GOVERNMENT OF MADHYA PRADESH

NARMADA VALLEY DEVELOPMENT AUTHORITY

CHIEF ENGINEER

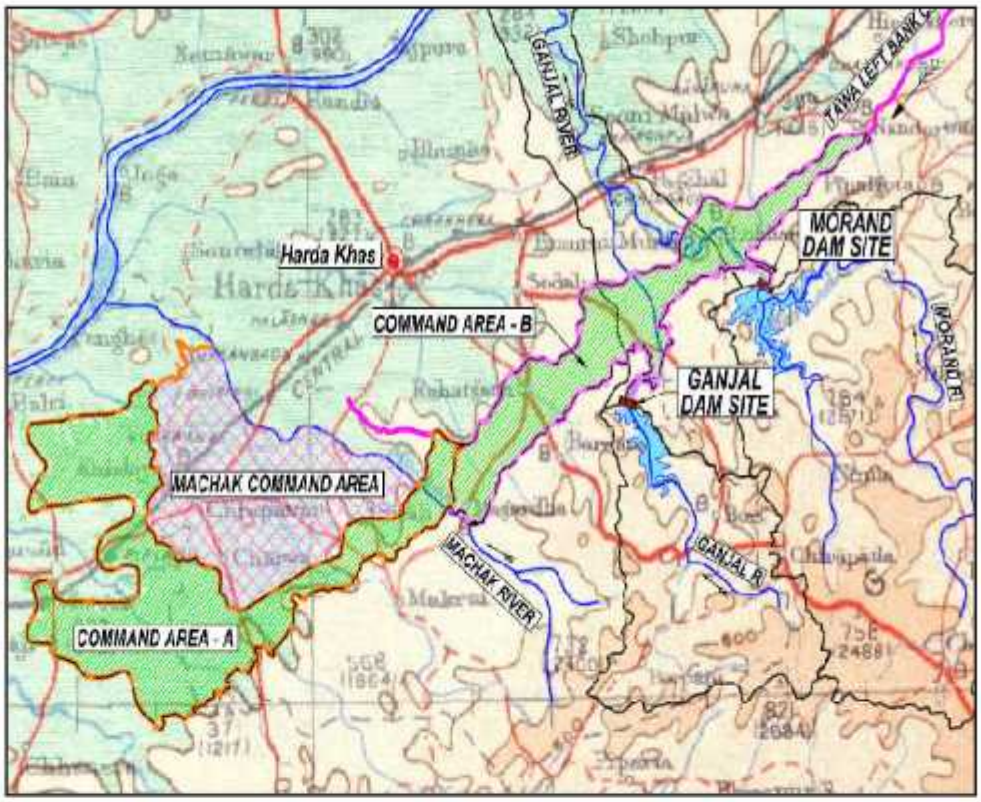
Indira Sagar Project (Canals) Sanawad District

West Nimar, Madhya Pradesh

CATCHMENT AREA TREATMENT REPORT

ON

MORAND AND GANJAL COMPLEX PROJECT



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GOVERNMENT OF MADHYA PRADESH

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Morand and Ganjal Complex Project

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Catchment Area Treatment Plan for Morand and Ganjal Complex Project

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES & ANNEXURE

1. INTRODUCTION

1.1 General

Enhanced sediment yield from the catchment area may pose threat to the proposed Morand and Ganjal Dam reservoirs. An inventory of soil and land resources in the catchment area is thus very important to identify the problematic area for sediment management purposes. Over exploitation of natural resources by deforestation, mining, over grazing is responsible for degradation of lands which not only destabilize the land and the eco-system but also catalyze soil detachment. It is, therefore, necessary to prevent land degradation through planned soil conservation practices on priority basis in each of the watersheds that are highly problematic and yielding higher sediments, ultimately to minimize sediment flow to the reservoir.

Formulation of soil conservation plans on scientific lines is possible only when basic data on soil and land are collected in a systematic way. Collection of detailed information on soil and land in the vast areas of catchments of River Valley Projects (RVPs) not only involves very high financial resources but also a huge contingent of technical and non-technical personnel. Keeping in view these limitations, a pragmatic method of identifying and treating such watersheds, yielding relatively larger sediments is considered to be more rational.

The ***All India Soil and Land Use Survey*** (AISLUS) has developed a methodology for demarcation of priority watersheds wherein deposits of larger sediments are assessed. The relevant parameters that influence soil detachment and its transportation to the reservoirs have been detailed and the methodology discussed in the report. Subsequent to the identification of the priority watersheds, detailed soil surveys and soil conservation programmes can be carried out on them. As a part of the programme, rapid reconnaissance soil survey is carried out in sub watersheds of Morand and Ganjal project by National Bureau of Soil Survey & Land Use Planning Nagpur, is used in prioritizing the micro catchment area.

The Proposed Morand and Ganjal complex is an irrigation project with an irrigated command area of 52,205 Ha in Seoni Malwa of Hoshangabad district and Timrani, Harda and Khirkiyan taluk of Harda district and Harsud taluk of Khandwa district of Madhya Pradesh. The geographic location of the project is given in **Figure 1.1**.

The project components are,

(i) A dam across Ganjal River a tributary of Narmada River of having total Catchment as 413.49 Sq.Km

(ii) A dam across Morand River a tributary of Ganjal River of having total Catchment of 1031.99 Sq.Km.

(iii) Morand Right Bank Canal (MRBC).

(iv) Morand Left Bank Canal (MLBC).

(v) Ganjal Left Bank Canal (GLBC).

(vi) Combined Canal.

(vii) Development of command area of 16875.00 Ha (called the command area B) on the banks of Morand and Ganjal rivers up to Tawa canal and an area of 35330.00 Ha between rivers Machak and Kalamachak.

Morand reservoir submerges an area of 2200.24 Ha, which includes 6 revenue villages. Ganjal reservoir submerges an area of 833.24 Ha, which includes 2 forest villages. Index Map Showing Project Location and its components is enclosed as **Annexure 1.**

The Catchment Area Treatment (CAT) Plan for the free draining catchment area has been prepared for areas with high erosion intensity. The CAT plan targets towards overall improvement in the environmental conditions of the region. The catchment area treatment involves

- Understanding of the erosion characteristics of the land and its terrain and,
- Suggesting remedial measures to reduce the erosion rate.

In the present study "**Silt Yield Index' (SYI)**, method has been used to calculate the sediment yield per unit area. In this method, the terrain is subdivided into various watersheds and the erodibility is determined on relative basis. SYI provides a comparative erodibility criteria of catchment (low, moderate, high, etc.) and do 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.

1.2 CATCHMENT CHARACTERISTICS

1.2.1 Location & Extent

Ganjal River is one of the tributaries of Narmada in the Northern slope of Satpura hill range. The river lies between East longitudes 77^0 28' 55.51" to 77^0 19' 50.58" and North latitudes 22^0 19' 25" to 22^0 13' 47.27" and is covered by 1:50000 Toposheets 55 F/7, 55 F/11, 55 F/8, 55 F/12, 55 G/9 and the proposed command areas on the banks of the rivers Morand and Ganjal (called Command Area B) is covered by 1:50000 Toposheets 55 F/7, 55 F/8 and 55 F/11 and the command area between the rivers Machak and Kala machak (called the

Command Area A) is covered by the Toposheets 55 F/4, 55 B/15, 55 B/16 and 55 B/12. Mossaic of Toposheets is given in **Figure 1.2.**

1.2.2 Shape and Size

Ganjal river catchment is one of the major sub-basins of the Narmada River in its 'Middle Zone'. The Ganjal River joined by its major tributary Morand drains an area of 1930 Sq. Km of Hoshangabad district.

Originating near village Dedamada in Hoshangabad district at an elevation of 752 metres the Ganjal River flows down the northern slope of Satpura range. All along its length the river flows in Hoshangabad district in Northwestern direction except for a short distance downstream of the proposed Ganjal dam site where it flows in North Easterly to North direction. The Ganjal Dam is proposed at about 62 Km from the source near the village Jawardha. The river up to dam site flows in hilly region and thereafter enters into plains.

From the dam site, after flowing for 64.37 Km, it joins the river Narmada at 775.70 Km length at an elevation of 264.

Morand River is a tributary of Ganjal River and originates near the village Bori in Hoshangabad district at an elevation of about 632.46 m. The river flows through out in Hoshangabad district in the northern direction in the initial reach and then in North - West direction till it meets Ganjal River. The Morand dam is proposed at about 107 Km from the source, near village Morghat just downstream of the confluence of Bhaji nala. Up to Morand dam site, the river flows in the hilly region, thereafter hills recede and the river flows in the plain.

1.2.3 Drainage

The general drainage pattern of the area is sub parallel, radial at places and dendritic to sub-dendritic in alluvial plain area.

1.2.4 Physiography & Geology

The sub catchments of Morand and Ganjal being in the Northern slope of Satpura hills is rugged and covered with rain forest with Predominant Teak. Beyond the proposed dam site it is undulating to plain in the downstream portion up to the confluence with Narmada River.

(a) Ganjal Dam Site

The catchment area of Ganjal dam is 413.49 Sq. Km. At the proposed dam site, the river flows through steep banks. The slope of the left bank is nearly vertical where as the right

bank has 1:5 slope. The depth of gorge is of the order of 24.5 to 22 m and width 330 m at the top and 150 m at the bottom.

The terrain condition is gently undulating with steep slopes. Hard and massive amygdaloidal basalt of Deccan trap are found at very shallow depths. Basalt, which is one of the most prevalent rock types on earth, is of volcanic origin. Relatively rich in iron and magnesium, the appearance and structure of basalts may vary significantly, though they are typically dark grey or black in color.

(b) **Morand Dam Site**

The catchment area of Morand dam is 1031.99 Sq. Km. At the proposed dam site, the river flows through steep banks. The slopes of both the banks are nearly vertical. The depth of Gorge at the site is of the order of 60.89 to 45.32 m and width 600 m at the top and 30 m at the bottom.

Exposed rock is available in the riverbed for the complete width. The rock at the site is massive hard argillaceous sand stones and carbonaceous shale's belonging to the upper Gondwana group. Beyond the left abutment hill, these are overlain by Deccan trap basalt flows.

1.2.5 Climate

The tropic of cancer crosses the Narmada basin in the upper plains area and the sub basin lies below this line. The climate of the sub basin is humid and tropical although at places extremes of heat (temperature up to 45^0C) and cold (temperature upto 3^0C) are often encountered. In the year, four distinct seasons occur in the sub basin. They are.

(i) Winter ranging from November to February.
(ii) Summer ranging from March to mid June.
(iii) Southwest monsoon ranging from mid - June to mid - September.
(iv) Post monsoon ranging from mid September to October.

1.2.5.1 Meteorological Data

Annual Rainfall data is available from the year 1965-66 to 2008-09 for the 5 rain gauge stations influencing the Morand and Ganjal catchment area. The data available is sparse with incomplete and missing data. The missing data is supplemented by using Annual Rainfall data of surrounding stations and drawing isohyets for each year and interpolating the missing data of the stations.

The Average Annual Rainfall and the Rainfall of dependabilities of the 5 rain gauging stations of interest are given below in **Table 1.1**.

Table 1.1: Average Annual Rainfall and the Dependabilities

Sl. No.	Stations	Average Annual Rainfall (mm)	Rainfall of Different Dependabilities (mm)		
			50%	75%	90%
1.	Chicholi	1067.50	1051.55	814.02	682.75
2.	Shahpur	1368.88	1294.92	1070.14	841.84
3.	Timarni (Dhekna)	1034.13	970.96	893.99	727.11
4.	Makrai	872.97	846.00	753.75	727.11
5.	Seoni (Malwa)	1131.35	1071.80	976.57	821.30
	Catchments				
1.	Chhidgaon	1067.51	1024.03	916.58	737.76
2.	Morand Dam	1084.56	916.58	912.37	731.35
3.	Ganjal	1034.42	737.76	901.16	741.18

The Average Annual Rainfall on the catchment varies from 1034.42 mm to 1084.56 mm and the variation is small. The climatic classification of Madhya Pradesh and Climatological Data of Hoshangabad IMD station is shown in **Figure 1.3 & 1.4 respectively.**

1.2.6 Water Resources

The Ministry of water resources, central ground water board has studied the ground water conditions in both Hoshangabad and Harda districts in which major portion of the command lies. Both the districts are drained by Narmada River and its tributaries. The Northern parts of both the districts are irrigated by Tawa Left Bank Canal. There are no minor irrigation tanks worth mentioning in the command areas proposed for Morand and Ganjal Complex.

The area has rich fertile soil especially in the lower alluvial area.

1.2.7 Present Land Use and Agriculture

In the broad way the area can be divided into two regions viz. Hilly region and plain.

The hilly region is characterized by hilly topography, poor soils, meagre agricultural resources and age old agricultural practice. This area is dominated mainly by tribes. The most important crops are Kodo, Kutki, Jowar, Bajra, Sawan and maize.

The plain with level stretches of land and fine black soils has large percentage of cultivated land, and large number of settlements and towns. Wheat, cotton, gram, soyabean, sugarcane are the main agricultural products of such area.

1.2.8 Soils

The soils in the sub basin have been classified broadly into the following groups:

(a) Medium black soils
(b) Shallow black soils

a) **Medium Black Soils**

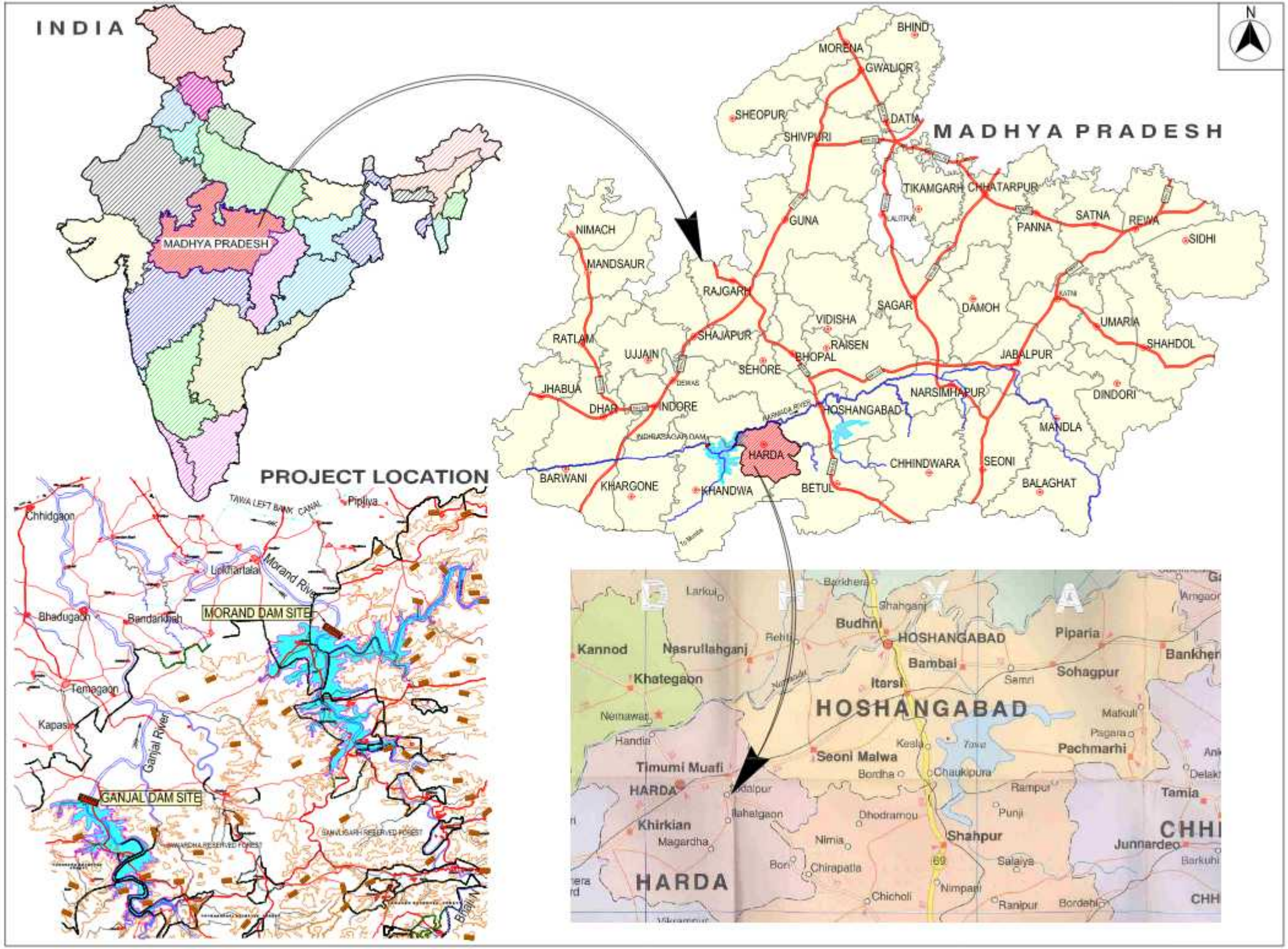
These soils range in texture from clay to sandy clay loam with clay contents varying from 31 to 50 percent. Most of the soils have stable aggregates and good structure, viz. granular, angular blocky and sub-angular [blocky].

The medium black soils crack extensively upon drying and are self-mulching. They are easily manageable and the yields are high.

b) **Shallow Black Soils**

They are located in areas of undulating topography. The texture of the soils ranges from loam to clay loam and the clay content generally varies from 15 to 30 percent. The structure of these soils is generally weak to well-developed, coarse to fine sub-angular and angular blocky. However, granular structure with stable aggregates also occurs at certain places.

Water intake and infiltration rates of the soils vary from area to area, as the texture is variable. The pH of the shallow black soils ranges between 7.0 and 8.0. The electrical conductivity is less than 1.0 mmhos/cm in most of the areas and organic carbon ranges between 0.1 and 0.4 percent. These soils are deficient in nitrogen and phosphorous and are medium to high in potassium. Good yield responses result forms the application of these nutrients.


INDIA
MADHYA PRADESH
N
MADHYA PRADESH
BHIND
MORENA
GWALIOR
SHEOPUR
DATIA
SHIVPURI
TIKAMGARH
CHHATARPUR
GUNA
LALITPUR
PANNA
SATNA
REWA
SIDHI
NIMACH
MANDSAUR
RAJGARH
SAGAR
DAMOH
VIDISHA
UMARIA
RATLAM
SHAJAPUR
RAISEN
SHAHDOL
UJJAIN
BHOPAL
JABALPUR
SEHORE
JHABUA
NARSIMHAPUR
DINDORI
DHAR
INDORE
HOSHANGABAD
MANDLA
HARDA
CHHINDWARA
SEONI
BARWANI
KHARGONE
KHANDWA
BETUL
BALAGHAT
PROJECT LOCATION
Chhidgaon
Pipliya
TAWA LEFT BANK CANAL
Lokharlala
Morand River
Bhadugaon
Bandarkhah
MORAND DAM SITE
Temagaon
Kapasi
Ganjal River
GANJAL DAM SITE
Bhajan
Larkui
Barkhera
Shahganj
Budhni
HOSHANGABAD
Piparia
Kannod
Nasrullahganj
Bambai
Sohagpur
Khategaon
Itarsi
Samri
HOSHANGABAD
Nemawar
Matkuli
Handia
Pagara
Seoni Malwa
Pachmarhi
Timumi Muafi
Bordha
Chaukipura
HARDA
Rampur
Tamia
Khirkian
Dhodramou
Punji
Magardha
Nimia
Shahpur
Junnardeo
Bori
Chirapatla
Salaiya
HARDA
Chicholi
Nimpani
Ranipur
Bordehi

LEGEND

1	COMMAND AREA	
2	EXISTING CANAL ALIGNMENT	
3	SUBMERGENCE AREA	
4	CATCHMENT BOUNDARY	
5	PROPOSED CANAL	

HOSHANGABAD
ITARSI
NARMADA RIVER
TAWA LEFT BANK CANAL
SEONI MALWA
HANDIA
NARMADA RIVER
GANJAL RIVER
CENTRAL RAILWAY
MORAND R
MORAND RBC
MORAND DAM SITE
TIMURNI
HARDA KHAS
COMMAND AREA
MORAND LBC
TAWA LEFT BANK CANAL
GANJAL LBC
GANJAL DAM SITE
DHANWARA
INDIRASAGAR RESERVOIR
ROLGAON
COMBINED CANAL
MACHAK RIVER
HARSUD
COMMAND AREA
SANKUGARH RESERVED FOREST
GORAKHAL RESERVED FOREST
SYAHI PROTECTED FOREST
JARKAHU RESERVED FOREST
KHATEGAON
NASRULLAHGANJ
SEHORE
RAISEN
KANNOD
DEWAS

N

CLIENT	NARMADA VALLEY DEVELOPMENT AUTHORITY (NVDA) BHOPAL, M.P
PROJECT	MORAND & GANJAL COMPLEX PROJECT
TITLE	INDEX MAP
CONSULTANT	SECON PRIVATE LIMITED BANGALORE - 66

SCALE	DRAWING NO.	REV.
1:2,50,000	SECON/NVDA/MAG/IM	00

FIGURE 1.2 : MOSAIC OF TOPOSHEETS COVERING MORAND AND GANJAL SUB BASIN & COMMAND AREA

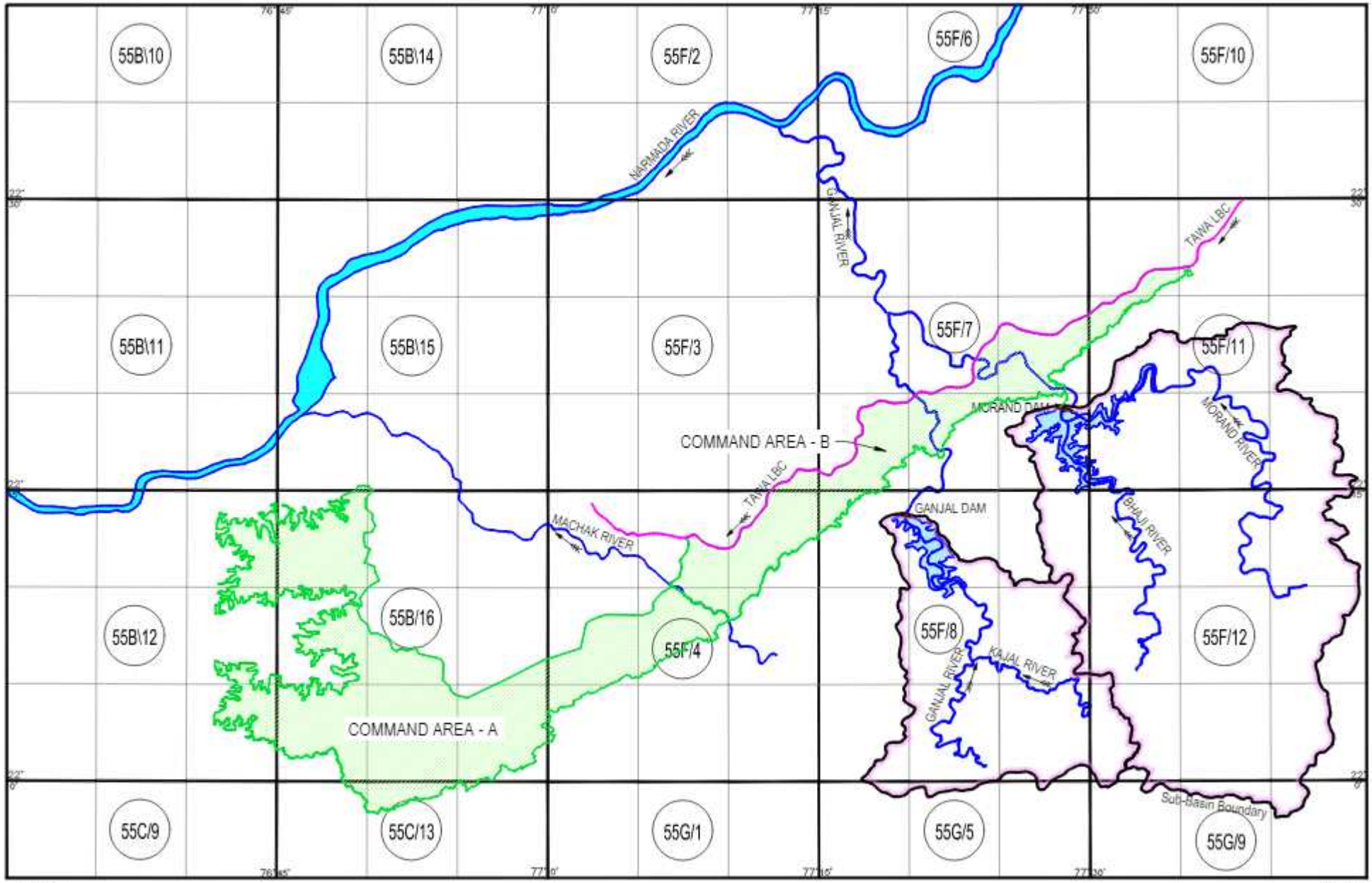


FIGURE 1.3: CLIMATIC CLASSIFICATION OF MADHYA PRADESH

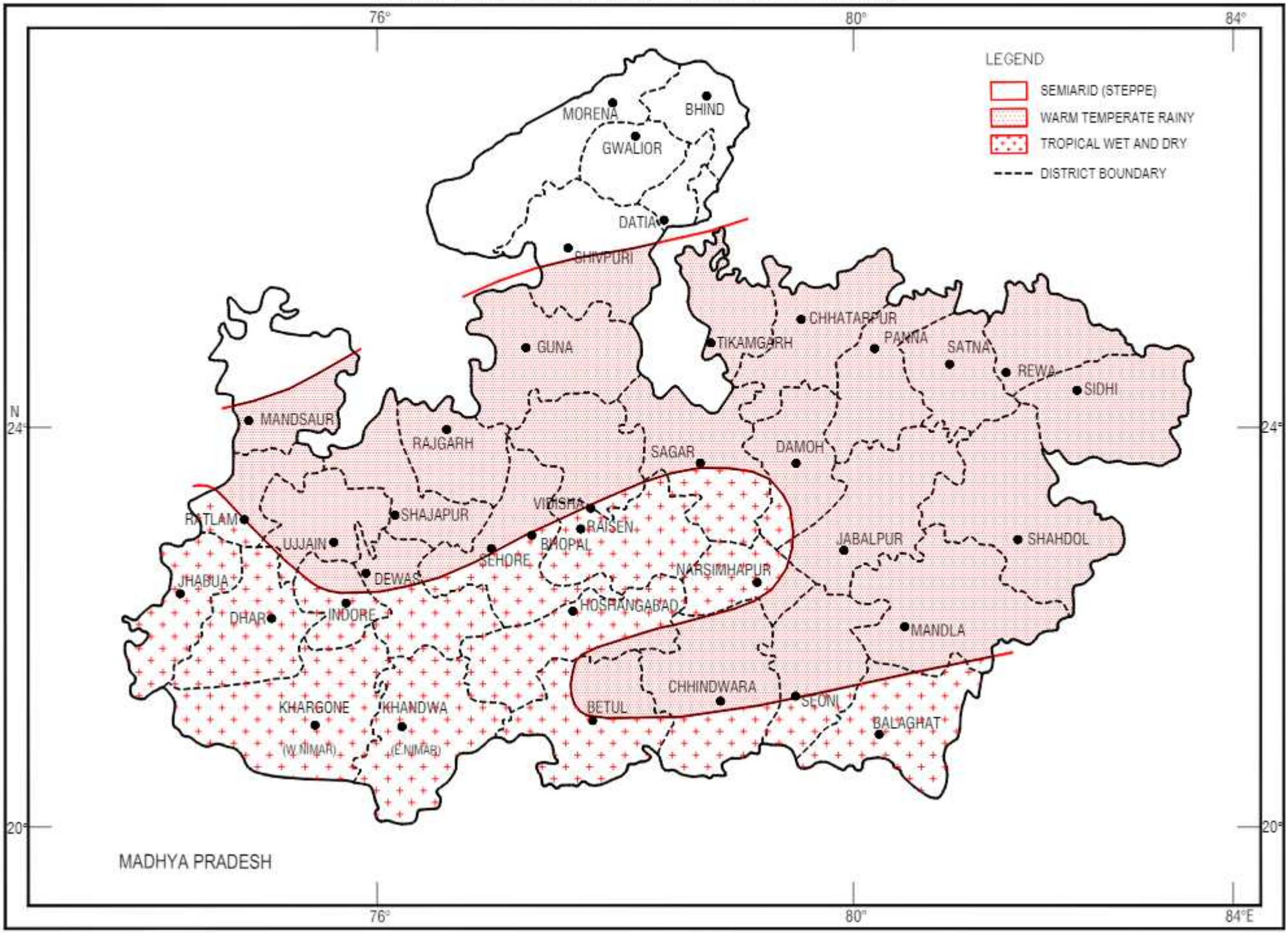
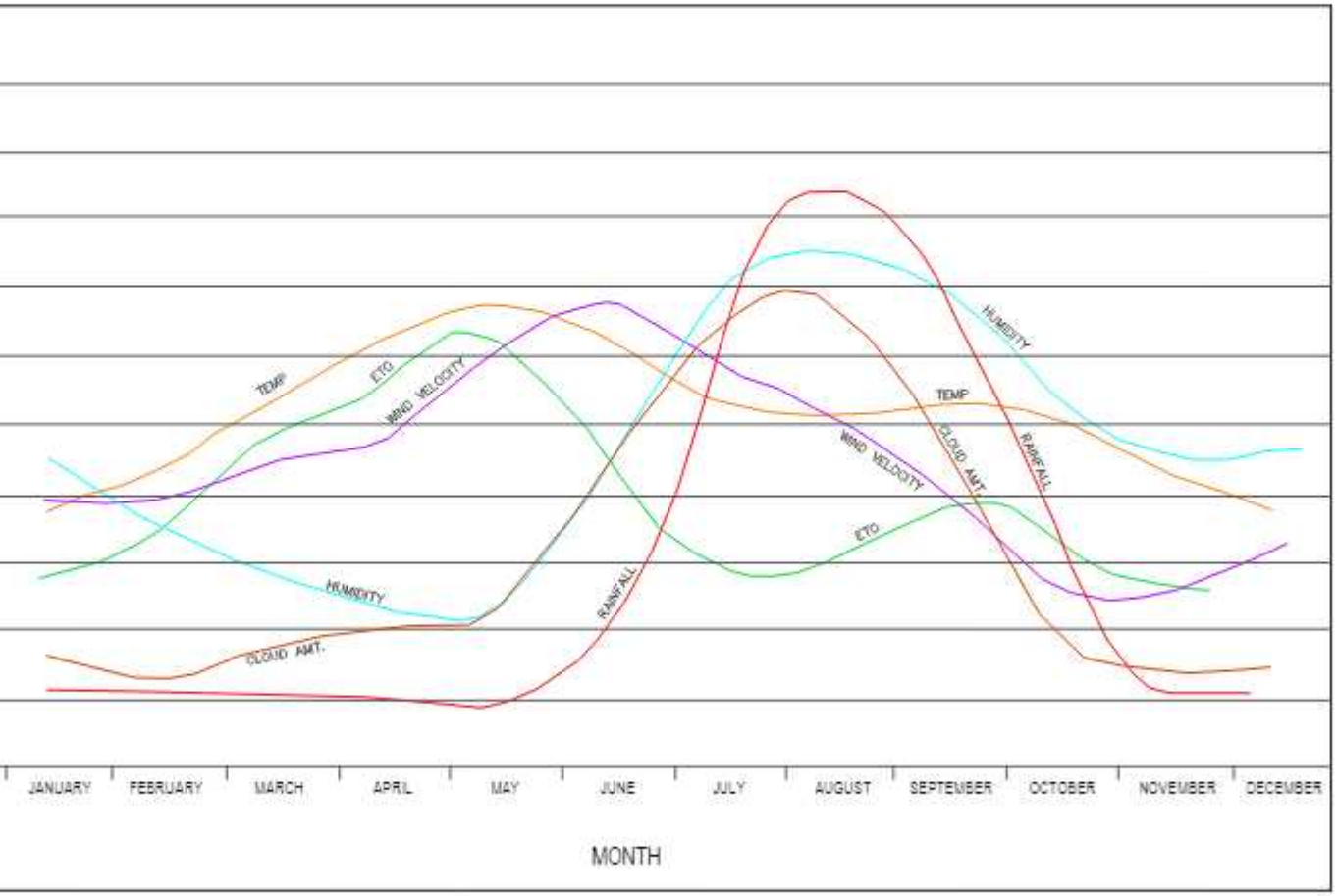


FIGURE 1.4 CLIMATOLOGICAL DATA - HOSHANGABAD

TEMP °C	HUMIDITY %	WIND VELOCITY m/s	CLOUD m/s	RAINFALL mm	ETO mm
45.00	90.00	9.00	9.00	450.00	450.00
40.00	80.00	8.00	8.00	400.00	400.00
35.00	70.00	7.00	7.00	350.00	350.00
30.00	60.00	6.00	6.00	300.00	300.00
25.00	50.00	5.00	5.00	250.00	250.00
20.00	40.00	4.00	4.00	200.00	200.00
15.00	30.00	3.00	3.00	150.00	150.00
10.00	20.00	2.00	2.00	100.00	100.00
5.00	10.00	1.00	1.00	50.00	50.00
0.00	0.00	0.00	0.00	0.00	0.00



2. APPROACH FOR THE STUDY & METHODOLOGY

A detailed database on natural resources, terrain conditions, soil type of the catchment area, socio-economic status, 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 Catchment Area Treatment (CAT) plan.

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

- Catchment Area Map.
- Slope Map
- Soil Map
- Land use Classification Map
- Current Management Practices

2.1 Data Available and Preparation

The data available from various sources has been collected. The ground maps, contour information, etc. are digitized and registered as per the requirement. Data is prepared depending on the level of accuracy required and any corrections required are made. All the layers are 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 firmed up to match the formats of inputs in the program. The grid size to be used was also decided to match the level of accuracy required, the data availability and the software and time limitations. Ground truthing and data collection was also included in the procedure.

Remote Sensing and Geographic Information System (**GIS**) has been used to store, analyze and display various spatial data. Remote Sensing has proved to be an extremely valuable tool in resources mapping, resources targeting, resources management, environmental monitoring, weather forecasting and disaster location and monitoring,. The most important application include geological, geomorphological, mineral, groundwater, snow melt runoff, soil, land use/land cover, land degradation mapping and monitoring, forest mapping, management of water and agriculture resources. The availability of multitemporal remote sensing data enables earth resource scientists to monitor, at periodic intervals the location of zones affected by disaster such as floods, drought, cyclones, landslides, forest fires, pests and diseases of crops, and environmental degradations due to soil erosion, shoreline erosion, deforestation, shifting cultivation, soil salinity / alkanity, desertification and pollution.

For the present study, the latest IRS P6 LISS IV (RESOURCESAT-1) Satellite Images were procured from NRSC (National Remote Sensing Center) Hyderabad and processed in advanced Image Processing tools such as Leica Photogrammetry Suite, PCI Geomatica, ArcGIS etc. is used for interpretation & classification.

2.1.1 Land Use and Land Cover

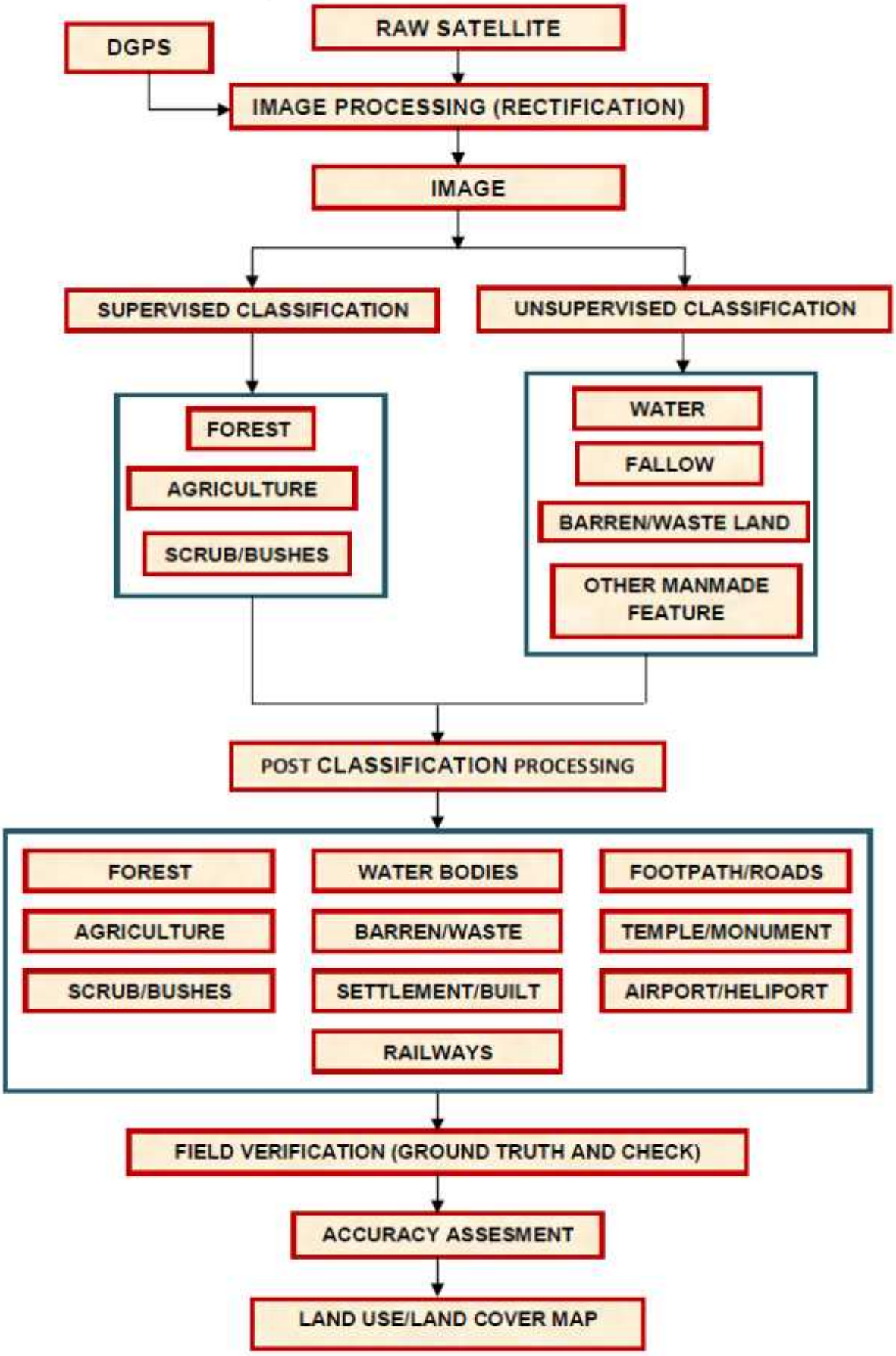
Accurate land use and land cover identification is the key to most of the planning processes. The land use pattern has been studied through satellite imagery data. Digital IRC-1C/1D and Panchromatic remote sensing satellite data was procured from National Remote Sensing Agency (NRSA), Hyderabad. The data was processed through Leica Photogrammetry Suite, PCI Geomatica, ArcGIS and other software packages. Ground truth studies were conducted in the area to validate various spectral signatures in the satellite images and correlate them with different land use domains. The FCC and classified imagery of the area are given below (refer **Figures 2.1 to 2.4**).

The IRS P6 LISS IV Satellite Image has a pixel size of 5.8 meters with spectral bands between 0.52 - 0.59, 0.62 - 0.68 and 0.77 - 0.86 microns. Based on the spectral signature of each feature, the land use pattern was extracted.

Below flow chart shows the steps involved in the extraction of Land Use information by the method of Spectral Signature Analysis.

The extracted Land use Land Cover data was analyzed in GIS Environment to calculate the area of each land cover type. Based on the analysis of Spectral Signature of IRS P6 LISS IV, the statistical values of individual features are tabulated **(Table 2.1)**.

Flow Chart of Image Classification for Land Information Extraction



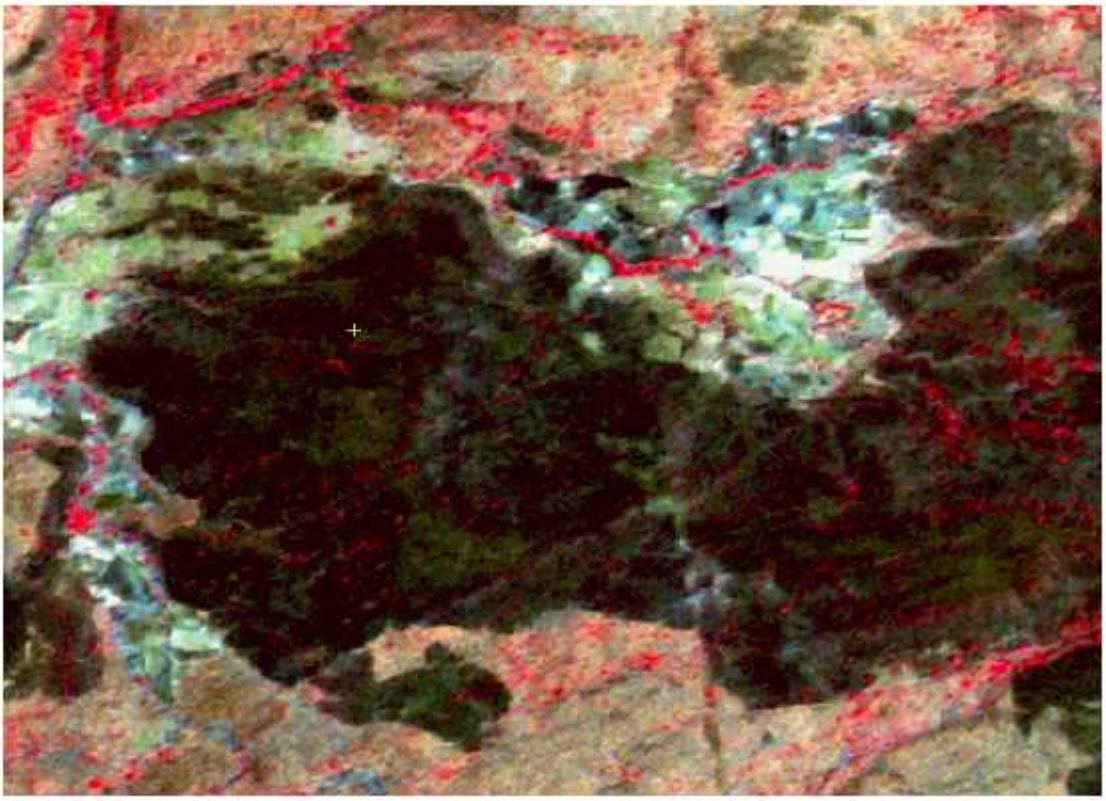


Figure 2.1: IRS P6 LISS IV Satellite Image used for the Analysis

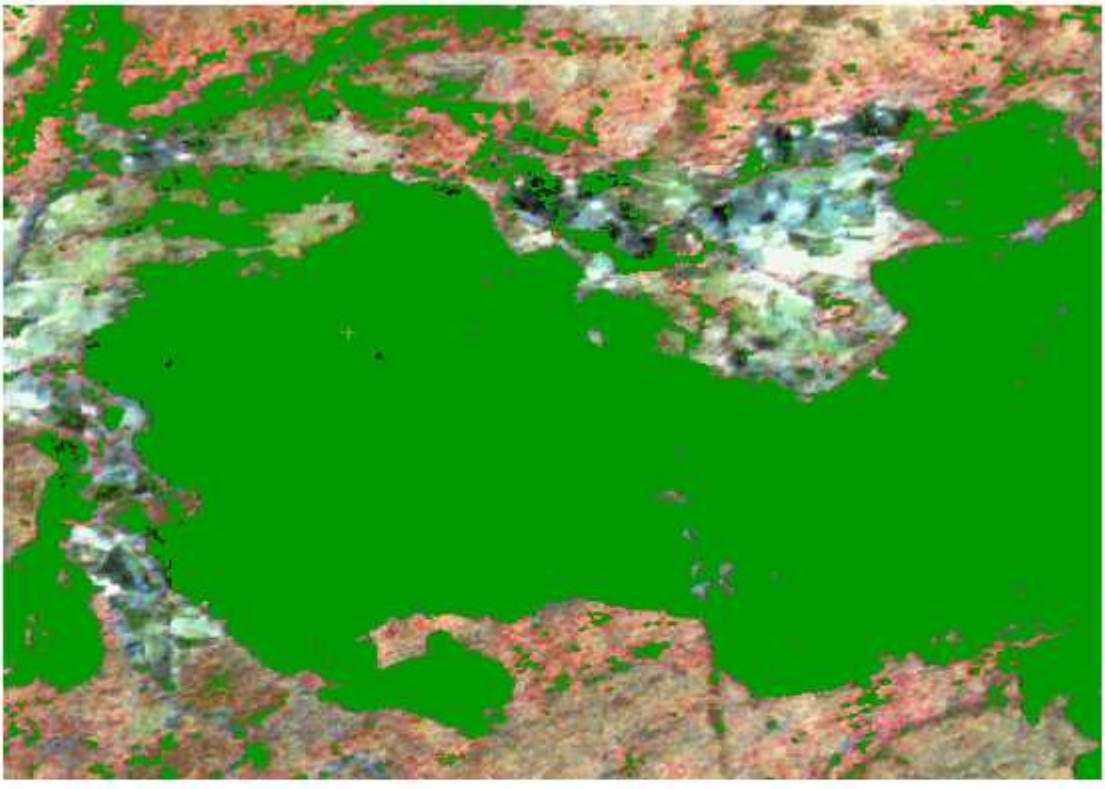


Figure 2.2: Extracted forest cover from IRS P6 LISS IV Satellite Image by the method of Spectral Reflectance Analysis

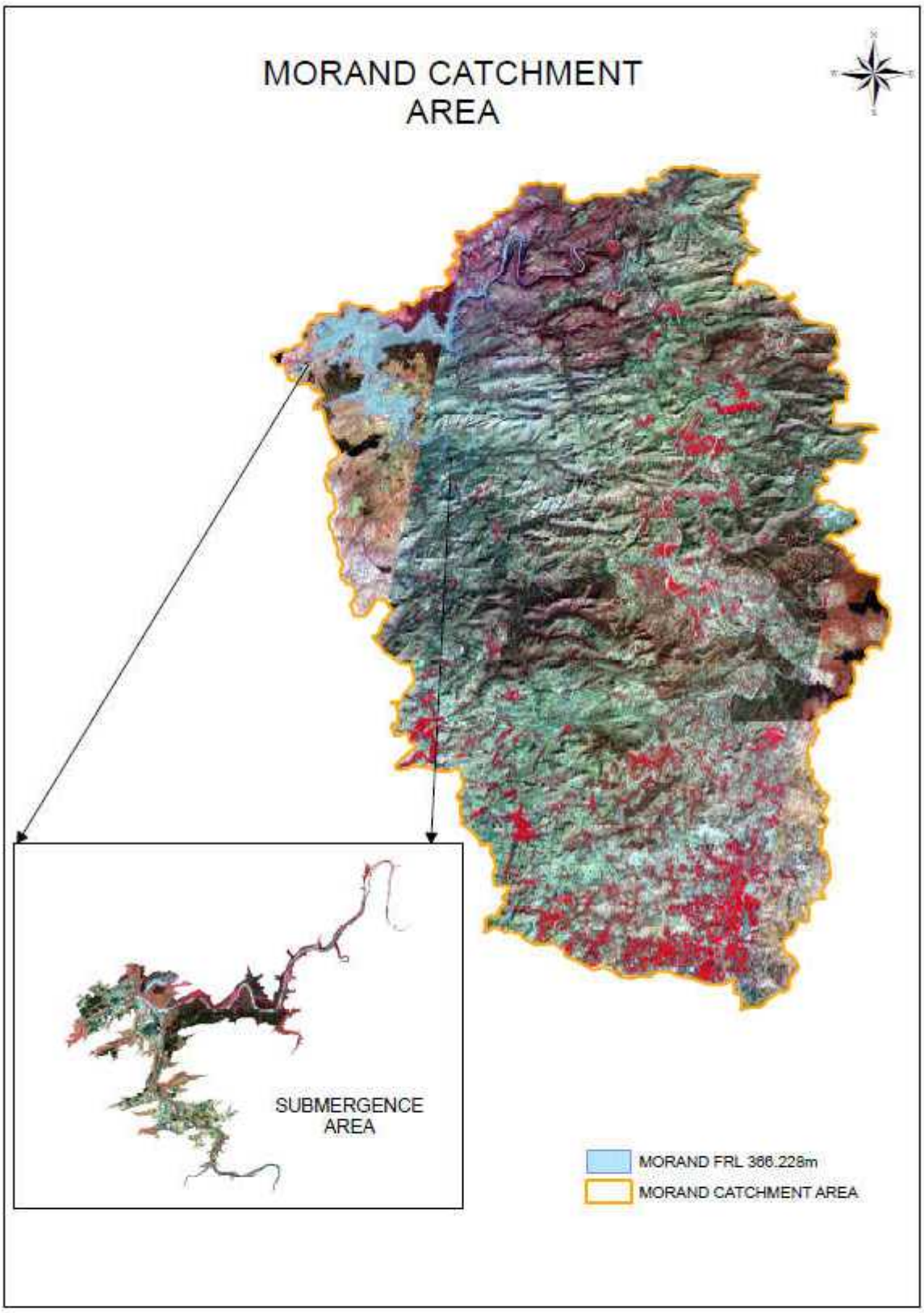


Figure 2.3(a): False Color Composite (FCC) IRS-P6 LISS IV Image for Morand Area

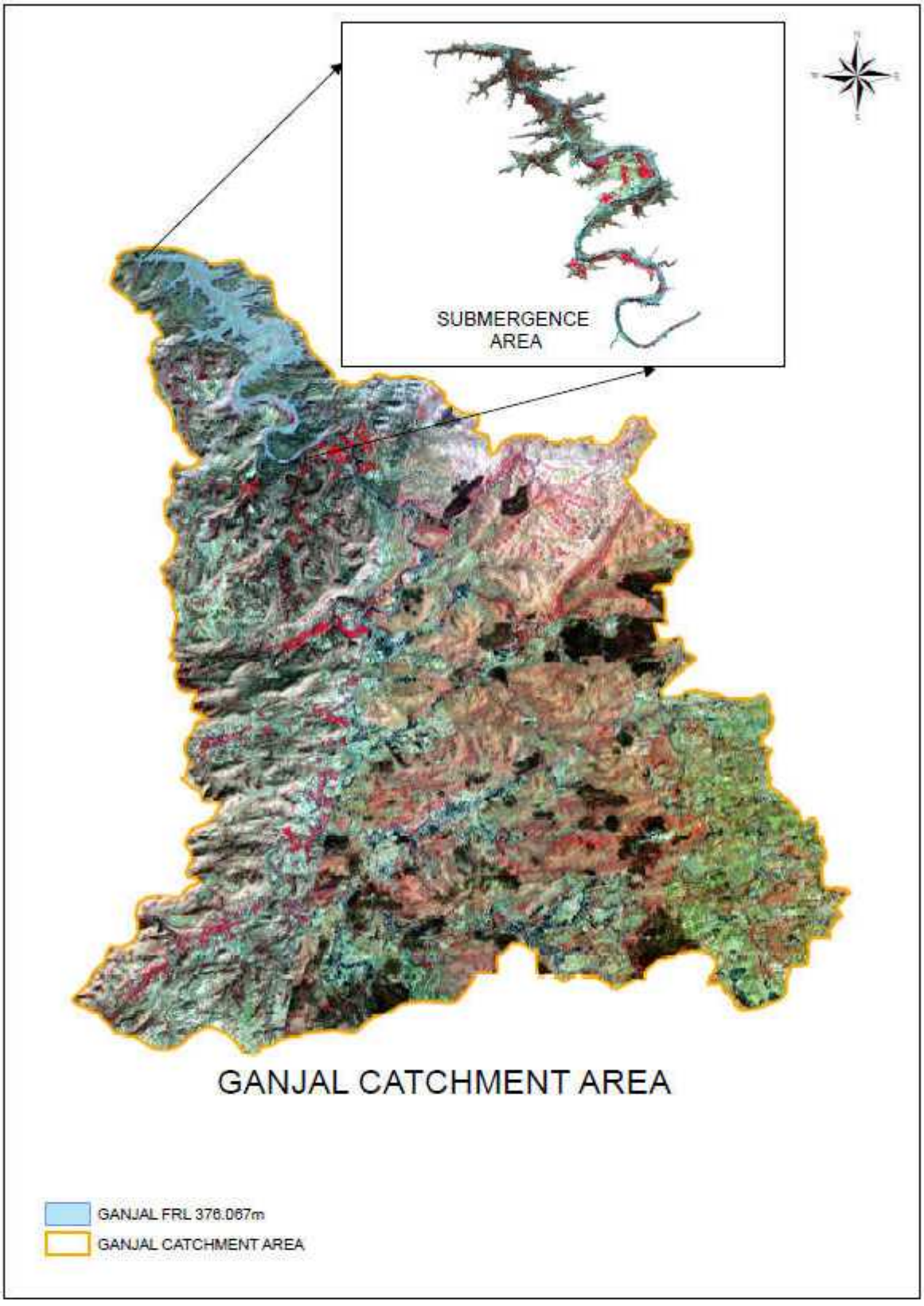


Figure 2.3(b): False Color Composite (FCC) IRS-P6 LISS IV Image for Ganjal Area

Table 2.1: Land Use Pattern of the Submergence and Catchment Area

Land	Submergence Area (Ha)			Catchment Area (Ha)		
	Morand	Ganjal	Submergence Area (%)	Morand	Ganjal	Catchment Area (%)
Water	200.95	112.51	10.333	1124.43	455.94	1.093
Agricultural land	576.57	14.11	19.472	2219.83	129.37	1.625
Fallow land	-	25.16	0.829	25807.87	7930.76	23.341
Degraded Land	100.51	19.92	3.970	8534.37	5375.36	9.623
Forest	705.12	579.01	42.332	34138.86	14919.45	33.939
Degraded Forest	519.90	74.64	19.600	30140.29	12144.25	29.253
Roads	7.85	5.46	0.438	823.66	249.17	0.742
Settlements	6.50	2.43	0.295	410.20	144.95	0.384
Tree Cover	82.84	-	2.731	-		
TOTAL	**2200.24**	**833.24**	**100**	**103199.51**	**41350.25**	**100**

2.1.2 Slope Class

Derived contours from topographical maps were used for preparation of Digital Elevation Model (DEM) of the free draining catchment area and to prepare a slope map. The first step in generation of slope map is to create surface using the elevation values stored in the form of contours or points. After marking the catchment area, all the contours on the topographical maps were derived. The output of the digitization procedure was the contours as well as points in form of x, y & z points. (x, y - location and z - their elevation). All this information was in real world co-ordinates (latitude, longitude and height in meters above sea level). The slope types adopted are as given below **Table 2.2.**

Table 2.2: Slope Types adopted

Slope Rank	Slope Range (%)	Description
2	0-15	Gentle slope
3	16-30	Moderate
4	31-45	Moderately Steep
5	46-60	Steep
6	>61	Very Steep

Slope map of the catchment area is enclosed as **Figure 2.5(a) & 2.5(b)** and the details are given in **Table 2.3.**

2.1.3 Drainage pattern

In traditional 2D capturing method of mapping, drainage map does not allow the engineers to exercise any analysis because of unavailability of true condition of the drainage such as elevation, flow, volume of water it can carry etc. To overcome this, the true drainage pattern should be extracted with the help of 3D input. For Morand and Ganjal, Stereo Satellite Images were utilized. The hydro features such as streams, canal, river, pond, Lake etc were captured/extracted from stereo satellite images in 3D environment. The 3D environment consists of special photogrammetry workstation which includes Stereo Glasses, Emitter, 3D Monitor and 3D mouse. These are utilized to trace hydro features which depict the true terrain. This data can be utilized in any engineering analysis in a GIS platform by overlaying it on Digital Elevation Model (DEM). The 3D simulates the reality and allows the decision makers to take decisions quickly and accurately. Refer **Figure 2.6(a) & (b).**

2.1.4 Soil Class

Soil map for the entire project area was prepared from the basic data/map of soil classification prepared by National Bureau of Soil Survey and Land Use Planning, Nagpur. This basic information was transferred to a GIS based map and was later used to designate/ classify areas of varying soil erosion proneness in combination with information on slope and forest cover. Refer **Figure 2.7(a) & (b)**. The description for soil classes has given in **Table 2.4**.

2.2 Soil Loss Using Silt Yield Index (SYI) Method

The Silt Yield Index Model (SYI), considering sedimentation as product of erosivity, erodability and aerial extent was conceptualized by AISLUS and has been in operational use since then to meet the requirements of prioritization of smaller hydrologic units within project catchment areas.

Methodology for the calculation of sediment yield index developed by All India Soil and Land Use Survey was followed in this study.

2.2.1 Erosion Intensity and Delivery Ratio

Determination of erosion intensity unit is based upon the integrated information on soil characters, physiography, slope, land use/land cover, lithology and structure. This is achieved through superimposition of different thematic maps overlays. This is achieved through data collected, weightage value and delivery ration 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. The composite

erosion intensity map was then superimposed on the drainage map with sub-watershed boundaries to evolve Composite Erosion Intensity Unit (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 erosion intensity within the watersheds. A basic factor of K=10 was used in determining the cumulative weightage values. The value of 10 indicates 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. The delivery ratio suggests the percentage of the eroded material that finally finds entry into the reservoir. The factors considered for computation of delivery ratios include texture of the eroded material (soil), drainage density, proximity to the active stream, relief length ratio in the subwatershed, slope, vegetation, sediments and basins and finally the distance from the reservoir. Refer **Table 2.5** given below for Delivery Ratio.

Table 2.5: Delivery ration criteria adopted for the project

Sl.No	Nearest Stream Distance (km)	Delivery Ratio
1	0 - 0.9	1
2	1.0 - 2.0	0.9
3	2.0 - 5.0	0.8
4	5.0 - 15.0	0.7
5	15.0 - 30.0	0.5

For treatment of catchment, the areas that require treatment have been delineated from the Composite Erosion Intensity Unit map. The sum of weightages was reclassified as per table given below to further subdivide the area as per the erosion intensity classes. The weightages for Land use, Slope and Soil were summed to get the erosion intensity classes.

Erosion Intensity and Weightages

Erosion Intensity Class	Sum of Weightage
Very Severe (E5)	12 -14
Severe (E4)	9 - 11
Moderate(E3)	6 - 8
Low (E2)	4 - 5
Negligible (E1)	0 - 3

2.2.2 Prioritization of Sub Watersheds and Sediment Yield Index (SYI)

The prioritization of smaller hydrologic units within the vast catchments is based on the SYI of the smaller units. The boundary values or range of SYI values for different priority categories are arrived at by studying the frequency distribution of SYI values and locating the suitable breaking points. 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:

a) Climatic factors comprising total precipitation, its frequency and intensity,
b) Geomorphic factors comprising land forms, physiography, slope and drainage characteristics,
c) Surface cover factors governing the flow hydraulics and
d) 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:

(i) Preparation of a framework of sub-watersheds through systematic delineation

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

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

(iv) Computing Silt Yield Index for individual watersheds/sub-watersheds.

(v) Grading of watersheds/sub-watersheds into very high, high, medium, low and very low priority categories.

Sediment Yield Index (SYI)

The Sediment Yield index defined as 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. The area of each of the mapping units is computed and silt yield indices of individual sub-watersheds are calculated using the following equation:

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

Where,

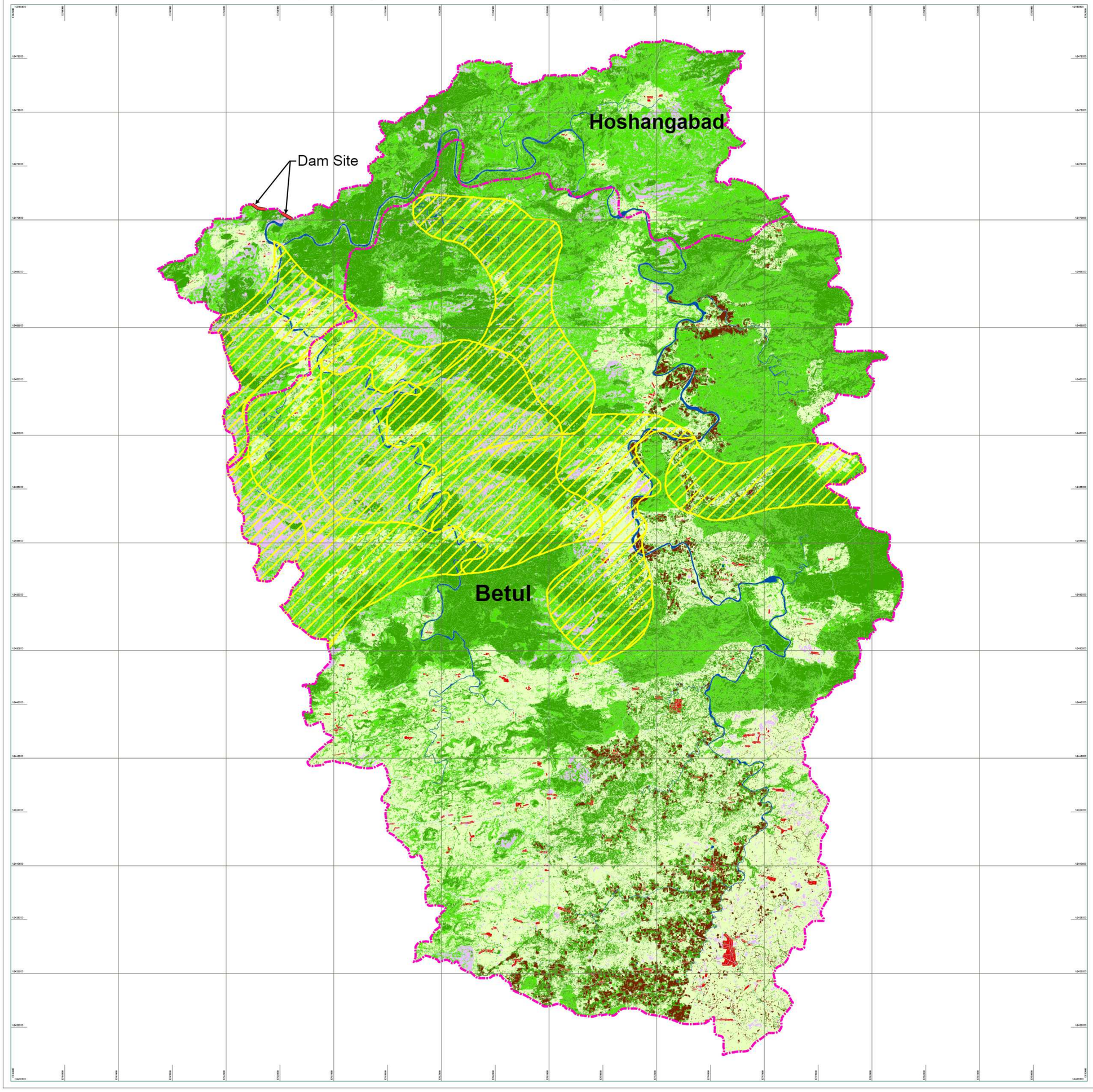
Ai = Area of i^{th} unit (EIMU)
Wi = Weightage value of i^{th} mapping unit
N = No. of mapping units
Aw = Total area of sub-watershed.
Di = Delivery ratio

Table 2.6: SYI values for classification of various categories of erosion intensity rates

Sl.No	Priority	SYI range
1	Very high	>1300
2	High	1200 - 1299
3	Medium	1100 - 1199
4	Low	1000 - 1099
5	Very Low	< 1000

From the total geographical area of Sub watersheds to the sediment yield index (SYI) was calculated for 41 sub-watersheds of Morand catchment and 21 sub-watersheds of Ganjal catchment and they were categorized into five erosion ranking classes i.e Very high, High, Moderate, Low and Very low according to priorities. These prioritized watersheds would require treatment according to their priority ranking for soil conservation measures. The details of Morand and Ganjal Prioritizations are given in **Table 2.7(a) - (d).**

Figure 2.4(a) Land Use Land Cover Map of Morand Catchment Area



N

Land Use/Land Cover

Classes	Area (in Ha)	
	Hoshangabad	Betul
WATER	274.57	849.86
AGRICULTURE LAND	3.25	2216.58
CURRENT FALLOW	1307.65	24500.22
DEGRADED LAND	1924.37	6610.00
FOREST	5495.15	28643.71
DEGRADED FOREST	6912.49	23227.80
ROAD	55.83	767.83
SETTLEMENTS	22.07	388.13

Dam Site

District Boundary

Watershed Priority

High

Projection System
WGS 1984
UTM Zone 43N
Units in Meters

Software Used
ArcGIS 10.2

No	DATE	REVISIONS	BY	CHKD	APPD	PROJ ENGR
0	04.06.14					

CLIENT: NARMADA VALLEY DEVELOPMENT AUTHORITY (NVDA)
BHOPAL, MADHYA PRADESH.

PROJECT: MORAND & GANJAL COMPLEX PROJECT

TITLE: LULC MAP OF MORAND CATCHMENT AREA

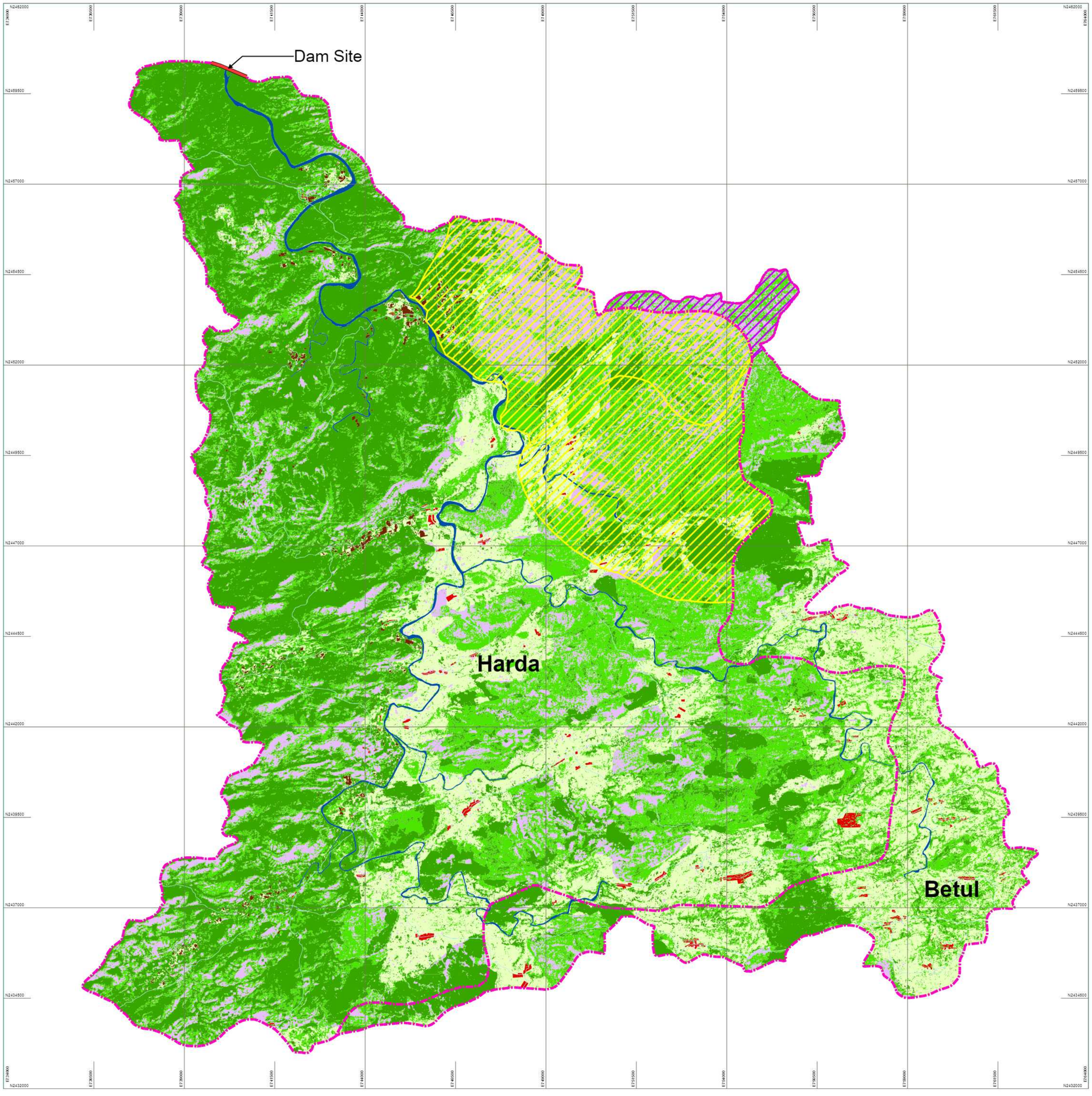
CONSULTANT: SECON PRIVATE LIMITED
BANGALORE – 66

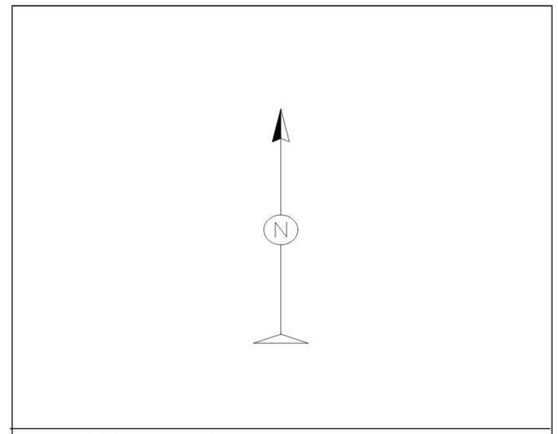
SCALE: 1: 75,000

DRAWING NO.: SECON/NVDA/MAG/LULC MAP/MC

REV.: 0

Figure 2.4(b) Land Use Land Cover Map of Ganjal Catchment Area





Land Use/Land Cover

Classes	Area (in Ha)	
	Harda	Betul
WATER	415.03	40.91
AGRICULTURE LAND	129.37	0.00
CURRENT FALLOW	5257.37	2673.39
DEGRADED LAND	4870.03	505.33
FOREST	13381.13	1538.32
DEGRADED FOREST	9985.75	2158.5
ROAD	193.05	56.12
SETTLEMENTS	99.47	45.48

Dam Site
District Boundary

Watershed Priority
High
Very High

Projection System
WGS 1984
UTM Zone 43N
Units in Meters

Software Used
ArcGIS 10.2

Satellite Image Used
Cartosat-I Stereo

No	DATE	REVISIONS	BY	CHKD	APPD	PROJ ENGR
0	02.06.14					

CLIENT: NARMADA VALLEY DEVELOPMENT AUTHORITY (NVDA)
BHOPAL, MADHYA PRADESH.

PROJECT: MORAND & GANJAL COMPLEX PROJECT

TITLE: LULC MAP OF GANJAL CATCHMENT AREA

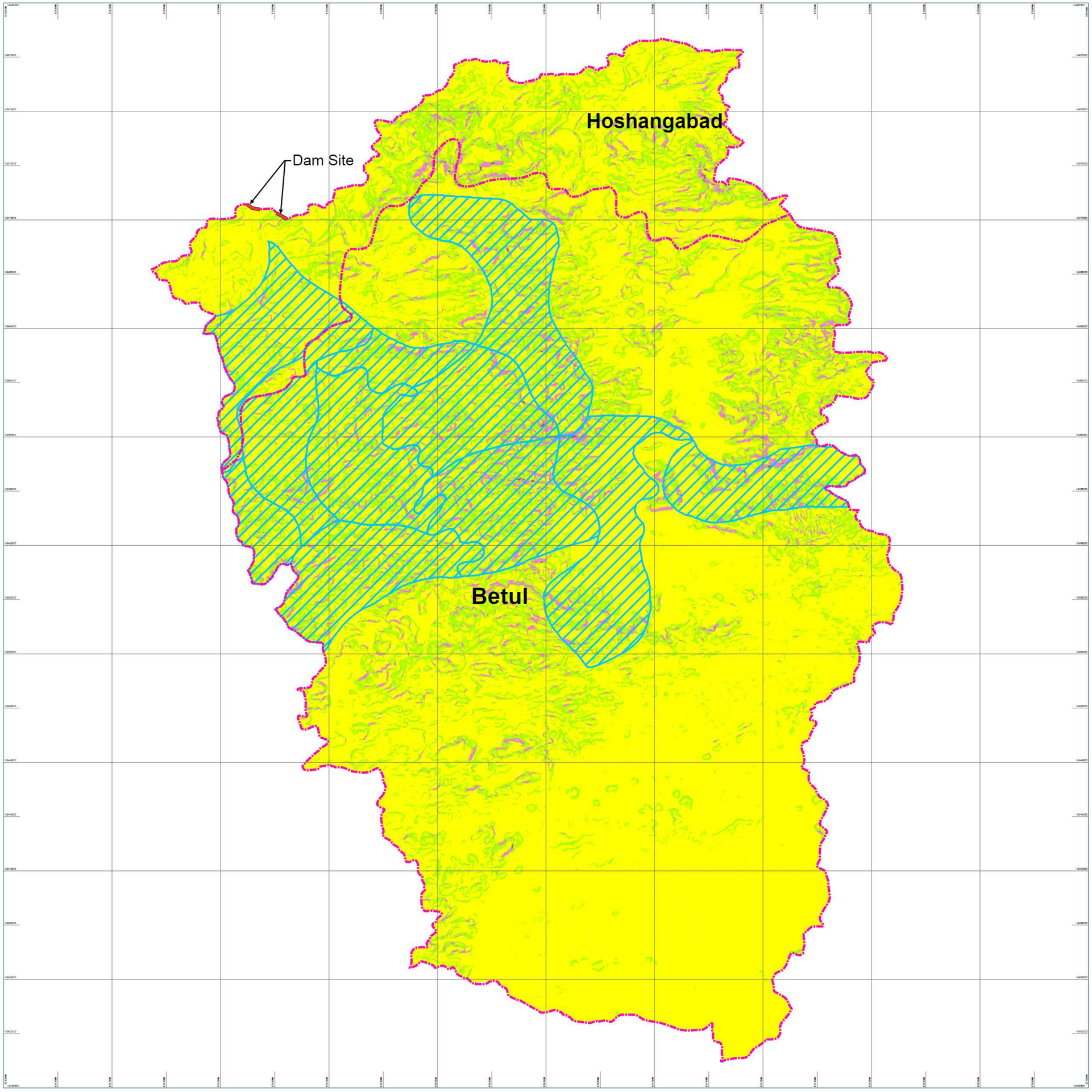
CONSULTANT: SECON PRIVATE LIMITED
BANGALORE - 66

SCALE: 1:50,000

DRAWING NO.: SECON/NVDA/MAG/LULC MAP/GC

REV.: 0

Figure 2.5(a) Slope Map of Morand Catchment Area



N

Percentage Slope

Slope Classes	Area (in Ha)	
	Hoshangabad	Betul
Gentle	10144.42	62375.45
Moderate	5043.98	20747.29
Moderately Steep	732.70	3764.47
Steep	65.77	292.50
Very Steep	8.51	24.47

Dam Site

District Boundary

Watershed Priority

High

Projection System
WGS 1984
UTM Zone 43N
Units in Meters

Software Used
ArcGIS 10.2

No	DATE	REVISIONS	BY	CHKD	APPD	PROJ ENGR
0	04.06.14					

CLIENT: NARMADA VALLEY DEVELOPMENT AUTHORITY (NVDA) BHOPAL, MADHYA PRADESH.

PROJECT: MORAND & GANJAL COMPLEX PROJECT

TITLE: SLOPE MAP OF MORAND CATCHMENT AREA

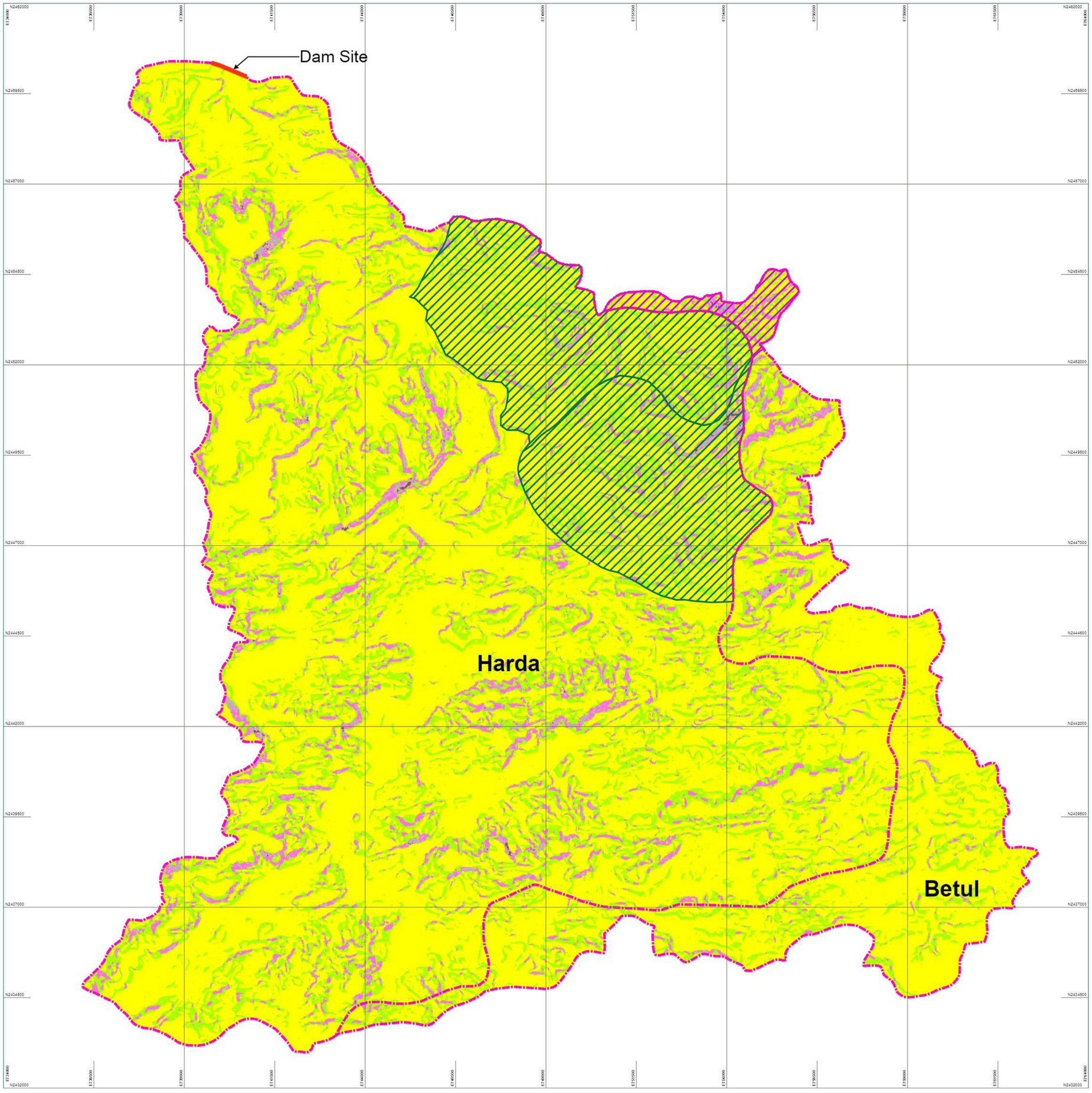
CONSULTANT: SECON PRIVATE LIMITED BANGALORE – 66

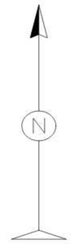
SCALE: 1: 75,000

DRAWING NO.: SECON/NVDA/MAG/SLOPE MAP/MC

REV.: 0

Figure 2.5(b) Slope Map of Ganjal Catchment Area





Percentage Slope

Slope Classes	Area (in Ha)	
	Harda	Betul
Gentle	21850.05	4754.66
Moderate	10193.89	1906.08
Moderately Steep	2049.48	334.78
Steep	208.26	23.33
Very Steep	26.74	2.11

Dam Site

District Boundary

Watershed Priority

High

Very High

Projection System
WGS 1984
UTM Zone 43N
Units in Meters

Software Used
ArcGIS 10.2

Satellite Image Used
Cartosat-I Stereo

No	DATE	REVISIONS	BY	CHKD	APPD	PROJ ENGR
0	02.06.14					

CLIENT: NARMADA VALLEY DEVELOPMENT AUTHORITY (NVDA)
BHOPAL, MADHYA PRADESH.

PROJECT: MORAND & GANJAL COMPLEX PROJECT

TITLE: SLOPE MAP OF GANJAL CATCHMENT AREA

CONSULTANT: SECON PRIVATE LIMITED
BANGALORE - 66

SCALE: 1:50,000

DRAWING NO.: SECON/NVDA/MAG/SLOPE MAP/GC

REV.: 0

FIGURE 2.6(a) : DRAINAGE MAP OF MORAND CATCHMENT

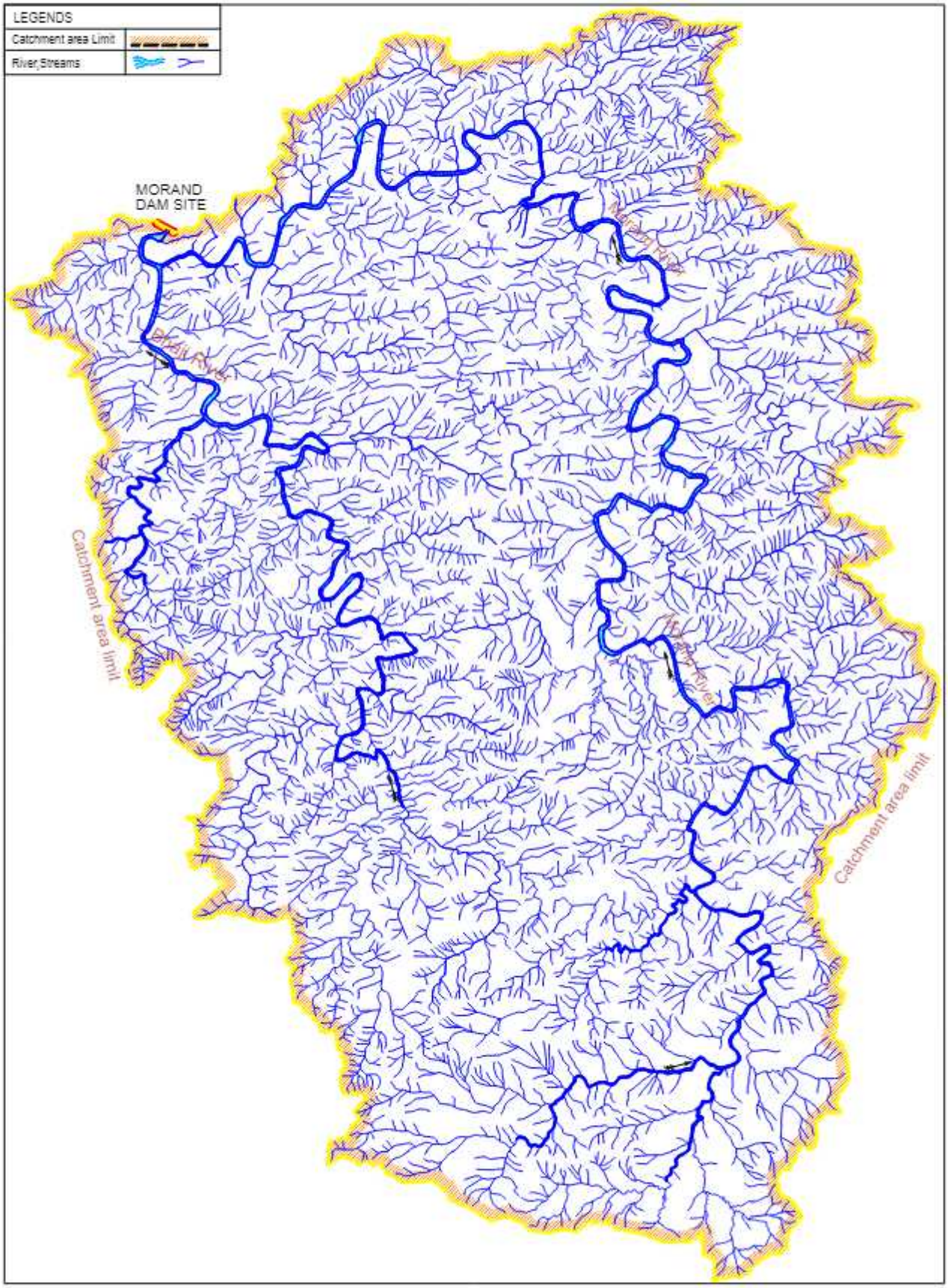


FIGURE 2.6(b) : DRAINAGE MAP OF GANJAL CATCHMENT

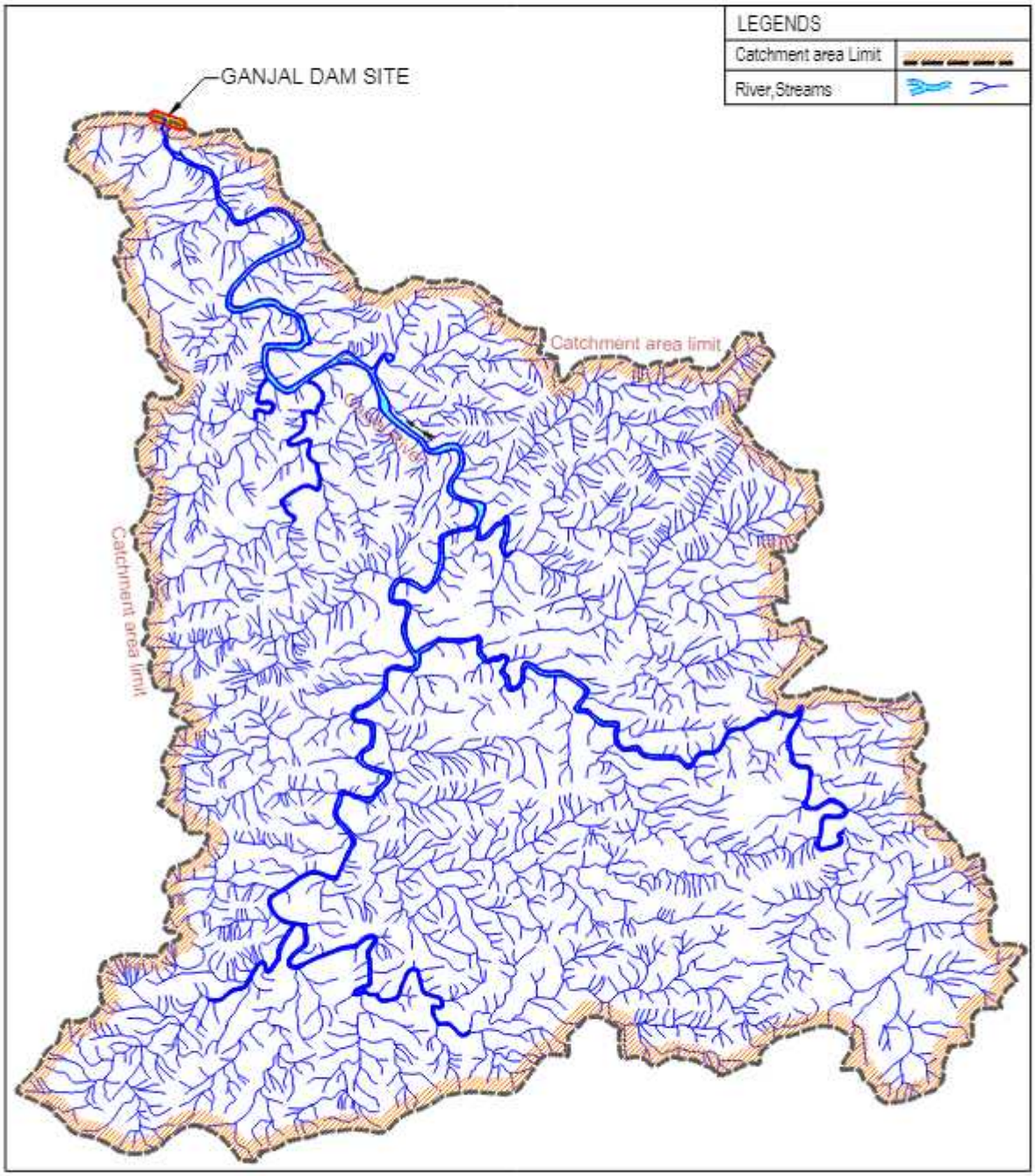
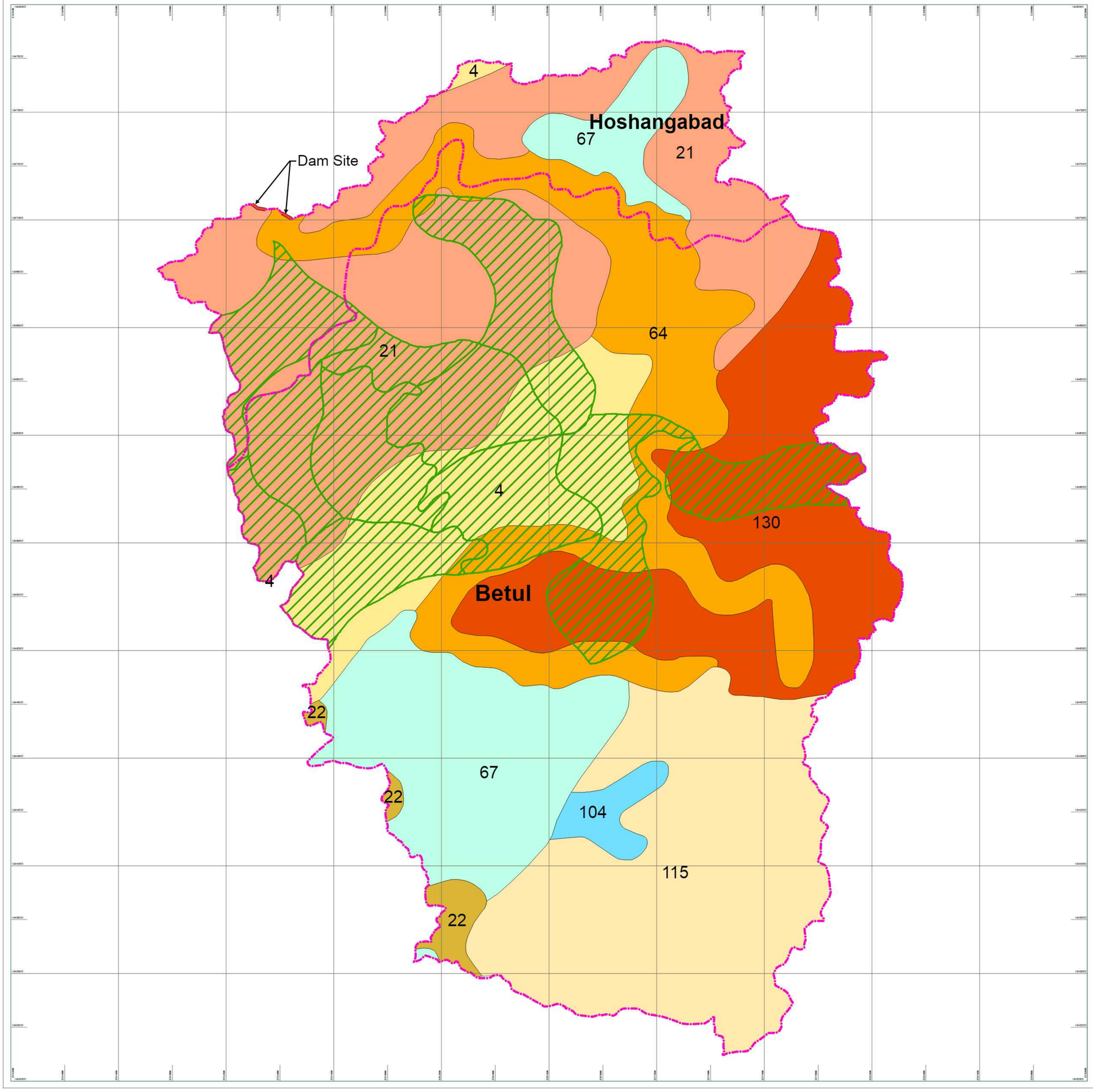
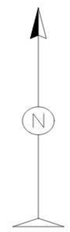


Figure 2.7(a) Soil Map of Morand Catchment Area





Soil Class (Mapping Unit)

- 4
- 21
- 22
- 64
- 67
- 104
- 115
- 130

Dam Site

District Boundary

Watershed Priority

High

Projection System
WGS 1984
UTM Zone 43N
Units in Meters

Software Used
ArcGIS 10.2

No	DATE	REVISIONS	BY	CHKD	APPD	PROJ ENGR
0	04.06.14					

CLIENT: NARMADA VALLEY DEVELOPMENT AUTHORITY (NVDA) BHOPAL, MADHYA PRADESH.

PROJECT: MORAND & GANJAL COMPLEX PROJECT

TITLE: SOIL MAP OF MORAND CATCHMENT AREA

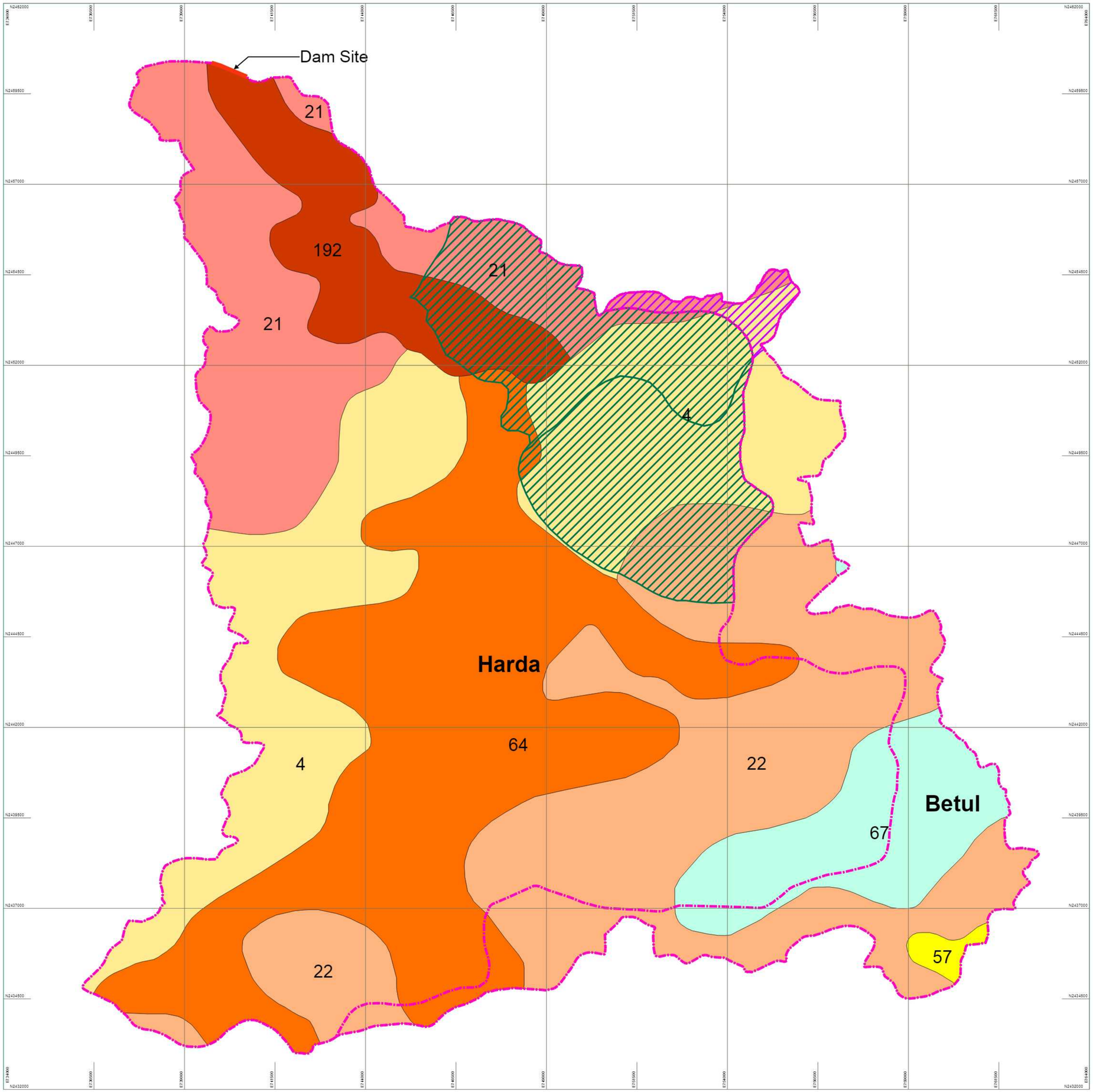
CONSULTANT: SECON PRIVATE LIMITED BANGALORE – 66

SCALE: 1:75,000

DRAWING NO. SECON/NVDA/MAG/SOIL MAP/MC

REV. 0

Figure 2.7(b) Soil Map of Ganjal Catchment Area



Soil Class (Mapping Unit)

- 4
- 21
- 22
- 57
- 64
- 67
- 192

Dam Site

District Boundary

Watershed Priority

- High
- Very High

Projection System
WGS 1984
UTM Zone 43N
Units in Meters

Software Used
ArcGIS 10.2

Satellite Image Used
Cartosat-I Stereo

No	DATE	REVISIONS	BY	CHKD	APPD	PROJ ENGR
0	02.06.14					

CLIENT: NARMADA VALLEY DEVELOPMENT AUTHORITY (NVDA)
BHOPAL, MADHYA PRADESH.

PROJECT: MORAND & GANJAL COMPLEX PROJECT

TITLE: SOIL MAP OF GANJAL CATCHMENT AREA

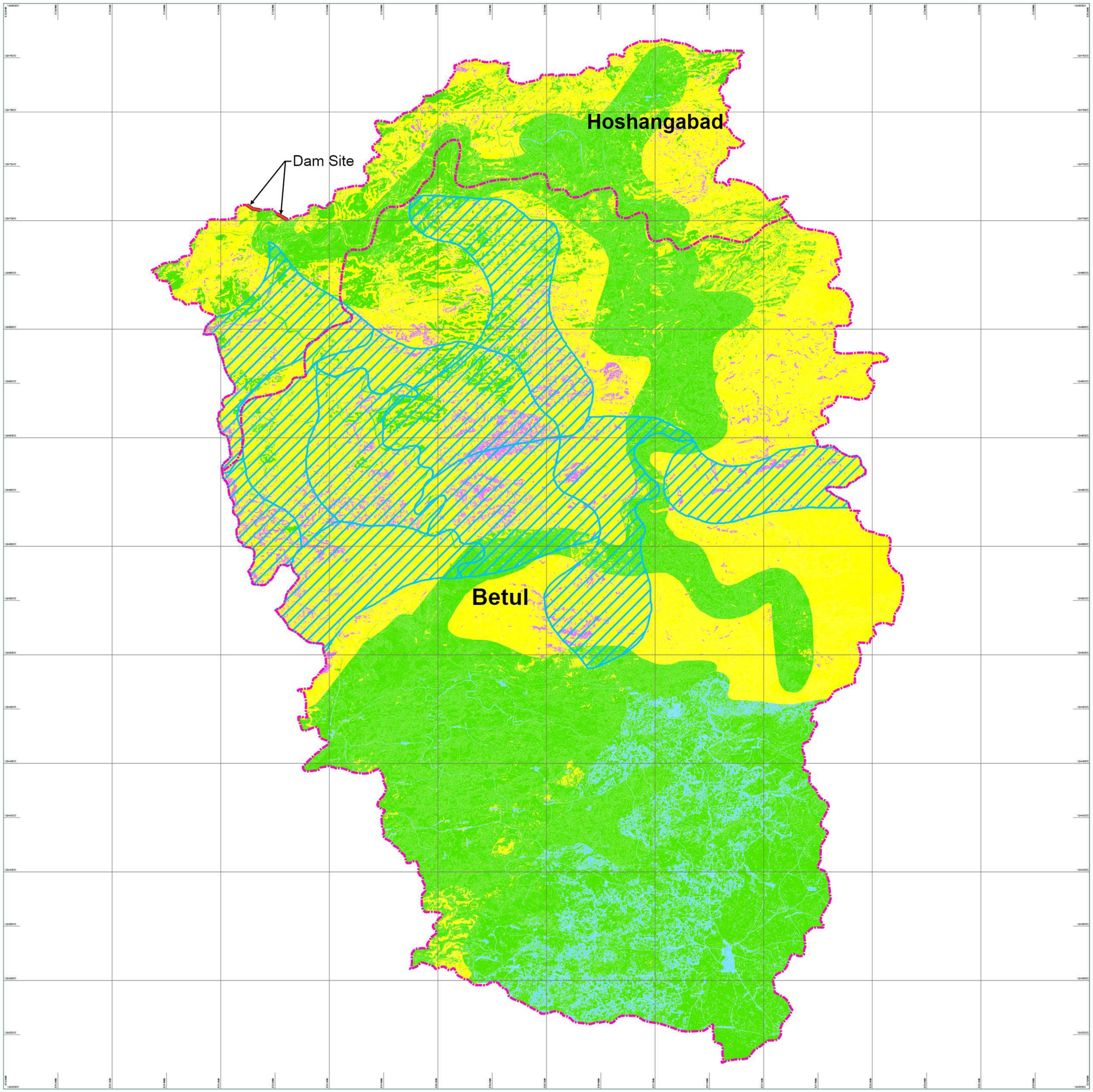
CONSULTANT: SECON PRIVATE LIMITED
BANGALORE - 66

SCALE: 1:50,000

DRAWING NO.: SECON/NVDA/MAG/SOIL MAP/GC

REV. 0

Figure 2.8(a) Erosion Intensity Class Map of Morand Catchment Area



Erosion Classes	Area (in Ha)	
	Hoshangabad	Betul
Moderate	8682.12	37657.92
Negligible	44.60	4594.61
Severe	507.10	3914.35
Slight	6761.57	40980.63
Very Severe	0.00	2.74

Dam Site
District Boundary
High

Projection System
WGS 1984
UTM Zone 43N
Units in Meters

Software Used
ArcGIS 10.2

No	DATE	REVISIONS	BY	CHKD	APPD	PROJ ENGR
0	04.06.14					

CLIENT: NARMADA VALLEY DEVELOPMENT AUTHORITY (NVDA) BHOPAL, MADHYA PRADESH.

PROJECT: MORAND & GANJAL COMPLEX PROJECT

TITLE: EROSION CLASS MAP OF MORAND CATCHMENT AREA

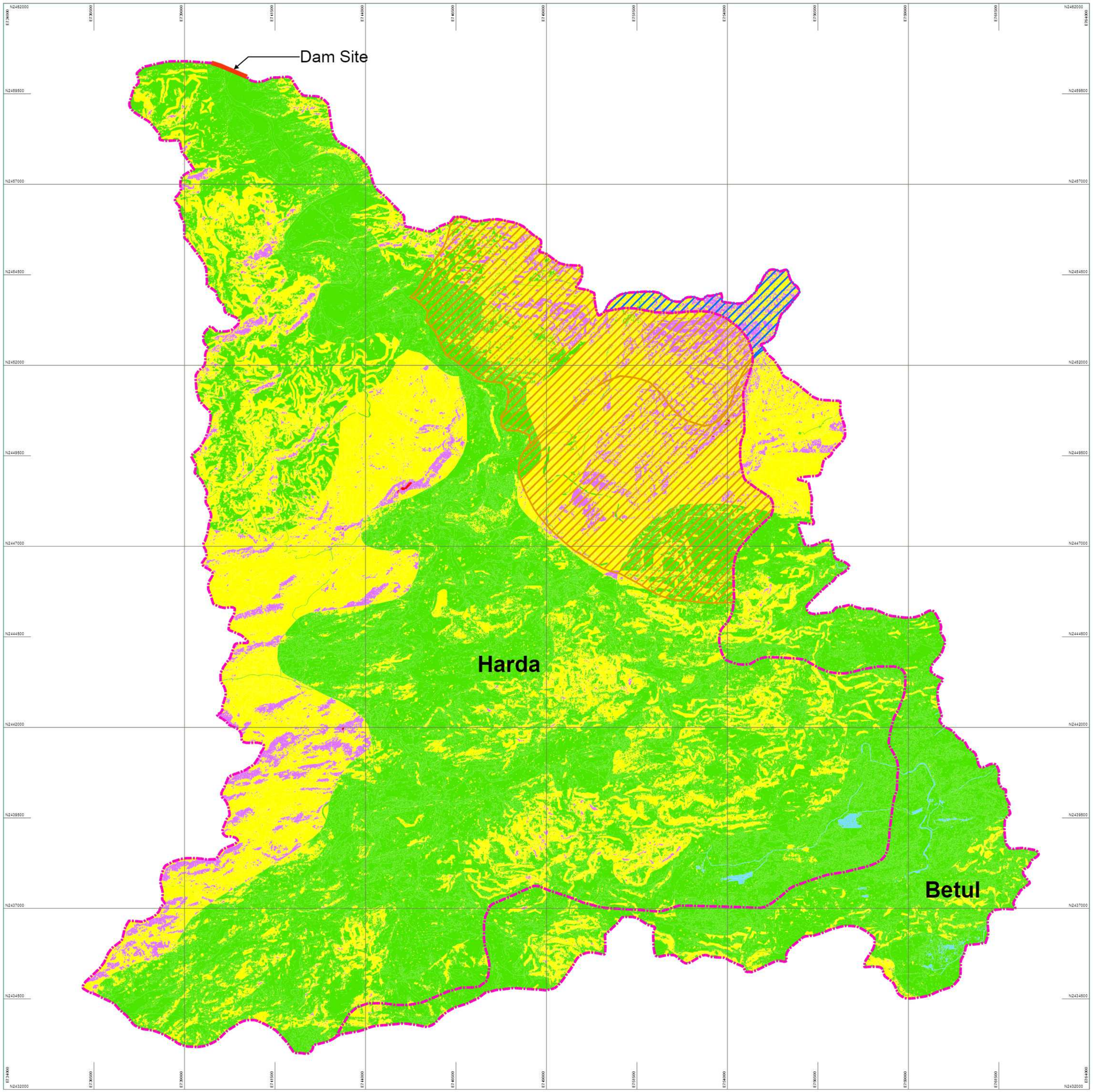
CONSULTANT: SECON PRIVATE LIMITED BANGALORE – 66

SCALE: 1: 75,000

DRAWING NO. SECON/NVDA/MAG/EROSION MAP/MC

REV. 0

Figure 2.8(b) Erosion Intensity Class Map of Ganjal Catchment Area



Erosion Classes	Area (in Ha)	
	Harda	Betul
Moderate	13550.05	1833.23
Negiligible	42.62	47.63
Severe	1936.69	256.68
Slight	18793.06	4883.31
Very Severe	6.01	0.13

Dam Site

District Boundary

Watershed Priority

High

Very High

Projection System
WGS 1984
UTM Zone 43N
Units in Meters

Software Used
ArcGIS 10.2

Satellite Image Used
Cartosat-I Stereo

No	DATE	REVISIONS	BY	CHKD	APPD	PROJ ENGR
0	02.06.14					

CLIENT: NARMADA VALLEY DEVELOPMENT AUTHORITY (NVDA)
BHOPAL, MADHYA PRADESH.

PROJECT: MORAND & GANJAL COMPLEX PROJECT

TITLE: EROSION CLASS MAP OF GANJAL CATCHMENT AREA

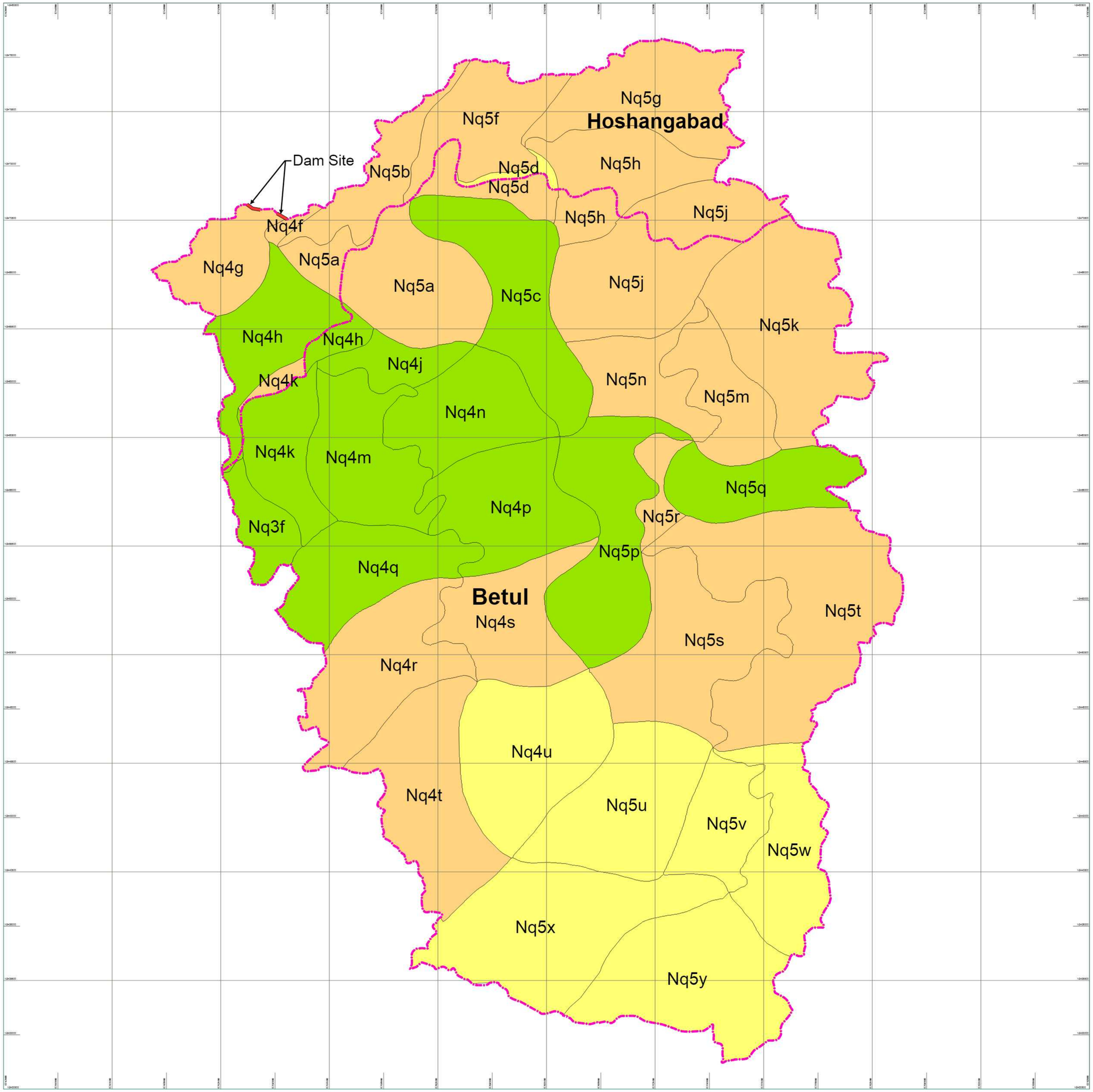
CONSULTANT: SECON PRIVATE LIMITED
BANGALORE - 66

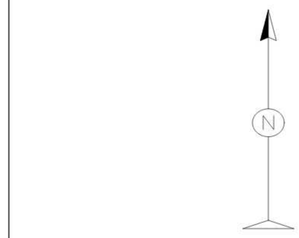
SCALE: 1:50,000

DRAWING NO.: SECON/NVDA/MAG/SLOPE MAP/GC

REV.: 0

Figure 2.9(a) Priority Wise Sub Watersheds of Morand Catchment Area





Priority

- Low
- Medium
- High
- Very High
- Dam Site
- District Boundary

Projection System
WGS 1984
UTM Zone 43N
Units in Meters

Software Used
ArcGIS 10.2

No	DATE	REVISIONS	BY	CHKD	APPD	PROJ ENGR
0	04.06.14					

CLIENT: NARMADA VALLEY DEVELOPMENT AUTHORITY (NVDA) BHOPAL, MADHYA PRADESH.

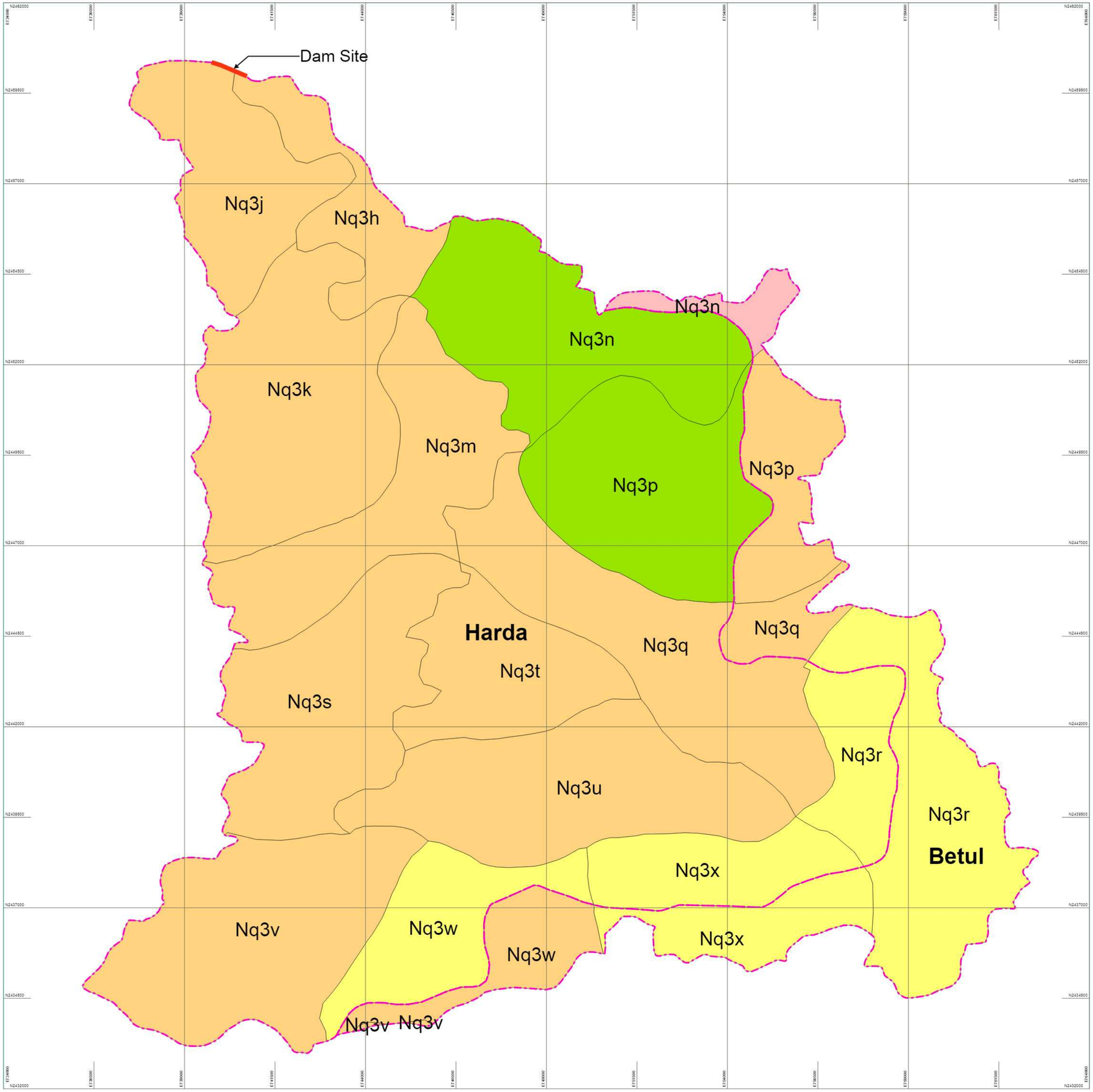
PROJECT: MORAND & GANJAL COMPLEX PROJECT

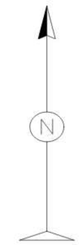
TITLE: PRIORITYWISE SUB WATERSHEDS OF MORAND CATCHMENT AREA

CONSULTANT: SECON PRIVATE LIMITED BANGALORE – 66

SCALE	1: 75,000	
DRAWING NO.	SECON/NVDA/MAG/PRIORITYWISE SUB WATERSHEDS/MC	REV. 0

Figure 2.9(b) Priority Wise Sub Watersheds of Ganjal Catchment Area





Priority

- Low
- Medium
- High
- Very High
- Dam Site
- Catchment Boundary
- Harda District Boundary

Projection System
WGS 1984
UTM Zone 43N
Units in Meters

Software Used
ArcGIS 10.2

Satellite Image Used
Cartosat-I Stereo

No	DATE	REVISIONS	BY	CHKD	APPD	PROJ ENGR
0	02.06.14					

CLIENT: NARMADA VALLEY DEVELOPMENT AUTHORITY (NVDA)
BHOPAL, MADHYA PRADESH.

PROJECT: MORAND & GANJAL COMPLEX PROJECT

TITLE: PRIORITYWISE SUB WATERSHEDS OF GANJAL CATCHMENT AREA

CONSULTANT: SECON PRIVATE LIMITED
BANGALORE – 66

SCALE: 1:50,000

DRAWING NO.: SECON/NVDA/MAG/PRIORITYWISE SUB WATERSHEDS/GC

REV. 0

Table 2.3 (i) : Slope Details for Sub-Watersheds (Betul District)

Sl.No	Sub-Watershed code	Slope Class										Total Area (Ha)
		0^0-15^0		15^0-30^0		30^0-45^0		45^0-60^0		>60^0		
		Gentle		Moderate		Moderately Steep		Steep		Very Steep		
		Area (Ha)	%	Area (Ha)	%	Area (Ha)	%	Area (Ha)	%	Area (Ha)	%	
I	Morand Catchment											
(a)	Betul District											
1	Nq 5q	1337.41	57.94	705.43	30.56	229.43	9.94	33.20	1.44	2.77	0.12	2308.24
2	Nq 5p	2762.71	69.00	951.87	23.77	256.11	6.40	30.33	0.76	2.91	0.07	4003.93
3	Nq 5c	2043.66	54.52	1363.55	36.37	306.75	8.18	32.26	0.86	2.42	0.06	3748.65
4	Nq 4q	1529.38	53.24	1102.25	38.37	231.87	8.07	8.88	0.31	0.09	0.00	2872.48
5	Nq 4p	1449.44	45.43	1353.51	42.42	353.51	11.08	30.09	0.94	3.90	0.12	3190.45
6	Nq 4n	1375.19	50.63	1077.02	39.65	232.57	8.56	27.36	1.01	3.93	0.14	2716.06
7	Nq 4m	1620.25	54.64	1116.47	37.65	210.82	7.11	16.63	0.56	1.22	0.04	2965.39
8	Nq 4k	1188.70	62.02	627.85	32.76	94.46	4.93	5.69	0.30	0.01	0.00	1916.70
9	Nq 4j	585.70	57.40	350.80	34.38	76.67	7.51	6.60	0.65	0.66	0.06	1020.43
10	Nq 4h	267.99	67.89	108.97	27.61	17.31	4.38	0.45	0.11	NIL	-	394.72
11	Nq 3f	570.24	57.31	361.59	36.34	60.66	6.10	2.52	0.25	NIL	-	995.01
I	Ganjal Catchment											
(a)	Betul District											
1	Nq 3n	162.82	43.62	159.30	42.68	44.60	11.95	5.25	1.41	1.26	0.34	373.24

Table 2.3 (ii) : Slope Details for Sub-Watersheds (Hoshangabad District)

Sl.No	Sub-Watershed code	Slope Class										Total Area (Ha)
		0^0-15^0		15^0-30^0		30^0-45^0		45^0-60^0		>60^0		
		Gentle		Moderate		Moderately Steep		Steep		Very Steep		
		Area (Ha)	%	Area (Ha)	%	Area (Ha)	%	Area (Ha)	%	Area (Ha)	%	
I	Morand Catchment											
(a)	Hoshangabad District											
1	Nq 4h	1612.59	68.14	676.27	28.58	73.99	3.13	3.42	0.14	0.15	0.01	2366.42

Table 2.3 (iii) : Slope Details for Sub-Watersheds (Harda District)

Sl.No	Sub-Watershed code	Slope Class										Total Area (Ha)
		0^0-15^0		15^0-30^0		30^0-45^0		45^0-60^0		>60^0		
		Gentle		Moderate		Moderately Steep		Steep		Very Steep		
		Area (Ha)	%	Area (Ha)	%	Area (Ha)	%	Area (Ha)	%	Area (Ha)	%	
I	Ganjal Catchment											
(a)	Harda District											
1	Nq 3n	1870.60	63.10	917.27	30.94	161.77	5.46	14.18	0.48	0.76	0.03	2964.59
2	Nq 3p	1702.62	59.34	944.80	32.93	189.33	6.60	26.21	0.91	6.12	0.21	2869.09

TABLE 2.4: DESCRIPTION OF SOIL UNITS IN MORAND AND GANJAL

Landform	Mapping Unit	Colour Code	Description	Land use	Soil Constraints	Soil Potential	Strategies
Plain land (moderately dissected)	192		Slightly deep to deep, well drained, fine soils on gently sloping with moderate erosion, high AWC and 189-210 days LGP, pH 7.6 – 8.2, CEC 35-44, BSP 85-95, Typic Haplusterts / Vertic Ustochrepts	Cultivated for rice, Wheat, Soyabean, Gram, Vegetables	Soil and Crop management practices	High potential for rice, Wheat, Jowar, Soyabean and Vegetable	Use of improved soil and crop management practices
Hills and Hill ranges	4		Very shallow to shallow, somewhat excessively to excessively drained loamy - skeletal soils on moderate to mod. Steep sloping, very severe erosion 90-120 days LGP days and pH 4.8 - 6.8, CEC 25-38, BSP Lithic / Typic Ustorthents and Ustochrepts	Mostly under dry deciduous mixed forest and patches planted for Teak, Bamboo	Landform, slope, low AWC, soil depth	Having medium potential for non-arable uses	Soil conservation measures should be adopted
Plateau	64		Moderately deep to deep, moderately well drained, fine soils on gently sloping, moderate erosion, high AWC, 120-150 days LGP, pH 7.2-8.0, CEC 52-60, BSP 88-97, Typic Haplusterts	Cultivated for Rice, Cotton, Wheat, Gram, Minor Millets and Patches under forest	Landform soils drainage	Suitable for cultivation of Rice, Wheat, Soyabean, Jowar	Soil conservation measures and improved management should be adopted.
Residual Hills with narrow valleys	22		In addition to the above properties the variation in pH 5.2-7.3, CEC 10.8-32, BSP 64-93 Lithic Ustorthents	Mostly under dry deciduous mixed forest and patches cultivated for minor billets	Landform, slope, low AWC, soil depth	Having medium potential for non-arable uses	Soil conservation measures should be adopted
Plateau with mounds	67		Deep moderate well drained, fine to fine-loamy soils on gently sloping with moderate erosion, very high AWC, 150-180 days LGP, pH 7-7.8, CEC 34-45, BSP 91-97, Typic Ustochrepts, Typic Haplusterts	Cultivated for Rice, Cotton, Wheat, Gram, Minor Millets and Patches under forest	Landform soils drainage	Suitable for cultivation of Rice, Wheat, Soyabean, Jowar	Soil conservation measures and proper soil and crop management practices

Landform	Mapping Unit	Colour Code	Description	Land use	Soil Constraints	Soil Potential	Strategies
Undulating Land	130		Sallow to deep, well drained loamy to fine - loamy soils, on moderately sloping with severe erosion. Very low AWC, 90-120 day LGP, pH 6-7, CEC 18-29, BSP 82-89, Lithic / Typic Haplustalfs, Ustochrepts	Patches cultivated for Rice, Minor Millets, Wheat, Gram etc.	Lanform and slope gradients and low AWC	Suitable for Rice, Wheat, Minor Millets and Vegetables	Soil conservation measures Bunding and Terracing
Residual Hills with narrow valleys	21		In addition to the above properties the variation in pH 5.2-7.3, CEC 10.8-32, BSP 64-93 Lithic Ustorthents	Mostly under dry, deciduous, mixed forest and patches cultivated for minor millets	Landform, slope, low AWC, soil depth	Having medium potential for non-arable uses	Soil conservation measures should be adopted
Escarpment with pediments	104		Slightlyt moderately deep, some what extensively drained,loamy to fine-loamy soils on moderately sloping,severe erosion very low AWC,and 90-120 days LGP,pH 5.2-6.2,CEC18-38,BSP7284,TypicHaplustalfs	Mostly under dry deciduous mixed forest and patches planted for Teak Sal.	Landform, slope, low AWC, soil depth	Medium potential non-erable use	Soil conservation measures bunding and terracing is required
Undulating land with valleys	115		Shallow to moderate deep, well drained, loamy to fine-loamy soils on gently sloping, moderate erosion, low AWC, 90-120 days LGP, pH 5.1-6, CEC 13-15, BSP 60-75, Lithic / Typic Ustochrepts / Haplustalfs	Cultivated for Rice, Minor Millets, Soyabean, Jowar	Landform slope gradients, low AWC	Medium potential for Rice, Wheat Gram etc.	Soil conservation measures bunding and terracing is required

Table 2.7(a) : Sediment Yield Index and Prioritization as per Erosion Intensity for Morand Catchment-Betul District

Watershed	Erosion Intensity Class	Area (Ha)	Weightage	Weightage x Area	DR	Gross Silt (5 x 6)	SYI	Priority
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Nq 5y	Negligible	1010.29	10	10102.87	1	10102.87	1078	Low
	Slight	3534.43	11	38878.68	1	38878.68		
	Moderate	2.15	13	28.00	0.9	25.20		
	Severe	0.00	18	0.00	0.9	0.00		
	Very Severe	0.00	20	0.00	0.9	0.00		
	Total	**4546.87**				**49006.74**		
Nq 5x	Negligible	1162.14	10	11621.40	1	11621.40	1081	Low
	Slight	3865.96	11	42525.52	1	42525.52		
	Moderate	241.68	13	3141.89	0.9	2827.70		
	Severe	0.89	18	15.97	0.9	14.37		
	Very Severe	0.00	20	0.00	0.9	0.00		
	Total	**5270.67**				**56989.00**		
Nq 5w	Negligible	307.85	10	3078.48	1	3078.48	1090	Low
	Slight	2607.20	11	28679.20	1	28679.20		
	Moderate	2.80	13	36.37	0.9	32.73		
	Severe	0.00	18	0.00	0.9	0.00		
	Very Severe	0.00	20	0.00	0.9	0.00		
	Total	**2917.85**				**31790.41**		
Nq 5v	Negligible	558.09	10	5580.94	1	5580.94	1070	Low
	Slight	1277.90	11	14056.94	1	14056.94		
	Moderate	0.12	13	1.59	0.9	1.43		
	Severe	0.00	18	0.00	0.9	0.00		
	Very Severe	0.00	20	0.00	0.9	0.00		
	Total	**1836.12**				**19639.31**		
Nq 5u	Negligible	828.21	10	8282.12	1	8282.12	1079	Low
	Slight	3027.89	11	33306.76	1	33306.76		
	Moderate	6.42	13	83.41	0.9	75.07		
	Severe	0.00	18	0.00	0.9	0.00		
	Very Severe	0.00	20	0.00	0.9	0.00		
	Total	**3862.52**				**41663.95**		
Nq 5t	Negligible	264.40	10	2644.03	1	2644.03	1148	Medium
	Slight	1766.95	11	19436.40	1	19436.40		
	Moderate	4620.09	13	60061.21	0.9	54055.09		
	Severe	43.14	18	776.56	0.9	698.90		
	Very Severe	0.00	20	0.00	0.9	0.00		
	Total	**6694.58**				**76834.43**		
Nq 5s	Negligible	311.09	10	3110.92	1	3110.92	1124	Medium
	Slight	2195.46	11	24150.08	1	24150.08		
	Moderate	1726.67	13	22446.66	0.9	20201.99		
	Severe	24.13	18	434.36	0.9	390.93		
	Very Severe	0.00	20	0.00	0.9	0.00		
	Total	**4257.35**				**47853.92**		
Nq 5r	Negligible	0.00	10	0.00	1	0.00	1120	Medium
	Slight	485.70	11	5342.73	1	5342.73		
	Moderate	148.37	13	1928.84	0.9	1735.96		
	Severe	5.01	18	90.10	0.9	81.09		
	Very Severe	0.00	20	0.00	0.9	0.00		
	Total	**639.08**				**7159.77**		
	Negligible	0.00	10	0.00	1	0.00		

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Nq 5q	Slight	45.78	11	503.59	1	503.59	1200	High
	Moderate	2100.76	13	27309.91	0.9	24578.92		
	Severe	161.70	18	2910.59	0.9	2619.53		
	Very Severe	0.00	20	0.00	0.9	0.00		
	Total	**2308.24**				**27702.04**		
Nq 5p	Negligible	0.00	10	0.00	1	0.00	1200	High
	Slight	838.39	11	9222.25	1	9222.25		
	Moderate	2764.80	13	35942.34	0.9	32348.11		
	Severe	400.31	18	7205.64	0.9	6485.07		
	Very Severe	0.43	20	8.66	0.9	7.79		
	Total	**4003.93**				**48063.22**		
Nq 5n	Negligible	0.00	10	0.00	1	0.00	1159	Medium
	Slight	1138.56	11	12524.12	1	12524.12		
	Moderate	687.17	13	8933.15	0.9	8039.84		
	Severe	128.43	18	2311.79	0.9	2080.61		
	Very Severe	0.04	20	0.82	0.9	0.74		
	Total	**1954.20**				**22645.31**		
Nq 5m	Negligible	0.00	10	0.00	1	0.00	1159	Medium
	Slight	825.22	11	9077.46	1	9077.46		
	Moderate	1041.73	13	13542.49	0.9	12188.24		
	Severe	79.16	18	1424.95	0.9	1282.46		
	Very Severe	0.00	20	0.00	0.9	0.00		
	Total	**1946.12**				**22548.16**		
Nq 5k	Negligible	0.03	10	0.26	1	0.26	1170	Medium
	Slight	805.00	11	8855.05	1	8855.05		
	Moderate	3963.87	13	51530.34	0.9	46377.31		
	Severe	130.20	18	2343.53	0.9	2109.18		
	Very Severe	0.06	20	1.13	0.9	1.02		
	Total	**4899.16**				**57342.82**		
Nq 5d	Negligible	0.00	10	0.00	1	0.00	1123	Medium
	Slight	605.38	11	6659.19	1	6659.19		
	Moderate	249.02	13	3237.30	0.9	2913.57		
	Severe	5.09	18	91.59	0.9	82.43		
	Very Severe	0.00	20	0.00	0.9	0.00		
	Total	**859.49**				**9655.19**		
Nq 5c	Negligible	0.00	10	0.00	1	0.00	1201	High
	Slight	729.77	11	8027.49	1	8027.49		
	Moderate	2648.17	13	34426.21	0.9	30983.59		
	Severe	370.31	18	6665.64	0.9	5999.08		
	Very Severe	0.39	20	7.82	0.9	7.04		
	Total	**3748.65**				**45017.20**		
Nq 5a	Negligible	0.00	10	0.00	1	0.00	1163	Medium
	Slight	1219.02	11	13409.18	1	13409.18		
	Moderate	1723.51	13	22405.69	0.9	20165.12		
	Severe	143.15	18	2576.78	0.9	2319.10		
	Very Severe	0.00	20	0.00	0.9	0.00		
	Total	**3085.69**				**35893.40**		
Nq 4u	Negligible	93.27	10	932.69	1	932.69	1099	Low
	Slight	3954.47	11	43499.12	1	43499.12		
	Moderate	97.53	13	1267.90	0.9	1141.11		
	Severe	0.00	18	0.00	0.9	0.00		
	Very Severe	0.00	20	0.00	0.9	0.00		
	Total	**4145.27**				**45572.92**		

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Nq 4t	Negligible	82.10	10	820.95	1	820.95	1100	Medium
	Slight	3742.30	11	41165.29	1	41165.29		
	Moderate	129.46	13	1683.04	0.9	1514.74		
	Severe	0.00	18	0.00	0.9	0.00		
	Very Severe	0.00	20	0.00	0.9	0.00		
	Total	**3953.86**				**43500.98**		
Nq 4s	Negligible	1.60	10	15.99	1	15.99	1155	Medium
	Slight	1104.96	11	12154.53	1	12154.53		
	Moderate	1609.38	13	20921.96	0.9	18829.77		
	Severe	79.71	18	1434.84	0.9	1291.36		
	Very Severe	0.07	20	1.47	0.9	1.32		
	Total	**2795.73**				**32292.97**		
Nq 4r	Negligible	29.54	10	295.44	1	295.44	1125	Medium
	Slight	2624.75	11	28872.23	1	28872.23		
	Moderate	818.82	13	10644.68	0.9	9580.21		
	Severe	65.71	18	1182.80	0.9	1064.52		
	Very Severe	0.00	20	0.00	0.9	0.00		
	Total	**3538.83**				**39812.41**		
Nq 4q	Negligible	0.00	10	0.00	1	0.00	1214	High
	Slight	155.30	11	1708.33	1	1708.33		
	Moderate	2413.95	13	31381.41	0.9	28243.26		
	Severe	303.22	18	5458.05	0.9	4912.24		
	Very Severe	0.00	20	0.00	0.9	0.00		
	Total	**2872.48**				**34863.84**		
Nq 4p	Negligible	0.00	10	0.00	1	0.00	1231	High
	Slight	695.28	11	7648.11	1	7648.11		
	Moderate	1955.64	13	25423.38	0.9	22881.04		
	Severe	538.86	18	9699.43	0.9	8729.49		
	Very Severe	0.66	20	13.21	0.9	11.89		
	Total	**3190.45**				**39270.53**		
Nq 4n	Negligible	0.00	10	0.00	1	0.00	1233	High
	Slight	488.02	11	5368.18	1	5368.18		
	Moderate	1772.69	13	23044.93	0.9	20740.44		
	Severe	454.27	18	8176.93	0.9	7359.24		
	Very Severe	1.09	20	21.73	0.9	19.55		
	Total	**2716.06**				**33487.41**		
Nq 4m	Negligible	0.00	10	0.00	1	0.00	1236	High
	Slight	216.58	11	2382.34	1	2382.34		
	Moderate	2277.70	13	29610.12	0.9	26649.10		
	Severe	471.11	18	8480.05	0.9	7632.05		
	Very Severe	0.00	20	0.00	0.9	0.00		
	Total	**2965.39**				**36663.49**		
Nq 4k	Negligible	0.00	10	0.00	1	0.00	1205	High
	Slight	145.90	11	1604.86	1	1604.86		
	Moderate	1597.42	13	20766.49	0.9	18689.84		
	Severe	173.38	18	3120.80	0.9	2808.72		
	Very Severe	0.00	20	0.00	0.9	0.00		
	Total	**1916.70**				**23103.42**		
Nq 4j	Negligible	0.00	10	0.00	1	0.00	1210	High
	Slight	132.82	11	1461.04	1	1461.04		
	Moderate	777.27	13	10104.56	0.9	9094.11		
	Severe	110.33	18	1985.99	0.9	1787.39		
	Very Severe	0.00	20	0.00	0.9	0.00		
	Total	**1020.43**				**12342.54**		

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Nq 4h	Negligible	0.00	10	0.00	1	0.00	1219	High
	Slight	27.29	11	300.14	1	300.14		
	Moderate	320.06	13	4160.77	0.9	3744.70		
	Severe	47.38	18	852.78	0.9	767.51		
	Very Severe	0.00	20	0.00	0.9	0.00		
	Total	**394.72**				**4812.35**		
Nq 3f	Negligible	0.00	10	0.00	1	0.00	1276	High
	Slight	46.54	11	511.90	1	511.90		
	Moderate	706.65	13	9186.49	0.9	8267.84		
	Severe	241.82	18	4352.77	0.9	3917.50		
	Very Severe	0.00	20	0.00	0.9	0.00		
	Total	**995.01**				**12697.24**		
Nq 5h	Negligible	0.00	10	0.00	1	0.00	1120	Medium
	Slight	436.87	11	4805.59	1	4805.59		
	Moderate	175.71	13	2284.23	0.9	2055.80		
	Severe	0.37	18	6.66	0.9	5.99		
	Very Severe	0.00	20	0.00	0.9	0.00		
	Total	**612.95**				**6867.39**		
Nq 5j	Negligible	0.00	10	0.00	1	0.00	1131	Medium
	Slight	2138.10	11	23519.12	1	23519.12		
	Moderate	1058.06	13	13754.82	0.9	12379.34		
	Severe	53.27	18	958.90	0.9	863.01		
	Very Severe	0.00	20	0.00	0.9	0.00		
	Total	**3249.44**				**36761.47**		

Table 2.7(b) : Sediment Yield Index and Prioritization as per Erosion Intensity for Morand Catchment-Hoshangabad District

Watershed	Erosion Intensity Class	Area (Ha)	Weightage	Weightage x Area	DR	Gross Silt (5 x 6)	SYI	Priority
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Nq 5j	Negligible	0.49	10	4.85	1	4.85	1151	Medium
	Slight	609.78	11	6707.59	1	6707.59		
	Moderate	866.19	13	11260.41	0.9	10134.37		
	Severe	31.05	18	558.82	0.9	502.94		
	Very Severe	0.00	20	0.00	0.9	0.00		
	Total	**1507.50**				**17349.75**		
Nq 5h	Negligible	15.90	10	159.00	1	159.00	1134	Medium
	Slight	1305.73	11	14363.07	1	14363.07		
	Moderate	637.32	13	8285.11	0.9	7456.60		
	Severe	47.58	18	856.43	0.9	770.79		
	Very Severe	0.00	20	0.00	0.9	0.00		
	Total	**2006.53**				**22749.47**		
Nq 5g	Negligible	27.77	10	277.72	1	277.72	1148	Medium
	Slight	1480.47	11	16285.21	1	16285.21		
	Moderate	1667.24	13	21674.14	0.9	19506.72		
	Severe	79.61	18	1432.91	0.9	1289.62		
	Very Severe	0.00	20	0.00	0.9	0.00		
	Total	**3255.09**				**37359.28**		
Nq 5f	Negligible	0.43	10	4.25	1	4.25	1152	Medium
	Slight	980.50	11	10785.52	1	10785.52		
	Moderate	1337.43	13	17386.55	0.9	15647.90		
	Severe	55.14	18	992.58	0.9	893.32		
	Very Severe	0.00	20	0.00	0.9	0.00		
	Total	**2373.50**				**27330.99**		
Nq 5d	Negligible	2.14	10	21.43	1	21.43	1099	Low
	Slight	199.59	11	2195.49	1	2195.49		
	Moderate	0.00	13	0.00	0.9	0.00		
	Severe	0.00	18	0.00	0.9	0.00		
	Very Severe	0.00	20	0.00	0.9	0.00		
	Total	**201.73**				**2216.93**		
Nq 5b	Negligible	0.01	10	0.14	1	0.14	1145	Medium
	Slight	834.12	11	9175.37	1	9175.37		
	Moderate	744.66	13	9680.62	0.9	8712.56		
	Severe	40.65	18	731.63	0.9	658.46		
	Very Severe	0.00	20	0.00	0.9	0.00		
	Total	**1619.45**				**18546.53**		
Nq 5a	Negligible	0.00	10	0.00	1	0.00	1129	Medium
	Slight	412.14	11	4533.50	1	4533.50		
	Moderate	187.81	13	2441.49	0.9	2197.34		
	Severe	8.24	18	148.23	0.9	133.41		
	Very Severe	0.00	20	0.00	0.9	0.00		
	Total	**608.18**				**6864.26**		

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Nq 4k	Negligible	0.00	10	0.00	1	0.00	1187	Medium
	Slight	25.47	11	280.16	1	280.16		
	Moderate	175.91	13	2286.87	0.9	2058.19		
	Severe	12.01	18	216.16	0.9	194.54		
	Very Severe	0.00	20	0.00	0.9	0.00		
	Total	**213.39**				**2532.89**		
Nq 4h	Negligible	0.00	10	0.00	1	0.00	1202	High
	Slight	333.96	11	3673.54	1	3673.54		
	Moderate	1812.40	13	23561.20	0.9	21205.08		
	Severe	220.07	18	3961.20	0.9	3565.08		
	Very Severe	0.00	20	0.00	0.9	0.00		
	Total	**2366.42**				**28443.69**		
Nq 4g	Negligible	0.00	10	0.00	1	0.00	1166	Medium
	Slight	486.39	11	5350.33	1	5350.33		
	Moderate	1152.33	13	14980.25	0.9	13482.22		
	Severe	59.34	18	1068.04	0.9	961.23		
	Very Severe	0.00	20	0.00	0.9	0.00		
	Total	**1698.06**				**19793.79**		
Nq 4f	Negligible	0.00	10	0.00	1	0.00	1119	Medium
	Slight	112.95	11	1242.47	1	1242.47		
	Moderate	38.59	13	501.71	0.9	451.54		
	Severe	0.45	18	8.09	0.9	7.28		
	Very Severe	0.00	20	0.00	0.9	0.00		
	Total	**151.99**				**1701.29**		

Table 2.7(c) : Sediment Yield Index and Prioritization as per Erosion Intensity for Ganjal Catchment-Betul District

Watershed	Erosion Intensity Class	Area (Ha)	Weightage	Weightage x Area	DR	Gross Silt (5 x 6)	SYI	Priority
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Nq 3n	Negligible	0.00	10	0.00	1	0.00	1331	Very High
	Slight	4.71	11	51.86	1	51.86		
	Moderate	234.49	13	3048.38	0.9	2743.54		
	Severe	133.91	18	2410.38	0.9	2169.34		
	Very Severe	0.12	20	2.46	0.9	2.22		
	Total	**373.24**				**4966.97**		
Nq 3p	Negligible	0.17	10	1.65	1	1.65	1191	Medium
	Slight	348.53	11	3833.88	1	3833.88		
	Moderate	853.90	13	11100.68	0.9	9990.61		
	Severe	115.94	18	2086.95	0.9	1878.26		
	Very Severe	0.00	20	0.00	0.9	0.00		
	Total	**1318.54**				**15704.39**		
Nq 3r	Negligible	49.64	10	496.39	1	496.39	1098	Low
	Slight	2848.93	11	31338.20	1	31338.20		
	Moderate	0.04	13	0.54	0.9	0.48		
	Severe	0.42	18	7.49	0.9	6.74		
	Very Severe	0.00	20	0.00	0.9	0.00		
	Total	**2899.02**				**31841.81**		
Nq 3v	Negligible	0.00	10	0.00	1	0.00	1119	Medium
	Slight	11.45	11	125.99	1	125.99		
	Moderate	3.77	13	49.04	0.9	44.13		
	Severe	0.05	18	0.90	0.9	0.81		
	Very Severe		20	0.00	0.9	0.00		
	Total	**15.28**				**170.94**		
Nq 3q	Negligible	0.68	10	6.78	1	6.78	1123	Medium
	Slight	343.86	11	3782.42	1	3782.42		
	Moderate	144.55	13	1879.12	0.9	1691.21		
	Severe	2.82	18	50.82	0.9	45.74		
	Very Severe	0.00	20	0.00	0.9	0.00		
	Total	**491.91**				**5526.14**		
Nq 3w	Negligible	0.00	10	0.00	1	0.00	1120	Medium
	Slight	684.04	11	7524.43	1	7524.43		
	Moderate	231.16	13	3005.04	0.9	2704.54		
	Severe	3.48	18	62.65	0.9	56.39		
	Very Severe	0.00	20	0.00	0.9	0.00		
	Total	**918.68**				**10285.35**		
Nq 3x	Negligible	131.78	10	1317.83	1	1317.83	1095	Low
	Slight	749.33	11	8242.67	1	8242.67		
	Moderate	123.17	13	1601.21	0.9	1441.09		
	Severe	0.02	18	0.29	0.9	0.27		
	Very Severe	0.00	20	0.00	0.9	0.00		
	Total	**1004.30**				**11001.85**		

Table 2.7(d) : Sediment Yield Index and Prioritization as per Erosion Intensity for Ganjal Catchment-Harda District

Watershed	Erosion Intensity Class	Area (Ha)	Weightage	Weightage x Area	DR	Gross Silt (5 x 6)	SYI	Priority
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Nq 3k	Negligible	0.00	10	0.00	1	0.00	1161	Medium
	Slight	1428.43	11	15712.78	1	15712.78		
	Moderate	2008.42	13	26109.47	0.9	23498.52		
	Severe	148.38	18	2670.89	0.9	2403.80		
	Very Severe	0.00	20	0.00	0.9	0.00		
	Total	**3585.24**				**41615.10**		
Nq 3j	Negligible	0.00	10	0.00	1	0.00	1138	Medium
	Slight	1270.55	11	13976.07	1	13976.07		
	Moderate	719.07	13	9347.90	0.9	8413.11		
	Severe	50.66	18	911.89	0.9	820.70		
	Very Severe		20	0.00	0.9	0.00		
	Total	**2040.28**				**23209.88**		
Nq 3m	Negligible	0.00	10	0.00	1	0.00	1175	Medium
	Slight	988.59	11	10874.46	1	10874.46		
	Moderate	1564.81	13	20342.56	0.9	18308.30		
	Severe	179.95	18	3239.17	0.9	2915.25		
	Very Severe	3.21	20	64.23	0.9	57.80		
	Total	**2736.56**				**32155.82**		
Nq 3s	Negligible	0.00	10	0.00	1	0.00	1190	Medium
	Slight	1248.85	11	13737.31	1	13737.31		
	Moderate	1474.53	13	19168.92	0.9	17252.03		
	Severe	330.67	18	5951.99	0.9	5356.79		
	Very Severe	0.65	20	12.94	0.9	11.64		
	Total	**3054.69**				**36357.77**		
Nq 3v	Negligible		10	0.00	1	0.00	1147	Medium
	Slight	2312.50	11	25437.48	1	25437.48		
	Moderate	1027.22	13	13353.89	0.9	12018.50		
	Severe	181.96	18	3275.37	0.9	2947.83		
	Very Severe	0.07	20	1.41	0.9	1.26		
	Total	**3521.76**				**40405.08**		
Nq 3h	Negligible	0.00	10	0.00	1	0.00	1124	Medium
	Slight	949.95	11	10449.45	1	10449.45		
	Moderate	257.84	13	3351.91	0.9	3016.72		
	Severe	22.68	18	408.18	0.9	367.36		
	Very Severe	0.00	20	0.00	0.9	0.00		
	Total	**1230.47**				**13833.52**		
Nq 3u	Negligible	0.00	10	0.00	1	0.00	1122	Medium
	Slight	2405.53	11	26460.86	1	26460.86		
	Moderate	905.08	13	11766.02	0.9	10589.41		
	Severe	16.09	18	289.56	0.9	260.60		
	Very Severe	0.00	20	0.00	0.9	0.00		
	Total	**3326.70**				**37310.88**		
Nq 3w	Negligible	37.30	10	372.98	1	372.98	1098	Low
	Slight	1541.14	11	16952.50	1	16952.50		
	Moderate	0.70	13	9.08	0.9	8.17		
	Severe	0.04	18	0.75	0.9	0.67		
	Very Severe	0.00	20	0.00	0.9	0.00		
	Total	**1579.17**				**17334.33**		
	Negligible	236.46	10	2364.58	1	2364.58		

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Nq 3x	Slight	870.11	11	9571.18	1	9571.18	1094	Low
	Moderate	187.92	13	2442.92	0.9	2198.62		
	Severe	6.05	18	108.94	0.9	98.04		
	Very Severe	0.00	20	0.00	0.9	0.00		
	Total	**1300.53**				**14232.43**		
Nq 3r	Negligible	270.98	10	2709.81	1	2709.81	1083	Low
	Slight	678.65	11	7465.12	1	7465.12		
	Moderate	127.38	13	1655.94	0.9	1490.34		
	Severe	0.63	18	11.43	0.9	10.29		
	Very Severe	0.00	20	0.00	0.9	0.00		
	Total	**1077.64**				**11675.56**		
Nq 3q	Negligible	0.00	10	0.00	1	0.00	1121	Medium
	Slight	2331.34	11	25644.78	1	25644.78		
	Moderate	848.18	13	11026.36	0.9	9923.73		
	Severe	15.20	18	273.67	0.9	246.30		
	Very Severe	0.00	20	0.00	0.9	0.00		
	Total	**3194.73**				**35814.82**		
Nq 3t	Negligible	0.00	10	0.00	1	0.00	1122	Medium
	Slight	1321.77	11	14539.49	1	14539.49		
	Moderate	516.63	13	6716.15	0.9	6044.54		
	Severe	8.57	18	154.30	0.9	138.87		
	Very Severe	0.00	20	0.00	0.9	0.00		
	Total	**1846.97**				**20722.90**		
Nq 3n	Negligible	0.00	10	0.00	1	0.00	1241	High
	Slight	673.99	11	7413.92	1	7413.92		
	Moderate	1719.82	13	22357.63	0.9	20121.87		
	Severe	570.78	18	10274.01	0.9	9246.61		
	Very Severe	0.00	20	0.00	0.9	0.00		
	Total	**2964.59**				**36782.40**		
Nq 3p	Negligible	0.00	10	0.00	1	0.00	1218	High
	Slight	619.41	11	6813.55	1	6813.55		
	Moderate	1849.03	13	24037.38	0.9	21633.64		
	Severe	398.56	18	7174.15	0.9	6456.73		
	Very Severe	2.08	20	41.67	0.9	37.50		
	Total	**2869.09**				**34941.43**		

3. CATCHMENT AREA TREATMENT PLAN

3.1 Area Identified for Catchment Area Treatment

The Catchment Area Treatment (CAT) Plan highlights the management techniques for adoption to control erosion in the catchment area of a water resource project. The life span of a reservoir is greatly reduced due to erosion in the catchment area and deposition of sediment in the reservoir. Adequate preventive measures are thus needed for the treatment of catchment for its stabilization against future erosion.

Based on the Sediment Yield Index (SYI), sub-watersheds that require treatment measures were prioritized using the simple rule that the sub-watersheds with a higher SYI were ranked higher in priority for treatment (Refer **Table 3.1**).

Table 3.1: Area identified for Treatment

Sub Water shed	Treatment Area(Ha)	SYI
Morand Catchment		
Betul District		
Nq 5q	2308.24	1200
Nq 5p	4003.93	1200
Nq 5c	3748.65	1201
Nq 4q	2872.48	1214
Nq 4p	3190.45	1231
Nq 4n	2716.06	1233
Nq 4m	2965.39	1236
Nq 4k	1916.70	1205
Nq 4j	1020.43	1210
Nq 4h	394.72	1219
Nq 3f	995.01	1276
Hoshangabad District		
Nq 4h	2366.42	1202
Total (i)	**28498**	
Ganjal Catchment		
Betul District		
Nq 3n	373.24	1331
Harda District		
Nq 3n	2964.59	1241
Nq 3p	2869.09	1218
Total (ii)	**6207**	
Grand Total	**34705**	

Sediment yield index (SYI) has been calculated for all the 15 sub-watersheds, following the All India Soil and Land Use Survey (AISLUS) method and the sub-watersheds were accordingly prioritized for treatment. As per Operation Guidelines for Soil Conservation Works (July 2008) the treatment plan is made up for 4 Years. Priority wise ranking has given in **Table 3.2**.

Table 3.2 (i): Year wise Treatment of Sub-watersheds (Betul District)

Years	District	Sub Water shed	Priority Ranking	SYI	Treatment Area(Ha)
I	**Morand Catchment**				
	Betul	Nq 3f	1	1276	995.01
		Nq 4m	2	1236	2965.39
		Nq 4n	3	1233	2716.06
	Ganjal Catchment				
	Betul	Nq 3n	1	1331	373.24
				Total (i)	**7049.70**
II	**Morand Catchment**				
	Betul	Nq 4p	4	1231	3190.45
		Nq 4h	5	1219	394.72
		Nq 4q	6	1214	2872.48
				Total (ii)	**6457.65**
III	**Morand Catchment**				
	Betul	Nq 4j	7	1210	1020.43
		Nq 4k	8	1205	1916.70
				Total (iii)	**2937.13**
IV	**Morand Catchment**				
	Betul	Nq 5c	10	1201	3748.65
		Nq 5p	11	1200	4003.93
		Nq 5q	12	1200	2308.24
				Total (iv)	**10060.82**
				Grand Total	**26505.30**

Table 3.2 (ii): Year wise Treatment of Sub-watersheds (Harda District)

Years	District	Sub Water shed	Priority Ranking	SYI	Treatment Area(Ha)
I	**Ganjal Catchment**				
	Harda	Nq 3n	2	1241	2964.59
				Total (i)	**2964.59**
II	**Ganjal Catchment**				
	Harda	Nq 3p	3	1218	2869.09
				Total (ii)	**2869.09**
				Grand Total	**5833.68**

Table 3.2 (iii): Year wise Treatment of Sub-watersheds (Hoshangabad District)

Years	District	Sub Water shed	Priority Ranking	SYI	Treatment Area(Ha)
III	**Morand Catchment**				
	Hoshangabad	Nq 4h	9	1202	2366.42
				Total (iii)	**2366.42**
				Grand Total	**2366.42**

Around 284.98 Sq.km of area considered for treatment out of 1031.99 Sq.km of Morand catchment, which is 20% of the catchment area. And for Ganjal 62.07 sq.km considered for treatment out of 413.49 Sq.km, which is 15% of total catchment area.

The thematic maps of each sub watershed are prepared (refer **Figure 3.1 & 3.2)**, to understand the nature of erosion in a particular land-use to further plan for treatment.

3.2 Activities to be undertaken

A total catchment area of 347.05 Sq.km falls under the high & very high category of priority and hence is required for catchment area treatment. Various treatment measures, biological as well as engineering, have been proposed in the CAT Plan to manage the catchment area in an integrated manner to prevent soil erosion and maintain the ecology of the region.

3.2.1 Engineering Measures

Gully erosion is one of the concerned soil erosion in the slope and hilly areas. The gullys would be treated with the help of engineering/ mechanical as well as vegetative methods. Check dams would be constructed in some of the areas to promote growth of vegetation that will consequently lead to the stabilization of the slopes/area and prevention of further deepening of gullies and erosion. For controlling the gullys, the erosive velocities are reduced by flattening out the steep gradient of the gully. This is achieved by constructing a series of checks which transform the longitudinal gradient into a series of steps with low risers and long flat treads. Different types of check dams would be required for different conditions comprising different materials depending upon the site conditions and the easy availability of material at local level. The engineering measures adopted for Morand and Ganjal Projects area described below.

Gully Plugs

The portion where the stream begins, the structure is constructed with arranging loose boulder perpendicular to the flow of water is called gully plug. These are provided to prevent soil erosion of land and reduce the flow of water and further prevent the formation of new streams and also these are very useful in moisture conservation and reduce the scouring and desiltation of the streams.

Check Dams

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. The dry rubble stone masonry check dams are proposed. The site where DRSM check dams are to be constructed is cleared and the sides are sloped 1:1. The bed of gully is excavated for foundation to a uniform depth of 0.45 m to 0.60 m and dry stones are packed from that level. Over the foundation, DRSM super structure of check dam is constructed.

Contour Trenching

It is a simple, and a low-cost method of checking the velocity of runoff in the ridge area of any watershed. A contour trench is a trench dug along a contour line. A contour line is a line, which joins together points of the same elevation. Digging a trench along such a line increases the chances of containing runoff for a longer period of time within the trench. It is also true that if trenches were not to follow a contour, such digging could actually increase the possibility of soil erosion because there would be a rise in the velocity of runoff following an increase in the slope of the land.

The main objectives for providing contour trenching are as follows

- Slowing down the velocity of runoff
- Checking soil erosion, and
- Improving local soil moisture profile

Contour trenches are constructed in the ridge area of a watershed. Rainwater, which falls in this area, flows unchecked carrying with it eroded soil into the flatter portion of the watershed referred to as the "valley". This eroded soil gets deposited as silt in the reservoirs and ponds, thereby reducing their life. Thus, any water harvesting work undertaken in the valley will become meaningless unless appropriate measures such as contour trenching are undertaken to control runoff and soil erosion on the ridge. Contour trenches serve to collect the rainwater that falls in the ridge area. This way the soil moisture profile in the area adjacent to the trench gets improved. Along with the water, the eroded fertile topsoil also gets deposited in the trench. It is, therefore, necessary to combine trench construction with plantation.

3.2.2 Biological Measures

It is always better to undertake preventive measures than to mitigate the factors that ultimately leads to soil erosion. Such preventive measures will indirectly help to conserve soil in the long run, keeping in view the importance of integrating eco-restoration strategy with socio-economic needs of the local community wherein both ecology and economics are developed. The biological measures have been proposed for severe and very severe

erosion intensity area. The preventive measures that are suggested for the project area have been discussed below.

3.2.2.1 Afforestation

This will include raising 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.

3.2.2.2 Pasture Development

As there are degraded patches of pastures in the area, this measure will be adopted to encourage development of new and healthy pasture areas for the use of cattle rears. Under this treatment suitable species of grasses and tree fodder (such as *Hyptis suaveolens and Lantana indica)* and leguminous plant species shall be planted in the land area earmarked for this 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 pastures should be closed for seeding purpose only.

3.2.2.3 Vegetative Hedges

Runoff velocity can be reduced drastically by planting vegetative hedges, bunch grass or shrubs on the contour at regular intervals. These hedges can increase the time for water to infiltrate into the soil, and facilitate sedimentation and deposition of eroded material by reducing the carrying capacity of overland flow.

3.3 Treatment of Individual Sub-Watersheds in the Catchment under the project

Areas under high and very high priority have been earmarked for treatment. The treatment is carried out separately for Forest area and Non-forest area of the catchment. The details of each sub watershed treatment measures are shown in **Table 3.3.** Under engineering measures 1216 nos. of Gully Plugs, 797 No's Check Dams and about 92 Km of Contour Trenching are proposed both in forest and non-forest area. The usable muck material may also be used for carrying out engineering work under the sub watershed wherever economically feasible and as per site requirement.

Since the measures are to be carried out by construction of individual structures such as Gully plugs, contour trenches, check dams etc., the numbers of such structures to be raised were calculated in the entire area and accordingly the financial provisions were provided. The Cost abstract for Forest area treatment and Non forest area treatment and detailed estimates are given in **Table 3.4** & **Table 3.5** respectively.

3.4 Cost of Other Components of CAT plan

Apart from the treatment works in the catchment area there are other aspects of the CAT plan to be addressed and their cost included in the overall plan. The eco-restoration works, social mobilization and awareness, documentation and publication, monitoring and evaluation are some of the integral ingredients which have to be considered and included while formulating the CAT plans as per suggestion made from time to time by MOEF and the related Forest Department.

3.4.1 Implementation of Support infrastructure cost

In order to execute the catchment area treatment plan, the forest department would be requested to establish a catchment area treatment circle or executed by forest department only. These works will be an added responsibility for the Forest Department that may not have adequate facilities and infrastructure to execute the work as suggested in the plan. Accordingly provision has been made for establishment of office and purchase of office equipments and repair of roads & footpaths in the catchment area. The cost estimate is given below,

Cost Estimate for Support Infrastructure

Sl. No	Particular	Unit	Qty	Rate (₹ in Lakhs)	Amount (₹ in Lakhs)
1	Forest Office Establishment	No	1	5.00	5.00
2	Forest Fire Fighting System	L.S		2.00	2.00
3	Road and Foot Path Development	L.S	1	4.00	4.00
4	Office Equipment and Stationery				
	(i) Purchase of Computer with complete accessories	No	2	0.50	1.00
	(ii) Purchase of printer with Xerox Machine	No	1	0.50	0.50
5	Office Vehicle	No	1	5.00	5.00
6	O&M charges for vehicles @ ₹ 75,000/Year for 4 Years	No	1x4	0.75/year	3.00
7	Administrative cost, Monitoring & Evaluation	L.S			3.00
8	Contingency	L.S			1.50
				Total	**25.00**

3.4.2 Eco-Restoration and Local Area Development

There is need to reduce the dependency of local population on the forest and other natural resources which are under severe pressure. The eco-restoration works and other activities related to area development and employment regeneration are suggested and should be carried out through community welfare committees (CWC) of local villages. These should

include the following measures, which would help in rejuvenating the ecosystems and in reducing the soil erosion in the region.

1. Plantation in the degraded patches of community/civil/ forest land.
2. Water conservation and harvesting in the villages.
3. Soil conservation measures in village areas.
4. Improvement in agricultural and horticultural practices.
5. Technical and financial support for harnessing alternate energy sources such as kerosene, LPG to reduce pressure on the forest for fuel wood.
6. Rural technology support programmes.
7. Awareness programmes for conservation of wildlife and natural resources.

The total cost estimate for these activities is proposed as **10.84 Lakhs** (1% of total cost of treatment measures).

3.4.3 Hydrologic and Sediment Monitoring

As per operation guidelines for Soil Conservation in the catchments of river valley project and flood prone river (July 2008), the provision of 2% of total cost is made for Hydrologic and sediment monitoring.

3.4.4 Monitoring and Evaluation

The regular monitoring and evaluation of annual work carried out under the plan is necessary not only from the administrative angle of exercising financial control and avoiding the tendency of spilling over the annual plan budget but required for carrying out course correction if need so arises. The effect of CAT plan by adopting biological measures are achievable in the longer run while the engineering measures may result immediate benefit. Therefore, there is need to carry out quantitative monitoring in the beginning. Therefore to meet the contigent expenditure on this count provision of ₹ 32.53 Lakhs has been made.

3.4.5 Period and Schedule of Implementation

The execution of CAT plan in the Project area would require extensive efforts on the part of executing agencies. Keeping in view the local topography and climate, it is being estimated that the entire treatable area would require at least 4 years to be completed. However, the maintenance of plantations would continue for one year and accordingly CAT plan has been prepared for 4 years. All these works would have to start with the pre-construction activities especially the studies in respect of micro-planning for each sub-watershed, which would require further detailed investigations. Based on the silt yield index of the sub-watersheds, the measures would be first taken up in sub-watershed.

3.5 Cost Estimates

The cost of all the works proposed in the CAT plan in enumerated in below Table. The total cost for Catchment area treatment plan is works out to be Rs. 6080.24 Lakhs, which includes cost towards administration during the implementation of work and cost spent over a period of four years. Present rate of plantion (with 400 plants per ha) is about Rs. 5.00 lakhs per ha, pasture land development is about Rs. Rs. 3.00 lakhs per ha. Average size of gully plugging is zrount 5 cubic meter both in forest area as well as in revenue area. Cost of each check dam in forest area is about Rs. 25000 while in revenue areas it is about Rs. 20000 per check dam. The rate of countour trenches has been taken as Rs. 130 per meter and rs. 150 per meter in forest area and revenue area respectively.

Table 3.6 (i): Cost estimate of Catchment area Treatment for Morand and Ganjal Complex Project (Betul District)

Sl. No.	Particular	Amount (Rs. in Lakhs)
I	**Treatment Works under Catchment Area**	
1	Treatment Works under Non Forest Area	
	(i) Biological Measures	135.29
	(ii) Engineering Measures	52.12
2	Treatment Works under Forest Area	
	(i) Biological Measures	4026.79
	(ii) Engineering Measures	250.80
		4465.00
II	**Work Cost**	
1	Preparation of watershed project reports (0.2% of (i))	8.9300
2	Entry point activity and constitution of watershed committee (0.2% of (i))	8.9300
3	Support to farm production system and micro enterprises (2% of (i))	89.3000
4	Natural Resource Management Activities (2% of (i))	89.300
	Sub Total (ii) =	**196.4600**
	Total (i+ii) =	**4661.4600**

Table 3.6 (ii): Cost estimate of Catchment area Treatment for Morand and Ganjal Complex Project (Hoshangabad District)

Sl. No.	Particular	Amount (in Lakhs)
I	**Treatment Works under Catchment Area**	
1	Treatment Works under Non Forest Area	
	(i) Biological Measures	30.19
	(ii) Engineering Measures	1.35
2	Treatment Works under Forest Area	
	(i) Biological Measures	217.65
	(ii) Engineering Measures	13.19
	Sub Total (i) =	**262.38**
II	**Work Cost**	
1	Preparation of watershed project reports (0.2% of (i))	0.5200
2	Entry point activity and constitution of watershed committee (0.2% of (i))	0.5200
3	Support to farm production system and micro enterprises (2% of (i))	5.2400
4	Natural Resource Management Activities (2% of (i))	5.240
	Sub Total (ii) =	**11.5200**
	Total (i+ii) =	**49.5200**

Table 3.6 (iii): Cost estimate of Catchment area Treatment for Morand and Ganjal Complex Project (Harda District)

Sl. No.	Particular	Amount (in Lakhs)
I	**Treatment Works under Catchment Area**	
1	Treatment Works under Non Forest Area	
	(i) Biological Measures	51.09
	(ii) Engineering Measures	0
2	Treatment Works under Forest Area	
	(i) Biological Measures	952
	(ii) Engineering Measures	69.9
	Sub Total (i) =	**1072.52**
II	**Work Cost**	
1	Preparation of watershed project reports (0.2% of (i))	2.1400
2	Entry point activity and constitution of watershed committee (0.2% of (i))	2.1400
3	Support to farm production system and micro enterprises (2% of (i))	21.4400
4	Natural Resource Management Activities (2% of (i))	21.440
	Sub Total (ii) =	**47.1600**
	Total (i+ii) =	**1119.6800**

Summary of Cost Estimate of Catchment Area Treatment for Morand and Ganjal Complex Project (Betul, Hoshangabad & Harda Districts)

Sl. No	Particular	Amount in Lakhs)
I	**Treatment works under catchment area**	
1	Treatment Works under Non Forest Area	
	(i) Biological Measures	216.57
	(ii) Engineering Measures	53.47
2	Treatment Works under Forest Area	
	(i) Biological Measures	5196.02
	(ii) Engineering Measures	333.84
	Sub Total (i) =	**5799.90**
II	**Work Cost**	
1	Preparation of watershed project reports (0.2% of (i))	11.59
2	Entry point activity and constitution of watershed committee (0.2% of (i))	11.59
3	Support to farm production system and micro enterprises (2% of (i))	115.98
4	Natural Resource Management Activities (2% of (i))	115.98
	Sub Total (ii) =	**255.14**
	Total (i+ii) =	**6055.04**

Table 3.3 (i) : Priority wise Treatment taken under Subwatersheds (Betul District)

Sl. No	District	Sub-Watershed	Area under treatment (Ha)	Forest area under Treatment					Non Forest area under Treatment						
				Biological Measures		Engineering Measures			Biological Measures				Engineering Measures		
				Afforestation (Ha)	Pasture Development (Ha)	Gully Plug (No's)	Check Dams (No's)	Contour Trenching (Km)	Horticulture (Ha)	Private Pasture Development (Ha)	Vegetative Recommended Treatment		Gully Plug (No's)	Check Dams (No's)	Contour Trenching (Km)
											Re-vegetative	Vegetative Hedges			
	Morand Catchment														
1	Betul	Nq 5q	2308.24	125.17	22.56	69	32	5866	44.60	332.61	110.87	221.74	22	14	2777
2		Nq 5p	4003.93	47.94	102.63	95	24	3402	73.55	948.09	316.03	632.06	47	41	3930
3		Nq 5c	3748.65	7.80	108.67	136	100	3277	-	69.71	23.24	46.47	2	8	-
4		Nq 4q	2872.48	3.58	89.65	52	54	8744	-	320.35	106.78	213.57	15	31	6667
5		Nq 4p	3190.45	12.84	157.31	107	78	10065	0.37	289.60	96.53	193.07	21	22	-
6		Nq 4n	2716.06	6.30	134.11	130	42	5023	-	99.40	33.13	66.27	9	4	-
7		Nq 4m	2965.39	4.27	139.87	101	63	4502	-	113.36	37.79	75.57	7	3	-
8		Nq 4k	1916.70	-	52.01	57	25	2506	-	269.48	89.83	179.65	17	9	-
9		Nq 4j	1020.43	0.15	33.05	43	17	803	-	179.81	59.94	119.87	7	9	-
10		Nq 4h	394.72	-	66.02	16	8	840	-	128.79	42.93	85.86	2	2	-
11		Nq 3f	995.01	-	47.38	38	27	3792	-	5.17	1.72	3.45	1	1	-
	Total		**26132.06**	**208.06**	**953.25**	**844.00**	**470.00**	**48820.00**	**118.52**	**2756.37**	**918.79**	**1837.58**	**150.00**	**144.00**	**13374.00**
	Ganjal Catchment														
12	Betul	Nq 3n	373.24	1.52	132.51	17	8	628	-	-	-	-	-	-	-
	Total		**373.24**	**1.52**	**132.51**	**17.00**	**8.00**	**628.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	Grand Total		**26505.30**	**209.59**	**1085.76**	**861.00**	**478.00**	**49448.00**	**118.52**	**2756.37**	**918.79**	**1837.58**	**150.00**	**144.00**	**13374.00**

Table 3.3 (ii) : Priority wise Treatment taken under Subwatersheds (Hoshangabad District)

Sl. No	District	Sub-Watershed	Area under treatment (Ha)	Forest area under Treatment					Non Forest area under Treatment						
				Biological Measures		Engineering Measures			Biological Measures				Engineering Measures		
				Afforestation (Ha)	Pasture Development (Ha)	Gully Plug (No's)	Check Dams (No's)	Contour Trenching (Km)	Horticulture (Ha)	Private Pasture Development (Ha)	Vegetative Recommended Treatment		Gully Plug (No's)	Check Dams (No's)	Contour Trenching (Km)
											Re-vegetative	Vegetative Hedges			
	Morand Catchment														
1	Hoshangabad	Nq 4h	2366.42	-	72.55	37	28	4334	-	394.18	131.39	262.79	6	6	-
	Total		**2366.42**	**0.00**	**72.55**	**37.00**	**28.00**	**4334.00**	**0.00**	**394.18**	**131.39**	**262.79**	**6.00**	**6.00**	**0.00**

Table 3.3 (iii) : Priority wise Treatment taken under Subwatersheds (Harda District)

Sl. No	District	Sub-Watershed	Area under treatment (Ha)	Forest area under Treatment					Non Forest area under Treatment						
				Biological Measures		Engineering Measures			Biological Measures				Engineering Measures		
				Afforestation (Ha)	Pasture Development (Ha)	Gully Plug (No's)	Check Dams (No's)	Contour Trenching (Km)	Horticulture (Ha)	Private Pasture Development (Ha)	Vegetative Recommended Treatment		Gully Plug (No's)	Check Dams (No's)	Contour Trenching (Km)
											Re-vegetative	Vegetative Hedges			
	Ganjal Catchment														
1	Harda	Nq 3n	2964.59	3.50	566.89	110	71	9170	-	147.99	49.33	98.66	-	-	-
2		Nq 3p	2869.09	15.99	384.22	52	70	15601	-	439.69	146.56	293.13	-	-	-
	Total		**5833.68**	**19.49**	**951.11**	**162.00**	**141.00**	**24771.00**	**0.00**	**587.68**	**195.89**	**391.79**	**0.00**	**0.00**	**0.00**

Table 3.4 (i) : Cost Estimates of Engineering and Biological Measres for Forest Area (Betul District)

Sl. No	District	Sub-Watershed	Forest area under Treatment									
			Biological Measures				Engineering Measures					
			Afforestation (Ha)	Cost @ Rs. 5,00,000/Ha (Rs. in lakh)	Pasture Development (Ha)	Cost @ Rs. 3,00,000/Ha (Rs. in lakh)	Gully Plug (No's)	Cost @ Rs. 1,500/No (Rs. in lakh)	Check Dams (No's)	Cost @ Rs. 25,000/No (Rs. in lakh)	Contour Trenching (m)	Cost @ Rs. 130/m (Rs. in lakh)
	Morand Catchment											
1	Betul	Nq 5q	125.17	625.85	22.56	67.68	69	1.04	32	80.00	5866	7.62
2		Nq 5p	47.94	239.70	102.63	307.89	95	1.43	24	5.04	3402	4.42
3		Nq 5c	7.80	39.00	108.67	326.01	136	2.04	100	21.00	3277	4.26
4		Nq 4q	3.58	17.90	89.65	268.95	52	0.78	54	11.34	8744	11.36
5		Nq 4p	12.84	64.20	157.31	471.93	107	1.61	78	16.38	10065	13.08
6		Nq 4n	6.30	31.50	134.11	402.33	130	1.95	42	8.82	5023	6.52
7		Nq 4m	4.27	21.35	139.87	419.61	101	1.52	63	13.23	4502	5.85
8		Nq 4k	-	-	52.01	156.03	57	0.86	25	5.25	2506	3.25
9		Nq 4j	0.15	0.75	33.05	99.15	43	0.65	17	3.57	803	1.04
10		Nq 4h	-	-	66.02	198.06	16	0.24	8	1.68	840	1.09
11		Nq 3f	-	-	47.38	142.14	38	0.57	27	5.67	3792	4.92
	Ganjal Catchment											
12	Betul	Nq 3n	1.52	7.60	39.72	119.16	17	0.26	8	1.68	628	0.81
	Total		**209.57**	**1047.85**	**992.98**	**2978.94**	**861.00**	**12.92**	**478.00**	**173.66**	**49448.00**	**64.22**
	Grand Total (Rs. in Lakhs)		**4026.79**				**250.80**					

Table 3.4 (ii) : Cost Estimates of Engineering and Biological Measres for Forest Area (Hoshangabad District)

Sl. No	District	Sub-Watershed	Forest area under Treatment									
			Biological Measures				Engineering Measures					
			Afforestation (Ha)	Cost @ Rs. 5,00,000/Ha (Rs. in lakh)	Pasture Development (Ha)	Cost @ Rs. 3,00,000/Ha (Rs. in lakh)	Gully Plug (No's)	Cost @ Rs. 1,500/No (Rs. in lakh)	Check Dams (No's)	Cost @ Rs. 25,000/No (Rs. in lakh)	Contour Trenching (m)	Cost @ Rs. 130/m (Rs. in lakh)
	Morand Catchment											
1	Hoshangabad	Nq 4h	-	-	72.55	217.65	37	0.56	28	7.00	4334	5.63
	Total		**0.00**	**0.00**	**72.55**	**217.65**	**37**	**0.56**	**28**	**7.00**	**4334.00**	**5.63**
	Grand Total (Rs. in Lakhs)		**217.65**				**13.19**					

Table 3.4 (iii) : Cost Estimates of Engineering and Biological Measres for Forest Area (Harda District)

Sl. No	District	Sub-Watershed	Forest area under Treatment									
			Biological Measures				Engineering Measures					
			Afforestation (Ha)	Cost @ Rs. 5,00,000/Ha (Rs. in lakh)	Pasture Development (Ha)	Cost @ Rs. 3,00,000/Ha (Rs. in lakh)	Gully Plug (No's)	Cost @ Rs. 1,500/No (Rs. in lakh)	Check Dams (No's)	Cost @ Rs. 25,000/No (Rs. in lakh)	Contour Trenching (m)	Cost @ Rs. 130/m (Rs. in lakh)
	Ganjal Catchment											
1	Harda	Nq 3n	3.50	17.50	170.07	510.21	110	1.65	71	17.75	9170	11.92
2		Nq 3p	15.99	79.95	114.64	343.92	52	0.78	70	17.50	15601	20.25
	Total		**19.49**	**97.45**	**284.71**	**854.13**	**162**	**2.43**	**141**	**35.25**	**24771.00**	**32.17**
	Grand Total (Rs. in Lakhs)		**951.58**				**69.85**					

Table 3.4 (iv) : Cost Estimates of Engineering and Biological Measres for Non Forest Area (Betul District)

Sl. No	District	Sub-Watershed	Non Forest area under Treatment											
			Biological Measures						Engineering Measures					
			Horticulture (Ha)	Cost @ Rs.50,000/Ha	Re-vegetative (Ha)	Cost 20000/Ha	Vegetative Hedges (Ha)	Cost @ Rs.1500/Ha	Gully Plug (No's)	Cost @ Rs. 1,500/No (Rs. in lakh)	Check Dams (No's)	Cost @ Rs. 20,000/No	Contour Trenching (Km)	Cost @ Rs.150/m
	Morand Catchment													
1	Betul	Nq 5q	44.60	22.30	110.87	22.17	221.74	3.33	22	0.33	14	2.94	2777	4.17
2		Nq 5p	73.55	26.77	316.03	63.20	632.06	9.48	47	0.71	41	8.61	3930	5.90
3		Nq 5c	-	-	23.24	4.64	46.47	0.70	2	0.03	8	1.68	-	-
4		Nq 4q	-	-	106.78	21.35	213.57	3.20	15	0.23	31	6.51	6667	10.00
5		Nq 4p	0.37	0.18	96.53	19.30	193.07	2.90	21	0.32	22	4.62	-	-
6		Nq 4n	-	-	33.13	6.62	66.27	0.99	9	0.14	4	0.84	-	-
7		Nq 4m	-	-	37.79	7.55	75.57	1.13	7	0.11	3	0.63	-	-
8		Nq 4k	-	-	89.83	17.97	179.65	2.69	17	0.26	9	1.89	-	-
9		Nq 4j	-	-	59.94	11.98	119.87	1.80	7	0.11	9	1.89	-	-
10		Nq 4h	-	-	42.93	8.58	85.86	1.29	2	0.03	2	-	-	-
11		Nq 3f	-	-	1.72	0.34	3.45	0.05	1	-	1	0.21	-	-
	Ganjal Catchment													
12	Betul	Nq 3n	-	-	-				-		-		-	-
	Total		**118.52**	**49.25**	**918.79**	**183.70**	**1837.58**	**27.56**	**150.00**	**2.24**	**144.00**	**29.82**	**13374.00**	**20.06**
	Grand Total (Rs. in Lakhs)		**135.29**						**52.12**					

Table 3.4 (v) : Cost Estimates of Engineering and Biological Measres for Non Forest Area (Hoshangabad District)

Sl. No	District	Sub-Watershed	Non Forest area under Treatment											
			Biological Measures						Engineering Measures					
			Horticulture (Ha)	Cost @ Rs.50,000/Ha	Re-vegetative (Ha)	Cost @ Rs.20000/Ha	Vegetative Hedges (Ha)	Cost @ Rs.1500/Ha	Gully Plug (No's)	Cost @ Rs. 1,500/No (Rs. in lakh)	Check Dams (No's)	Cost @ Rs. 20,000/No	Contour Trenching (Km)	Cost @ Rs.150/m
	Morand Catchment													
1	Hoshangabad	Nq 4h	-	-	131.39	26.25	262.79	3.94	6	0.09	6	1.26	-	-
	Total		**0.00**	**0.00**	**131.39**	**26.25**	**262.79**	**3.94**	**6.00**	**0.09**	**6.00**	**1.26**	**0.00**	**0.00**
	Grand Total (Rs. in Lakhs)		**30.19**						**1.35**					

Table 3.4 (vi) : Cost Estimates of Engineering and Biological Measres for Non Forest Area (Harda District)

Sl. No	District	Sub-Watershed	Non Forest area under Treatment											
			Biological Measures						Engineering Measures					
			Horticulture (Ha)	Cost @ 50000/Ha	Re-vegetative (Ha)	Cost @ Rs.20000/Ha	Vegetative Hedges (Ha)	Cost @ Rs.1500/Ha	Gully Plug (No's)	Cost @ Rs. 1,500/No (Rs. in lakh)	Check Dams (No's)	Cost @ Rs. 20,000/No	Contour Trenching (Km)	Cost @ Rs.150/m
	Ganjal Catchment													
1	Harda	Nq 3n	-	-	49.33	15.90	98.66	1.48		0.00		0.00	-	-
2		Nq 3p	-	-	146.56	29.31	293.13	4.40		0.00		0.00	-	-
	Total		**0.00**	**0.00**	**195.89**	**45.21**	**391.79**	**5.88**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	Grand Total (Rs. in Lakhs)		**51.09**						**0.00**					