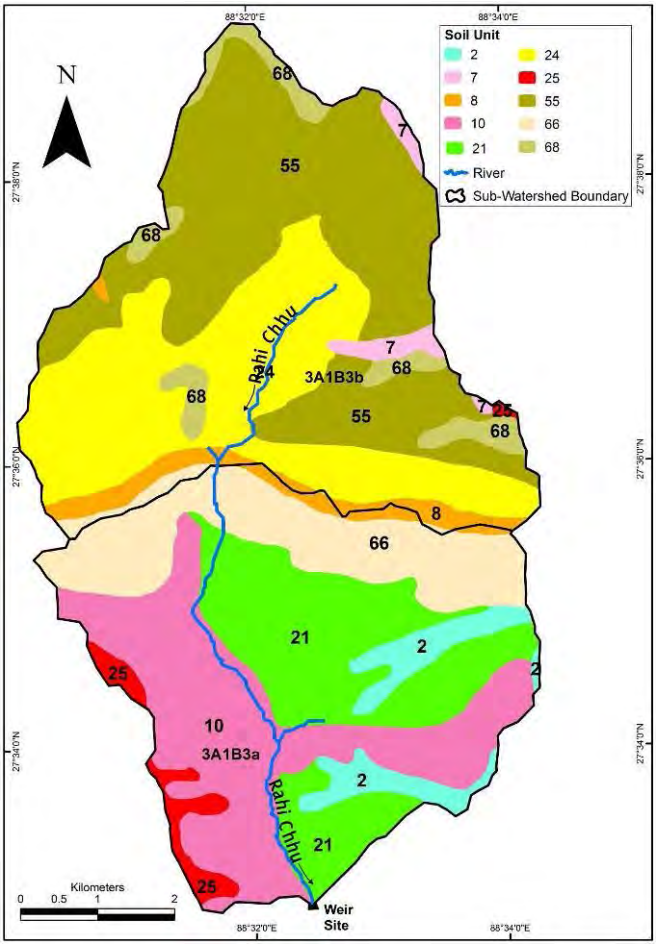


Figure 5: Soil Map of Rahi Kyoung HEP Catchment Area
(For details of Soil Unit legend refer Table 4)

Table 4: Description of Soil Units in Rahi Kyoung HEP Catchment Area

Soil Unit	Description	Taxonomic Classification	Area (sq km)	Area (%)
2	Deep, moderately well drained, fine soils on steep slope with loamy surface, slight stoniness and moderate erosion; associated with Moderately deep, well drained, fine-silty soils with loamy surface, slight stoniness and moderate erosion.	Fine, thermic Typic Haplumbrepts Fine-silty, thermic Typic Haplumbrepts	2.01	3.76
7	Moderately deep, somewhat excessively drained, fine-loamy soils on moderately steep slope with loamy surface, moderate erosion and slight stoniness; associated with Moderately deep, somewhat excessively drained, loamy-skeletal soils with loamy surface, moderate erosion and slight stoniness.	Fine-loamy, thermic Cumulic Haplumbrepts Loamy-skeletal, thermic Typic Udorthents	0.63	1.18
8	Deep, excessively drained, fine-loamy soils on moderately steep slope with loamy surface, moderate erosion and slight stoniness; associated with Moderately deep, excessively drained, coarse-loamy soils with loamy surface, moderate erosion and slight stoniness.	Fine-loamy, thermic Pachic Haplumbrepts Coarse-loamy, thermic Typic Haplumbrepts	1.68	3.15
10	Deep, somewhat excessively drained, fine-loamy soils on very steep slope with loamy surface, moderate erosion and slight stoniness; associated with Moderately deep, somewhat excessively drained, coarse-loamy over fragmental soils with loamy surface, moderate erosion and slight stoniness.	Fine-loamy, thermic Typic Haplumbrepts Coarse-loamy over fragmental, thermic Typic Udorthents	8.84	16.52
21	Deep, somewhat excessively drained, coarse-loamy soils on very steep slope with loamy surface, moderate erosion and slight stoniness; associated with Moderately shallow, somewhat excessively drained, loamy-skeletal soils with gravelly loamy surface, severe erosion and slight stoniness.	Coarse-loamy, thermic Typic Hapludolls Loamy-skeletal, thermic Entic Hapludolls	8.01	14.97
24	Moderately deep, somewhat excessively drained, loamy-skeletal soils on very steep slope with loamy surface, moderate erosion and slight stoniness; associated with Moderately shallow, somewhat excessively drained, coarse-loamy soils with loamy surface, moderate erosion and slight stoniness.	Loamy-skeletal, mesic Typic Haplumbrepts Coarse-loamy, thermic Typic Udorthents	10.45	19.53
25	Moderately deep, somewhat excessively drained, coarse-loamy soils on very steep slope with loamy surface, moderate erosion and slight stoniness; associated with Moderately shallow, somewhat excessively drained, coarse-loamy soils with gravelly loamy surface, severe erosion and moderate stoniness.	Coarse-loamy, thermic Typic Haplumbrepts Coarse-loamy, thermic Typic Udorthents	0.97	1.81
55	Moderately shallow, somewhat excessively drained, coarse-loamy soils on steep slope with gravelly loamy surface, moderate erosion and moderate stoniness; associated with Shallow, somewhat excessively drained, loamy-skeletal soils with gravelly loamy surface, severe erosion and moderate stoniness.	Coarse-loamy, mesic Typic Haplumbrepts Loamy-skeletal, mesic Lithic Udorthents	13.00	24.31
66	Shallow, excessively drained, loamy skeletal soils with gravelly loamy surface, very severe erosion and moderate stoniness; associated with Rocks.	Loamy-skeletal, thermic Lithic Udorthents	6.03	11.26
68	Very shallow, excessively drained, loamy-skeletal soils on cliff with gravelly loamy surface, severe erosion and slight stoniness; associated with Rocks.	Loamy-skeletal, mesic Lithic Udorthents	1.89	3.53
TOTAL			**53.50**	**100**

Table 5: Sub-Watershed wise areas falling under different soil units in Rahi Kyoung HEP Catchment Area

Soil Units	Sub Watersheds				Total	
	3A1B3a		3A1B3b			
	Area (sq km)	Area (%)	Area (sq km)	Area (%)	Area (sq km)	Area (%)
02	2.01	7.76	0.00	0.00	**2.01**	**3.76**
07	0.00	0.00	0.63	2.28	**0.63**	**1.18**
08	0.42	1.64	1.26	4.56	**1.68**	**3.15**
10	8.84	34.15	0.00	0.00	**8.84**	**16.52**
21	8.01	30.94	0.00	0.00	**8.01**	**14.97**
24	0.01	0.02	10.44	37.80	**10.45**	**19.53**
25	0.92	3.57	0.05	0.17	**0.97**	**1.81**
55	0.00	0.00	13.00	47.08	**13.00**	**24.31**
66	5.67	21.93	0.35	1.27	**6.03**	**11.26**
68	0.00	0.00	1.89	6.84	**1.89**	**3.53**
Total	**25.88**	**100**	**27.62**	**100**	**53.50**	**100**

3.2.3 Land Use/ Land Cover Map

For the present study, LANDSAT 8 digital satellite data of Path 139 and Row 41 dated 28th December 2015 was used for interpretation & classification (**Figure 6**). The data was procured in GeoTIFF format. The interpretation of geo-referenced satellite data has been done using standard enhancement techniques and experiences of qualified professionals. For the assessment of accuracy, landuse/landcover maps prepared by National Remote Sensing Centre (NRSC), Indian Space Research Organisation (ISRO) of Dept. of Space with State Council for Science & Technology, Government of Sikkim as partner under Natural Resource Census (NRC) project of National Natural Resource Repository (NRR) programme; Google Earth were also referred.

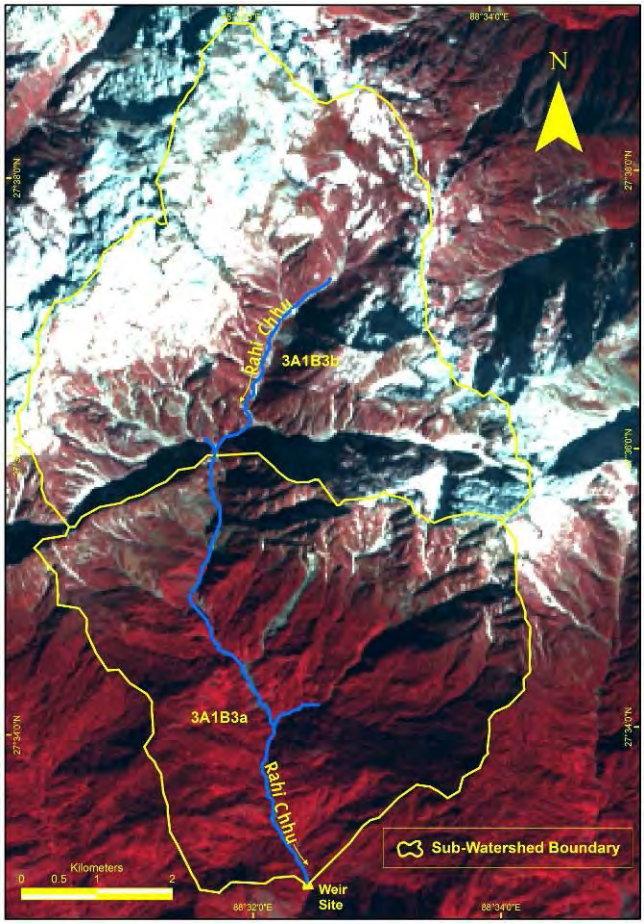


Figure 6: Satellite Imagery of Rahi Kyoung HEP Catchment Area

The classified land use/ land cover map of the catchment area is shown as **Figure 7**. The land use/ land cover pattern of the proposed Rahi Kyoung HEP catchment area as well as of Sub-Watershed has been given in **Table 6**. As can be seen from the map and table (**highlighted cells**) the land use/ land cover pattern can be classified into seven classes, out of these seven classes, moderately dense forest covers the maximum area i.e. around 27% followed by scrub land i.e. around 23%. However, in case of sub-watersheds, the percentage coverage by classes are bit different. In sub-watershed 3A1B3a, moderately dense forest covers more than 50% followed by open forest i.e. around 24%. In sub-watershed 3A1B3b scrub land covers the maximum area i.e. around 38% followed by snow cover which covers around 32%. All the settlements are in sub-watershed 3A1B3a.

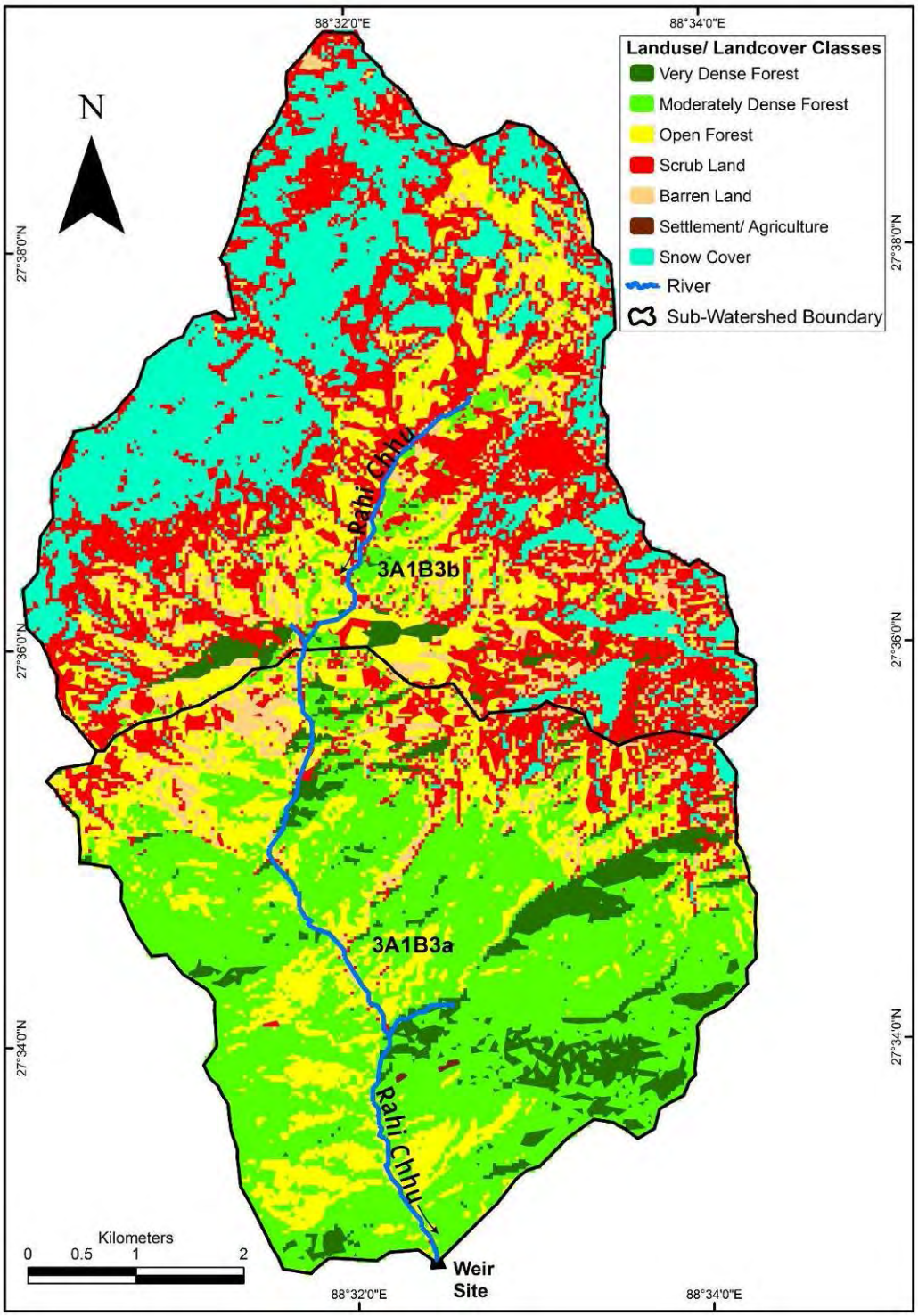


Figure 7: Land Use/ Land Cover Map of Rahi Kyoung HEP Catchment Area

Table 6: Sub-Watershed wise area falling under different land use/ land cover categories in Rahi Kyoung HEP Catchment Area

Landuse/ Landcover Classes	Sub Watersheds				Total	
	3A1B3a		3A1B3b			
	Area (sq km)	Area (%)	Area (sq km)	Area (%)	Area (sq km)	Area (%)
Very Dense Forest	2.59	10.01	0.45	1.64	**3.04**	**5.69**
Moderately Dense Forest	13.66	52.78	0.82	2.96	**14.48**	**27.06**
Open Forest	6.18	23.88	4.99	18.08	**11.17**	**20.88**
Scrub Land	2.18	8.43	10.39	37.62	**12.57**	**23.50**
Barren Land	1.01	3.89	2.03	7.34	**3.04**	**5.67**
Snow Cover	0.24	0.94	8.94	32.35	**9.18**	**17.16**
Settlement/ Agriculture	0.02	0.07	0.00	0.00	**0.02**	**0.03**
Total	**25.88**	**100**	**27.62**	**100**	**53.50**	**100**

3.3 Modeling

Soil loss has been calculated through RUSLE (Revised Universal Soil Loss Equation) model which is computed by the following equation:

Soil Loss (A) = R*K*LS*C*P

Wherein;

A = Soil loss (Tons/ha/year)

R is Rainfall & Runoff Erosivity Factor (MJ/ha/mm/year), which depends upon the annual average rainfall in mm.

K is Erodibility Factor (Tons/MJ/mm), which depends on the organic matter, texture permeability and profile structure of the soil. Also, it is a constant value for each soil type.

LS is Topographic Factor (dimensionless), which depends upon flow accumulation and steepness and length of slope in the area.

C is Vegetation Cover and Crop Management Factor (dimensionless), which is the ratio of bare soil to vegetation and non-photosynthetic material. It is a constant value for each land use category.

P is Support Practice Factor (dimensionless), which takes into account specific erosion control practices like contour bunding, bench terracing etc. This factor is taken as 1 for bare soil where no erosion control practice is taking place.

3.4 Output Presentation

A thematic map for soil loss of the catchment area has been prepared using RUSLE model mentioned in the above section. The catchment area was then demarcated into different soil erosion intensity classes based upon the extent of soil loss (see **Table 7 & Figure 8**). As can be seen from the figure and table (**highlighted cells**), around 29% of the catchment area is prone to less than 1 tons/ha/annum soil erosion, which can be termed as negligible soil erosion intensity class. Very Low, Low and Moderate soil erosion intensity class individually covers more than 10% of the area. Around 11% of the area is prone to Severe and Very Severe soil erosion intensity class i.e more than 40 tons/ha/annum.

Table 7: Soil loss ranges in Rahi Kyoung HEP Catchment area

S. No.	Soil loss in tons/hectare/annum	Area (ha)	Area (%)	Soil Erosion Intensity
1	<1	1526.11	28.53	Negligible
2	1-5	478.07	8.94	Slight
3	5-10	570.69	10.67	Very Low
4	10-20	1171.95	21.91	Low
5	20-40	993.19	18.56	Moderate
6	40-80	425.56	7.95	Severe
7	> 80	184.42	3.45	Very Severe
	Total	**5350.00**	**100**	

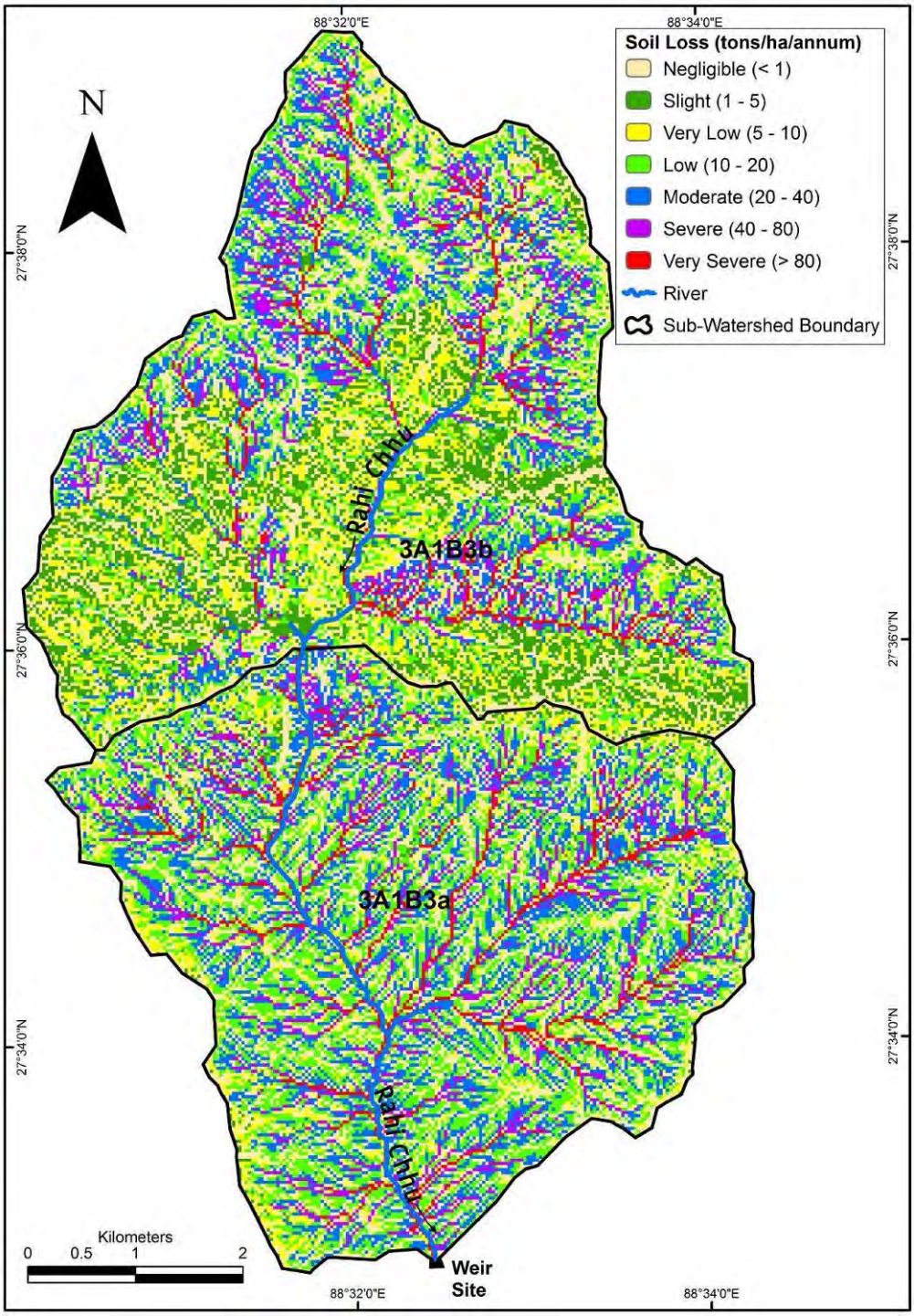


Figure 8: Soil Erosion Intensity Map of Rahi Kyoung HEP Catchment Area

4 PRIORTIZATION USING SILT YIELD INDEX (SYI) METHOD

`Silt Yield Index' (SYI), method has been used for prioritization of sub-watersheds in the catchment for treatment. The Silt Yield Index (SYI) is defined as the Yield per unit area and SYI value for hydrologic unit is obtained by taking the weighted arithmetic mean over the entire area of the hydrologic unit by using suitable empirical equation. The Silt Yield Index Model (SYI) considers sedimentation as product of erosivity, morphometry and delivery ratio of a particular sub-watershed and was conceptualized by Soil and Land Use Survey of India (SLUSI) as early as 1969 and has been operational since then to meet the requirements of prioritization of smaller hydrologic units within river valley project catchment areas. Silt yield index (SYI) was calculated using following empirical formula:

$$SYI = \Sigma \frac{(Ai * Wi) * Di * 100}{Aw} ; \quad \text{where } i = 1 \text{ to } n$$

where,

Ai = Area of ith unit (EIMU)
Wi = Weightage value of ith mapping unit
n = No. of mapping units
Aw = Total area of sub-watershed.
Di = Delivery ratio

4.1 Erosion Intensity Mapping Unit

Erosion Intensity Mapping Units (EIMU) are demarcated and defined as per the soil erosion intensity map prepared above. Various EIMU categories, such as Very Severe, Severe, Moderate, Low, Very Low, and Negligible & Slight (clubbed together), were then used to calculate sub-watershed-wise SYI. Erosion Intensity Mapping Units (EIMU) is a composite expression of physiography, land use, and conservation practices adopted. While computing soil erosion intensity in a catchment all the factors (physiography, land use, and conservation practices) are already taken into consideration. Therefore, EIMUs are assumed as per the soil erosion intensity in the sub-watershed. The sub-watershed wise area under each EIMU class is given in **Table 8**.

Table 8: Sub-watershed wise area under each EIMU class in Rahi Kyoung HEP Catchment Area

EIMU Class	Sub- Watersheds wise Area (Ha)		Total Area (Ha)
	3A1B3a	3A1B3b	
Very Severe	107.13	77.30	184.42
Severe	229.53	196.03	425.56
Moderate	574.77	418.42	993.19
Low	714.85	457.09	1171.95
Very Low	211.07	359.62	570.69
Negligible/ Slight	750.54	1253.64	2004.18
Total Area (Ha)	**2587.90**	**2762.10**	**5350.00**

4.2 Weightage Value

Each erosion intensity unit is assigned a weightage value. When considered collectively, the weightage value represents approximately the comparative erosion intensity. A basic factor of K = 10 was used in determining the weightage values. The value of 10 indicates a static condition of equilibrium between erosion and deposition. Any addition to the factor K (10+X) is suggestive of erosion in ascending order whereas subtraction, i.e. (10-X) is indicative of deposition possibilities. The weightage value assigned to erosion mapping unit in a sub-watershed ranges from 11-20.

4.3 Delivery Ratio

Delivery ratios were adjusted for each of the erosion intensity unit. The delivery ratio suggests the percentage of eroded material that finally finds entry into reservoir or river/ stream. Delivery ratios are assigned to all erosion intensity units depending upon their distance from the nearest stream. The criteria adopted for assigning the delivery ratio are as follows:

Nearest Stream	Delivery ratio
0 - 0.9 km	1.00
1.0 - 2.0 km	0.95
2.1 - 5.0 km	0.90
5.1 - 15.0 km	0.80
15.1 - 30.0 km	0.70

4.4 Silt Yield Index

The area of each of the mapping units is computed and silt yield indices of individual sub-watersheds are calculated using the equations mentioned above. The SYI values for classification of various categories of erosion intensity rates are given in **Table 9**.

Table 9: SYI Classification of Sub-Watersheds in Rahi Kyoung HEP Catchment Area

Sub-Watershed	EIMU	EIMU Area (EA) in ha.	Weightage Factor (WF)	Silt Yield (SY) = EA * WF	Delivery Ratio (DR)	SYI = (SY*DR*100)/SA
3A1B3a	1	107.13	20	2143	0.9	1287
	2	229.53	18	4132		
	3	574.77	16	9196		
	4	714.85	14	10008		
	5	211.07	12	2533		
	6	750.54	12	9007		
Total		**2587.90**		**37018**		**1287**
3A1B3b	1	77.30	20	1546	0.85	1155
	2	196.03	18	3528		
	3	418.42	16	6695		
	4	457.09	14	6399		
	5	359.62	12	4315		
	6	1253.64	12	15044		
Total		**2762.10**		**37528**		**1155**

4.5 Prioritization of Sub-Watersheds

The sub-watersheds are subsequently rated into various categories corresponding to their respective SYI values. The criteria followed for priority categorization of sub-watersheds depending upon their SYI values is given in **Table 10** and the priority classification of individual sub-watershed is given in **Table 11** and **Figure 9**.

Table 10: Criteria for Priority

Priority categories	SYI Values
Very high	> 1300
High	1200-1299
Medium	1100-1199
Low	1000-1099
Very Low	<1000

Table 11: Priority Number as per SYI Classification in Rahi Kyoung HEP Catchment Area

Sub-Watershed	SYI Value	Priority	Priority Number
3A1B3a	1287	High	1
3A1B3b	1155	Medium	2

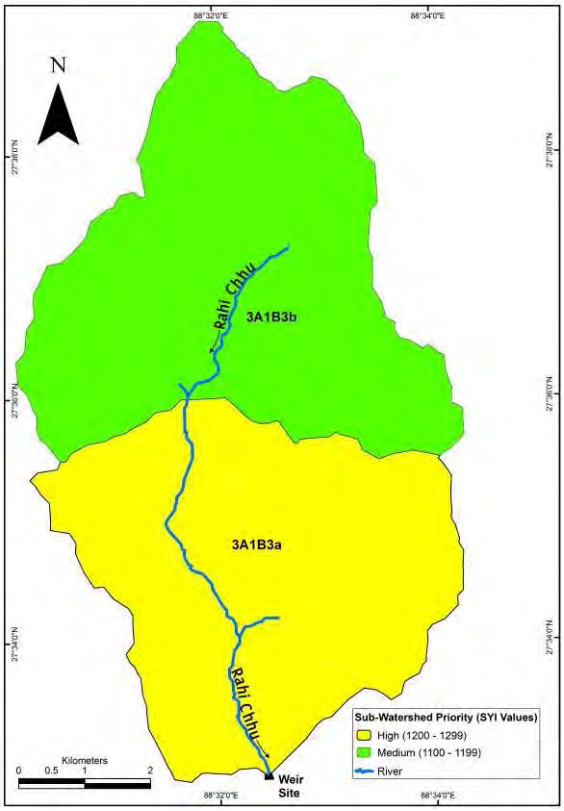


Figure 9: Priority Classification Map of Rahi Kyoung HEP Catchment Area

5 TREATMENT PLAN

5.1 Area to be taken up for treatment

As already mentioned that the catchment area of Rahi Kyoung HEP is 53.50 sq km. However, out of this area, 48.81 sq km. falls under the jurisdiction of Khangchendzonga National Park (**see Figure 10**). Therefore, an area of only 4.69 sq km will be considered for treatment measures. For the treatment of the area under the jurisdiction of Khangchendzonga National Park, sufficient measures will be provided in the Biodiversity Conservation and Management Plan of Environment Management Plan.

Treatment measures are to be taken up in the areas which are prone to Very Severe and Severe erosion in the area outside the jurisdiction of Khangchendzonga National Park i.e. 4.69 sq km. Such an area was extracted and in all total area of **57.23 ha** was extracted with **41.04 ha** under severe erosion category and **16.19** ha under Very Severe erosion category. The area will be treated by the means of biological and engineering treatment measures. Biological measures will cater for 20 ha of the area and engineering measures will cater for the rest 37.23 ha of the area. The period for implementing CAT plan interventions including maintenance has been taken as 7 years. All the prescribed treatment measures will be implemented in the second year itself. First year has been kept for micro planning and other entry point activities.

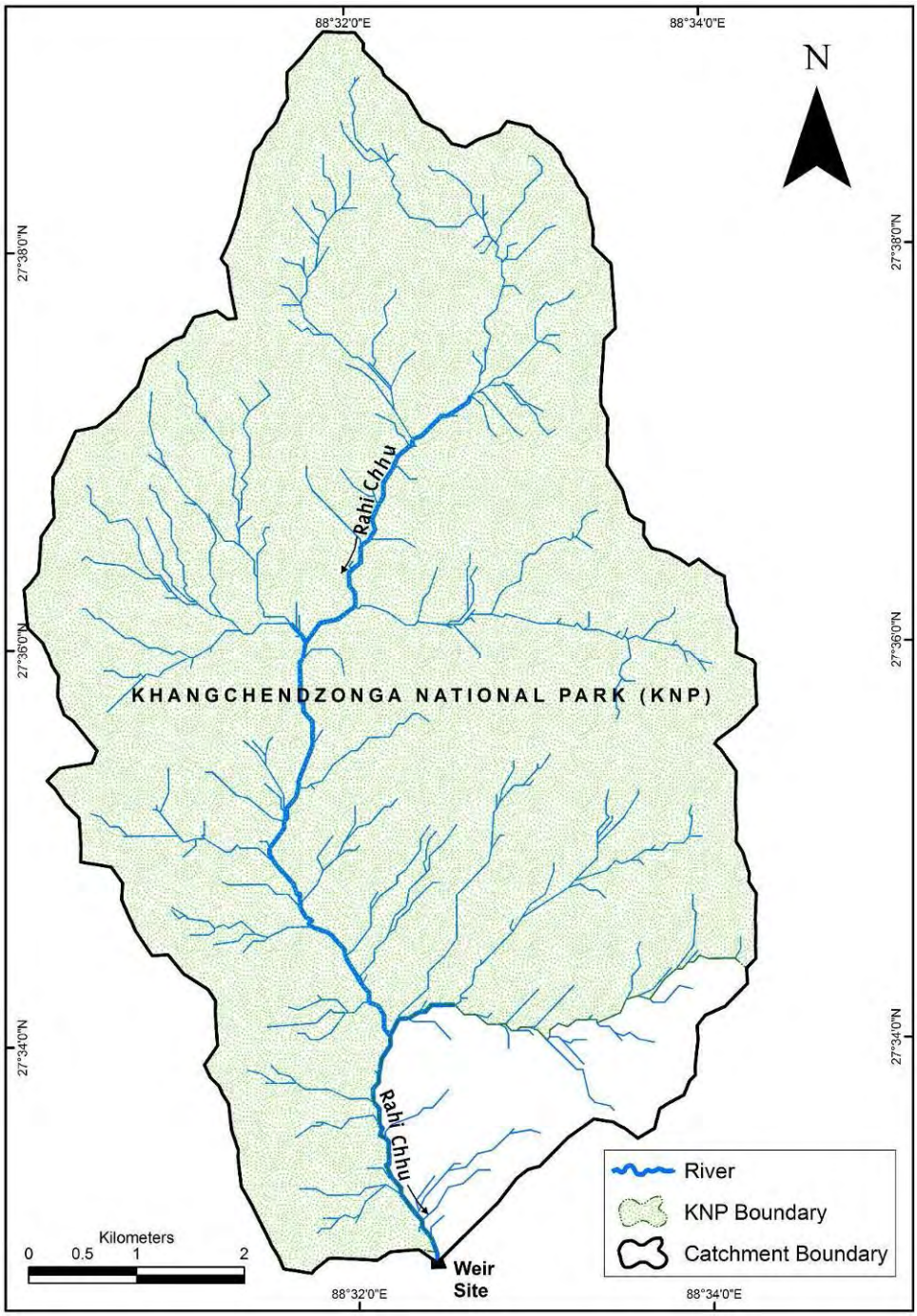


Figure 10: Location of Khangchendzonga National Park in the Catchment Area of Rahi Kyoung HEP

5.2 Treatment Measures

Watershed management is the optimal use of soil and water resources within a given geographical area so as to enable sustainable production. It implies changes in land use, vegetative cover, and other structural and non-structural action that are taken in a watershed to achieve specific watershed management objectives. The overall objectives of watershed management programme are to:

- increase infiltration into soil;
- control excessive runoff;
- manage & utilize runoff for useful purpose.

The basis of site selection for different engineering treatment measures under CAT are given in **Table 12**.

Table 12: Basis for selection of catchment area treatment measures

Treatment measure	*Basis for selection*
Afforestation	Open forests, degraded surface with high soil erosion, gentle to moderate slope
Assisted Natural Regeneration	Existing moderately dense forests
Brushwood Check Dams	Gullies formed around the streams
Dry Stone Masonry Check Dams	In the streams of 3rd to 5th order
Gabion Check Dams	Wherever loose boulders are not stable in particular stretch of a stream
Contour Bunding	Control of soil erosion from agricultural areas on moderate to steep slopes

5.2.1 Biological Measures

The biological measures would comprise of:

- Afforestation
- Assisted Natural Regeneration

5.2.1.1 Afforestation

A well stocked forest plays a very important in control of soil erosion. Thus, it is proposed to increase the vegetal cover in the area. As most of areas in Sikkim have sufficient rainfall and light, the growth of plants is very fast. Afforestation programme would be taken up in open forests and degraded surfaces where slope is less 45 degrees. It is suggested to undertake plantation of shrubs as well as trees. The area to be brought under afforestation programme and its unit cost is given at **Table 13**.

The preference would be given to planting of only local shrubs and trees with a judicious mixture of rapid colonizers as well as fruit trees. Suggested tree species to be planted are *Castanopsis indica, Betula alnoides, Alnus nepalensis, Michelia champaca,, Juglans regia, Schima wallichii, Cedrela toona, Prunus cerasoides, Schima wallichii, Cedrela toona, Chukrasia tubularis, Alnus nepalensis, Bischofia javanica, Engelhardtia spicata, Prunus spp., Pyrus spp, Citrus spp., etc.*

Following are some of the important grasses, bamboos and legumes:
Grasses: *Phragmites australis*, Cocks foot (*Dactylis glomerata*), Perennial Rye grass (*Lolium perenne*), Tall Fescue (*Festuca arundinacea*), Brome grass (*Bromus inermis*), Georgia selection, Timothy grass (*Phleum pratense*), Poa grass, *Eleusine coracana*, *Setaria italica*, *Panicum* spp., etc.

Bamboos: *Arundinaria maling* (Malingo)*, A. ningal* (Ningal)*, A. racemosa* (Dave Malingo)*, A. suberecta* (Sanu Maling)*, A. aristata, Bambusa nutans (*Mala Bans)*, B. pallida* (Kalinga)*, Cephalostachyum capitatum* (Gope Bans), *Dendrocalamus hamiltoni* (Choya Bans), *D. sikkimensis* (Bhalu Bans).

Legumes: White clover (*Trifolium repens*), Red clover (*Trifolium pratense*), Lucerene (*Medicago sativa*), Vetch (*Vicia villosa*), Sainfoin (*Onobrychis viciaefolia*), Caucasian clover (*Trifolum ambiguum*)

In addition species suggested for medicinal plants cultivation are as follows:
Aconitum heterophyllum (Bikh), *Acorus calamus* (Bojho), *Picrorhiza kurroo, Nardostachys jatamansi* (Jatamansi), *Rhododendron* sp., *Buddleja asiatica* (Bhinsenpatee) *Terminalia chebula, T. belerica, Emblica officinalis* (Amla), *Aloe barbadensis* (Ghiu Kumari), *Swertia chirata* (Chirata).

The above list is only suggestive. Other species of plants could be taken up for planting depending on locality factors.

5.2.1.2 Assisted Natural Regeneration

It is important to enhancing the establishment of secondary forest from moderately dense forests, degraded grassland and shrub vegetation by protecting and nurturing the mother trees and their wildlings inherently present in the area. Assisted natural regeneration is proposed to accelerate, rather than replace, natural successional processes by removing or reducing barriers to natural forest regeneration such as soil degradation, competition with weedy species, and recurring disturbances (e.g., fire, grazing, and wood harvesting). The area to be brought under assisted natural regeneration programme and its unit cost is given at **Table 13**.

5.2.2 Engineering Measures

The engineering treatment measures require less time to be put in place and can provide quick solutions. These would comprise mainly of Brushwood check dams, Dry stone masonry check dams, Gabion check dams and Contour bunding.

5.2.2.1 Brushwood Check Dams

Brushwood check dams are very feasible where vegetative material for construction is abundant. Brushwood check dams can only be constructed in small gullies not deeper than 1m depth. As material required for construction of these types of dam is available locally these can be constructed faster and in very short span of time thereby effectively reducing the erosion in early phase of Project. The numbers of check dams are estimated using number of first order streams in an area under severe and very severe erosion intensity, and constructed at an interval of 100 m. The number of brushwood check dams suggested and its unit cost is given at **Table 13.**

5.2.2.2 Dry Stone Masonry Check Dams

Dry stone masonry check dams/ walls can be made of boulder piled up across the gulley and along the banks if they are locally available. Such structures for damming a gulley or a stream to refine the flow velocity and to control bank erosion are called dry stone masonry/ loose bolder check dams/ walls. The number of dry stone masonry check dams suggested and its unit cost is given at **Table 13.**

5.2.2.3 Contour Bunding

Contour Bunding is used for retaining the water by creating obstruction to control erosion. It consists of constructing narrow based trapezoidal bunds on contours to improve runoff

rainwater in such a manner that it percolates and recharges the root profile on either side of the bunds. Bunds are simply embankments like structures, constructed across the land slope. The area to be treated under Contour Bunding scheme and its unit cost is given at **Table 13**.

5.2.2.4 Gabion Check Dams

If dry stone masonry check dams are considered not to be stable in a particular reach of the stream, Gabion structure or stone masonry structures can be installed. This is not very much encouraged because the terrain is stiff and the cement has to be carried by human labour. Carrying the cement will be tedious, time consuming and sometimes cement itself can get damaged during the carriage or while it is stocked at site for use. Therefore with proper judgment about the site conditions these structures may be installed. The number of gabion check dams suggested and its unit cost is given at **Table 13.**

Table 13: Summary of treatment measures and their cost for CAT Plan

Treatment Measures	Quantity	Unit Cost (Rs)*	Total Cost (Rs.)
Afforestation (Ha)	5	75,500	3,77,500.00
Assisted Natural Regeneration (Ha)	15	35,000	5,25,000.00
Brushwood Check Dams (Nos)	27	26,000	7,02,000.00
Dry Stone Masonry Check Dams (Nos)	29	33,280	9,65,120.00
Gabion Check Dams (Nos)	12	40,000	4,80,000.00
Contour Bunding (Ha)	0.1	25,000	2,500.00
TOTAL			**30,52,120.00**

Note*: Unit Cost has been taken as per the cost norms given in Annexure I

6 OTHER COMPONENTS OF CAT PLAN

Apart from the biological and engineering treatment measures in the catchment area there are other aspects of the CAT Plan to be addressed and their cost included in the overall cost estimate of the plan. The charges for operational support, forest protection, social mobilization, documentation and publication, monitoring and evaluation and providing environmental services are some of the integral ingredients which have to be considered and included while formulating the CAT plans.

6.1 Administrative Charges

For an efficient management of forest resources, it is essential that operational support to the Forest Department is adequately developed. Similarly, in remote localities there are no places for shelter for the staff, people and trekkers. Therefore, a budgetary provision of **Rs 1.76 lakh** has been kept for this component.

6.2 Provision for Micro Planning

The year-wise areas requiring treatment measures have been suggested but have not been marked. The spatial location of specific treatment to be carried out in the catchment area would require extensive detailing during the implementation of CAT and a provision for micro-planning has been made in the total CAT financial allocation. For this purpose a provision of **Rs 0.70 lakh** is being made.

6.3 Monitoring & Evaluation

Monitoring and evaluation will be undertaken as a part of project management. A process of self-evaluation at specified intervals of time will ensure the field level verification of suggested treatment measures and efficacy of the CAT plan.

The year-wise areas requiring treatment measures have been suggested but have not been marked. The spatial location of specific treatment to be carried out in the catchment area would require extensive detailing during the implementation of CAT and a provision for micro-planning has been made in the total CAT financial allocation. Thereafter, annual work plan would be prepared well in advance after undertaking initial ground surveys during micro-planning, specifying physical and financial targets, sites, locations and beneficiaries of each component of the project activity. Month-wise work schedule of various items of each component for the financial year would also be prepared in advance and its timely implementation would be ensured. Monthly progress report on all activities would be submitted by the Range Officers to Divisional Forest Officer. The monitoring committee shall be constituted at the project level for this purpose which too would monitor on a regular basis the quality and quantity of works being carried out under the CAT plan area.

A provision of **Rs 1.06 lakh** has been made for this component.

6.4 Contingencies

A provision of **Rs 3.52 lakh** has been kept under this component for some leeway to adjust any unforeseen expenditure.

7 COST ESTIMATE

The estimated cost of implementation of CAT plan including monitoring and evaluation is **Rs. 42.24 lakh** and is given at **Table 14**. The phasing of physical and financial targets is given in **Table 15.**

Table 14: Estimated cost of CAT Plan Implementation

S. No.	Item	Rate (Rs)	Unit	Target	
				Physical	Financial (Rs)
I	**Biological Measures**				
1	Afforestation				
	i) Creation	48,600	Ha	5	2,43,000.00
	ii) Maintenance for 5 years	26,900	Ha	5	1,34,500.00
2	Assisted Natural Regeneration				
	i) Creation	25,900	Ha	15	3,88,500.00
	ii) Maintenance for 5 years	9,100	Ha	15	1,36,500.00
3	Wages for plantation watchman i.e. unskilled labourer round the year for 6 years (one watchman for every 20 ha) @ Rs. 5,000 p.m. per watchman. Total area: 20 ha. Admissible watchman: 1 no.	5,000	Watchmen x Years (1x6)	72	3,60,000.00
	SubTotal I (1+2+3)				**12,62,500.00**

S. No.	Item	Rate (Rs)	Unit	Target	
				Physical	Financial (Rs)
II	**Engineering Measures**				
4	Brushwood Check Dams	26,000	No	27	7,02,000.00
	Maintenance Cost @ 5% of the cost				35,100.00
5	Check Dams (DRSM)	33,280	No	29	9,65,120.00
	Maintenance Cost @ 5% of the cost				48,256.00
6	Gabion Check Dams	40,000	No	12	4,80,000.00
	Maintenance Cost @ 5% of the cost				24,000.00
7	Contour Bunding	25,000	Ha	0.1	2,500.00
	Maintenance Cost @ 5% of the cost				125.00
	Sub Total II (4+5+6+7)				**22,57,101.00**
A	**Treatment Cost (Sub Total I + II)**				**35,19,601.00**
III	**Administrative Measures**				
8	Administrative Charges @5% of Treatment Cost				1,75,980.05
9	Micro Planning Charges @2% of Treatment Cost				70,392.02
10	Monitoring & Evaluation Charges @3% of Treatment Cost				1,05,588.03
11	Contingencies @10% of Treatment Cost				3,51,960.10
B	**Sub Total III**				**7,03,920.20**
	Total CAT Plan Cost (A + B)				**42,23,521.20**
	OR SAY				**42,24,000.00**

Table 15: Year wise physical & financial targets of treatment measures for CAT Plan

S. No.	Treatment Measures	Year I		Year II		Year III		Year IV		Year V		Year VI		Year VII		Total	
		Phy.	Fin. (Rs. in Lakh)	Phy.	Fin. (Rs. in Lakh)	Phy.	Fin. (Rs. in Lakh)	Phy.	Fin. (Rs. in Lakh)	Phy.	Fin. (Rs. in Lakh)	Phy.	Fin. (Rs. in Lakh)	Phy.	Fin. (Rs. in Lakh)	Phy.	Fin. (Rs. in Lakh)
I	**BIOLOGICAL MEASURES**																
1	**Afforestation (Ha)**			5	2.43											**5**	**2.43**
	1st Year maintenance					5	0.43									**5**	**0.43**
	2nd Year maintenance							5	0.31							**5**	**0.31**
	3rd Year maintenance									5	0.20					**5**	**0.20**
	4th Year maintenance											5	0.20			**5**	**0.20**
	5th Year maintenance													5	0.20	**5**	**0.20**
2	**Assisted Natural Regeneration (Ha)**			15	3.89											**15**	**3.89**
	1st Year maintenance					15	0.39									**15**	**0.39**
	2nd Year maintenance							15	0.31							**15**	**0.31**
	3rd Year maintenance									15	0.22					**15**	**0.22**
	4th Year maintenance											15	0.22			**15**	**0.22**
	5th Year maintenance													15	0.22	**15**	**0.22**
3	**Watch & Ward**			1	0.60	1	0.60	1	0.60	1	0.60	1	0.60	1	0.60		**3.60**
	Sub Total I				**6.92**		**1.42**		**1.22**		**1.02**		**1.02**		**1.02**		**12.63**
II	**ENGINEERING MEASURES**																
4	Brushwood Check Dams (Nos)			27	7.02											**27**	**7.02**
	Maintenance Cost @ 5% of the cost						0.35										**0.35**
5	Dry Stone Masonry Check Dams (Nos)			29	9.65											**29**	**9.65**
	Maintenance Cost @ 5% of the cost						0.48										**0.48**
6	Gabion Check Dams (Nos)			12	4.80											**12**	**4.80**
	Maintenance Cost @ 5% of the cost						0.24										**0.24**
7	Contour Bunding (Ha)			0.1	0.03											**0.1**	**0.03**
	Maintenance Cost @ 5% of the cost						0.00										**0.00**
	Sub Total II				**21.50**		**1.07**										**22.57**
A	**Treatment Cost (Sub Total I +**				**28.41**		**2.50**		**1.22**		**1.02**		**1.02**		**1.02**		**35.20**

S. No.	Treatment Measures	Year I		Year II		Year III		Year IV		Year V		Year VI		Year VII		Total	
		Phy.	Fin. (Rs. in Lakh)	Phy.	Fin. (Rs. in Lakh)	Phy.	Fin. (Rs. in Lakh)	Phy.	Fin. (Rs. in Lakh)	Phy.	Fin. (Rs. in Lakh)	Phy.	Fin. (Rs. in Lakh)	Phy.	Fin. (Rs. in Lakh)	Phy.	Fin. (Rs. in Lakh)
	II)																
III	**ADMINISTRATIVE MEASURES**																
8	Administrative Charges @5% of Total		0.35		0.35		0.35		0.35		0.35						**1.76**
9	Micro planning @2% of Treatment Cost		0.70														**0.70**
10	Monitoring & Evaluation Cost @3% of Treatment Cost						0.35				0.35				0.35		**1.06**
11	Contingencies @10% of Treatment Cost				2.84		0.25		0.12		0.10		0.10		0.10		**3.52**
B	**Sub Total III**		**1.06**		**3.19**		**0.95**		**0.47**		**0.81**		**0.10**		**0.45**		**7.04**
	Total CAT Plan Cost (A + B)		**1.06**		**31.60**		**3.45**		**1.69**		**1.83**		**1.12**		**1.48**		**42.24**

ANNEXURE I

1. Per Hectare Cost Norm for Afforestation

S. No.	Particulars of Work	Unit	Qty.	Rate (Rs.)	Amount (Rs.)
A	**SURVEY, DEMARCATION & FENCING:-**				
1	Survey & demarcation and preparation of map	Dl	5	150	750.00
2	Erection of barbed wire fencing (5 strands per 100 Rmt.) @ Rs. 11206 per Rmt.	Rmt	55	11,206	6,163.30
	Total A				**6,913.30**
B	**RAISING OF PLANTATION**				
1	Clearance of brushwood, planting lines & staking of debris	Dl	15	150	2,250.00
2	Alignment of pits & preparation of stakes & staking	Dl	10	150	1,500.00
3	Digging of pits 30 cm x 30 cm x 30 cm	Dl	25	150	3,750.00
4	Transportation of seedlings to the planting site i/c planting of seedlings	Dl	30	150	4500.00
5	Raising of polypot seedlings for plantation	No.	1100	9.4	10,340.00
6	Making of Inspection Path 1 mtr wide	Dl	3	150	450.00
7	Fireline cutting 3 mtr wide along the periphery	Dl	5	150	750.00
8	Tending 4 x weeding @ 12 Dls/ ha per weeding	Dl	48	150	7200.00
9	Entry Point Activities	Ha.	1	10,000	10,000.00
10	Provision for Soil & Moisture Conservation Measures	Ha.	0.2	4,600	920.00
	Total B				**41,660.00**
	Sub Total (A+B)				**48,573.30**
	Maintenance				
I	**1st Year Maintenance**				
1	Raising of seedlings for casualty replacement @ 15%	No.	165	9.4	1,551.00
2	Tending 3 x weeding @ 12 Dls/ ha per weeding	Dl	36	150	5,400.00
3	Casualty replacement @ 15%	Dl	7	150	1,050.00
4	Maintenance of barbed wire fencing @ 5% of erection cost				308.17
5	Maintenance of Inspection path	Dl	1	150	150.00
6	Maintenance of Fire line	Dl	1	150	150.00
	Total I				**8,609.17**
II	**2nd Year Maintenance**				
1	Raising of seedlings for casualty replacement @ 10%	No.	110	9.4	1,034.00
2	Tending 2 x weeding @ 12 Dls/ ha per weeding	Dl	24	150	3,600.00
3	Casualty replacement @ 10%	Dl	7	150	1,050.00
4	Maintenance of barbed wire fencing @ 5% of erection cost				308.17
5	Maintenance of Inspection path	Dl	1	150	150.00
6	Maintenance of Fire line	Dl	1	150	150.00
	Total II				**6,292.17**
III	**3rd Year Maintenance**				
1	Raising of seedlings for casualty replacement @ 5%	No.	55	9.4	517.00
2	Tending 1 x weeding @ 12 Dls/ ha per weeding	Dl	12	150	1,800.00
3	Casualty replacement @ 5%	Dl	7	150	1,050.00
4	Maintenance of barbed wire fencing @ 5% of erection cost				308.17
5	Maintenance of Inspection path	Dl	1	150	150.00
6	Maintenance of Fire line	Dl	1	150	150.00
	Total III				**3,975.17**
IV	**4th Year Maintenance**				
1	Raising of seedlings for casualty replacement @ 5%	No.	55	9.4	517.00
2	Tending 1 x weeding @ 12 Dls/ ha per weeding	Dl	12	150	1,800.00
3	Casualty replacement @ 5%	Dl	7	150	1,050.00
4	Maintenance of barbed wire fencing @ 5% of erection cost				308.17
5	Maintenance of Inspection path	Dl	1	150	150.00
6	Maintenance of Fire line	Dl	1	150	150.00
	Total IV				**3,975.17**
V	**5th Year Maintenance**				

S. No.	Particulars of Work	Unit	Qty.	Rate (Rs.)	Amount (Rs.)
1	Raising of seedlings for casualty replacement @ 5%	No.	55	9.4	517.00
2	Tending 1 x weeding @ 12 Dls/ ha per weeding	Dl	12	150	1,800.00
3	Casualty replacement @ 5%	Dl	7	150	1,050.00
4	Maintenance of barbed wire fencing @ 5% of erection cost				308.17
5	Maintenance of Inspection path	Dl	1	150	150.00
6	Maintenance of Fire line	Dl	1	150	150.00
	Total V				**3,975.17**
	Maintenance Total				**26,826.83**
	GRAND TOTAL	**Ha.**	**1**		**75,400.13**
	Or Say				**75,500.00**

2. Per Hectare Cost Norm for Assisted Natural Regeneration

S. No.	Particulars of Work	Unit	Qty.	Rate (Rs.)	Amount (Rs.)
A	**SURVEY, DEMARCATION & FENCING:-**				
1	Survey & demarcation and preparation of map	Dl	5	150	750.00
2	Erection of barbed wire fencing (5 strands per 100 Rmt.) @ Rs. 11206 per Rmt.	Rmt	55	11206	6,163.30
	Total A				**6,913.30**
B	**RAISING OF PLANTATION**				
1	Clearance of brushwood, planting lines & staking of debris	Dl	3	150	450.00
2	Alignment of pits & preparation of stakes & staking	Dl	2	150	300.00
3	Digging of pits 30 cm x 30 cm x 30 cm	Dl	6	150	900.00
4	Transportation of seedlings to the planting site i/c planting of seedlings	Dl	7	150	1,050.00
5	Raising of polypot seedlings for plantation	No.	250	9.4	2,350.00
6	Making of Inspection Path 1 mtr wide	Dl	3	150	450.00
7	Fireline cutting 3 mtr wide along the periphery	Dl	5	150	750.00
8	Tending 4 x weeding @ 3 Dls/ ha per weeding	Dl	12	150	1,800.00
9	Entry Point Activities	Ha.	1	10000	10,000.00
10	Provision for Soil & Moisture Conservation Measures	Ha.	0.2	4600	920.00
	Total B				**18,970.00**
	Grand Total (A+B)				**25,883.30**
	Maintenance				
I	**1st Year Maintenance**				
1	Raising of seedlings for casualty replacement @ 15%	No.	38	9.4	357.20
2	Tending 3 x weeding @ 3 Dls/ ha per weeding	Dl	9	150	1,350.00
3	Casualty replacement @ 15%	Dl	2	150	300.00
4	Maintenance of barbed wire fencing @ 5% of erection cost				308.17
5	Maintenance of Inspection path	Dl	1	150	150.00
6	Maintenance of Fire line	Dl	1	150	150.00
	Total I				**2,615.37**
II	**2nd Year Maintenance**				
1	Raising of seedlings for casualty replacement @ 10%	No.	25	9.4	235.00
2	Tending 2 x weeding @ 3 Dls/ ha per weeding	Dl	6	150	900.00
3	Casualty replacement @ 10%	Dl	2	150	300.00
4	Maintenance of barbed wire fencing @ 5% of erection cost				308.17
5	Maintenance of Inspection path	Dl	1	150	150.00
6	Maintenance of Fire line	Dl	1	150	150.00
	Total II				**2,043.17**
III	**3rd Year Maintenance**				
1	Raising of seedlings for casualty replacement @ 5%	No.	13	9.4	122.20
2	Tending 1 x weeding @ 3 Dls/ ha per weeding	Dl	3	150	450.00
3	Casualty replacement @ 5%	Dl	2	150	300.00
4	Maintenance of barbed wire fencing @ 5% of erection cost				308.17
5	Maintenance of Inspection path	Dl	1	150	150.00

S. No.	Particulars of Work	Unit	Qty.	Rate (Rs.)	Amount (Rs.)
6	Maintenance of Fire line	Dl	1	150	150.00
	Total III				**1,480.37**
IV	**4th Year Maintenance**				
1	Raising of seedlings for casualty replacement @ 5%	No.	13	9.4	122.20
2	Tending 1 x weeding @ 12 Dls/ ha per weeding	Dl	3	150	450.00
3	Casualty replacement @ 5%	Dl	2	150	300.00
4	Maintenance of barbed wire fencing @ 5% of erection cost				308.17
5	Maintenance of Inspection path	Dl	1	150	150.00
6	Maintenance of Fire line	Dl	1	150	150.00
	Total IV				**1,480.37**
V	**5th Year Maintenance**				
1	Raising of seedlings for casualty replacement @ 5%	No.	13	9.4	122.20
2	Tending 1 x weeding @ 12 Dls/ ha per weeding	Dl	3	150	450.00
3	Casualty replacement @ 5%	Dl	2	150	300.00
4	Maintenance of barbed wire fencing @ 5% of erection cost				308.17
5	Maintenance of Inspection path	Dl	1	150	150.00
6	Maintenance of Fire line	Dl	1	150	150.00
	Total V				**1,480.37**
	Maintenance Total				**9,099.63**
	GRAND TOTAL	**Ha.**	**1**		**34,982.93**
	Or Say				**35,000.00**

3. Cost Norm for per Brushwood Check Dam

Description	Material Cost			Labour Cost			Total Cost (Rs)
	Qty	Rate (Rs)	Cost (Rs)	Man Days	Rate (Rs)	Cost (Rs)	
Survey and Alignment	1	425	425	2.5	800	2,000	**2,425**
Purchase & Transportation of Wooden Pegs	50	150	7,500				**7,500**
Construction of Bunds by fixing wooden pegs	50	200	10,000	4	450	1,800	**11,800**
Plantation of Bushed at 0.5 cm distance				3.5	450	1,575	**1,575**
Plantation of trees at distance of 2.5 m				3	450	1,350	**1,350**
Inter stabilising - three times				3	450	1,350	**1,350**
Total cost			**17,925**			**8,075**	**26,000**

4. Cost Norm for per Dry Stone Masonry Check Dam

Description	Material Cost			Labour Cost			Total Cost (Rs)
	Qty	Rate (Rs)	Cost (Rs)	Man Days	Rate (Rs)	Cost (Rs)	
Dry Rubble Masonry 8*1.5*2	60	120	7,200	25	800	20,000	27,200
Contingency			2,500			3,580	6,080
Total cost			**9,700**			**23,580**	**33,280**

5. Per Hectare Cost Norm for Contour Bunding

Description	Man Days	Rate (Rs)	Cost (Rs)
Earth work excavation for trenches 7*0.6*1.0 m	42	450	18,900
Filling earth / sand in 1.5 m layers 7*.6*1.0 m	10	450	4,500
Contingency			1,600
Total cost			**25,000**