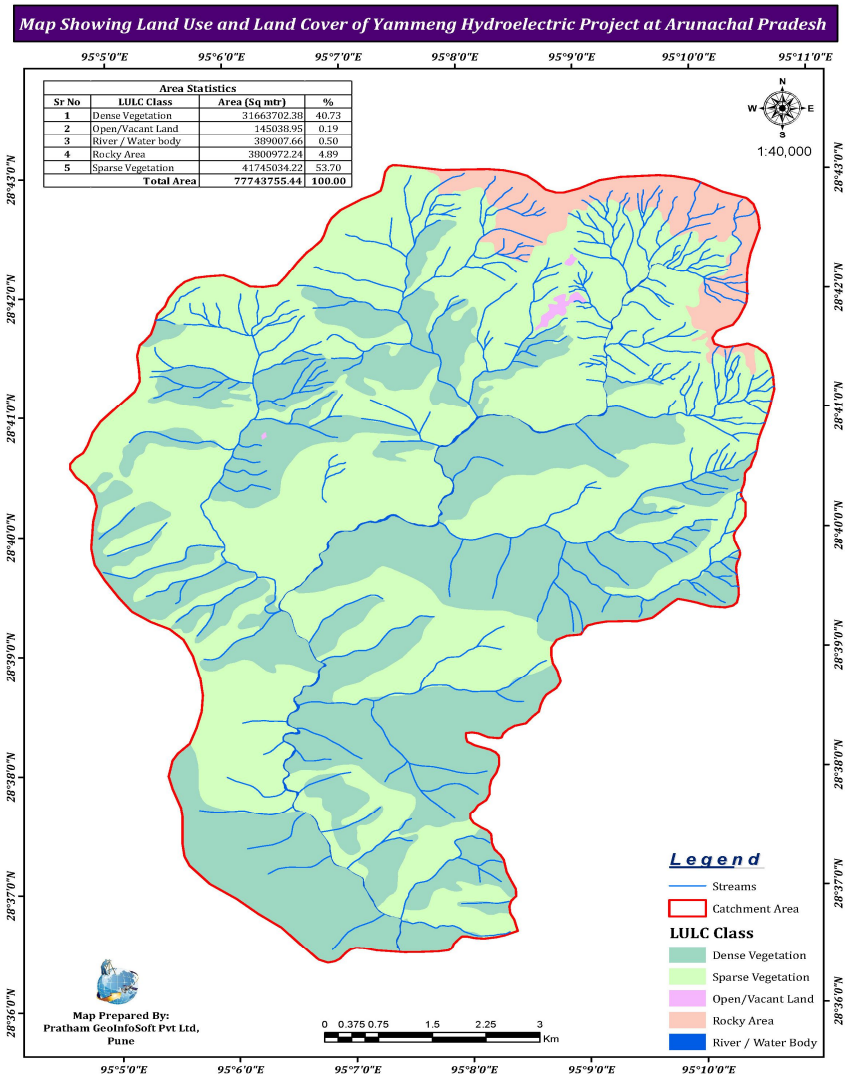
CATCHMENT AREA TREATMENT PLAN FOR YAMMENG HYDROELECTRIC PROJECT, ARUNACHAL PRADESH



PREPARED BY

PRATHAM GEOSOFT, PUNE

FOR

YAMMENG GREEN ENERGY PRIVATE LIMITED,

MUMBAI

EXECUTIVE SUMMARY

1 A comprehensive catchment area management and development plan is necessary to realize the full benefits of any large-scale reservoir project by minimizing the sedimentation of the reservoir by siltation as also damage to the vanes that come in contact with the silt-laden water. The objectives of the catchment area treatment plan are containment, restoration, and improvement in bio-diversity.

2 The proposed Hydroelectric Project is a 12 x 3 MW, a small, run of river project. The project is proposed on Yammeng river in Upper Siang District of Arunachal Pradesh near Yingkiong. Yammeng is tributary of Yamne, while Yamne is major tributary of river Siang which meet Brahmaputra near Pasighat.

3 The project is located at about 3.0 km upstream of village Gobuk

4 The catchment area of the proposed scheme lies between Longitude 95°05'00'' E to 95°10'56'' E and Latitude 28°36'25'' N to 28°42'56'' N and the proposed diversion structure is at, Longitude 95°7'33" E and Latitude 28°36'24" N '' N.

5 The catchment area up to the proposed barrage site is 81.8 km2. The total length of the river up to diversion site is 12.5 km from its origin.

6 The highest point in the catchment is at about EL. 3500 m and the riverbed elevation at the proposed diversion structure is about 950.0 m.

7 Most of the catchment is in good condition and covered by vegetation.

8 A small portion of catchment can be classified as Barren, fallow and open areas and requires good treatment.

9 A sub-catchment is a discrete geo-hydrological unit, complete within itself. The entire catchment area consists of various well-defined sub-watersheds.

10 For the catchment, interventions such as digging of continuous contour trenches, construction of gully plugs, loose boulder structures, gabion structures, earthen nalla bunds, cement nalla bunds are planned. Work has been divided into 2 phases of 1 years each, with the critically degraded watersheds being treated in the first phase.

11 The total cost of catchment area treatment for the entire area is 1% of the project cost and INR. 1,08,92,200 (One Crore Eighty Lakh Ninety Two Thousand and Two Hundred only).. The costs have been calculated using the rate of Rs. 150/- per labor day. This is inclusive of the watershed treatments that already been carried out.

CHAPTER 1. INTRODUCTION

The proposed Yammeng Hydroelectric Project is proposed to be developed on Build, Own, Operate and Transfer (BOOT) basis by M/s Yammeng Green Energy Pvt. Ltd. The project is proposed to be located on Yammeng, a tributary of Yammneg River, in Upper Siang District in Arunachal Pradesh. Siang basin is one of the drainage basins of the Brahmaputra. The barrage is envisaged just Upstream of the Gobuk village. The Yammeng Hydro Electric Project (3X 4 MW) is a small run of River (ROR) Project. No gauge and discharge data of the project catchment are available.

Scope of the present study is to prepare Catchment Area Treatment (CAT) Plan for the catchment area of Yammeng HEP. Hence, the catchment area has been delineated from the source of Yammeng river to the diversion structure of Yammeng HEP.

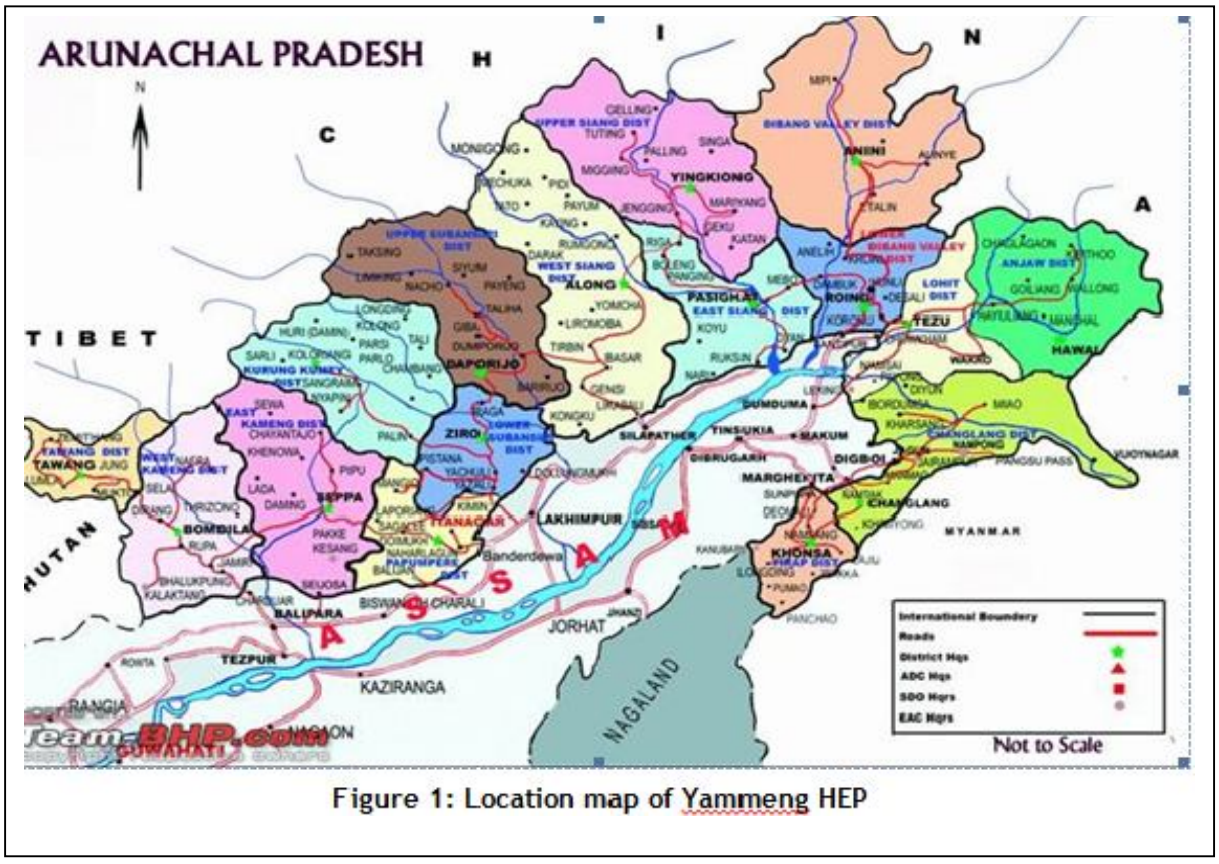
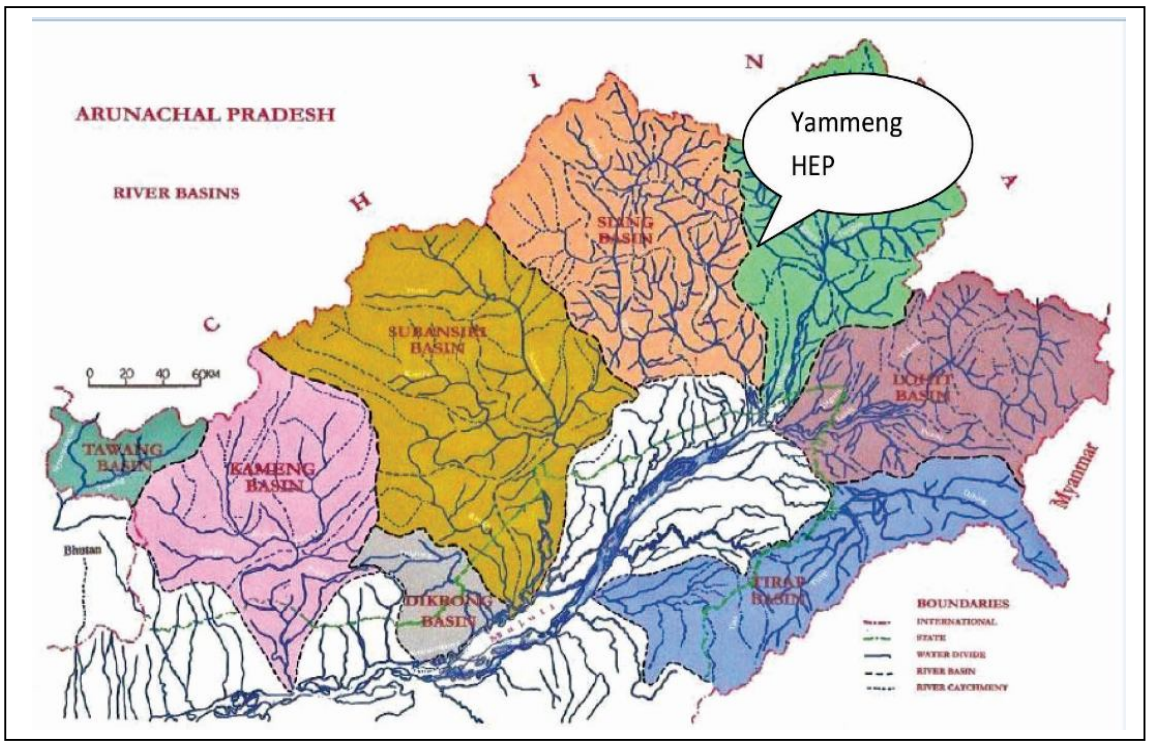


Figure 1: Location map of Yammeng HEP

The original Scheme comprised of an overflow barrage of 20 m height. At this location the width of river flow is about 30 M. The barrage site of the project was proposed at a location geographically upstream of Gobuk village.

Fig. 2. Details of the Yammeng and adjoining river basins



Main Features

The Yammeng Hydro-Electric Project envisages construction of a Power House with an installed capacity of 12 MW.

The main components of the Scheme as planned are:

a) 20 M high Barrage

b) Intake

c) De sander

d) Head Race Tunnel

e) Surge shaft

f) Single line of Pen stock, trifurcating in to three penstock connecting to three units

g) Surface Power House to accommodate 3 generating units of 4 MW each and with service bay, control room, switchgear room, office etc.

h) Tail Race Pool & Tail Race Channel.

i) An Out Do or Yard (ODY)

j) Transmission line.

The project envisages utilization of Yammeng river water by constructing a barrage of about 19.5 m height from river bed. It is a run of the river scheme. The details of project are given as below:

Nearest village	Gobuk
District	Upper Siang
Latitude	28°36'24" N
Longitude	95°7'33" E
River basin	Yamne
River	Yammeng
Catchment area (km^2)	82
Full Reservoir Level (FRL), m	968
Maximum Water Level (MWL)	968.5
River Bed Level (m)	950.0

CHAPTER 2. NEED FOR CATCHMENT AREA TREATMENT

The Catchment area of a dam or reservoir or of an Hydroelectric project is the area from where it derives its water supply. This includes the valley in which the reservoir / barrage is situated and the surrounding slopes up to the ridgeline. Any rainfall in this area runs off the slopes and into the main drain where it is impounded by the reservoir.

It follows that soil erosion has a direct impact on the water quality in the reservoir. Further, all dams / barrages have a design life based on the existing siltation rate. Construction activity at the dam site vastly increases the siltation rate and decreases the life of the dam / barrage. While the required head is maintained for a hydro-electric project, and it appears that sedimentation will not reduce the efficiency of a dam, the effect of increased silt in the bed must be considered. It is observed that the presence of silt has an adverse effect on the turbines.

The Ministry of Environment and Forests along with the Central Water Committee has evolved guidelines which would enable dam builders and irrigation engineers to treat the catchment areas adequately prior to, or at least, along with, the construction of reservoirs and canals.

It is now appreciated that a comprehensive catchment area management and development plan is necessary to realize the full benefits of any large-scale reservoir project. These activities should precede the construction activities, since construction involves destabilizing earth and making it more vulnerable to erosion.

As a pre-requisite for effective management of the reservoirs, as also to minimize further damage, we are proposing a Catchment Area Treatment plan which would ensure the economic life of the dam as per the technical design parameters.

CHAPTER 3. AIM AND OBJECTIVES

The main aims of the catchment area treatment plan are

a. Short term*: Containment*

Control of erosion and checking degradation of land

b. Mid-term: *Restoration*

Sustained restoration of the land and its resources

c. Long-term: *Improvement in bio-diversity*

To put in place a diversity of plants this would lead to natural restoration and regeneration of the eco system.

The objectives of the catchment area treatment plan may be listed as follows

- Conservation of the important natural resources like soil and water.
- Prevention of siltation in the dam and thus maintaining the design capacity, depth and live storage capacity of the dam.
- Economic up gradation of people in surrounding areas, as well as environmental conservation through afforestation and reforestation activities.
- Improvement in the density and the biodiversity of flora and fauna thus making the ecosystem more stable and mature.
- Supplementation of production of fodder and fuel to promote livestock development.
- Increase in the soil moisture content and the groundwater table level, which will result into the betterment of soil fertility and productivity.
- Reduction in the risk associated with the crop production, by softening the severity of the dry season by water conservation structures.
- Land treatment for increased vegetation and forest tree density in the area, are also envisaged.

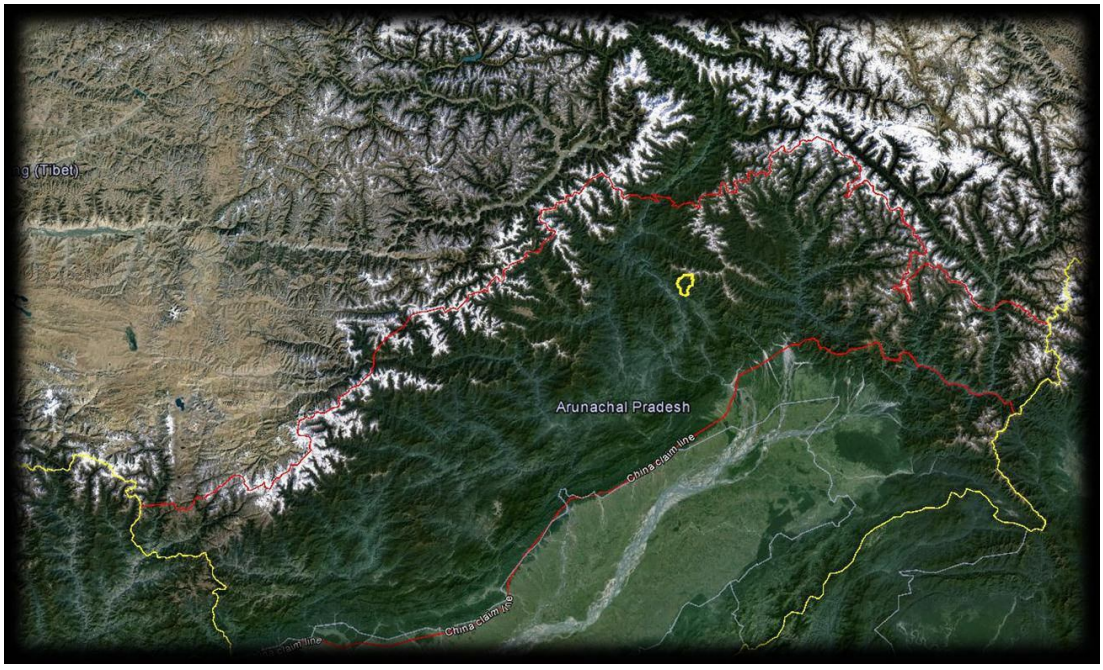
CHAPTER 4. STATUS OF THE CATCHMENT

The catchment area comprising of 81,000 ha is in reasonably good condition. Land use within the catchment is mainly forest for 94.5% of the catchment.

All the accessible area has been considered for catchment area treatment. Afforestation, reforestation of degraded forests, area treatments like CCT, and drain line treatments like gully plugs and nallah bunds have been considered. Afforestation and soil conservation has been considered for hilly land.

The catchment area of the proposed scheme lies between Longitude 95°05'00'' E to 95°10'56'' E and Latitude 28°36'25'' N to 28°42'56'' N and the proposed diversion structure is at, Longitude 95°7'33" E and Latitude 28°36'24" N '' N. The catchment area up to the proposed barrage site is 81.8 km2. The total length of the river up to diversion site is 12.5 km from its origin. The highest point in the catchment is at about EL. 3500 m and the riverbed elevation at the proposed diversion structure is about 950.0 m.

Image showing Arunachal Pradesh and Catchment area of Proposed Yammeng Hydroelectric Project



CHAPTER 5. METHODOLOGY

Rationale for phasing of the Catchment Area Treatment Plan:

The following procedure has been applied for phasing of the Catchment Area Treatment Plan.

1. The subject watershed has been divided as per forest and non-forest land. The treatments vary as per the land classification as some treatments such as repairs to farm bunds can only be carried out on private lands. In addition, the soil on forest lands is generally less disturbed and prone to soil erosion than private lands.

2. These areas have then been studied and their various physical characteristics examined. The following factors have been considered for evaluation:

- ✓ Geology: the nature of the underlying rocks and soil determines the rate at which they are eroded, and hence influences the sediment yield.
- ✓ Existing Silt Traps: A tank or check dam within the catchment area influences the siltation yield by acting as a silt trap / stilling basin. This drastically reduces the sediment yield as the sediment from the catchment area of the structure is almost wholly absorbed by the structure.
- ✓ Nature of land use: is a key factor in determining erodibility of the catchment. Cultivated land is most susceptible to erosion followed by fallow and barren land. Land with dense forest cover is least susceptible to erosion.
- ✓ Topography: The nature of the land including slope, drainage density are influential in determining the rate of sedimentation.

3. Based on our previous experience, it was determined that a period of four years is sufficient for implementation of treatment measures. This time is that required for project implementation, and not operations and maintenance. If thought necessary, a further period of two years may be considered for looking after plantations.

   The plantations shall be comprised of indigenous hardy species that do not need much of attention. Maintenance shall be restricted to replacing any lost plants. The plants are expected to be established after this maintenance period, and suitable species may be selected.

4. Each sub-catchment can be treated within eighteen months. Roughly equal distribution of areas leads to ease in management and deployment of resources.

5. *PRIORITIZATION OF CATCHMENT AREA TREATMENT*

1. The catchment area is comprised of ----- sub-watersheds. The catchment area treatments been planned considering these sub-watersheds individually. However, in order to complete the work

within the stipulated period, work on each may be carried out simultaneously. The sub-watersheds have been ranked in decreasing order of their expected sediment yields; i.e. greater the siltation rate, higher the priority.

2. The sediment yield for each sub-watershed has been calculated using an empirical model (Kumar, 1985, Rao & Mahabaleswara, 1990) using input parameters in terms of spatial information of land use, vegetation cover, soils, slope, and drainage density, besides runoff and rainfall intensity.
3. The model is as follows:

$$Vs = 1.067 \times 10^{-6} . p^{1.384} . A^{1.292} . Dd^{0.392} . S^{0.129} . Fc^{2.51}$$

Where,

Vs =	Sediment Yield	P =	Annual precipitation, cm
A =	Watershed Area, sq.km	Dd =	Drainage density, km/sq.km
Fc =	Vegetative Cover Factor	S =	Watershed Average Slope

$$Fc = \frac{0.21F1 + 0.2F2 + 0.6F3 + 0.8F4 + F5}{5}$$

Where,

F1 =	Protected Forest Area	F4 =	Grass and Pasture Land
F2 =	Unclassified Forest Area	F5 =	Wasteland
F3 =	Cultivated Area		

6. SEQUENCING OF TREATMENT ACTIVITIES WITHIN EACH PHASE

1. Within each sub-catchment, the full spectrum of area, and drain-line, soil conservation methods needs to be applied. Here, the monsoon is a deciding factor when it comes to the sequencing of works.
2. Area-based soil conservation activities, i.e. plantation, grassland development, etc need to be done during the monsoons to allow the plants to become established. A nursery for plants will have to be set up before this. If the nursery is set up in January-February, the plants will be well grown by the monsoons. Transplanting the plants to their permanent sites can be carried out in the monsoon, when their will no longer be any need for irrigation.
3. As for the other works, the treatments involve working of soil. This may take the form of digging, uncovering the soil beneath boulders, etc. This worked soil is loose and especially vulnerable to erosion by wind and water.
4. If works are carried out in the pre-monsoon months, this loose soil will be exposed to the full force of the monsoon showers before the soil has a chance to settle. Large-scale erosion will then take

place, which will prove detrimental to the project. Hence, these activities should be carried out in the post-monsoon period, i.e. October to March.

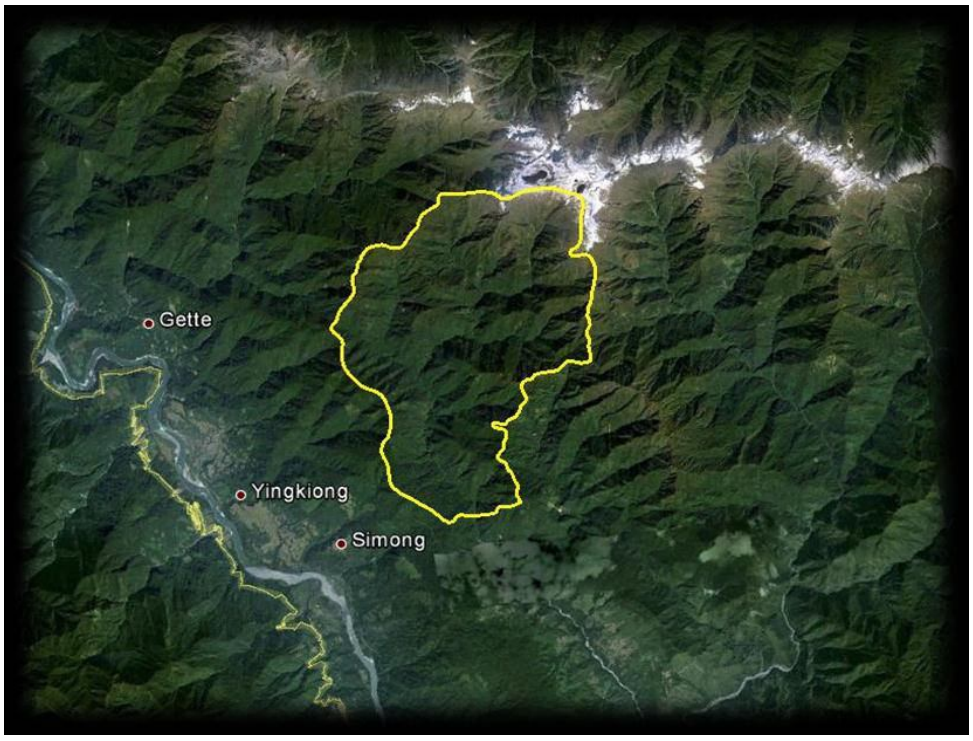
5. As works in each area are to be completed within the phase period, they are to be implemented almost simultaneously. In addition, sequencing of works within this period, i.e. before the onset of the monsoons will not affect the project.
6. Thus, it may be noted that siltation rate of the sub-catchment has been considered for phasing of the program while logistical concerns are addressed for the sequencing of works within each phase.

CHAPTER 6. PROPOSED CATCHMENT AREA DEVELOPMENT PLAN

The catchment area of the proposed scheme lies between Longitude 95°05'00'' E to 95°10'56'' E and Latitude 28°36'25'' N to 28°42'56'' N and the proposed diversion structure is at, Longitude 95°7'33" E and Latitude 28°36'24" N '' N. The catchment area up to the proposed barrage site is 81.8 km2. The total length of the river up to diversion site is 12.5 km from its origin. The highest point in the catchment is at about EL. 3500 m and the riverbed elevation at the proposed diversion structure is about 950.0 m.

Presently there is no existing hydroelectric project upstream or downstream of this Project, across this river. **Figure 4.3** shows the map of the catchment area of the Yammeng up to barrage site.

Image showing Catchment area of Yammeng HEP



River System and Basin Characteristics

The main course of Yammeng River originates from about EL.3000.00 m above Mean Sea Level and is a major tributary of Yamne River which ultimately joins the Bhramputra River. The river, in its initial upper reaches of about 8.5 km, flows in North-South direction taking almost a straight course and then takes a turn in South-East direction and flows down about 13.5 km to join the river Yamne. However, prior to joining the Yamne River, Yammeng River is again turning in the North-South direction. Thus, after approx. 22.0 kms from its source, it joins the Yamne River, which is amajor tributary of the Bharamputra River. The Yammeng River on its right side is bounded by main Siang River basin and on the left side with Yamne river basin.

The average bed gradient of the river over the entire stretch is about 9.5m/km. The river valley is located between steep and high mountain ranges in its upper regions and is very narrow. Along the lower stretches, the valley is usually wider. It is joined by various nallah in its course from its origin. The total length of the river up to diversion site is 12.5 km from its origin. The average slope of the river in the vicinity of project area is about 1 in 36.

About the Catchment area

Yammeng Hydroelectric Project is a run of the river scheme proposed on Yammeng River in Upper Siang District of Arunachal Pradesh near Yingkiong. River Yammeng is a tributary of main river Yamne, which is a major tributary of river Siang meets at last Brahmaputra near Pasighat in this region.

The catchment area of the Yammeng up to barrage site location is around 82 sq. km. The entire catchment falls in Indian Territory. The scheme falls under the Siang river basin river in the Upper Siang District.

Available Inflow

The yield series for Yammeng Hydroelectric Project site on 10 daily bases has been developed and analyzed in Chapter 3 on “Hydrology”. The yield series has been developed at the barrage site on the basis of Water availability study for the Siang Middle project. Water availability study for the Siang Middle was carried out using the observed discharge data at Pangin and Ranaghat G&D sites as mentioned in Pre-feasibility report of Yammeng H.E. Project. The 10 daily yield series developed on the basis of Water availability study for the Siang Middle project are shown in Annexure –5.1.

Delineation of sub watersheds:

For giving practical shape to the systematic, scientific and rational approach of watersheds as units of planning and development, a framework of watersheds is a pre-requisite. It is thus essential to have not only a hierarchical system of delineating bigger hydrological units into watersheds but a codification system also needs to be developed so that each watershed could be identified as an individual entity without losing linkage with the bigger units i.e. catchment, sub-catchment, etc., to which it belongs.

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.

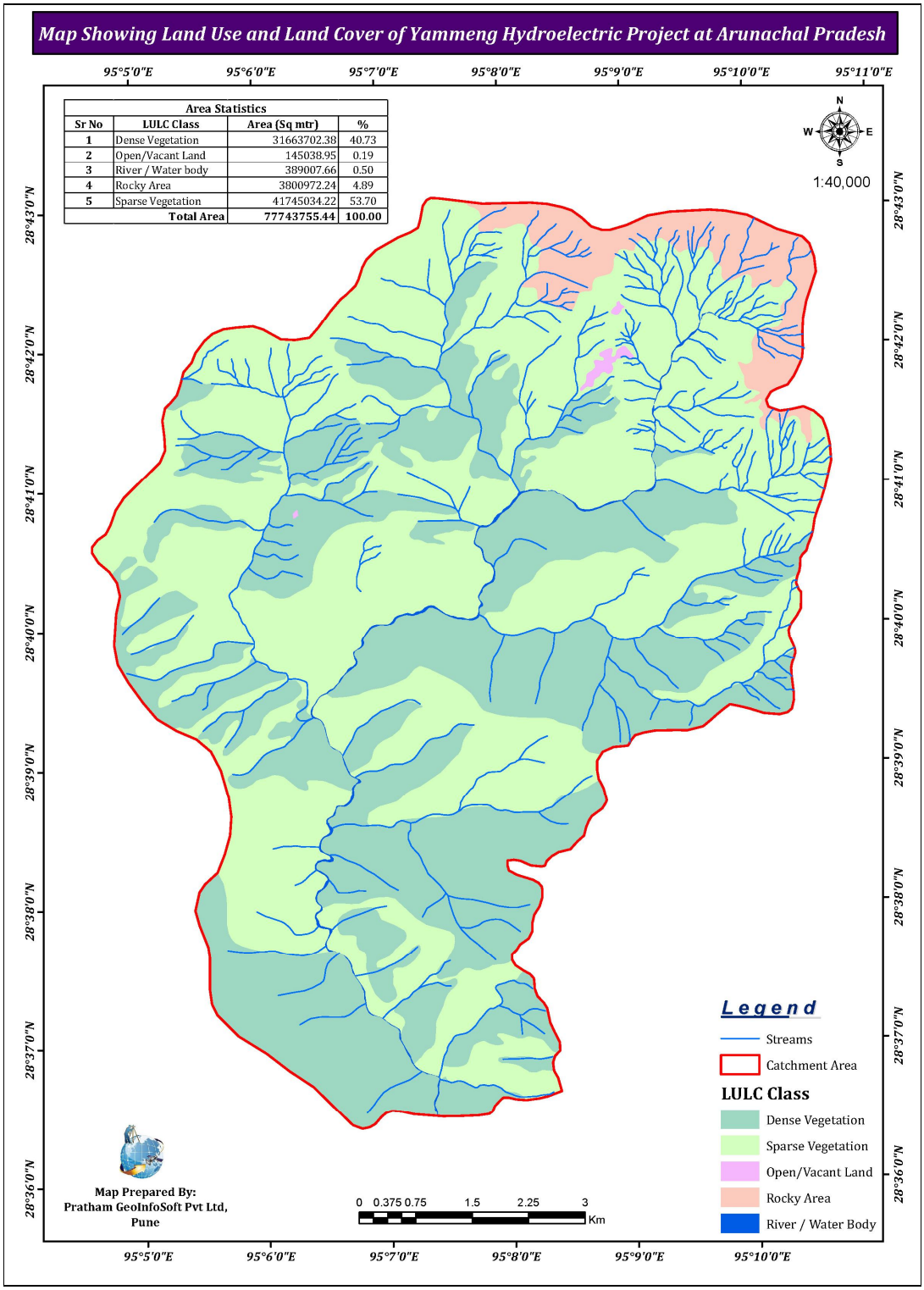
Land use and land cover studies of delineated catchment area:

Land Use Land Cover derived from Google Image

From Google image, in total about five LULC classes were derived for 77.7438 sq. km of the study area. Among the prominent classes observed was Spare and Dense Vegetation together accounting for 94.43% of the entire catchment. Other classes include Rocky Area 4.89%, Open/Vacant Land covering 0.19 % while the River / Water body covering about 0.50 % of the area. The details are provided in the table as well as a processed satellite image.

Land Use and Land Cover (LULC) classes of the Catchment area			
Sr.no.	LULC Class	Area (Sq.mt)	%
1	Sparse Vegetation	41745034.22	53.70
2	Dense Vegetation	31663702.38	40.73
3	Rocky areas	3800972.24	4.89
4	River / water body	389007.66	0.50
5	Open areas	145038.95	0.19
	Total area	77743755.44	100

The image of catchment showing Land Use and Land cover (LULC) classification

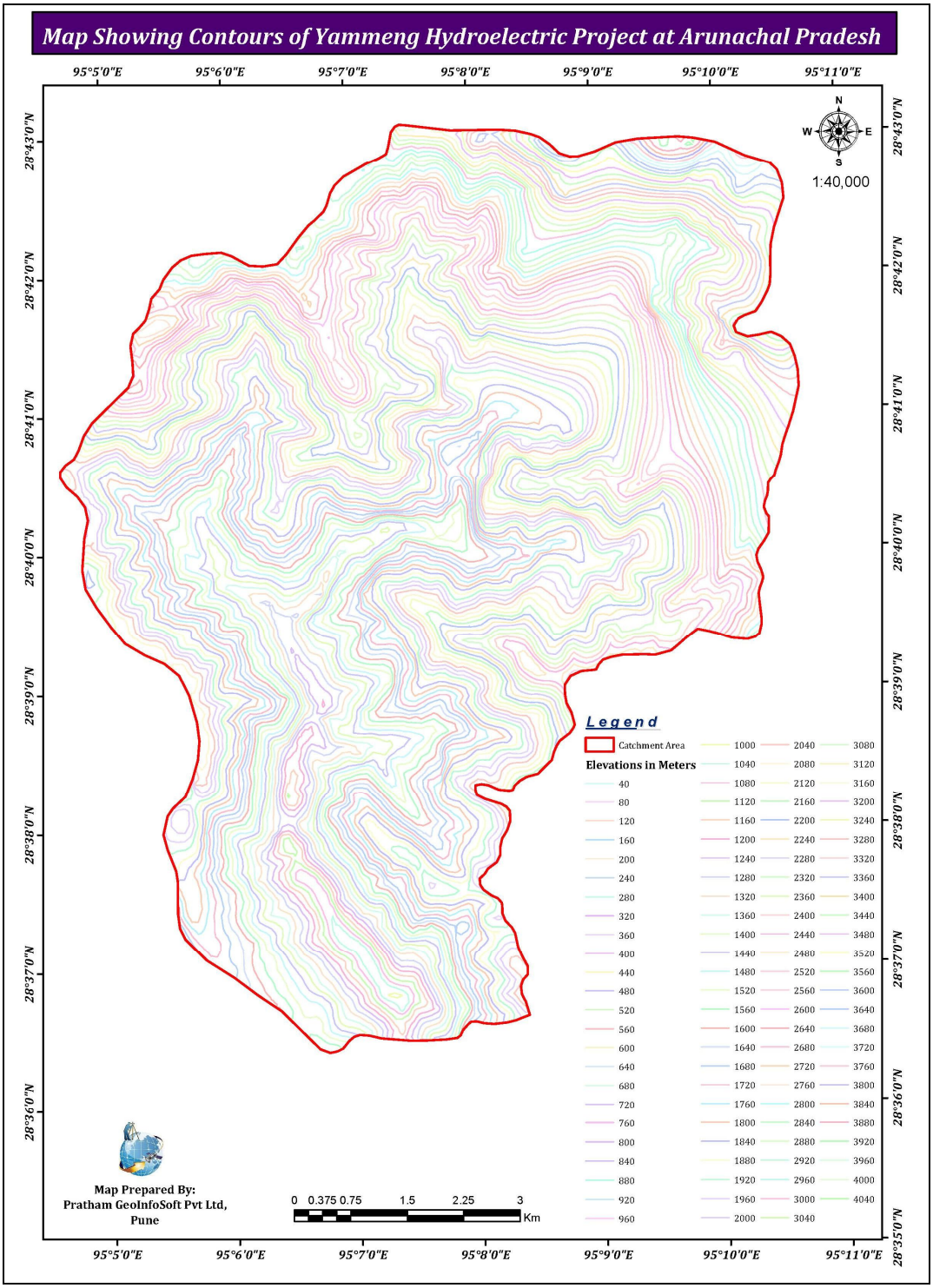


Note:

In high hills, variability of site parameters such as topography, soils, land use, climate and rainfall matters. Not all areas contribute equally to the erosion problem. Therefore, to address this issue, latest and accurate data will be taken for the analysis that i.e. the satellite data. This along with the ground information was been taken into account for obtaining terrain characteristics. Geographic Information

System (GIS) will be used as a tool to obtain characteristics on catchment areas in terms of location of dam, areas of the submergence, and detailed land use categories.

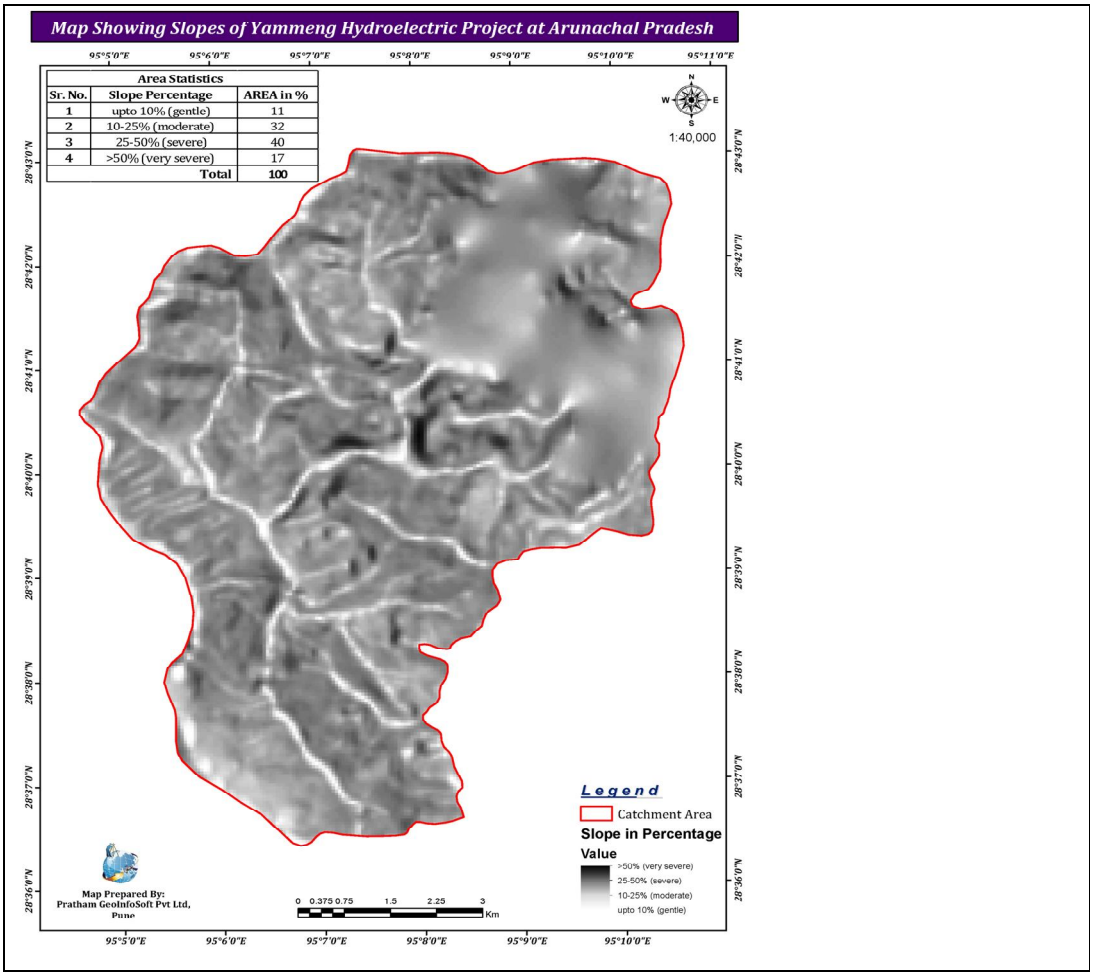
A Digital Terrain Model (DTM) of the area will be prepared, and will be used to derive a slope map. The slope will be further divided in various slope percentages.



Methodology/ matrix for calculation of Composite Erosion Intensity Unit

Erosion	Slope Landcover	Landuse/ depth	Soil DR Unit	Weightage/ Intensity
Very Severe	Very very steep >50%	Open forest, scrub forest	Shallow	20/0.95
Severe	Steep to very steep 25 -50%	Open forest, scrub, cultivation	Moderately shallow	18/0.90
Moderate to slight	Strongly sloping to moderately steep 10-25%	Dense forest, open forest, cultivation	Moderately deep	13-15/0.90
Slight to Negligible	Gently sloping to moderately sloping 5-10%	Dense forest, open forest	Deep	11/0.85

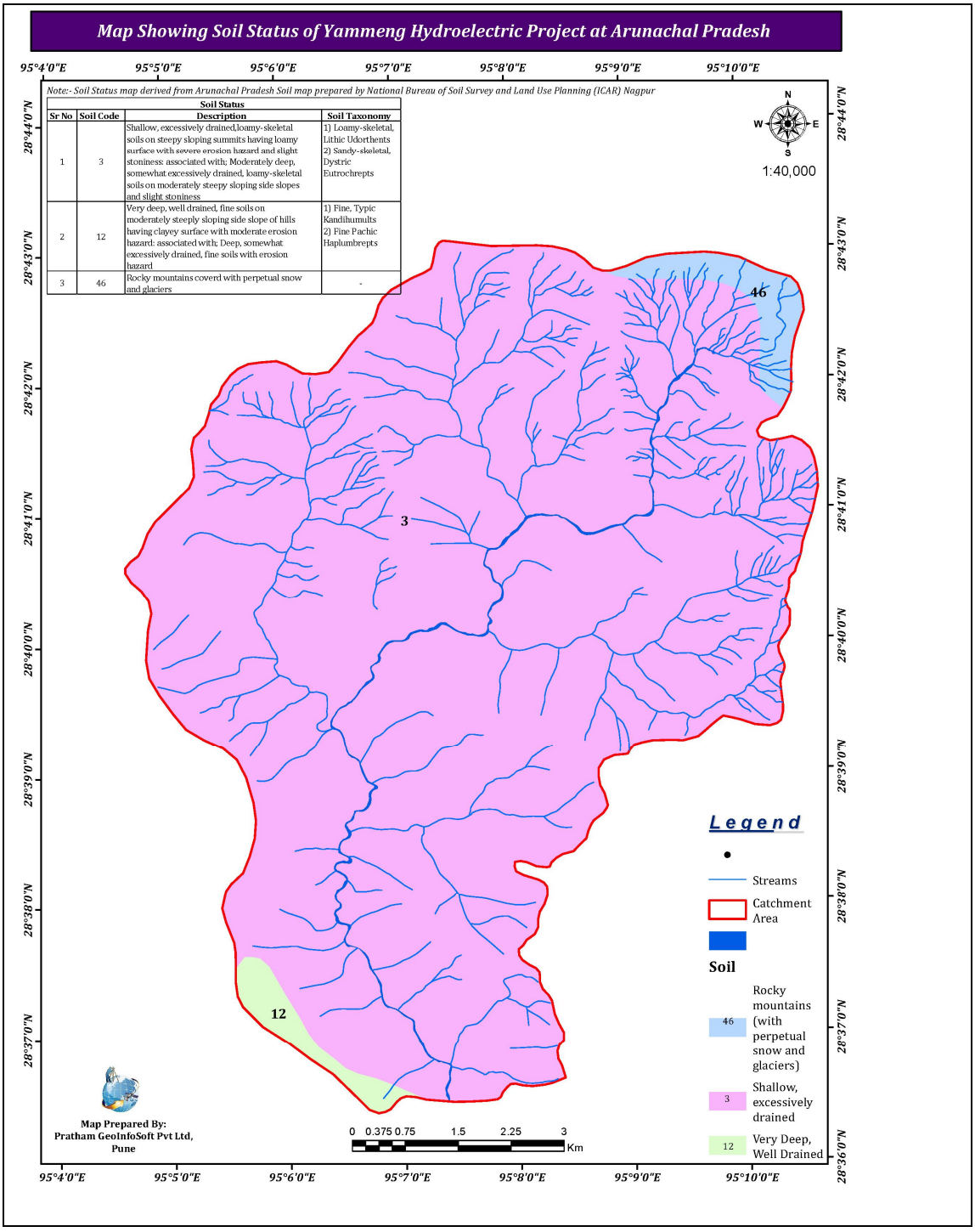
Preparation of Slope maps



Slope maps indicate that severe to very severe slope contribute to around 50% of the catchment area. The rest of the areas posses moderate to gentle slopes.

SOIL MAPS:

Soil maps were digitized based upon Soils map of Arunachal Pradesh, prepared and published by National Bureau of Soil Survey & Land Use Planning (NBSS&LUP), Nagpur in co-operation with Department of Agriculture, Govt. of Arunachal Pradesh.



As per the data and map published by NBSS&LUP, the soil type and classification is as under:

Table Soil class, association type and percentage of the free area draining

Sr No	Soil Code	Description	Soil Taxonomy
1	3	Shallow, excessively drained,loamy-skeletal soils on steepy sloping summits having loamy surface with severe erosion hazard and slight stoniness: associated with; Moderately deep, somewhat excessively drained, loamy-skeletal soils on moderately steepy sloping side slopes and slight stoniness	1) Loamy-skeletal, Lithic Udorthents 2) Sandy-skeletal, Dystric Eutrochrepts
2	12	Very deep, well drained, fine soils on moderately steeply sloping side slope of hills having clayey surface with moderate erosion hazard: associated with; Deep, somewhat excessively drained, fine soils with erosion hazard	1) Fine, Typic Kandihumults 2) Fine Pachic Haplumbrepts
3	46	Rocky mountains coverd with perpetual snow and glaciers	-

Estimation of Soil loss

Soil loss can be estimated using Silt Yield Index (SYI) method. The application of SYI method for prioritisation of sub water sheds in catchment area involves the evaluation of:

1. Geomorphic factors comprising slope and drainage characteristics; landforms and physiography.
2. Surface covers factors governing the flow hydraulics.
3. Climatic factors comprising total precipitation, its frequency and intensity
4. Management factors.

The area of each of the mapping units is arrived at and Silt Yield Index of individual sub-water sheds will be computed using following equation:

a. Silt Yield Index:

$$SYI = \frac{(Ai \times Wi) \times 100}{Aw}$$

For catchment area development, three types of interventions are proposed in the project area. These are as follows:

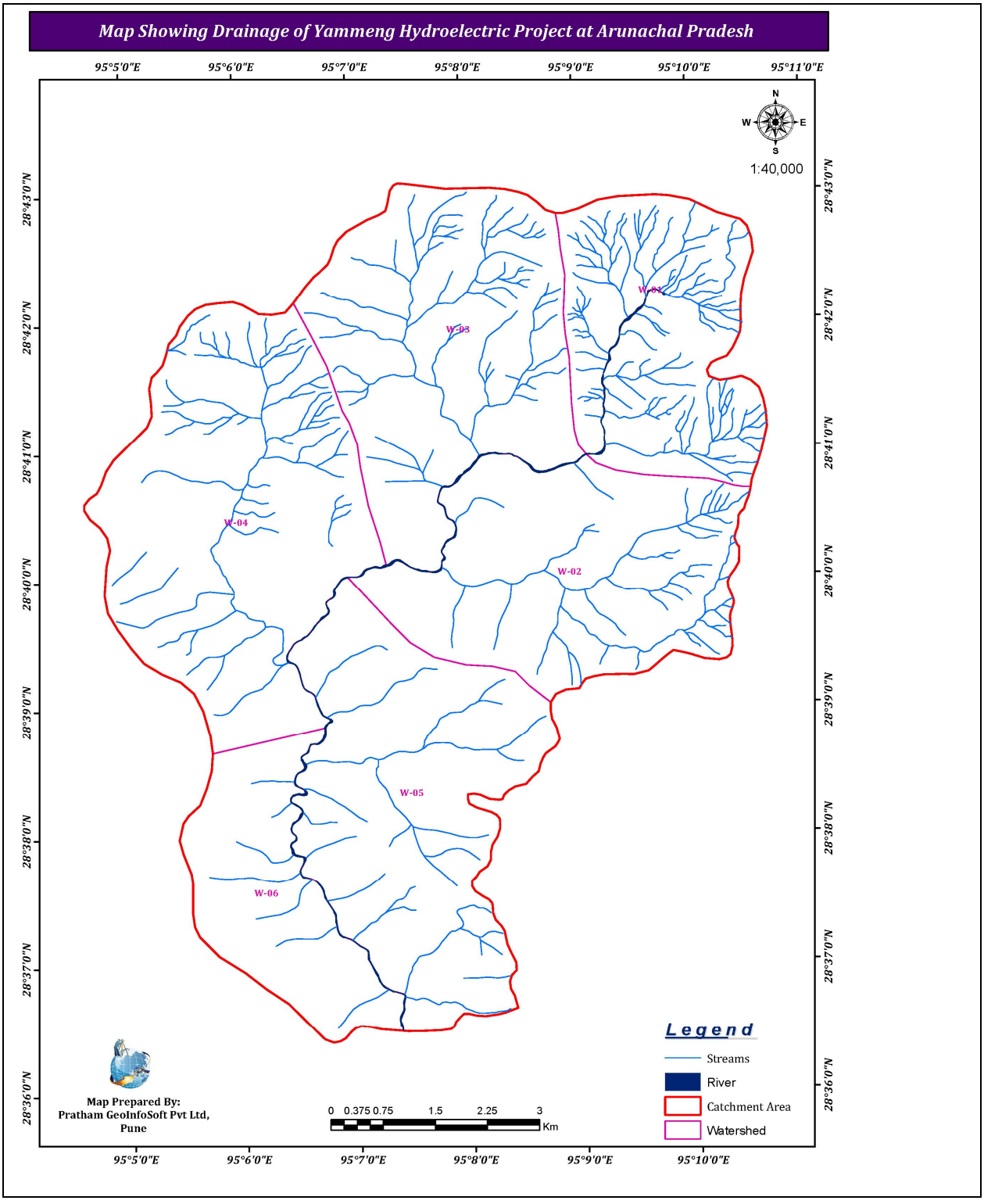
A) Drainage line treatment for soil Conservation.
B) Soil Conservation Activity for Area Treatment
C) Plantation and Afforestation – for increasing the soil cover

All works are to be completed in two phases of two years each. The physical and financial targets to be met in each of the two phases have been detailed in the estimate. It takes into account existing watershed activities in the catchment.

Watersheds / drainage maps:

Most of the rivers in Yammeng river watershed are majorly rainfed, a small portion in the northern / north eastern part is snowfed stream. During its initial course it flows from north-east to south, then south west and finally towards south.

Yammeng river have been divided into 6 major watersheds. The image showing 6 watersheds viz. W1, W2, W3, W4, W5 & W6 are delineated on the map. The Watershed W1 is the northernmost and mostly fed by snowfed stream. While in the remaining watersheds no snowfed stream are reported.
The details can be visualized from the digitized satellite map of drainages.


Map Showing Drainage of Yammeng Hydroelectric Project at Arunachal Pradesh
95°5'0"E
95°6'0"E
95°7'0"E
95°8'0"E
95°9'0"E
95°10'0"E
95°11'0"E
28°43'0"N
28°42'0"N
28°41'0"N
28°40'0"N
28°39'0"N
28°38'0"N
28°37'0"N
28°36'0"N
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W
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S
1:40,000
W-01
W-02
W-03
W-04
W-05
W-06
Legend
Streams
River
Catchment Area
Watershed
0 0.375 0.75 1.5 2.25 3
Km
Map Prepared By:
Pratham GeoInfoSoft Pvt Ltd,
Pune

Details of the Yammeng River Watershed Area				
NAME	Area in sq km	Area in sq m	area in Ha	Percentages
W-04	17.693289	17633288.71	1769.329	22.08807318
W-05	15.78593	15067593.23	1578.593	19.70695087
W-01	10.98047	10097046.73	1098.047	13.70787675
W-02	13.499379	13249378.86	1349.938	16.85245017
W-03	14.658243	14658243.12	1465.824	18.29916101
W-06	7.48605	7038204.789	748.605	9.345488013
TOTAL	**80.103361**		8010.336	**100**

All these areas have moderate to steep slope class most of the sub-watersheds have area around 1000-1500 ha. The average slope class is %. Gently sloping covers 7.46% of this watershed. Only 5 of the sub-watersheds have area more than 500 ha. Steep slope class is around 40-50%. Most of the sub-watersheds has area more than 500 ha (see Fig. 2.12).

CHAPTER 7. CALCULATION OF SILT YIELD INDEX

Silt yield index (SYI) has been calculated for all the 6 sub-watersheds, following the All India Soil and Land Use Survey (AISLUS) method and accordingly prioritized for treatment. It can be noted that around 94.5% of the catchment area has presence of forest / good vegetation. The focus was therefore on the remaining 5% area which accounts to around 450 ha.

Based upon the degradation and other parameters, watershed among these 6 sub watersheds were selected as a priority for treatment.. The maximum estimated SYI value of 1422.71 is recorded for W02 sub-watershed while minimum value of 1091.42 is calculated from W06 sub-watershed. Both the sub-watersheds fall in the Yammeng watershed. An area of 450 ha will be taken for treatment in the first and second year according to the prioritization of SYI.

Table for Computation of Silt Yield Index (also provided as annexure 1)

A	B	C	D	E	F	G	H
Sub-watershed code	Erosion intensity	Area* (ha)	Weightage	Area x weight- age	Delivery ratio	Gross silt yield	Sediment yield index
				(C*D)		(E*F)	(H/C)*100
W01	a	110.90	17	1885.346699	0.95	1791	
	b	541.34	16	8661.394736	0.9	7795	
	c	397.49	14	5564.902196	0.85	4730	
	d	48.31	11	531.454748	0.80	425	
Total		1098.047				**14742**	**1342.54**
W02	a	80.96	19	1538.187829	0.95	1461	
	b	604.50	17	10276.52925	0.85	8735	
	c	647.30	16	10356.83133	0.85	8803	
	d	17.18	15	257.6560042	0.8	206	
Total		1349.938				**19206**	**1422.71**
W03	a	0.00	0	0	0.00	0	
	b	13.65	17	231.9985912	0.85	197	
	c	1311.84	15	19677.66715	0.85	16726	
	d	140.33	12	1683.990571	0.8	1347	
Total		1465.824				**18270**	**1246.43**
W04	a	43.30	18	779.4312157	0.90	701	
	b	649.60	17	11043.25909	0.85	9387	
	c	1050.71	14	14709.88572	0.85	12503	
	d	25.72	12	308.6120019	0.8	247	
Total		1769.329				**22839**	**1290.80**
W05	a	0.00	0	0	0.00	0.00	
	b	318.69	15	4780.315441	0.85	4063	

	c	1189.88	14	16658.34704	0.85	14160	
	d	70.02	12	840.2804679	0.8	672	
Total		1578.593				**18895**	**1196.96**
W06	a	2.62	17	44.55682519	0.85	38	
	b	174.05	15	2610.792157	0.85	2219	
	c	555.81	13	7225.478493	0.8	5780	
	d	16.13	11	177.3767809	0.75	133	
Total		748.605				**8170**	**1091.42**

PRIORITISATION OF SUB WATERSHEDS FOR CATCHMENT AREA TREATMENT MEASURE

Sub-Watersheds	Silt Yield Index *	Priority Ranking
W01	**1342.54**	I
W02	**1422.71**	I
W03	**1246.43**	II
W04	**1290.80**	II
W05	**1196.96**	III
W06	**1091.42**	III

Prioritized SYI value of erosion intensity rates with Sub-watershed code

Priority Category	SYI Values
1. Very High	>1300
2. High	1200 -1299
3. Medium	1100-1199
4. Low	1000-1099
5. Very Low	<1000

YEARWISE TREATMENT OF CATCHMENT AREA

Year	Sub-watershed Number	SYI Values	Sub Watershed Area
Year I	W01	**1342.54**	1769.329
Year I	W02	**1422.71**	1578.593
Year I	W03	**1246.43**	1098.047
Year II	W04	**1290.80**	1349.938
Year II	W05	**1196.96**	1465.824
Year II	W06	**1091.42**	748.605
Total			8010.336

CHAPTER 8. TREATMENT OF CATCHMENT AREAS

Drainage Line Treatment

1. Gully Plugs:

- Dry rubble structures are proposed across small gullies formed on the slopes. On the higher reaches, plugging them with vegetative support is proposed. These gullies are in the pre-youth stage. If not checked in time, then due to soil erosion these gullies may widen. The nalla then developed may cut through agricultural land and damage downstream areas.
- Gully plugs are also essential on the boundaries of agricultural land. During high rainfall periods, the flow concentrates within the low-lying strip of land, which damages the existing earthen bund by eroding its sides. Hence, gully plugs are the most suitable structures. These keep the soil in position but allow the water to flow through the voids within the structure.
- For details please refer to Annexure No 1

2. Loose Boulder Structure:

- The design and construction of loose boulder structures is similar to that of gully plugs. The loose boulder structures are larger than gully plugs. These are proposed on the sub streams of our project area, which will reduce the erosion of nala banks and bed. The total number of loose boulder structures in the project area can be finalized only after a detailed field survey.
- For detailed estimates please refer to Annexure No 1.

3. Gabion Structure:

- These are low head `Dual Purpose Structures' used for nala bed stabilization, and as temporary water storage structures to enhance the ground water table. Although meant to be soil conservation structures, these bunds are also expected to impound some water after 2-3 years and thereby contribute to ground water recharge. Structures are proposed as per survey conducted on streams.
- For details, please refer Annexure No 1.

4. Earthen Nalla Bund:

- Earthen structure to impound water immediately and thereby also helps to contribute to ground water recharge. This water also easily available for nearby agricultural field. These structures are proposed as per survey conducted on streams.

5. Cement Nalla Bund :

- Cement structure with removable gates, which are expected to build on major stream to impound water in later months of monsoon. This water is especially used for nearby agricultural field. These structures are proposed as per survey conducted on streams.

Area Treatment:

- *Aim*: To reduce the loss of soil cover by intercepting the soil erosion and increase soil moisture by temporary storage of water on the upper side of the bund.
- Based on the land capability classification made by considering the Survey Numbers and the treatment finalized by the farmers, we have arrived at the appropriate interventions, required in each survey no and hence total area.

1. Terrace Bund Improvement:

- The intervention is meant to stop the degradation of soil on the slight sloping grounds (slope range between 0 to 5 per cent). This treatment is beneficial for increasing the soil moisture and thus the fertility of land. Provision will be made for suitable waste weir to drain out the excess quantity of runoff, without causing any hazard to the fields. Locally available material will be used.
- This activity reduces the hazard to crop due to runoff. Material used for bunds is locally available soil from fields. Grass development will be done on the bunds, which should strengthen the bunds and simultaneously achieve the fodder production
- For details, please refer to Annexure No 1.

2. Repairs of Farm Bunds:

- This treatment is suggested for those areas where the soil conservation department will carry out the bunding activities. This will be in addition to raising of existing farm bunds and construction of loose boulder outlets to facilitate drainage in these soils.
- Green manuring, mulching are also recommended for soil and water conservation and also to regenerate depleted soil.
- For details refer Annexure No 1.

3. Continuous Contour Trenching with Mixed Forestry, Reforestation:

- Contour Trenching satisfies the dual purpose of soil and water conservation effectively. This treatment is generally given within the slope range between 10 to 20 per cent having IV to VI capability class of land. Development of forest trees is also proposed in this area, which will increase the soil binding capacity. This also checks the water run-off from steep land.
- For details, please refer to Annexure No 1.

Afforestation and Reforestation Development:

1. Afforestation /Reforestation:

- Afforestation in new areas and Reforestation in the existing area (where plant density and diversity has reduced) are included in this.
- Under afforestation and reforestation activities multipurpose tree species that are suitable to this area based on farmers' plantation experience will be planted.
- For details please refer Annexure No 1.
- Recommended Species

  Castanopsis indica, Lannea coromandelica, Ostodes paniculata, Albizia procera, Duabanga grandiflora, Macaranga denticulata and Pandanus nepalensis are the dominant tree species in the area with the high density. Density of shrub species was observed highest at sampling sites located between Siyat and Lagru with 3920 individuals/ha to 4062 individuals/ha. The shrubs with highest density are Ardisia thyrsiflora, Chromolaena odoratum, Boehmeria macrophylla, Chromolaena odoratum, Bambusa tulda, Ascophyllum spinulosa and Oxyspora paniculata. Herbaceous flora density in the area was recorded highest in between Siyat and Padu area ranging from 3,65,000 individuals/ha to 3,67,000 individuals/ha. Athyrium angustum, Urtica parviflora, Pogonatherum paniceum, Pteris subindivisa, Pilea umbrosa, Pilea scripta, Pteris vittata, Miscanthus nepalensis and Saccharum narenga are most dominant species with high density

a) Avenue: Kokam, Sitecha Ashok, Sisham, Indian cork, Silver Oak, Suru, Kashid
b) On hilly area: Teak , Neem,Behda, Palas, Khair, Moha, Tamarind, Kinjal, Bahava, Arjun, Banyan, Amla, Jambool,
c) On the submerged area: Sps. like Poplar
d) Fodder development: Davna, Para grass, Local useful grass fodder species.

TIME SCHEDULE INDICATING THE PHASES IN WHICH THE CATCHMENT AREA TREATMENT PLAN WILL BE IMPLEMENTED

Sr.No	Activity / Treatment Measures	Period
A	Area Treatment	
1	Fodder Development	October to December
2	Repairs of Farm Bunds	October to May
3	Terrace Bund Improvement	October to May
4	Planting On Farm Bund	June to Sept
5	Reforestation	June to Sept
6	Afforestation	June to Sept
B	Drainage Line Treatment	
1	Gully Plugging	October to May
2	Loose Boulder Structure	October to May
3	*Gabion Bandhara*	October to May
4	*Earthen Nala Bund*	October to May
5	*Cement Nala Bund*	October to May

Area treatment like repairs to farm bunds and bund improvement is to be carried out in the pre-monsoon stage to prevent further damage in the following monsoon. Nurseries for plants should also be established now. Plantation and fodder development activities are to be carried out in the monsoon. This will eliminate the need for manual irrigation. Drain-line treatments are to be carried out in the post-monsoon stage. At this time, the ground is easily worked, not slushy and the land is not subject to water erosion for the next six months.

CHAPTER 9. COST ESTIMATE FOR CATCHMENT AREA TREATMENT

Sr No	Item			FIRST PHASE (Year I)		SECOND PHASE (Year II)	
		Unit	Unit Cost	Physical	Financial	Physical	Financial
A	**Area Treatment on Public Land**						
1	Reforestation	ha	20000	75	1500000	75	1500000
2	Afforestation	ha	25000	75	1875000	40	1000000
	Total Amount of A INR				**3375000**		**2500000**
B	**Drainage Line Treatment**						
1	Gully Plugging	No.	600	120	72000	75	45000
2	Loose Boulder Structure	No.	7000	80	560000	50	350000
3	Gabion Bandhara	No.	30000	40	1200000	30	900000
4	Earthern Nalla Bund	No.	15000	40	600000	20	300000
	Total Amount of B INR				**2432000**		**1595000**
	Total (A +B) INR						**9902000**
	Contingency@10%						**990200**
	Grand Total	INR	**One Crore Eighty Lakh Ninety Two Thousand and Two Hundred Only**				**10892200**

Kindly note that, more than 94.43% of total catchment of 8100 ha is covered with good vegetation cover. Therefore only area available for treatment is 450 ha for both the biological and engineering measures. The estimated cost is around INR 1.08 Crores including INR of 9.9 lakh towards the contingency.

CHAPTER 10. AGENCIES RESPONSIBLE

Forest and Agriculture Department will be responsible for carrying out the work in the Catchment Area of Yammeng Hydroelectric Project. The financial support required for execution of this project will be made available by the project authority.

CHAPTER 11. FINANCIAL FORECAST

The total cost of catchment area treatment for the entire area is INR. 1,08,92,200 (One Crore Eighty Lakh Ninety Two Thousand and Two Hundred only). The costs have been calculated using the rate of Rs. 150/- per labor day.

Estimated cost of CAT Plan Implementation

S. No.	Item	Amount (Rs)
I	**BIOLOGICAL MEASURES**	
1	Reforestation (150 ha)	**30,00,000**
2	Afforestation (150 ha)	28,75,000
	Total	**58,75,000**
II	**ENGINEERING MEASURES**	
3	Earthen Check Dams (60 Nos)	9,00,000
4	Loose boulder Structure (130 Nos)	9,10,000
5	Gabion Structures (70 Nos)	21,00,000
6	Silt Observation Units (gully plug) 195 nos.)	1,17,000
	Total	**40,27,000**
	Contingency@10% on I & II	**9,90,200**
III	**Sub-total (I + II)**	1,08,92,200
IV	**COST OF OTHER COMPONENTS**	
7	Operational Support	
8	Forest Protection Plan	
9	Energy Saving Devices	
10	Provision for Micro Planning	
11	Publicity and Awareness	
12	Training of Forest Staff	
13	Provision for Forestry Research	
14	Eco Tourism	
15	Payment for Eco Services	
16	Wildlife Protection, Management and Conflict Resolution	
17	Monitoring and Evaluation	
V	**GRAND TOTAL (III + IV): One Crore, Thirteen lakh, Sixty Thousand, Two Hundred and Fifty Only**	**1,08,92,200**

CHAPTER 12. CONCLUSIONS

The Catchment Area Treatment (CAT) Plan highlights the management techniques for to control erosion in the catchment area of a water resources project. The life span of a reservoir is greatly reduced due to erosion in the catchment area. Adequate preventive measures are thus needed for the treatment of catchment for its stabilization against future erosion. The directly draining catchment area has been considered for treatment under the present project.

If all the interventions are implemented as per the plan, the rate of siltation will drastically reduce. Not only the design life of the barrage / dam will be achieved, but the life will be extended. Along with the projected benefits of the project, it will contribute significantly to the conservation of ecological resources. The area will regain its lost bio-diversity.

ANNEXURES

1. SYI CALCULATIONS

ANNEXURE 1: TABLE FOR SILT YIELD INDEX

Table for Computation of Silt Yield Index							
A	B	C	D	E	F	G	H
Sub-watershed code	**Erosion intensity**	**Area* (ha)**	**Weightage**	**Area x weight-age**	**Delivery ratio**	**Gross silt yield**	**Sediment yield index**
				(C*D)		(E*F)	(H/C)*100
W01	a	110.90	17	1885.347	0.95	1791	
	b	541.34	16	8661.395	0.9	7795	
	c	397.49	14	5564.902	0.85	4730	
	d	48.31	11	531.4547	0.80	425	
Total		1098.047				**14742**	**1342.54**
W02	a	80.96	19	1538.188	0.95	1461	
	b	604.50	17	10276.53	0.85	8735	
	c	647.30	16	10356.83	0.85	8803	
	d	17.18	15	257.656	0.8	206	
Total		1349.938				**19206**	**1422.71**
W03	a	0.00	0	0	0.00	0	
	b	13.65	17	231.9986	0.85	197	
	c	1311.84	15	19677.67	0.85	16726	
	d	140.33	12	1683.991	0.8	1347	
Total		1465.824				**18270**	**1246.43**
W04	a	43.30	18	779.4312	0.90	701	
	b	649.60	17	11043.26	0.85	9387	
	c	1050.71	14	14709.89	0.85	12503	
	d	25.72	12	308.612	0.8	247	
Total		1769.329				**22839**	**1290.80**
W05	a	0.00	0	0	0.00	0.00	
	b	318.69	15	4780.315	0.85	4063	
	c	1189.88	14	16658.35	0.85	14160	
	d	70.02	12	840.2805	0.8	672	
Total		1578.593				**18895**	**1196.96**
W06	a	2.62	17	44.55683	0.85	38	
	b	174.05	15	2610.792	0.85	2219	
	c	555.81	13	7225.478	0.8	5780	
	d	16.13	11	177.3768	0.75	133	
Total		748.605				**8170**	**1091.42**

2. ESTIMATES FOR VARIOUS TREATMENTS

1. Reforestation cost per hectare

(Planting of fast growing fuel and fodder species with the aim of soil conservation)				
Slope: All types				
Depth of soil : Variable, shallow depth of soil				
Cost of Labour: Rs. 150/ day				
Sr.	**Item**	**Cost of Labour**	**Cost of Material**	**Total Cost**
No.		**(Rs.)**	**(Rs.)**	**(Rs.)**
1	Contour trenching(600X0.3X0.6)	10800	---------	10800
	(@ 1.5 cum per labour day)			
2	Planting of 450 plants per ha	6000	2884.5	8884.5
		16800	2884.5	19684.5

4. Afforestation cost per hectare				
(Planting of fast growing fuel and fodder species with the aim of soil conservation)				
Slope: All types				
Depth of soil : Variable, shallow depth of soil				
Sr.	**Item**	**Cost of Labour**	**Cost of Material**	**Total Cost**
No.		**(Rs.)**	**(Rs.)**	**(Rs.)**
1	Contour trenching(600X0.3X0.6)	10800	---------	10800
	(@ 1.5 cum per labour day)			
2	Planting of 1000 plants per ha	7884	6410	14294
		13068	6410	25094

5. Loose boulder structure

Slope: All types
Depth of soil : Variable, shallow depth of soil

Average length : 10 m Top width : 0.6m
Average height : 1 m Bottom width : 2.6m
Foundation : 0.3 m Cross section : 1.6sq.m.

Labour Rate: Rs.150/- per day

Sr. No.	Item	Cost of Labour (Rs.)	Cost of Material (Rs.)	Total Cost (Rs.)
1	Site clearing	150		150
2	Excavation for foundation @1.5cum per labour day	450		450
3	Filling of foundation with boulders @rs. 100/- cum	900		900
4	Construction of the structure with stone after dressing cum @ Rs.210 per cum	3360		3360
5	Transportation of stone upto 100m @ Rs.100 per cum	1600		1600
6	Grass seeding and planting trees/agave (10 nos)	78.84	64.1	142.94
		6538.84	64.1	6602.94

6. Gabion structure

Slope: <10%
Depth of soil : >30 cm

1. Total length of structure including Keying of 2m on either side : 24m
2. Height of gabian structure : 1m
3. Top width : 0.45m
4. Base width : 2.45m (section = 1.45 sq.m.)
5. Foundation : 0.5m
6. GI mesh (15cm X 15cm) of 3mm thickness = 8m X 24m : 192 sq.m
7. Pitching on D/S side : 2m X 20m @ Rs.40/sq.m.

Labour Rate: Rs. 150/- per day

Sr. No.	Item	Cost of Labour (Rs.)	Cost of Material (Rs.)	Total Cost (Rs.)
1	Excavation work on both banks (2 X 2 X 2.6) cum	450	-------	450
2	Excavation of foundation (20 X 2.6 X 0.5) cum	1500	-------	1500
3	Filling with dry rubble 15-20 cm size incl. compaction and gap filling (34.8 + 26)cum	1500	-------	1500
4	Shaping of nala slope	900	-------	900
5	Pitching on nala slides @ Rs.40 per sq.m.	1800	-------	1800
6	Ramming of soil on the banks	450	-------	450
7	Galvanised wire mesh 192 sq.m.	-------	21120	21120
8	Transportation charges (L.S.)	-------	1000	1000
6	Grass seeding and planting trees/agave (20 nos)	300	150	450
		14629.68	22248.2	29170

7. Gully plug

Slope: all types
Depth of soil : variable, suitable for shallow depths
Average length : 5.0 m Top width : 0.6 m
Average height : 0.60 m Bottom width : 0.60 m

Labour Rate: Rs. 150/- per day

Sr. No.	Item	Cost of Labour (Rs.)	Cost of Material (Rs.)	Total Cost (Rs.)
1	Site clearing	150	-------	150
4	Construction of the Gully plug	300	-------	300
	with stone, @ 1.80 cum			
5	Transportation of stone upto	150	-------	150
	100m distance.			
	Total Cost of Gully plug Rs.	304		600

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