10.1 CATCHMENT AREA TREATMENT PLAN

10.10.1 Introduction

Land and water resources have optimum interaction and synergetic effect if developed in scientific and rational manner. In a larger sense land is represented by soil, which is usually susceptible to erosion due to various meteorological conditions such as total annual precipitation, snowfall, intensity of precipitation, wind velocity and directions, extent of vegetal cover and the topography of the catchment. Sedimentation of reservoir is a function of soil erosion rate of the river catchment area. It impinges upon the useful capacity of reservoir and the availability of water for its designated use. The erosion of top soil from land reduces its fertility and the vegetation growth. Thus, no water resources scheme of medium and major classification can be successful by keeping in seclusion from it the most interactive gradient of nature i.e. land. Thus, it becomes imperative to evolve a plan based on scientific approach to prevent soil erosion to the extent possible.

The study of erosion and sediment yield from catchment is of utmost importance as the deposition of sediment in reservoir reduces its capacity, thus affecting the water available for the designated use. The eroded sediment from catchment when deposited on streambeds and banks causes braiding of river reach. The removal of top fertile soil from catchment also adversely affects the agricultural production. Another important factor that adds to the sediment load, and which contributes to soil degradation is grazing pressure. A large number of cattle, sheep, and goats graze the pastures continuously for about six months. Due to this pressure, the productivity of these pastures is also declining further. The lack of proper vegetal cover is a factor to cause degradation and thereby results in severe run off/soil erosion, and subsequently premature siltation of the reservoir. Thus, a well-designed Catchment Area Treatment (CAT) Plan is essential to ameliorate the above-mentioned adverse cause and process of soil erosion. The catchment area treatment involves the understanding of the erosion characteristics of the terrain and suggesting remedial measures to reduce the erosion rate. For this reason the catchment of the directly draining rivers, streams, tributaries, etc. are treated and the cost is included in the project cost.

Watershed is the basic unit of a catchment. Watershed is a natural hydrological and geographic unit of spatial extent characterized by surface run-off confined to a defined course at a particular point. The boundary of the watershed is delineated by the line of water divided in a basin with reference to specific point drainage. The pre-requisite for a watershed management is the collection of multipronged data e.g., geology, geomorphology, topography, soil, landuse/landcover, climate, hydrology, drainage pattern, etc. The catchment of “Bhaunrat Dam” consists of 13 sub-watersheds. The multipronged data generated from various published sources and actual data collected from these watersheds on the above-mentioned parameters forms the basis of the Action Plan for Catchment Area Treatment is presented here.

As a part of the EIA study for the proposed “Bhaunrat Dam”, a Catchment Area Treatment (CAT) plan for the free draining catchment area (**Figure-10.1**) has been prepared for areas with high soil erosion intensity. The CAT Plan targets towards overall improvement in the environmental conditions of the region.

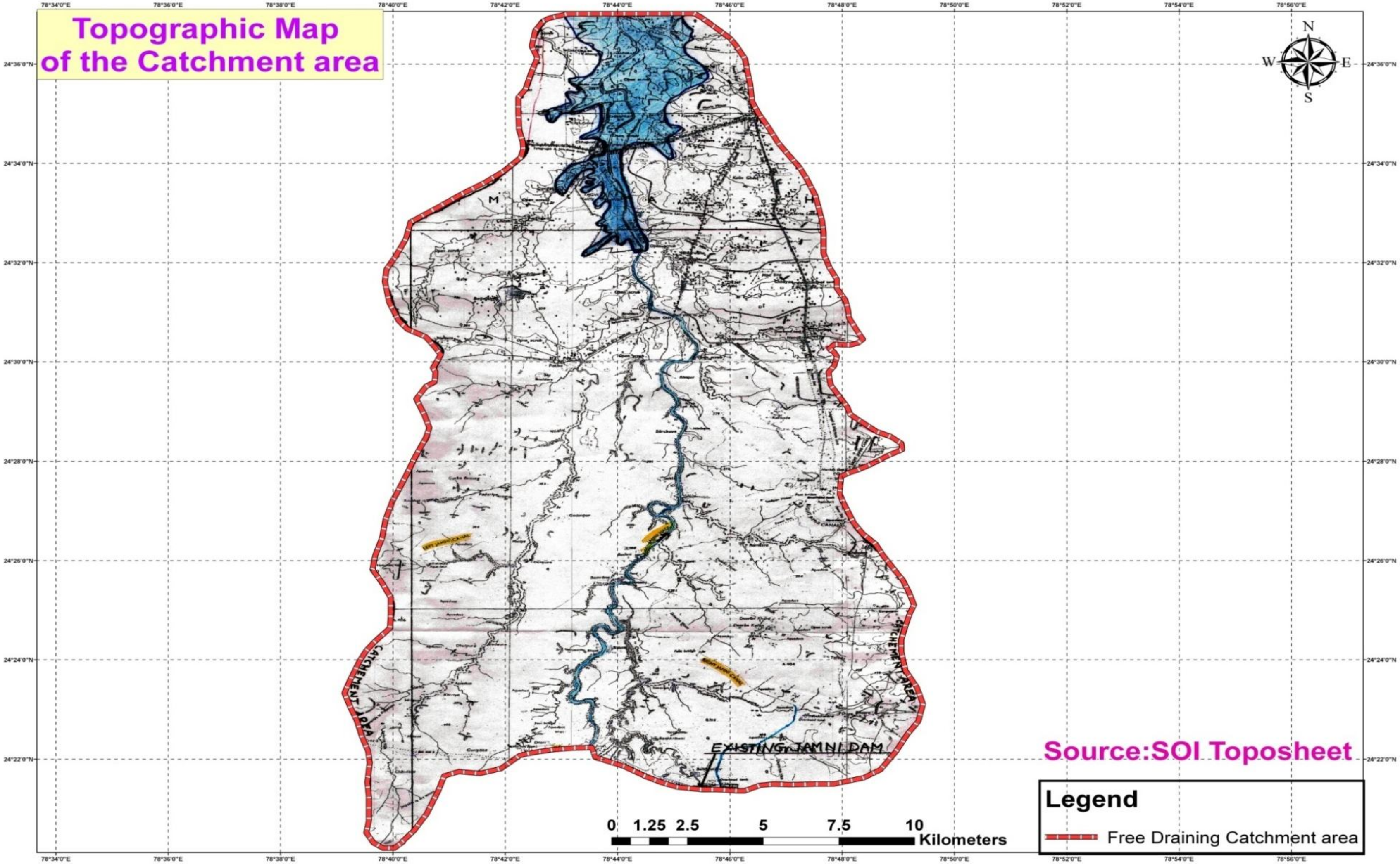

Figure 10.1: Topographic Map of Free Draining Catchment

10.10.2 CATCHMENT AREA

The total catchment area of Jamni River is 749.40 Sq. km out of which 414 sq. km was utilized by existing Jamni Dam.

10.10.3 Free Draining Catchment

The free drainage catchment for the present project is 335.40 Sq. km. The free drainage catchment area consists of catchment area between the existing Jamni Dam and proposed Bhaunrat Dam.

The free draining watershed ICIC5 has been further sub-divided into 13 sub-watersheds the aerial extent of which is apportioned in **Table 10.7** and depicted in **Figure 10.2** & **Figure 10.3.**

Table No. 10.7: Area of Sub water shed

S. No.	Watershed Code	Area(sq km)
1.	Sub Watershed-1(SW-1)	12.98
2.	Sub Watershed-2(SW-2)	35.18
3.	Sub Watershed-3(SW-3)	86.74
4.	Sub Watershed-4(SW-4)	30.58
5.	Sub Watershed-5(SW-5)	30.45
6.	Sub Watershed-6(SW-6)	23.37
7.	Sub Watershed-7(SW-7)	20.53
8.	Sub Watershed-8(SW-8)	18.81
9.	Sub Watershed-9(SW-9)	45.67
10.	Sub Watershed-10(SW-10)	5.56
11.	Sub Watershed-11(SW-11)	7.12
12.	Sub Watershed-12(SW-12)	8.13
13	Sub Watershed-13(SW-13)	10.21
	Total	**335.40**

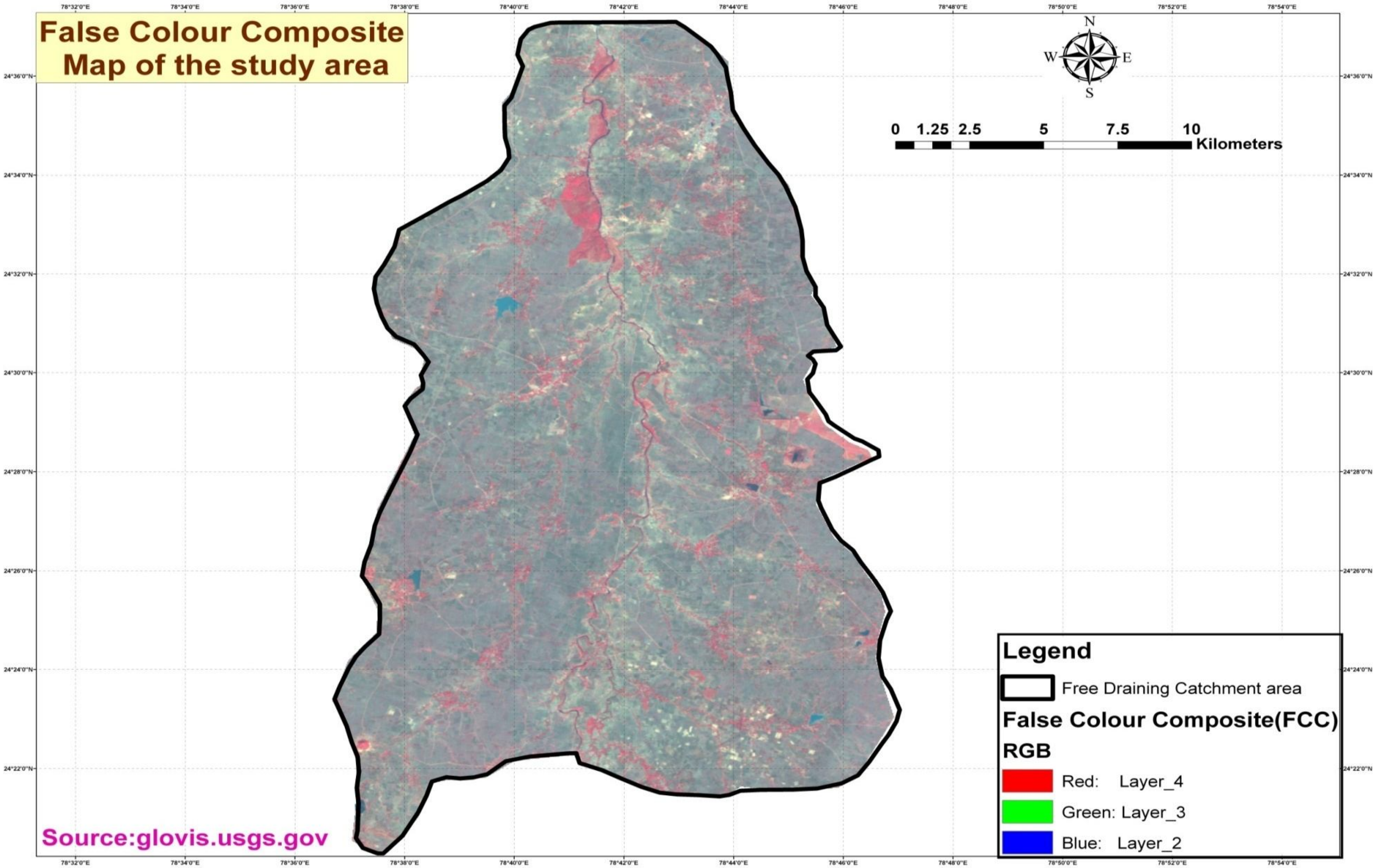

Figure 10.2: Satellite Imagery of Free Draining Catchment

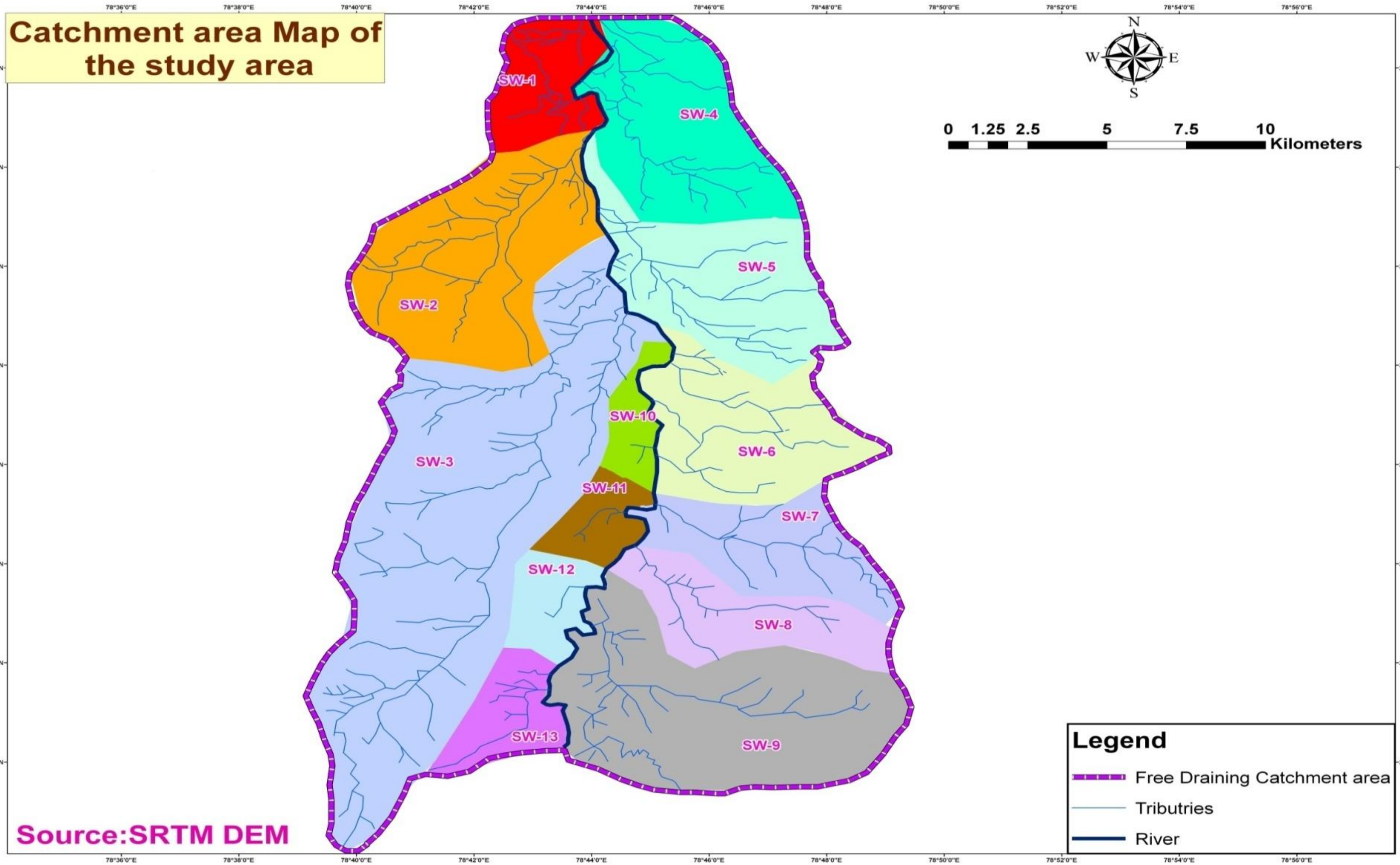

Figure 10.3: Sub-Watershed Location Map of Free Draining Catchment

10.10.4 TOPOGRAPHY

The catchment area lies in Lalitpur, District. The digital elevation map of the catchment area is show in **Figure 10.4**. The elevation of the catchment area varies from 345 meter to 470 meter and most of the area lies at elevation 345 to 377 meter above MSL.

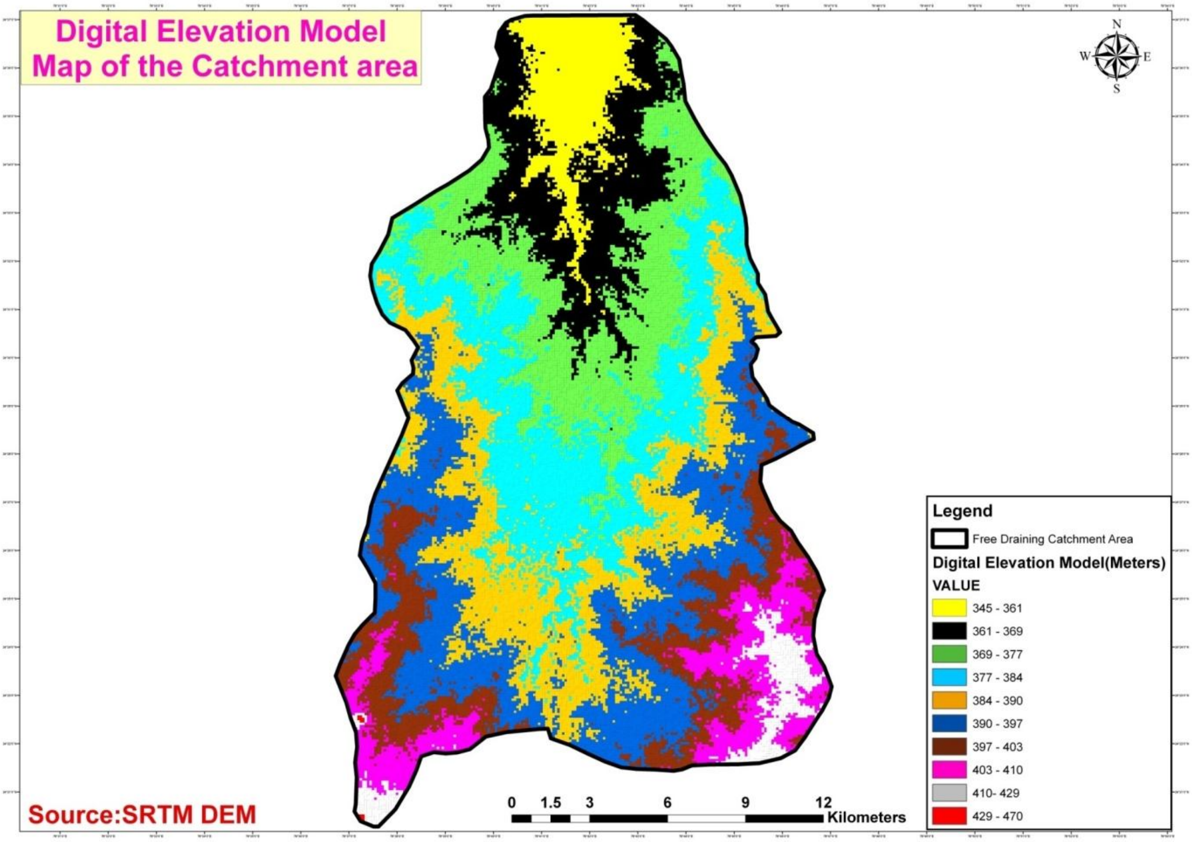

Figure 10.4: Digital Elevation Model Map of the Catchment Area

10.10.5 SOIL

The soil resource map of Uttar Pradesh (NBSS Publication No 58) has been used in the present study. The soil map presented in **Figure 10.5** reveals that the soil of the area belong to category 270, 271, 275, 277 as per NBSS Publication. The details of the category are as follows:

270: Moderately shallow, well drained, fine loamy soils on gentle slopes with loamy surface and severe erosion; associated with: Deep, well drained, fine montmorillonitic soils with clayey surface and moderate erosion.

271: Moderately deep, moderately well drained, fine montmorillonitic soils on gentle slopes with clayey surface and moderate erosion; associated with: Moderately deep, well drained, fine loamy soils with loamy surface and slight erosion.

275: Deep, moderately well drained, fine montmorillonitic soils on very gentle slopes with clayey surface and moderate erosion; associated with: Deep, well drained, fine loamy soils with loamy surface and moderate erosion.

277: Deep, moderately well drained, fine, montmorillonitic, calcareous soils on gentle slopes with loamy surface and moderate erosion; associated with: Moderately deep, well drained, fine loamy soils with loamy surface moderate erosion.

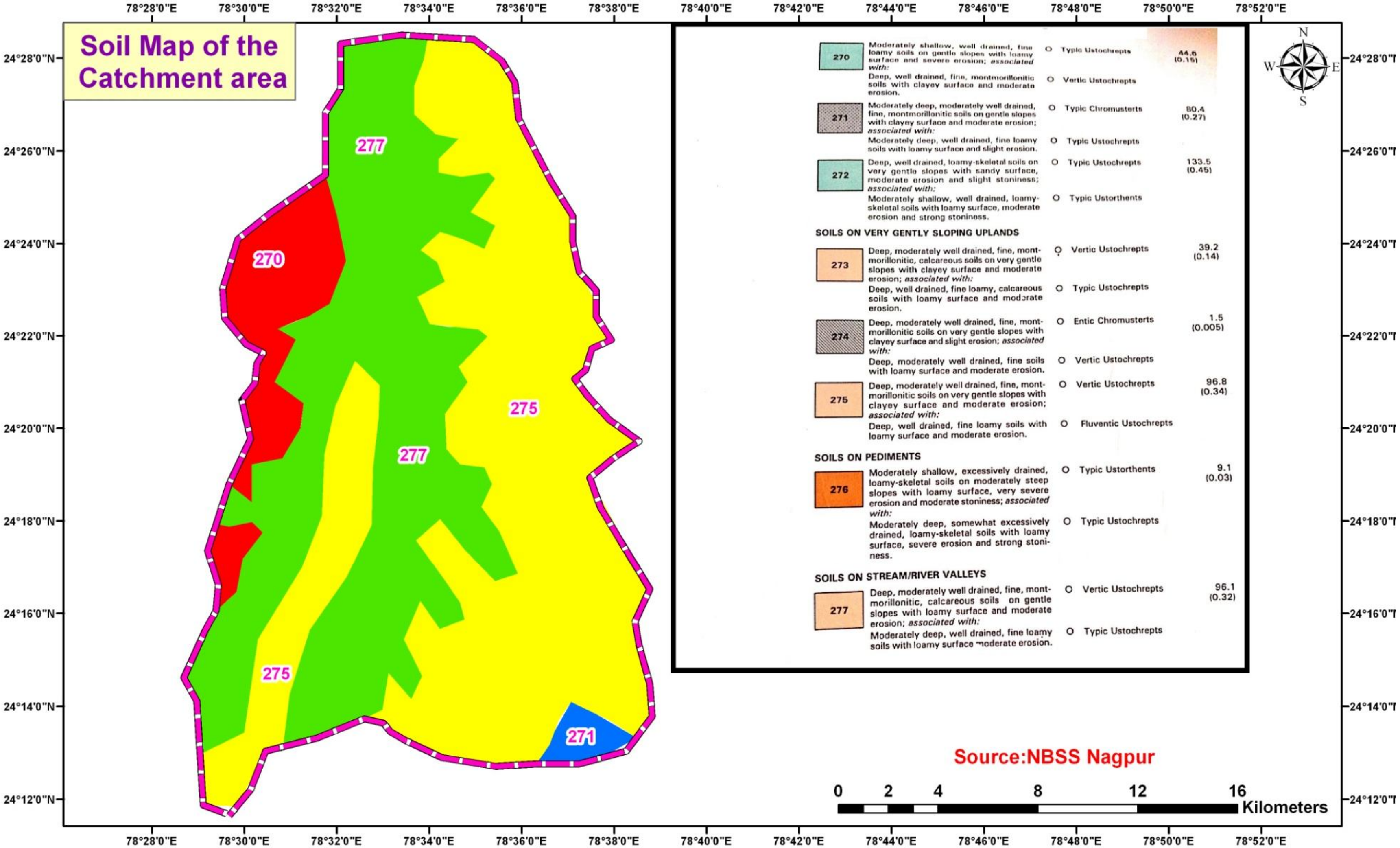

Figure 10.5: Soil Map of Free Draining Catchment

10.10.6 METHODOLOGY USED FOR THE STUDY

The Digital Satellite data of IRS P6 LISS-III acquired from NRSA was evaluated on ERDAS Imagine Software. The standard False Colour Composite (FCC) was been generated by assigning blue, green and red colors to visible green, visible red and near infrared bands respectively. Expressing image pixel addresses in terms of a map coordinate base is often referred to as geo-coding. As various thematic layers were to be overlaid for this project, all the layers were geo-referenced to real world coordinates. The 1:50,000 scale toposheets of the catchment area were used for the purpose of geo-referencing. A large number of GCPs were selected for reasonably accurate geo-referencing/geo-coding. A map projection system (real world) was also defined.

Histogram of the scene under study has been generated to check the range of spectral values present in the scene. In order to use total grey range and to optimize the contract, the actual grey level ranges of three bands were linearly stretched independently. The zoomed images were studied wherever necessary. The interpretation key necessary for identifying different features has been developed systematically on the basis of image characteristics and associated elements viz. shape, size, shadow, pattern, color/tone, texture, association, location and available ground truth. Among these characteristics, shape, size, shadow and pattern are basically dependent on the scale of the image whereas the color/tone and texture depends upon the brightness, contrast and resolution of the image. Various land units were identified, delineated and the map was validated.

Detailed field survey was conducted for study of soil characteristics, and erosion prone areas and landslides in the catchment area. The vulnerable and problematic areas were identified in different physiographic zones in the entire catchment area. The data was generated on physiographic, land-use/land cover, litho-logy, structure, drainage pattern, slope characteristics, landslides/slips, etc. These data sets were used for preparation of the thematic maps, calculation of sediment yield index and Erosion Intensity Units in the catchment area according to the following procedures:

10.10.7 Landuse-Landcover Classification

- Prior to ground truthing, the satellite data was classified using unsupervised classification technique. Further, after collecting ground truth details maximum likelihood classification based supervised classification method was used with remote sensing image data.

- After the supervised classification procedure, a land-use map was prepared which the team at field verified, and any errors or omissions were identified.

- A reclassification of the land-use categories implementing the details and corrections, if any, was done. The reclassification output was used for the preparation of the final land-use classification map. This map after due verification was then composed and printed, as desired.

- The Landuse map of Study and free draining catchment area is presented in **Figure-10.6**. The Land-use/Land-cover details
- for free-draining catchment is presented in **Table 10.8**.

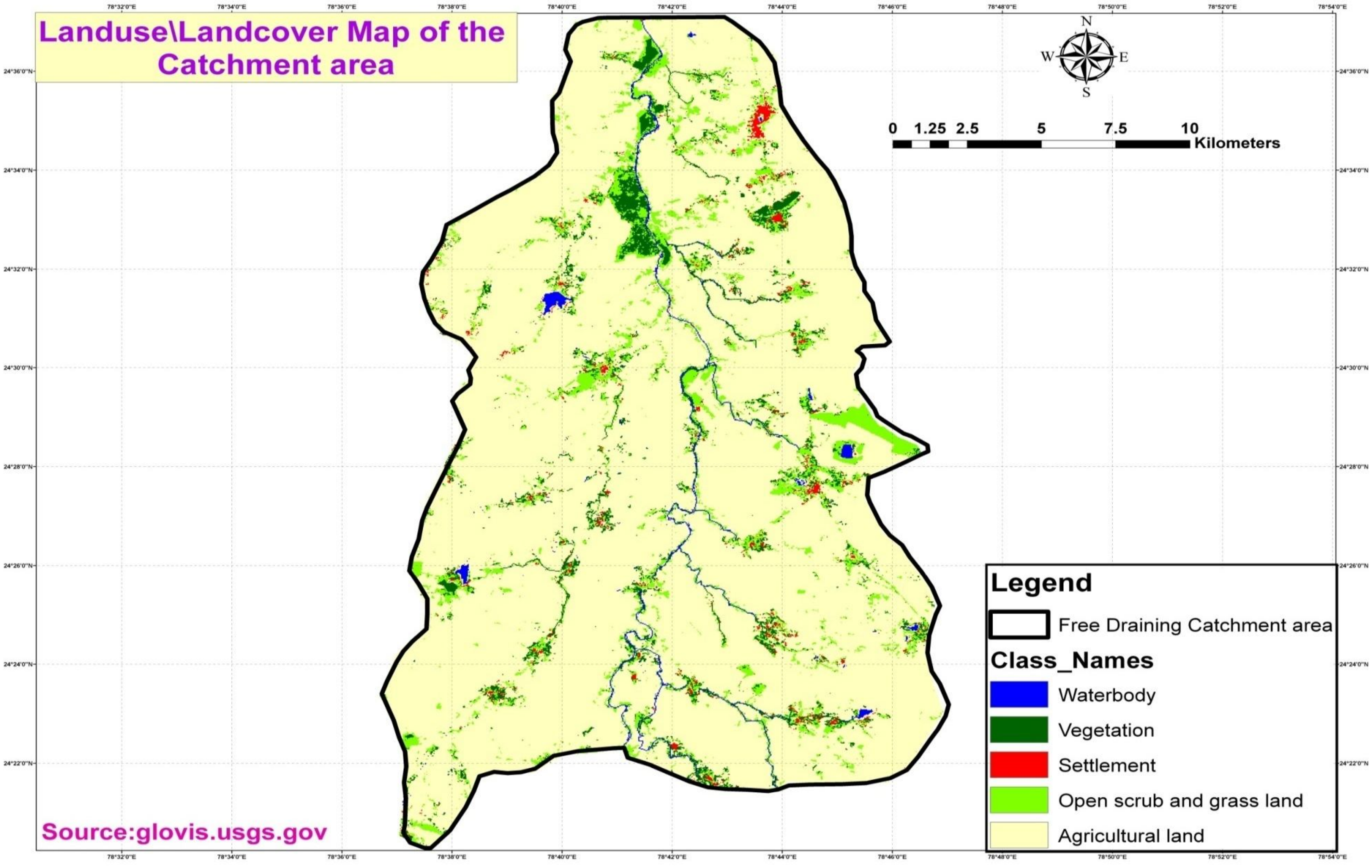

Figure 10.6: Landuse Map of Free Draining Catchment Area

Table 10.8: Landuse Details of Sub-watersheds in the Free Draining Catchment

S. No	Class	Area(SQ km)	% of Area
1.	Agricultural land	294.11	87.69
2.	Open scrub and grass land	20.22	6.03
3.	Vegetation	13.67	4.07
4.	Water body	3.39	1.01
5.	Settlement	4.01	1.20
	Total	**335.40**	

10.10.8 Slope Map Preparation

- Slope is a measure of change in the value of altitudes over distance, which can be expressed in degrees of as a percent. The first step generation of slope map is to create surface using the elevation values stored in the form of contours or points. Surface is a representation of geographic information as a set of continuous data in which the map features are not spatially discrete, i.e., between any two locations, there are no clear or well defined breaks between possible values of the map feature. Models, built from regularly or irregularly spaced sample points on the surface can represent surfaces.
- Slope map of the catchment area was prepared using the elevation information for the area from contour heights. Toposheets of the scale 1:50,000 were collected for the entire directly draining catchment area. These toposheets were then manually pasted together to form a seamless mosaic of the area and the directly drained catchment boundary for the proposed Bhaunrat Dam Project was marked on them.
- After marking the catchment area, all the contours on the topo-sheet were digitized. The output of the digitization procedure was the contours as well as points contour in the form of x, y & z points. (x, y location and their elevation). All this information was in real world coordinates (latitude, longitude and height in meters above sea level).
- A Digital Terrain Model (DTM) of the area was then prepared, which was used to derive a slope map. The slope was divided in classes of slope percentages.
- The slope of a watershed plays an important role in controlling the soil and water retention thereby affecting the land-use capability. The percentage of the slope in a watershed determines the soil erosion susceptibility and forms the basis for classifying different of the watershed into suitable capability classes for formulating suitable soil erosion conservation measures. Broadly, the following slope classes and ranges (**Table 10.9.**) as per norms of All India Soil & Land Use Survey were adopted for the present study.

Table 10.9: Slope Class

Slope Rank	Slope Range (Degrees)	Description
1.	0-20	Very Gentle Slope
2.	20-35	Gentle Slope
3.	35-50	Moderate Slope
4.	50-80	Steep Slop
5.	Above 80	Very Steep Slope

The Slope map of the free draining catchment is presented in **Fig.-10.7**.

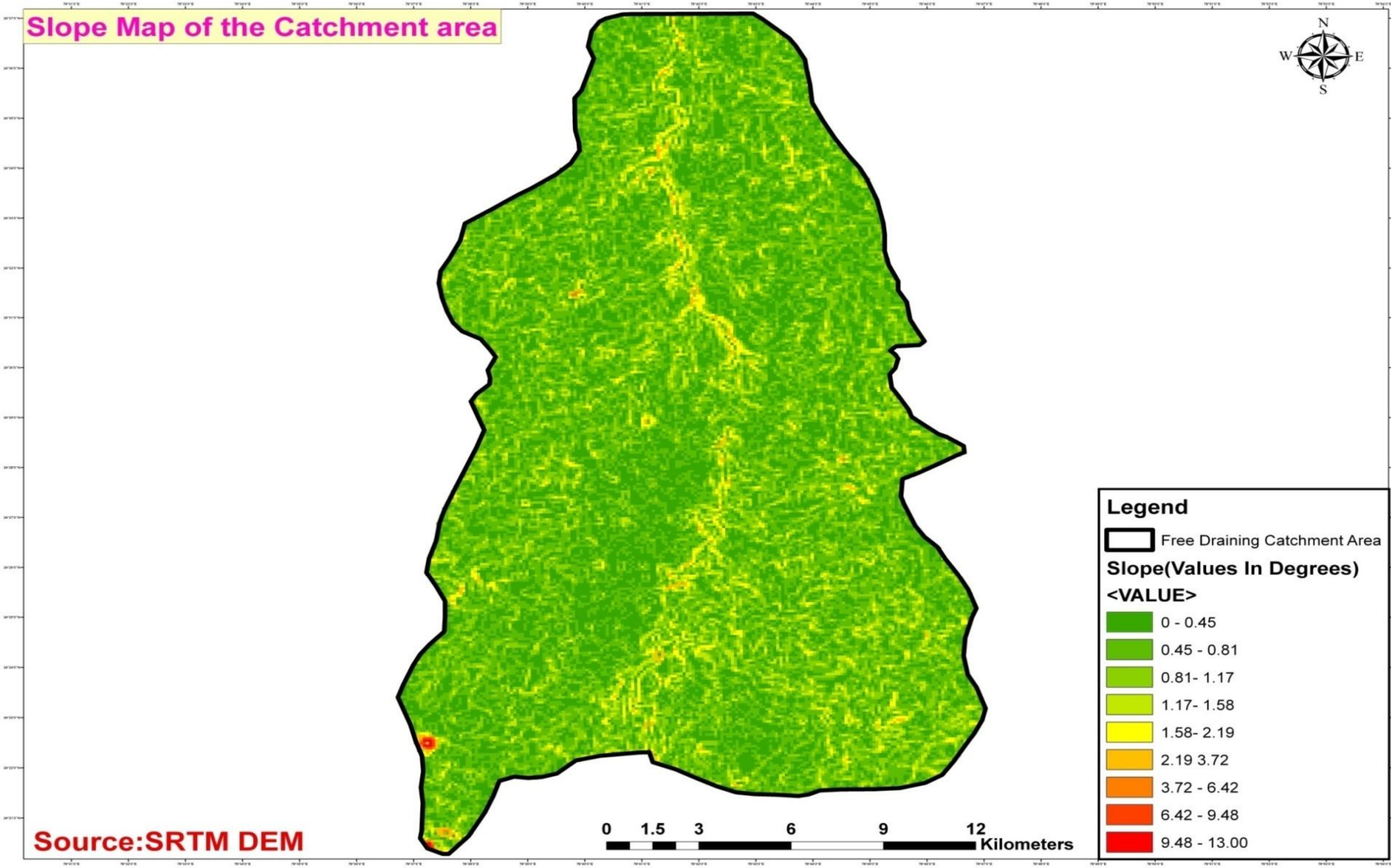

Figure 10.7: Slope map of the catchment area

10.10.9 Soil Loss Using Silt Yield Index (SYI) Method

- The Silt Yield Index Model (SYI), considering sedimentation as product of erosivity, erodibility and aerial was conceptualized in the All India Soil and Land Use Survey (AISLUS) as early as 1963 and has been in operational use since then to meet the requirements of prioritization of smaller hydrologic units within river valley project catchment areas.

- Methodology for the calculation of sediment yield index developed by All India Soil & Land Use Survey (Development of Agriculture, Govt. of India) was followed in this study.

(i) Erosion Intensity and Delivery Ratio

- Determination of erosion intensity unit is primarily based upon the integrated information on soil characters, physiography, slope, land-use/land-cover, lithology and structure. This is achieved through super-imposition of different thematic map overlays. Based upon the field data collected during the field survey and published data, weightage value and delivery ration were assigned to each erosion intensity unit. The composite map for delineating different erosion intensity units was prepared through superimposition of the maps showing soil types, slope and land-use/land-cover. This thematic mapping of erosion intensity for entire catchment was done using the overlay and union techniques. Based on ground truth verification conducted during fieldwork and published data, weightage and delivery ratio was assigned to each erosion intensity units. The composite erosion intensity map was then superimposed on the drainage map with sub-watershed boundaries to evolve CEIU for individual sub-watershed.

- Each element of erosion intensity unit is assigned a weightage value. The cumulative weightage values of the erosion intensity units represent approximately the relative comparative erosion intensity within the watersheds. A basic factor of K=10 was used in determining the cumulative weightage values. The value of 10 indicated an equilibrium condition between erosion and deposition. Any value of K (10+X) is suggestive of erosion intensity in an ascending order whereas the value of K (10-X) is suggestive of deposition intensity in descending order.

- The delivery ratios were calculated for each composite erosion intensity unit. The delivery ration suggests the percentage of eroded material that finally finds entry into the reservoir or river/stream. Total area of different erosion intensity classes (composite erosion intensity unit) in each watershed was then calculated.

- The delivery ratio is generally governed by the type of material, soil erosion, relief length ratio, cover conditions, distance from the nearest stream, etc. However, in the present study the delivery rations to the erosion intensity units were assigned upon their distance from the nearest stream (being the most important factor responsible for delivery of the sediments) according to the following scheme. The delivery ratio criteria adopted for the study is presented in **Table 10.10**.

Table 10.10: Delivery Ratio (DR) Criteria Adopted for the Project

Nearest Stream	Delivery Ratio (DR)
0-0.9 km	1.00
1.0-2.0 km	0.90
2.1-5.0 km	0.80
5.1-15.0 km	0.70
15.1-30.0 km	0.50

(ii) Sediment Yield Index & Prioritization of Sub-Watersheds

- The erosivity determinates are the climatic factors and soil and land attributes that have direct or reciprocal bearing on the units of the detached soil material. The relationship can be expressed as:

Soil erosivity = f (Climate, physiography, slope, soil parameters land use/land cover, soil management)

- The Silt Yield Index (SYI) is defined as the Yield per unit area and SYI value for hydrologic unit is obtained by taking the weightage arithmetic mean over the entire area of the hydrologic unit by using suitable empirical equation.

- Prioritization of Watersheds/Sub-watershed within the vast catchments is based on the SYI of the smaller units. Studying the frequency distribution of SYI values and locating the suitable breaking points arrive at the boundary values or range of SYI values for different priority categories. The watersheds/sub-watersheds are subsequently rated into various categories corresponding to their respective SYI values.

- The application of SYI model for prioritization of sub-watersheds in the catchment areas involves the evaluation of:
  - o Climatic factors comprising total precipitation, its frequency and intensity
  - o Geomorphic factors comprising land forms, physiography, slope and drainage characteristics
  - o Surface cover factors governing the flow hydraulics
  - o Management factors.
- The data on climatic factors can be obtained for different locations in the catchment area from the meteorological stations whereas the field investigations are required for estimating the other attributes.

- The various steps involved in the application of model are:

o Preparation of a framework of sub-watershed through systematic delineation

o Rapid reconnaissance surveys on 1:50,000 scale leading to the generation of a map indicating erosion-intensity mapping units.

o Assignment of weightage values to various mapping units based on relative silt-yield potential.

- o Computing Silt Yield Index for individual watersheds/sub watersheds.
- o Grading of watersheds/sub-watersheds into very high, high medium, low and very low priority categories.

- The area of each of the mapping units is computed and silt yield indices of individual sub-watersheds are calculated using the following equations:

Silt Yield Index

SYI = (Ai x Wi x Di) x 100/Aw ; where I = 1 to n

Where

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

The SYI values for classification of various categories of erosion intensity rates were taken for the present study as:

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

(Refer pp 27-28 of AISLUS Bulletin-99)

10.10.10 CATCHMENT AREA TREATMENT PLAN

It is known that there are mainly five categories of Land uses for which a proper treatment plan should be developed. First is the Agricultural Land as this activity can never be eliminated. It is also known that agriculture activities, if faulty, result in heavy loss of fertile soil. Second, being open forest land for obvious conservation reasons. Third is scrub or degraded land, which contributes heavily to the silt load and possibilities exist to bring this area under pastures and other plantation to meet the local demand of fuel and fodder and thus decreasing the biotic pressure on the forests and leading to environment friendly approach of sustainable development. The fourth and most important category is Barren land because with practically no vegetal cover, the area produces huge amount of silt load. The fifth is dense forest land where in at few places soil conservation measures are required. For treatment of catchment area, the areas that require treatment have been delineated from the Composite Erosion Intensity Unit Map. The sum of weightages was reclassified as per the **Table 10.11** below to further subdivide the area as per the erosion intensity classes. The Weightages for Landuse, Slope & Soil were summed to get the Erosion Intensity Classes.

Table 10.11: Erosion Intensity & Weightages

Erosion Intensity Class	Sum of weightages
Very severe (E5)	12 to 14
Severe (E3)	9 to 11
Moderate (E3)	6 to 8
Low (E2)	4 to 5
Negligible (E1)	0 to 3

Only those areas which fall under very severe and severe erosion intensity category would be taken up for conservation treatment measures. The Erosion Intensity map of the free draining catchment is presented in **Fig-10.8**.

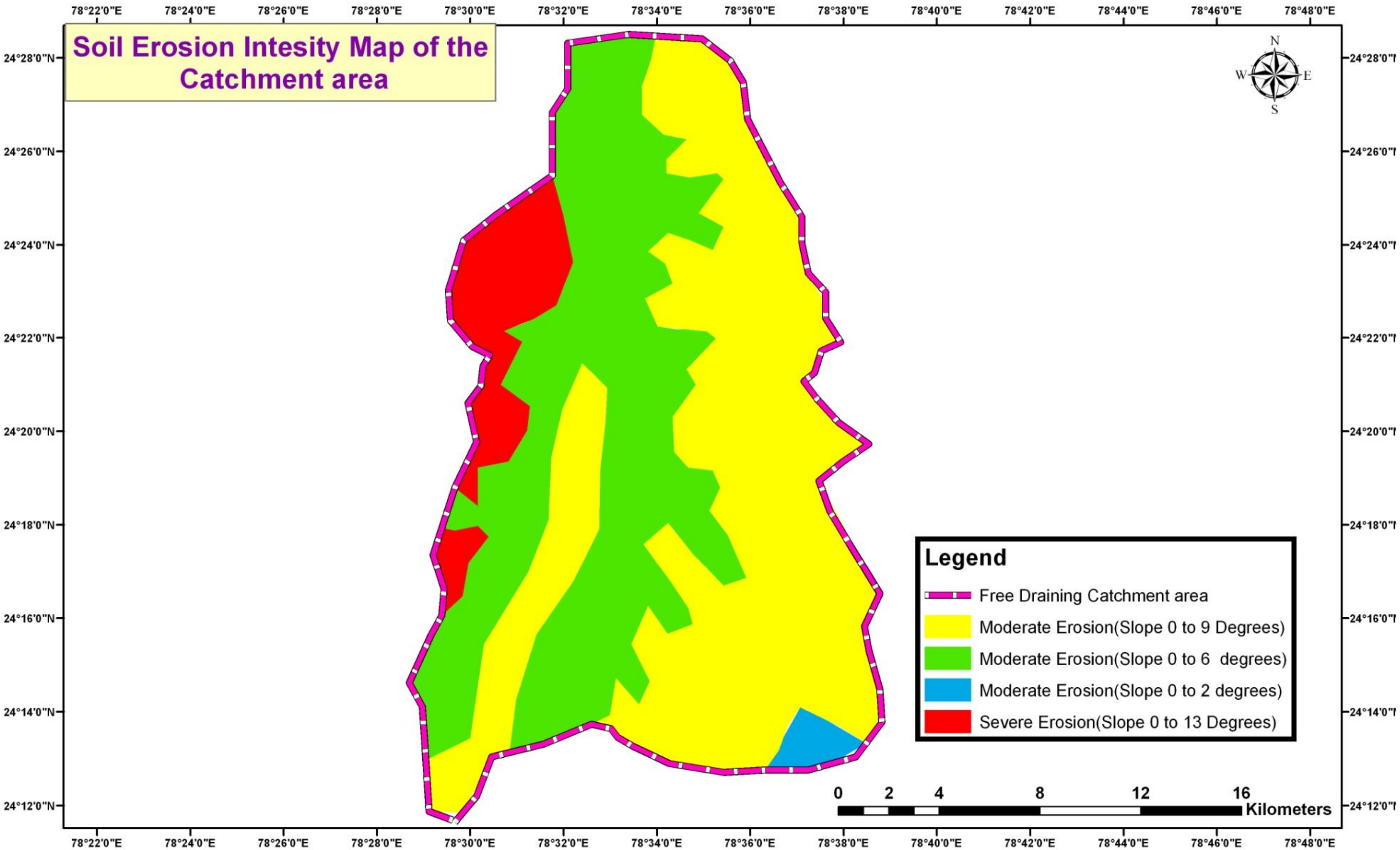

Figure 10.8: Soil Erosion Intensity Map of the Catchment Area

Considering the topographic factors, soil type, climate, land-use/land-cover in the catchment area following engineering and biological measures have been proposed to be undertaken with the aim to check the soil erosion, prevent/check siltation of reservoir and to maintain its storage capacity in the long run.

10.10.11 Erosion and Landuse

The erosion acts differently in different land-use types. It is important to understand the nature of erosion in a particular land-use class to further plan for treatment.

10.10.12 Agricultural Land

Around 294.11 Sq. Km area of the free-draining catchment constituting 87.69% of the total free drainage catchment comes under this category. Very few or no measures are taken to conserve soil and tendency exists to interrupt the natural drainage due to faulty agricultural practices. Runoff often exceeds the safe velocity on long slope lengths.

Agro-forestry practices should be introduced; Contour hedgerow technology of agricultural practice should be followed. Temporary and semi permanent soil conservation structures like brushing dams, wiring woven, gabion check dams etc. *be* done.

10.10.13 Open Scrub

Under the waste land category about 20.22 Sq. Km area constituting 6.03% of the free draining catchment is present. Waste land is characterized by highly degraded land surface and rock outcrops. Very little or no vegetation cover exists. Huge gullies, frequent land slips and high to extreme high erosion rates are other prominent features. Plantation is proposed for this land.

10.10.14 Vegetation

Around 13.67 Sq. Km area constituting 4.07% of the free draining catchment area is classified under this land-use category. Silvi-pasture plantation and natural rejuvenation can be done.

10.10.15 Activities to Be Undertaken

10.10.15.1 Engineering Measure

- **Forest Wood Check dams and Retaining Walls**
  Forest Wood check dams are useful in arresting further erosion of depressions, channels and gullies on the denuded landslides. In addition, retaining walls would be constructed to provide support at the base of threatened slopes.

- **Slope Modification by stepping or terracing**
  The slope stability increases considerably by grading it. The construction of steps or terraces to reduce the slope gradient is one of the measures.

- **Gully Control-Check Dams**
  Gullies are mainly formed on account of physiography, soil type and heavy biotic interference in an area. The scouring of streams at their peak flows and sediment-laden run-off cause gullies. The gullies would be required to be treated with engineering/mechanical as well as vegetative methods. Checkdams would be constructed in some of the areas to promote growth of vegetation that will consequently lead to the stabilization of slopes/area and prevention of further deepening of gullies and erosion. Different types of check dams would be required for different conditions comprising of different materials depending upon the site

conditions and the easy availability of material (stones) at local level and transport accessibility. The types of check dams recommended for treatment are:

- **Stream Bank Protection**
  Stream bank erosion is caused by a variety of reasons such as destruction of vegetative cover, mass movement on unstable bank slopes, undermining of top portion of lower bank by turbulent flow and sliding of slopes when saturated with water. The stream bank protection would include wire crated and vegetative spurs.

10.10.15.2 Biological Measures

- **Restoration of Degraded Areas**
  In critically degraded areas, plantation of locally useful diverse and indigenous plant species such as timber plantation species, fodder species, considers, fuel wood species, grasses, shrubs, legumes, medicinal and aromatic plants would be undertaken. For raising plantation, nurseries would be developed.

- **Afforestation**
  This will include rising of multi-tier mixed vegetation of suitable local species in the steep and sensitive catchment areas of rivers/streams with the objective of keeping such areas under permanent vegetative cover. Furthermore, degraded areas would also be brought under some vegetation cover by way of timber plantation.

- **Plantation of horticulture crops**
  Under this treatment plan, suitable horticultural crop species like, shall be distributed to families residing in villages within the catchment with the objective of supplementing their income.

- **Pasture Development**
  As there are degraded patches of pasture in the area, this measure will be adopted to encourage development of new and healthy pasture areas for the use of cattle. Under this treatment, suitable species of grasses and tree fodder, and leguminous plant species be planted in the land area earmarked for the purpose.

  Effective fencing would also be provided for protection of saplings. Before any new area is taken up, eradication of weeds and unpalatable grass species is equally important. It is recommended that some parts of the pasture should be closed for seeding purpose only.

10.10.15.3 Cost for Catchment Area Treatment Plan

A financial provision upto two percent of the project cost has been kept for catchment area treatment which will be executed through forest department.