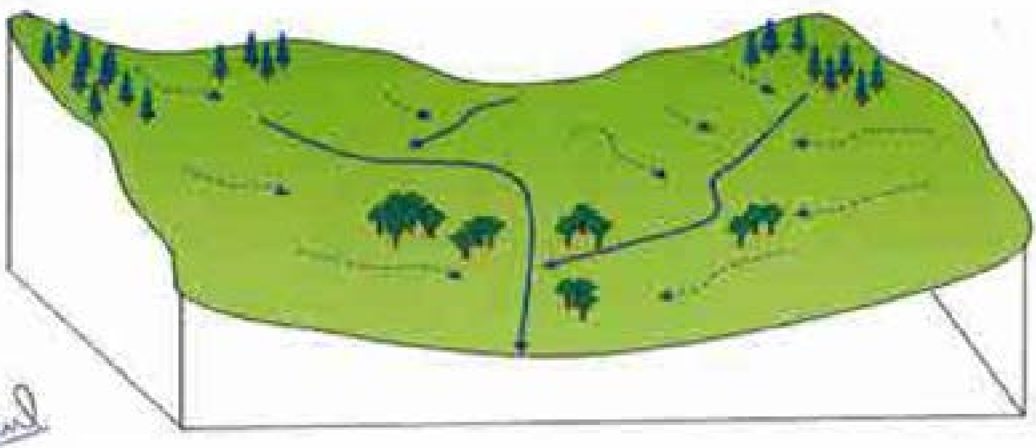
SOIL MOISTURE CONSERVATION REPORT

Gondulpara Coal Mine

(Village: Gondulpara, North Karanpura Coalfields, Tehsil: Barkagaon, District: Hazaribagh, Jharkhand)

Project Proponent:

M/s. Adani Enterprises Ltd. (AEL)



Prepared by

VARDAN ENVIRONET

Plot 82-A, IMT Manesar, Sector-5, Gurugram (Haryana)

E-Mail: hydro@vardan.co.in

Contact: 0124-4343750, 09899651342

March-2023

TABLE OF CONTENTS

AFROZ
VICE PRESIDENT

LIST OF TABLES

LIST OF FIGURES

AFT... VICE PRESIDENT ...ULDIH COAL PROJECT ...TERPRISES LIMITED

Executive Summary

- Administratively, the coalfield falls in the districts of Hazaribagh, Chatra, Latehar, Ranchi Jharkhand State. It is elliptical in shape having axes of 64 Km in east-west direction and 32 Km in north-south direction. The North Karanpura Coalfield forms a prominent east west trending valley between Hazaribagh plateau in the north and Ranchi plateau in the south. The north and south Karanpura coalfields are separated by an east-west elongated metamorphic patch in the south-east (ASWA PAHAR).
- The Gondulpara block represents a rugged topography with hills in the eastern part and river valley toward west and north. A hill range traverses along the eastern and southeastern parts covering substantial area of the block. Hills are steep with maximum elevation of over 516m. southeast of borehole CMKB-144. The difference between foot hills and the highest peak is about 60m. The minimum elevation along the Badmahi river is about 417m.The Badmahi River, flowing southerly through the block in the northern and western parts controls the main drainage of the area.
- The Gondulpara Coal block covering an area of total 4.10 sq.km area and it is bounded by 23°50'20 - 23°51'20"N and Longitude 85°18'20" - 85°20'15"E. The block is located at about 35 km from Hazaribagh town, This area is a part of Survey of India Topo Sheet No.73 E/5 (on R.F.150000).
- The study Area's climate is classified as warm and temperate.
- The outlet of the catchment lies on Badamahi river, left tributary of Damodar River in India.
- Cost estimate for Biological Conservation Plan which include green belt and sowing of seeds will cost around Rs. 83,20,000
- Cost estimate for Engineering Conservation Plan which include Catch pits and Check dams or toe walls will cost around Rs. 21,42,000
- The estimated cost of implementation of Soil Moisture Conservation plan is Rs. 1.26 Cr.

[illegible]

about 120 km away.

Land Requirement:

Table 1: Land Requirement

SL. No.	Land Type	Existing/Pre-Mining Use	Area (Ha)
1.	Forest Land	Rev. and Protected Forest	219.80
2.	Tenancy Land	Agriculture, Township and Road	223.22
3.	Govt. Land	Grazing, Barren, Township and Others	70.16
		Total	513.18

2.0 Need of Soil Moisture Conservation

It is well known that catchments of rivers are subject to sedimentation. Sedimentation encompasses the sequential processes of sediment erosion, entrainment, transportation, deposition, and compaction. The constant erosion and sedimentation in the reservoir reduce its capacity, affecting water availability for the designated use. When eroded sediment from the catchment is deposited in streambeds and banks, it braids the river reach. The removal of top fertile soil from the catchment has a negative impact on the region's land productivity. As a result, a well-designed Soil Moisture Conservation Plan is required to mitigate the aforementioned negative effects of soil erosion. Soil erosion is defined as the detachment, transportation, and deposition of soil particles from one location to another via a transporting agent such as air, water, or animals. Rainfall intensity and runoff, slope gradient and length, soil erodibility, and vegetation cover all have a significant impact on soil erosion (land use pattern). As a result, research into erosion and sediment yield from catchments is critical.

The Soil Moisture Conservation Plan emphasizes management techniques for controlling erosion in the catchment area. An effective conservation plan is essential for making the project environmentally friendly and sustainable. As a result, a well-designed Soil Moisture Conservation Plan is required to mitigate the aforementioned negative process of soil erosion.

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

Soil erosion can be defined as detachment, transportation and deposition of soil particles from one place to other by means of transporting agent like air, water or animals. Soil erosion is mainly affected by rainfall intensity and runoff, slope gradient and length, soil erodibility and

[illegible]

- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]

[illegible]

i. [illegible]
ii. [illegible]
iii. [illegible]
iv. [illegible]
v. [illegible]

[illegible]

[illegible]

[illegible]

[illegible]

Table 2: Land Degradation and Restoration Schedule

[illegible] Ha)									
[illegible]		[illegible]				[illegible]			
[illegible] period)		[illegible]	[illegible] (Extn [illegible]	Infra/[illegible]	[illegible]	[illegible]	Dump (Extn +Top Soil)	[illegible]	Total
[illegible] [year	2025				[illegible]	[illegible]	0	[illegible]	[illegible]
Y-1	2025-26	[illegible]	[illegible]	29.82	77.8900	[illegible]	[illegible]	0	[illegible]
Y-3	[illegible]	[illegible]	[illegible]	[illegible]	171.1700	[illegible]	47.536	[illegible]	61.2880
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	220.7020	[illegible]	[illegible]	17.19	128.4990
[illegible]	2034-35	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	97.013	[illegible]	[illegible]
[illegible]	2039-40	[illegible]	129.35	57.82	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	2044-45	[illegible]	[illegible]	[illegible]	[illegible]	130.89	129.35	[illegible]	[illegible]
[illegible]	2049-50	270.38	129.35	57.82	457.5500	[illegible]	[illegible]	[illegible]	286.6400
[illegible]	2054-55	326.01	129.35	57.82	[illegible]	[illegible]	129.35	[illegible]	[illegible]
[illegible]	2056-57	326.01	[illegible]	57.82	[illegible]	166.89	129.35	[illegible]	[illegible]
Post Closure									
Y-35	[illegible]	326.01	[illegible]	57.82	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Source: Mine Plan

[illegible]

[illegible]

[illegible]		[illegible]			[illegible]		[illegible] Backfilling		[illegible]	
[illegible]		[illegible]			[illegible]		[illegible]		[illegible]	
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	2021									
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	1.41	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	90.01	[illegible]	52.97	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Y-32	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]										
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	220.722		[illegible]

[illegible]

AFROZ
VICE PRESIDENT
COAL PROJECT

2.4. Top Soil Management

Table 4: Top Soil Management

Top Soil Management- (Including Action plan for Top Soil management) (Tentative) (in mm³)							
Year/Stage		Top Soil Removal Plan	Top Soil Used				
(Life of the mine plus post closure period)			Spreading Over Embankment	Spreading Over Backfill area	Spreading Over External OB Dump area	Used in Green Belt area	Total Utilized
Up to Base year	2021						
Y-1	2025-26	0.12	0	-	-	-	
Y-3	2027-28	0.45	0	-	-	-	
Y-5	2029-30	0.65	0	-	-	-	
Y-10	2034-35	1.41	0.11	0	1.30	-	1.41
Y-15	2039-40	1.74	0.11	0.33	1.30	-	1.74
Y-20	2044-45	2.21	0.11	0.80	1.30	-	2.21
Y-25	2049-50	2.70	0.11	1.29	1.30	-	2.70
Y-30	2054-55	3.26	0.11	1.85	1.30	-	3.26
Y-32	2056-57	3.26	0.11	1.85	1.30	-	3.26
Y-30	2050-51	-	-	-	-	-	-
Y-32	2052-53	-	-	-	-	-	-
Post Closure							
Y-35	2055-56	3.26	0.11	1.85	1.30		3.26

3.0 Project Description

3.1 Study Area Details

The study area is located in the Hazaribagh District of Jharkhand, with latitudes ranging from 23° 49' 53.04" to 23° 56' 6.72" N and longitudes ranging from 85° 16' 10.2" to 85° 24' 27" E (Shown in **Figure 1**).

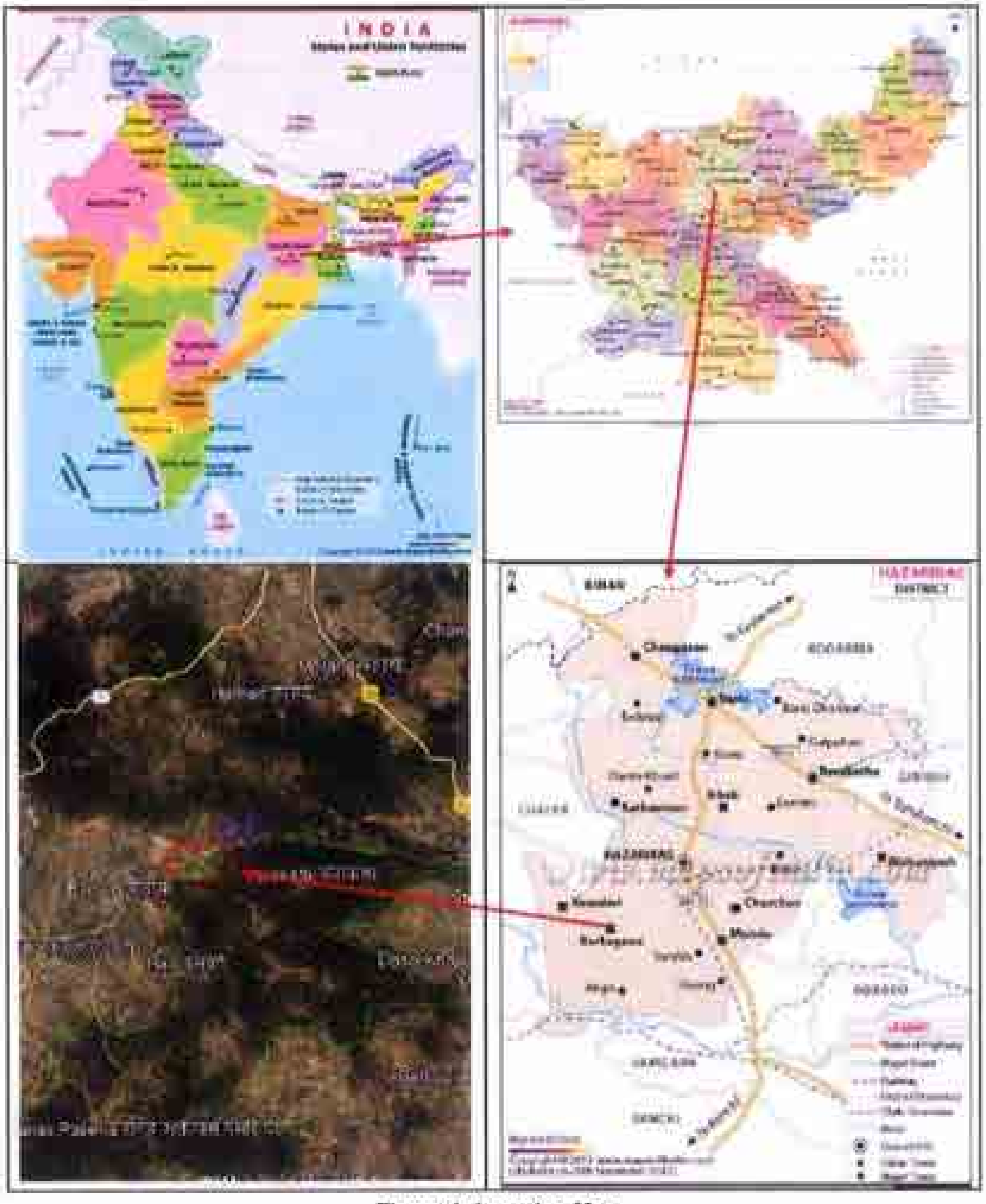


Figure 1: Location Map

AFROZ

3.2 Climate and Rainfall

The study Area's climate is classified as warm and temperate. The summers are much rainier than the winters in Hazaribagh district. This location is classified as Cwa by Köppen and Geiger. The average temperature in Hazaribagh is 22.9 °C. The least amount of rainfall occurs in December. The average in this month is 8 mm. The greatest amount of precipitation occurs in July, with an average of 328 mm. The temperatures are highest on average in May, at around 29.7 °C. The lowest average temperatures in the year occur in January, when it is around 14.8 °C. The variation in the precipitation between the driest and wettest months is 320 mm. The variation in temperatures throughout the year is 14.9 °C.

The month with the highest relative humidity is August (86.34 %). The month with the lowest relative humidity is April (32.24 %).

The month with the highest number of rainy days is July (26.23 days). The month with the lowest number of rainy days is December (1.40 days).

Table 5: Meteorological Information of Study Area

	Jan	Feb	Mar	April	May	Jun	July	Aug	Sept	Oct	Nov	Dec
Avg. Temperature °C (°F)	14.8 °C	18.6 °C	23.4 °C	28.2 °C	29.7 °C	28.1 °C	25.4 °C	25 °C	24.6 °C	22.8 °C	19 °C	15.6 °C
	(58.6) °F	(65.4) °F	(74.1) °F	(82.8) °F	(85.4) °F	(82.5) °F	(77.7) °F	(77.1) °F	(76.3) °F	(72.8) °F	(66.1) °F	(59.9) °F
Min. Temperature °C (°F)	8.9 °C	12.3 °C	16.5 °C	20.8 °C	23.4 °C	24.3 °C	23.2 °C	22.8 °C	22.1 °C	18.7 °C	13.8 °C	9.9 °C
	(48) °F	(54.2) °F	(61.7) °F	(69.4) °F	(74.2) °F	(75.8) °F	(73.8) °F	(73.1) °F	(71.8) °F	(55.7) °F	(56.9) °F	(49.8) °F
Max. Temperature °C (°F)	21.2 °C	25.1 °C	30.2 °C	35.3 °C	36 °C	32.6 °C	28.5 °C	28.2 °C	28 °C	27.1 °C	24.6 °C	21.7 °C
	(70.1) °F	(77.2) °F	(86.4) °F	(95.6) °F	(96.9) °F	(90.6) °F	(83.3) °F	(82.7) °F	(82.4) °F	(80.6) °F	(76.3) °F	(71) °F
Precipitation / Rainfall mm	17	19	18	17	47	228	328	283	201	77	12	8
Humidity (%)	63%	36%	40%	32%	45%	65%	85%	86%	83%	76%	67%	66%
Rainy days (d)	2	2	3	3	7	14	20	20	17	8	1	1
avg. Sun hours (hours)	8.9	9.6	10.7	11.3	11.5	8.8	7	6.4	7	8.3	9	8.8

In Hazaribagh, the month with the most daily hours of sunshine is May with an average of 11.49 hours of sunshine. In total there are 356.25 hours of sunshine throughout May. The month with the fewest daily hours of sunshine in Hazaribagh is January with an average of 9.02 hours of sunshine a day. In total there are 270.71 hours of sunshine in January. Around 3294.82 hours of sunshine are counted in Hazaribagh throughout the year. On average there are 108.41 hours of sunshine per month. (Source: https://en.climate-data.org/)

The meteorological data available on IMD website for Ranchi is also collected and furnished as follows;

Table 6: Meteorological Information of Ranchi (1971-2000), IMD

Month	Atmospheric Pressure (mb)		Temperature (°C)		Relative Humidity (%)		Rainfall (mm)
	8:30	17:30	Mean Max.	Mean Min.	8:30	17:30	
January	943.1	939.9	27.3	5.8	65	45	21.8
February	941.7	938.4	30.5	7.5	59	40	24.4
March	939.7	936	35.9	11.8	43	29	22.8
April	937	932.8	39.1	17.1	42	28	27.3
May	933.2	929.6	41.2	19.2	51	37	59.6
June	929.3	926.4	39.2	20.6	72	63	250.9
July	929.3	927	33.1	21	87	82	341.9
August	930	927.7	31.4	20.8	88	83	341.3
September	934.3	931.6	31.5	19.8	83	78	266.2
October	939.1	936.1	31.3	15.1	71	63	80.2
November	942.2	939.2	28.8	10.5	62	52	14.4
December	943.4	940.6	26.2	6.4	63	48	11.9
Range/ Total	**926.4 - 943.4**		**5.8 - 41.2**		**28 - 88**		**1462.7**

Monthly Rainfall Data of Ranchi (2000-2020), IMD													
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Rainfall
2000	0	1	0	13	33.3	207.4	252.9	140.7	180.4	3.3	0	0	**832**
2001	0.5	2	38	5.8	41.9	185.6	333.1	163.1	7.9	74.4	0	0	**852.1**
2002	27.2	6.3	27.5	4.1	15.3	60.9	236.4	227.1	352.2	28.7	0	1	**986.7**
2003	5.4	2.5	11.7	33.3	0	89.4	128.8	267.9	168.1	147.1	0	9.9	**864.1**
2004	7.9	0	0	21.8	27.5	231.5	178.7	503.1	132.4	0	0	0	**1102.9**
2005	22.8	49.6	10.7	2	0.3	111.3	308.2	101.2	108.3	19.8	7.1	0	**741.3**
2006	0	0	44.5	0.3	24.1	205.1	451.9	372.9	313.2	22.9	3.6	0	**1438.5**
2007	0	65.2	37.4	30	29.2	40.5	376.5	211.7	264.1	6.2	1.3	0	**1052.1**
2008	11.2	12.7	0	14.5	24.1	385	580.1	190.7	186.1	15.6	1	0	**1421**
2009	10.6	0	0.3	3.6	91.9	77.5	196.9	249.9	280.1	67.9	0	0	**978.7**
2010	0	11.4	0	17.5	44.9	54.7	177.5	62.8	109.8	45.3	7.6	30.2	**561.7**
2011	3	1	1.6	2	53.6	339.5	180	461.7	386.5	9.1	0	0	**1438**
2012	75.2	0.5	0	21.4	16	87.6	232.6	374.2	248.9	29.9	61.7	10.9	**1158.9**
2013	0	25.9	17.4	29	13.9	248.9	237.9	193.8	127.6	402.7	0	0	**1297.1**
2014	3	34.8	56.1	0	15.9	176.9	275.8	137.5	159	82.5	0	0	**941.5**
2015	39.1	0	11.2	14.3	84.2	257.4	358.9	188.6	40.6	23.9	0	0.3	**1018.5**
2016	5.1	0	25.2	0	37.6	27.7	279.5	254.1	83.6	5.6	0	0	**718.4**
2017	0.6	50	1.6	2	2	172.5	668.3	247.4	118.1	71.4	2.3	0	**1336.1**
2018	0	10.4	1.5	2.5	43.8	79.1	343.2	153.7	241.2	26.9	0	68.8	**971.1**
2019	2	30	42.2	36	22	100.2	101.8	252.5	216	132.1	0	22.1	**956.9**
2020	45.7	4	69.1	15	19.3	238.3	166.3	433.2	171.4	5.6	2	0	**1189.9**
Average	**12.4**	**14.2**	**19.8**	**12.8**	**30.5**	**160.8**	**288.8**	**247.0**	**185.5**	**58.1**	**4.1**	**6.8**	**1040.8**

3.3 Geomorphology and Drainage of Study Area

The land forms / geomorphic units and structures such as fractures, fissures and faults have been interpreted from the recent satellite image. All the landform / geomorphic units and structures occurring in the study area are mapped. The district consists of Plateaus, residual hills and intermontane valleys. The lower plateau is situated all around surrounding the central plateau. The height of the lower plateau averages to 450m. The Damodar valley region is situated in the southern part and extends through the blocks of Keredari, Barkagaon, Patratu, Ramgarh and Gola blocks. The geomorphology and structures of the area plays the vital role in identifying the ground water potential zones. The majority of the study area covering 10 Km radius from the Mine boundary underlined by Pediplain and Moderately dissected hills.

The district is drained by two major rivers, the Damodar and the Barakar river with a few minor tributaries like Naikari, Behera, Kusum, Bokaro, Mohana and Kumari. The Naikari with drainage from the south and further down the Behera joins the Damodar River.

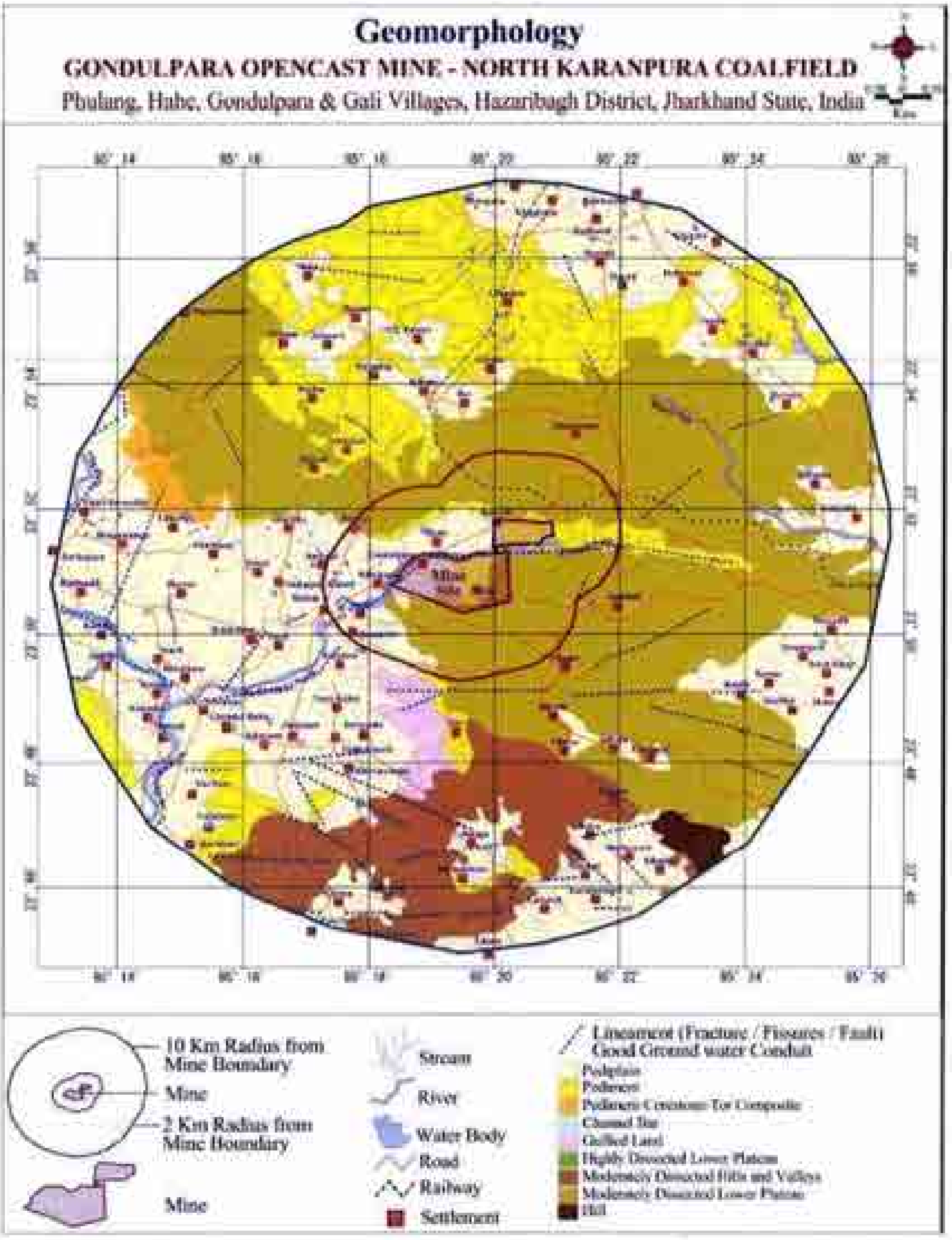


Figure 2: Geomorphological Map of Study Area

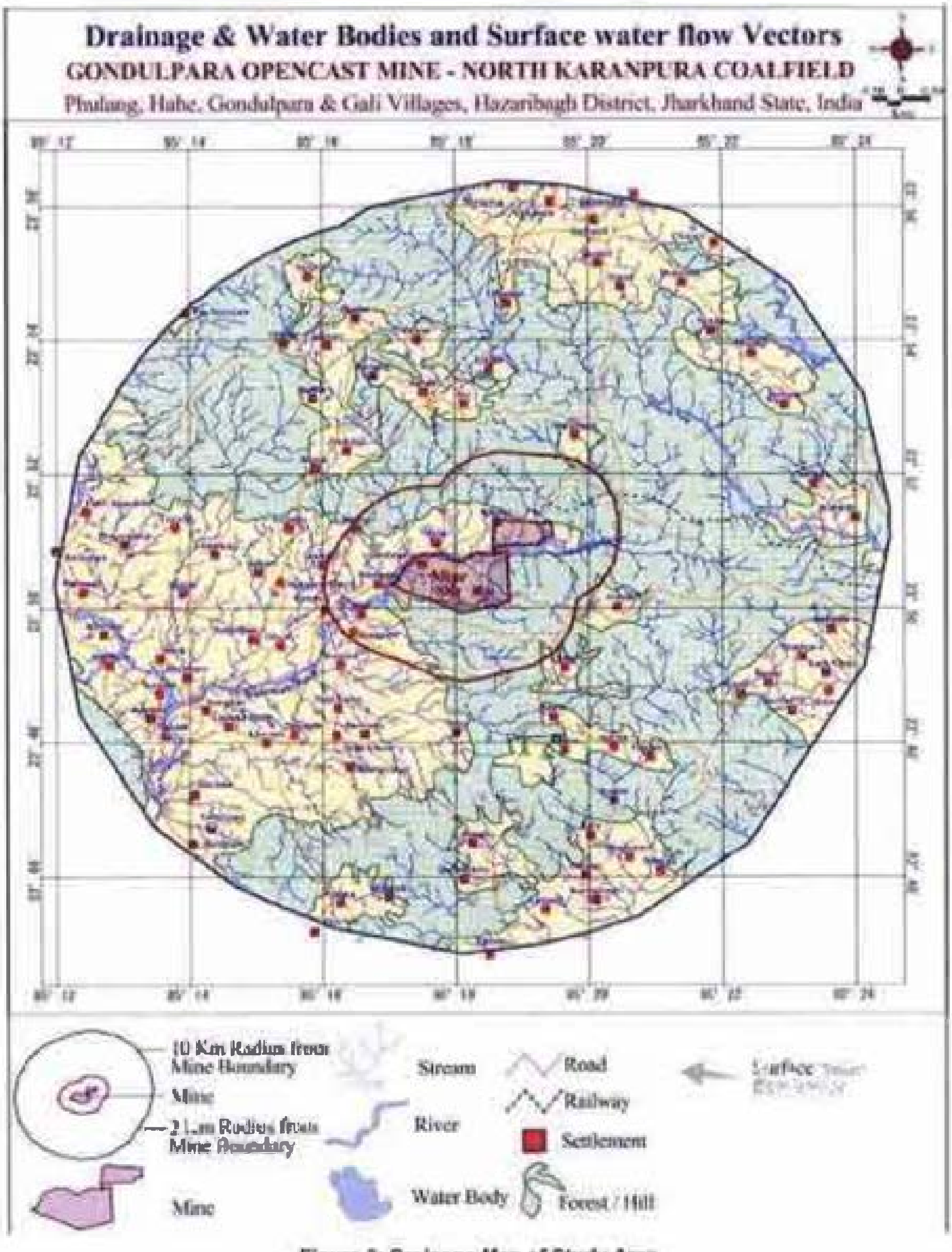


Figure 3: Drainage Map of Study Area

AFROZ
VICE PRESIDENT
GONDULPARA COAL PROJECT
ADANI ENTERPRISES LIMITED

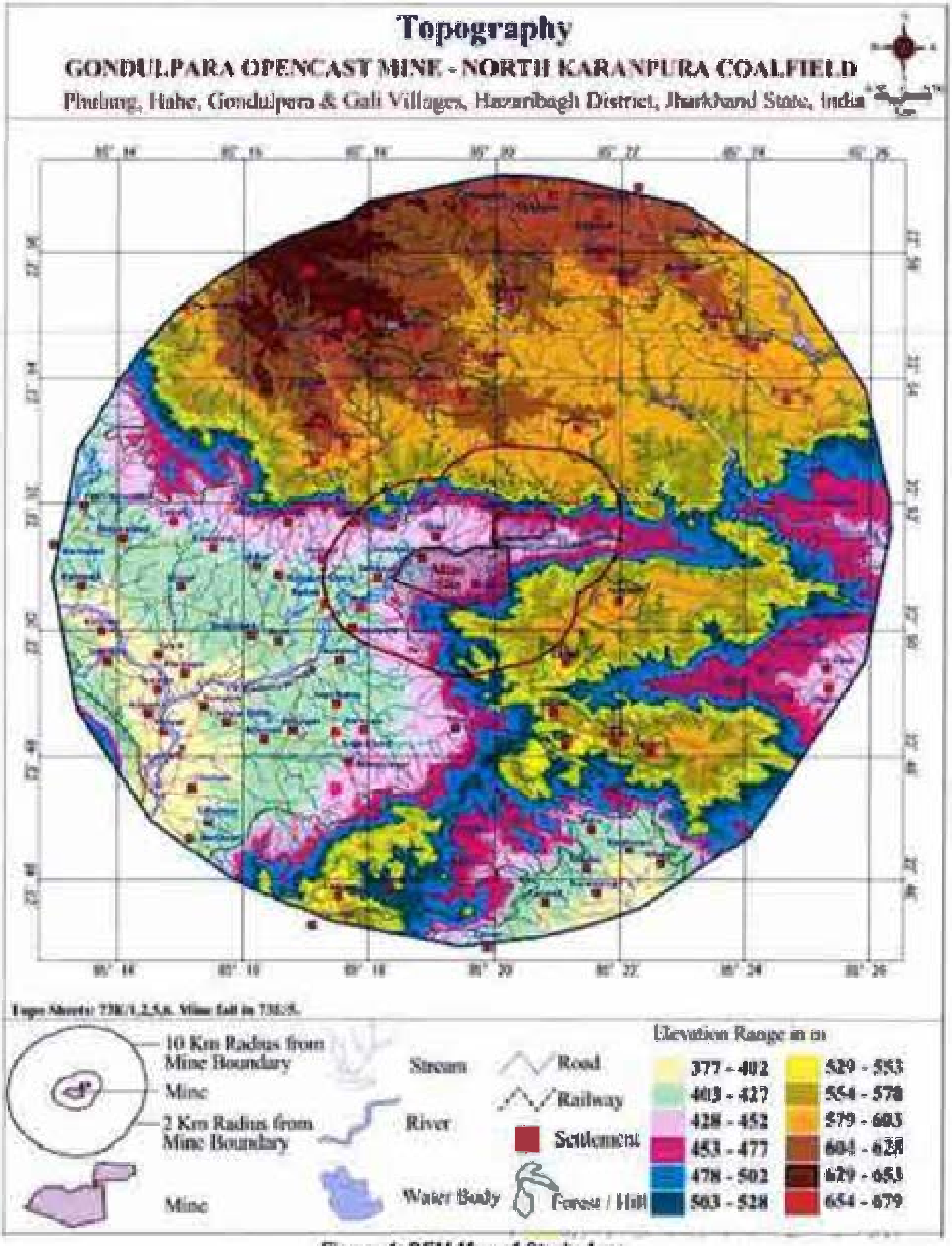


Figure 4: DEM Map of Study Area

3.4 Details of wetlands

A wetland is a distinct ecosystem that is flooded by water, either permanently or seasonally, where oxygen-free processes prevail. Any wetland site which has been listed under the Ramsar Convention that aims to conserve it and promote sustainable use of its natural resources is called a Ramsar Site. The total number of Ramsar sites in India is 46. The nearest Wetland is Kabartal Wetland which is about 214 Km in the north from the Mine's boundary. The Mine site is located 500 m. away from The Ramsar site map is given below figure.

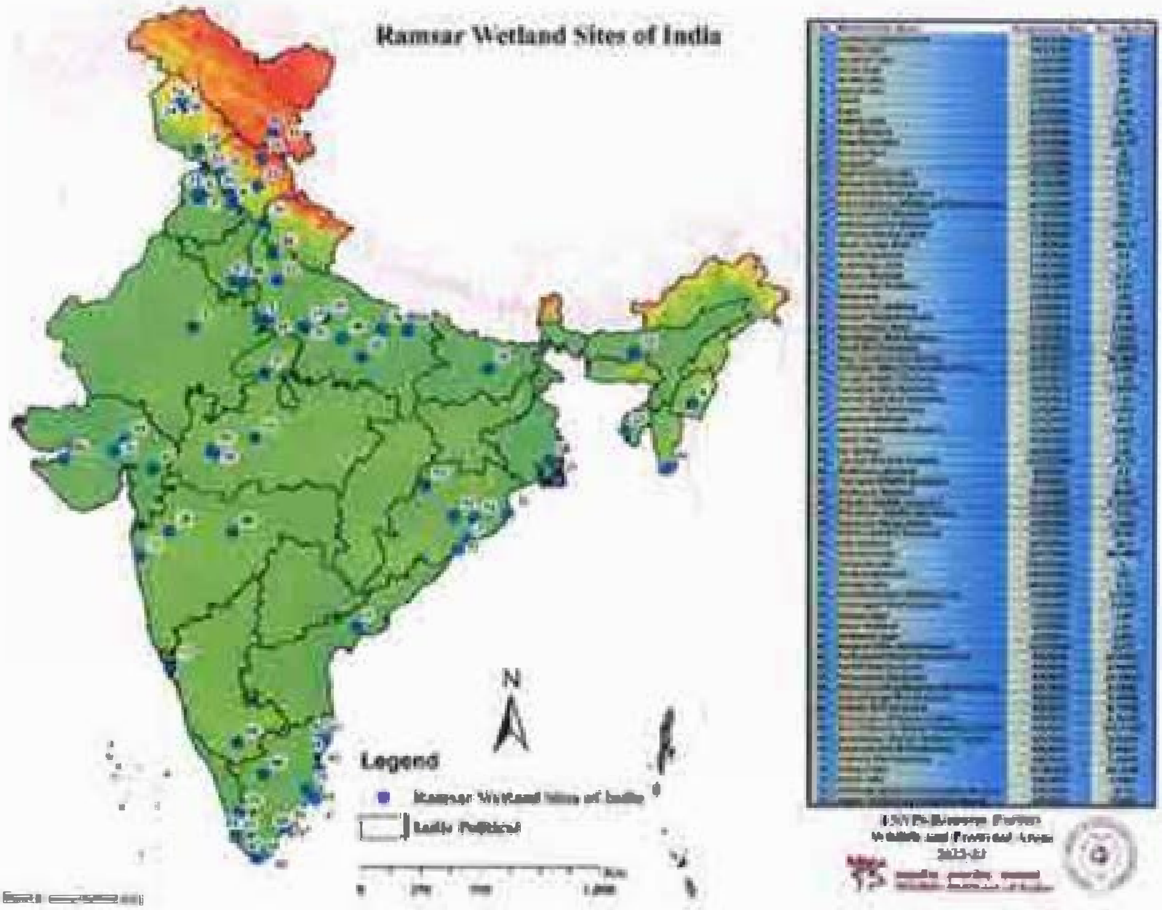


Figure 5: Ramsar Map of India

3.5 Geology

Geologically the district is underlain by Cholanagpur granite gneiss, phyllite mica-schist. It is unconformably overlain by lower Gondwana formations consisting of Sandstone, Shales and Coal seams. Ground water mainly occurs under water table condition in weathered residuum and semi-confined condition in deeper fractures. Granite rocks show maximum thickness of weathered mantle in favorable topographic and drainage condition.

AFROZ
VICE PRESIDENT
COAL PROJECT
LIMITED

A complete sequence of the Lower Gondwana sediments from the basal Talchir Formation (Upper Carboniferous to Early Permian) to Panchet Formation (Lower Triassic) is preserved within this coal basin. The Upper Gondwanas are represented by Mahadeva Fonnation (Upper Triassic). About 2 Km of Gondwana sediments is expected to be preserved within this coal basin. The Talchir Formation crop out discontinuously along the northern, eastern and southern margins. The Barakar and Karharbari formations. The rocks of Barren Measure and Raniganj formations crop out successively in the axial region of the basin. Panchet formation gradationally succeeds the Raniganj Formation, which in turn is overlain unconformably by rocks of Mahadeva Formation. Rocks of Mahadeva Formation are conspicuous landmark occurring as isolated hillocks in the eastern, central, north western and south western parts of the coalfield.

Table 7: Geological Succession

Group	Sub-Group	Formation	Lithology
Quaternary		Alluvium	Alluvium soil
	Raj mahal traps	Igneous intrusive	Dolerite and Mica peridotite
Upper Gondwana	-	Mahadeva	Sandstone with shale
	-	Panchet	Sandstone with Sandy shale.
Lower Gondwana	Damuda	Raniganj	Carbonaceous shale and thin coal seams
		Barren Measure	Interbedded shale and sandstone
		Barakar	Conglomerate shale, greywacke Interbedded shale and sandstone, fire clay and coal seams
		Karharbari	Greywacke dark molted sandstone with occasionally shale bands, fireclay and coal seams
		Talchir	Boulder conglomerate sandstone, Tilloids and Tillites
---------------------------Unconformity---------------------------			
		Metamorphism	Granite gneisses, Pegmatites, Phyllites and quartzite

Source: Ground water year book of Jharkhand

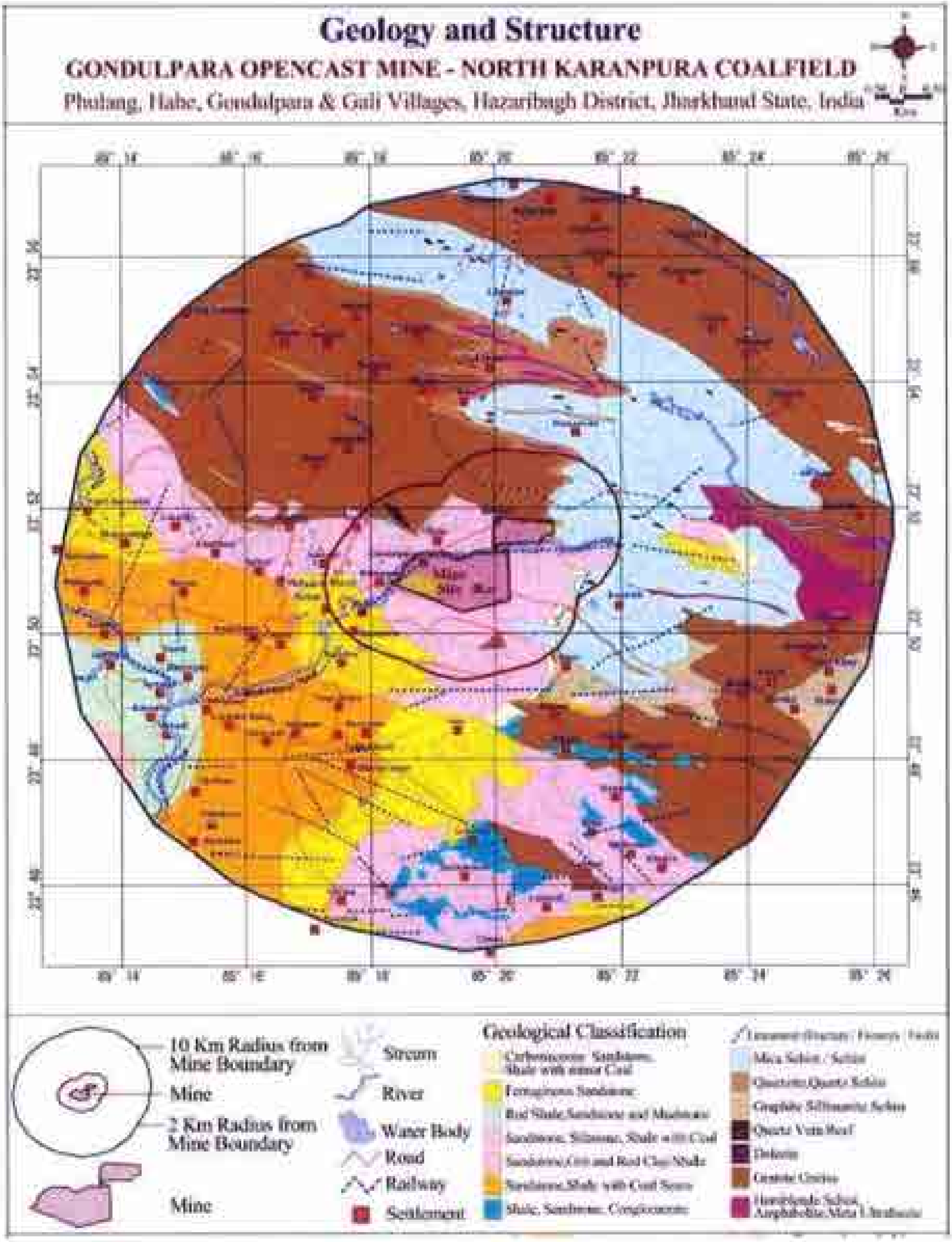


Figure 6: Geological Map of Study Area

3.6 Hydrogeology

Geologically the area is underlain by Chotanagpur granite gneiss, phyllitemica-schist. It is unconformably overlain by lower Gondwana formations consisting of Sandstone, Shales and Coal seams. Ground water mainly occurs under water table condition in weathered residuum and semi-confined condition in deeper fractures. Granite rocks show maximum thickness of weathered mantle in favorable topographic and drainage condition.

Aquifer System: Two types of aquifers are observed in both Granite- gneiss and Gondwana rocks. Phreatic aquifer is observed in weathered formations and Semi-confined to confined aquifers in deeper fractures. Water levels in phreatic aquifers vary between 3-10mbgl. Piezometric head in Granite- gneiss varies between 2-9 mbgl.

3.6.1. Depth to water level:

To understand the ground water situation of the study area covering 10 km radius, ground water level monitoring was carried out in 24 wells located in different places of the buffer zones (21 wells within 10 Km radius and 3 wells outside 10 Km radius) of the study area.

Core zone: The minimum and maximum depth of bore wells in the core zone is 15 m (Dug wells). Yield varies from 2.0 to 6.0 m^3 /day. Post-monsoon water level varies from 1.5 m to 2.6 m below ground level. In Pre-monsoon period it varies from 4.5 m to 5.9 m below ground level. Seasonal fluctuation in water level in these bore wells in the core zone varies from 2.7 m to 3.5 m.

Buffer zone: The minimum and maximum depth of bore wells in the buffer zone is 15 m to 18 m respectively. Yield varies from 2 to 7.0 m^3 /day. Post-monsoon water level varies from 0.9 m to 3.8 m below ground level. In Pre-monsoon period it varies from 2.1 m to 9.8 m below ground level. Seasonal fluctuation in water level in these bore wells in the core zone varies from 1.2 m to 6.8 m.

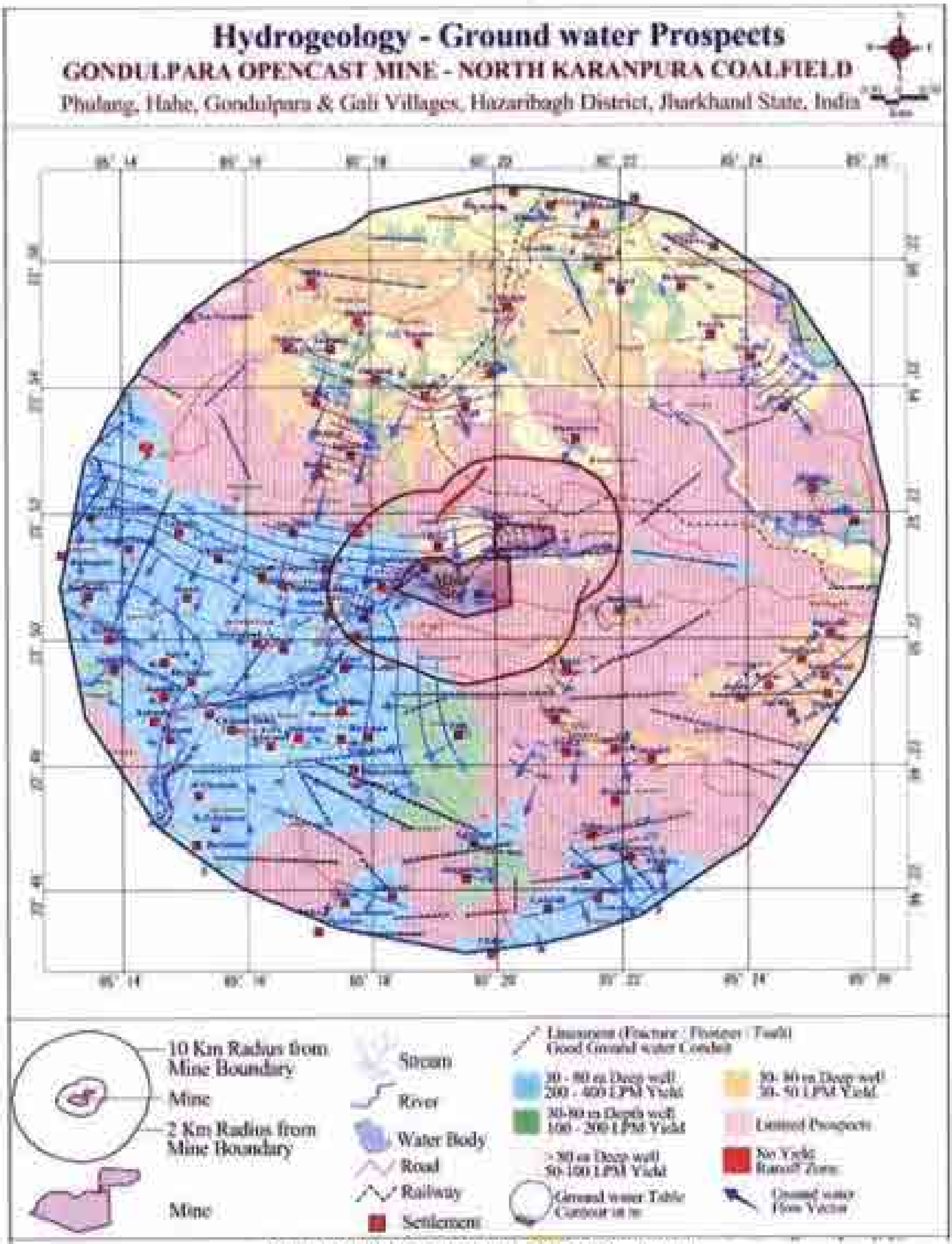


Figure 7: Hydrogeological Map of Study Area

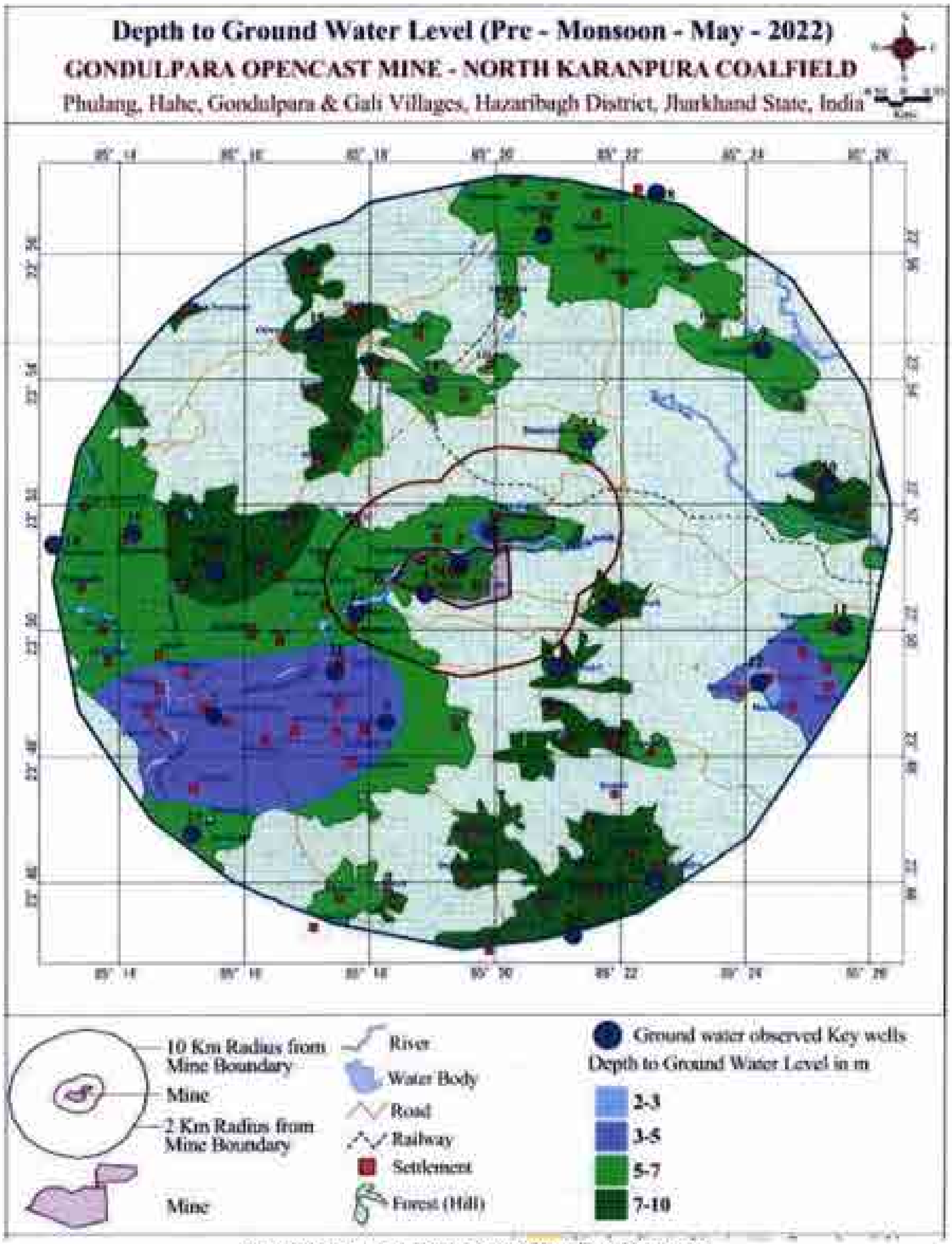


Figure 8: Depth to Water Level Map (Pre-Monsoon)

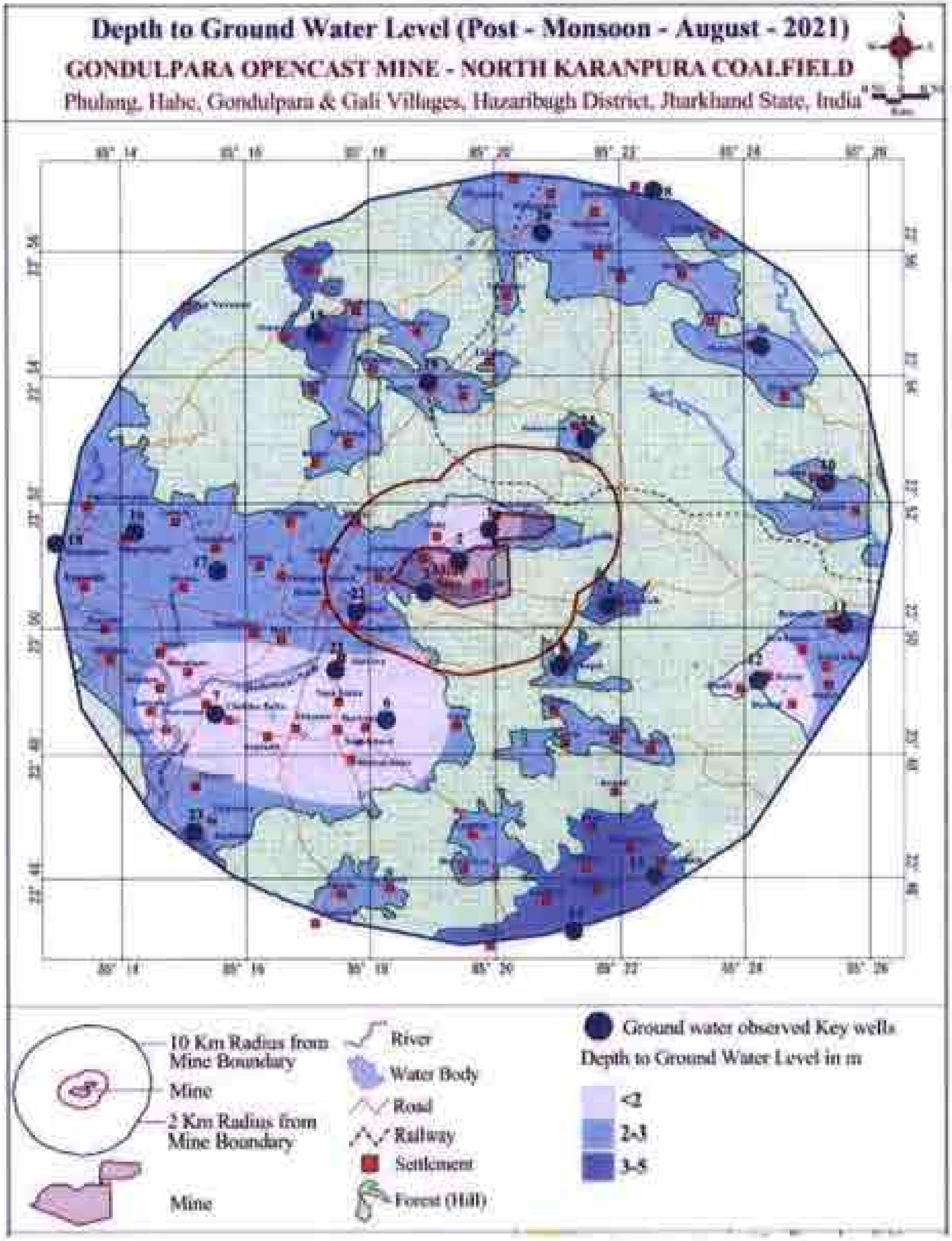


Figure 9: Depth to Water Level Map (Post-Monsoon)

AFROZ
VICE PRESIDENT
GONDULPARA COAL PROJECT
ENTERPRISES LIMITED

4.0 Methodology adopted for the study

The various steps, covered in the study, are as follows:

- Defining/delineation of the study area
- Defining data requirement
- Data acquisition and pre-processing
- Computing soil loss using GIS
- Output

The above-mentioned steps are briefly described in the following paragraphs;

4.1 Delineation of the Study Catchment

The catchment area has been delineated using Shuttle Radar Topographic Mission (SRTM) Digital Elevation Model (DEM) available at 30 m spatial resolution. The outlet of the catchment lies on Badamahi river, left tributary of Damodar River in India. The location of the outlet is near Babupara village in Barkagaon Block in Hazaribagh District.

The topography of the catchment is highly heterogeneous and the elevation of the catchment varies from 416 MSL to 679 MSL spanning over 6757.08 Ha area. The catchment topography and area map are shown in ***Figure 10 & 11.***

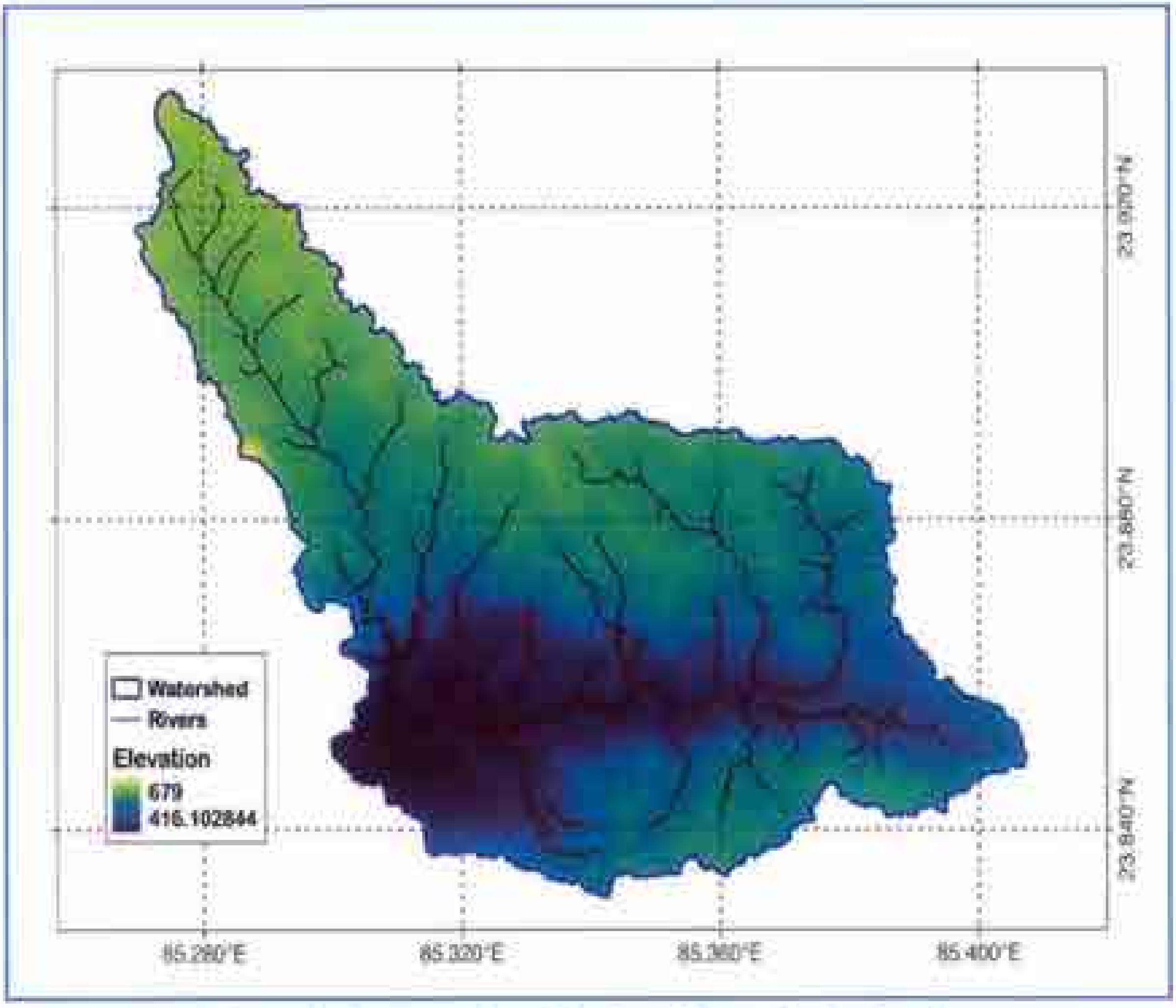


Figure 10: Catchment Area of Badamahi river at Study Location

Table 8: Details of Sub-watersheds delineated for Badamahi River

Sl No.	Basin Name	River Name	Sub-Watershed Number	Sub-Watershed Area (sq. km.)
1	Ganga Basin (Lower Ganga Basin)	Badamahi River	C1	16.016
2			C2	24.123
3			C3	27.431
Total Area				**67.570**

FEROZ
VICE PRESIDENT
... COAL PROJECT
...ENTERPRISES LIMITED

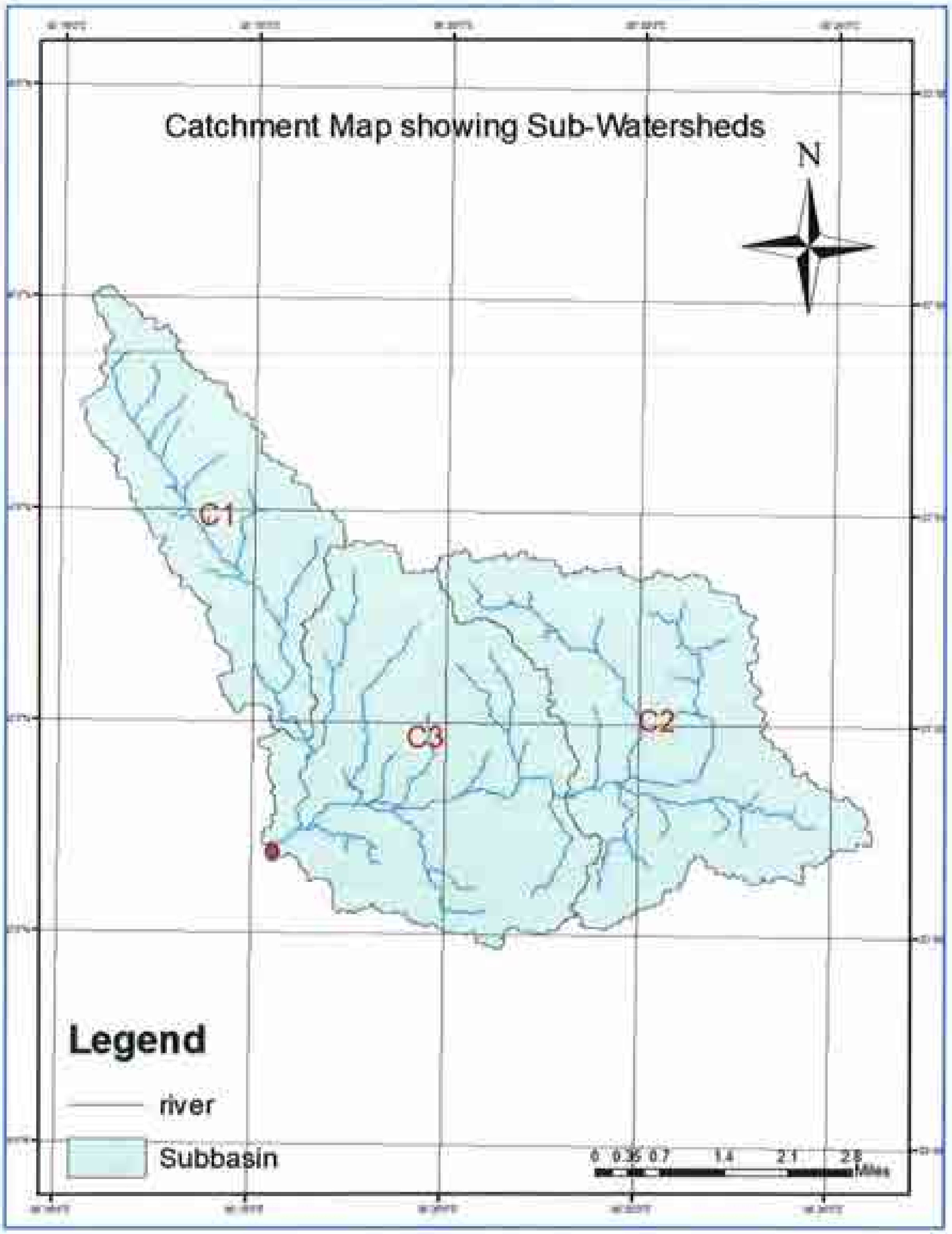


Figure 11: Catchment Area Map Showing Sub-Watersheds

4.2 Defining Data Requirement

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

- Catchment Area/ Sub-Watershed Map
- Slope Map
- Soil Map
- Land use Classification Map
- Rainfall Intensity

4.3 Modeling

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

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

Where;

A = Soil loss (Tons/ha/year)

R is Rainfall & Runoff Erosivity Factor (MJ mm/ha-1 /h-1 /year-1), which depends upon the annual average rainfall in mm. Data required for R factor is rainfall intensity.

K is Soil Erodibility Factor (Tons/ha/h/ha-1 /MJ-1 /mm-1), which depends on the organic matter, texture permeability and profile structure of the soil. Also, it is a constant value for each soil type. Data required for K factor is soil type.

LS is Topographic Factor (dimensionless) which depends upon flow accumulation and steepness and length of slope in the area. Data required for LS factor is slope length and slope gradient.

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

P is Conservation Supporting Practice Factor (dimensionless), which takes into account specific erosion control practices like contour bunding, bench terracing etc.

4.4 Data Acquisition and Pre-Processing

4.4.1 Rainfall Erosivity (R) Factor

R factor is a function of the falling raindrop and rainfall intensity and is estimated as the product of the kinetic energy (E) of the raindrop and the maximum intensity of rainfall (I30) over the duration of 30 min in a storm. The erosivity of rain is calculated for each storm, and these values are summed up for each year. In this study, the storm-wise rainfall data were not available for the computation of rainfall erosivity factor (R); therefore, the relationship between seasonal value of R and average rainfall has been used. The rainfall erosivity factor has been defined as R = 22.8 + 0.64*MAP (Rab Babu et al., 1979), where, R is the average seasonal erosivity factor (MJ mm/ha-1 /h-1 /year-1), and MAP is the annual average rainfall (mm). For this purpose, the IMD gridded rainfall of years 1995 to 2015 was used across the catchment and an annual rainfall map was prepared in the study catchment using IDW interpolation technique. The spatial pattern of the rainfall erosivity factor (R) is shown in ***Figure 12*** below.

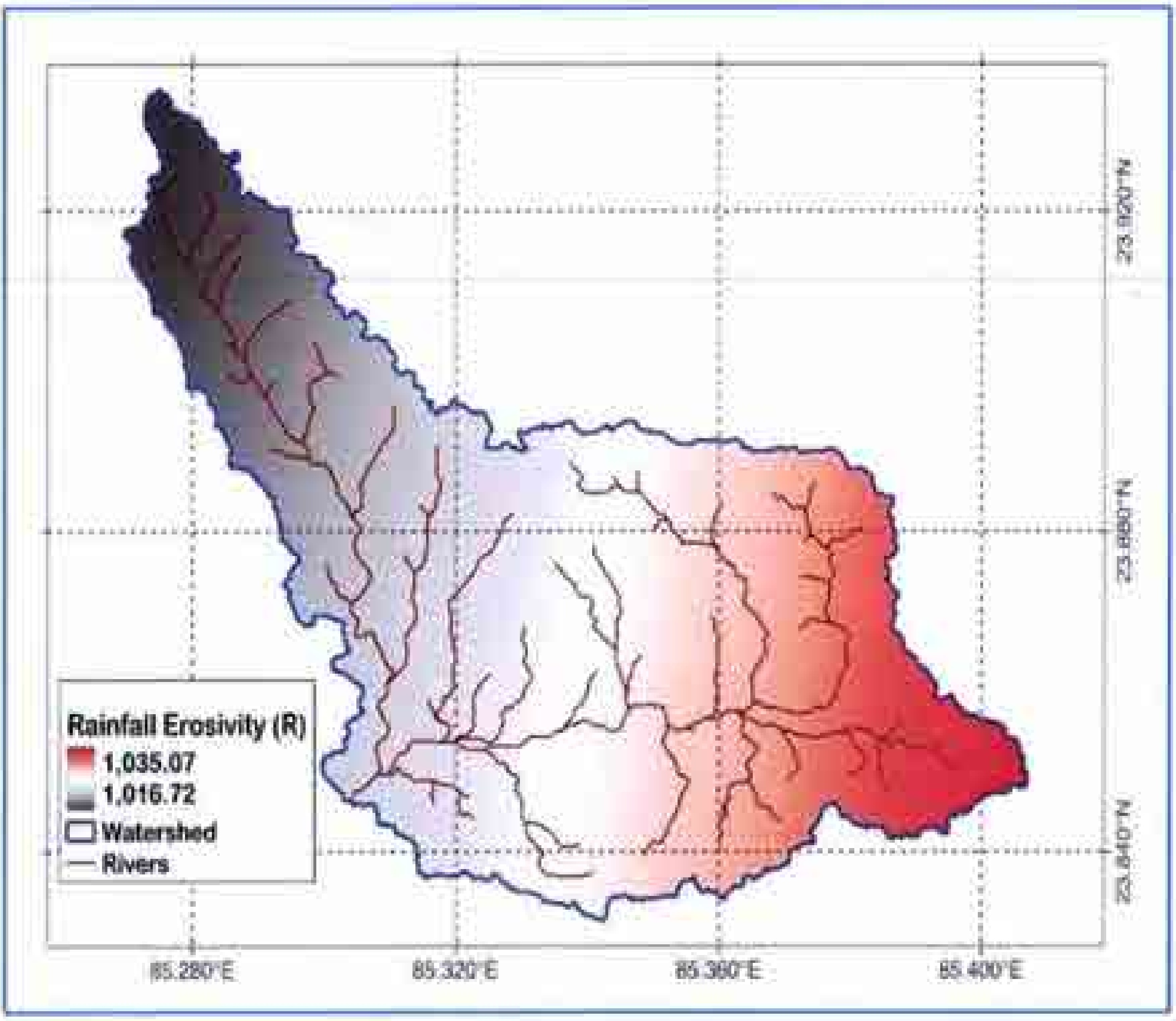


Figure 12: Spatial distribution of rainfall erosivity factor (R) in the study area

4.4.2 Crop Management Factor (c)

The C factor is an expression of the effect of surface cover and roughness, soil biomass, and soil-disturbing activities on rates of soil loss at a particular site. The value of C decreases as surface cover and soil biomass increase, thus protecting the soil from rain splash and runoff.

The total project area is 6757.15 Ha mainly comprising forests (43.04 %) and agriculture (16.87 %). The category wise land use pattern from satellite information is shown below in ***Table 9***. The spatial distribution of these land use categories is shown in ***Figure 13*** below;

Table 9: Land use/cover composition in the study area

Sr. No.	LU_Class	Area (Ha)	Area (Km²)	Area (%)
1	Forest	4303.96	43.04	63.69
2	Shrubland	91.06	0.91	1.35
3	Grassland	382.68	3.83	5.66
4	Agriculture	1686.86	16.87	24.96
5	Built-Up	22.88	0.23	0.34
6	Barren/ Sparsely Vegetated	255.31	2.55	3.78
7	Open Water	14.39	0.14	0.21
Total		**6757.15**	**67.57**	**100.00**

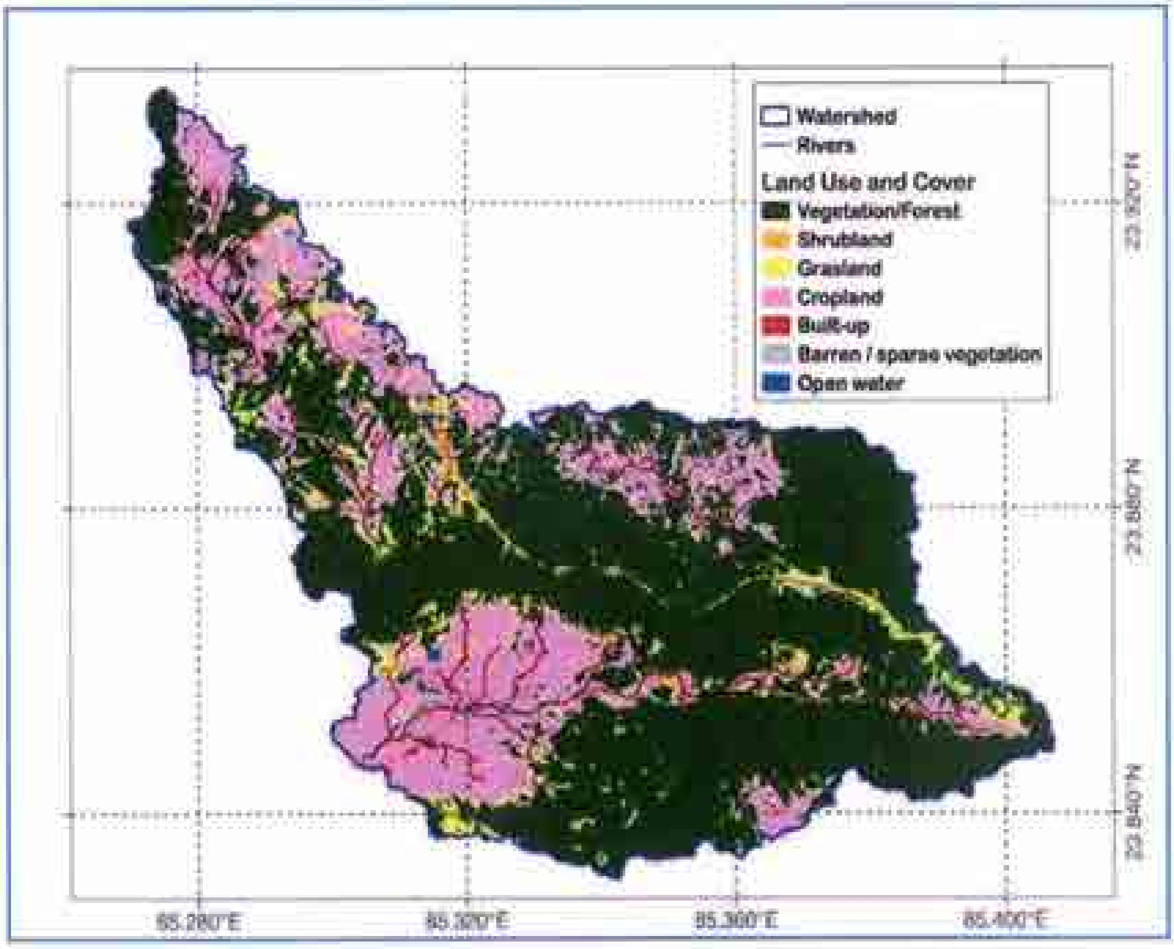


Figure 13: Spatial distribution of land use/cover in the study area

In the present study, the land use/land cover map obtained from ***ESA World Cover data*** has been used in the allocation of C factor for different land use classes and shown in ***Figure 14***.

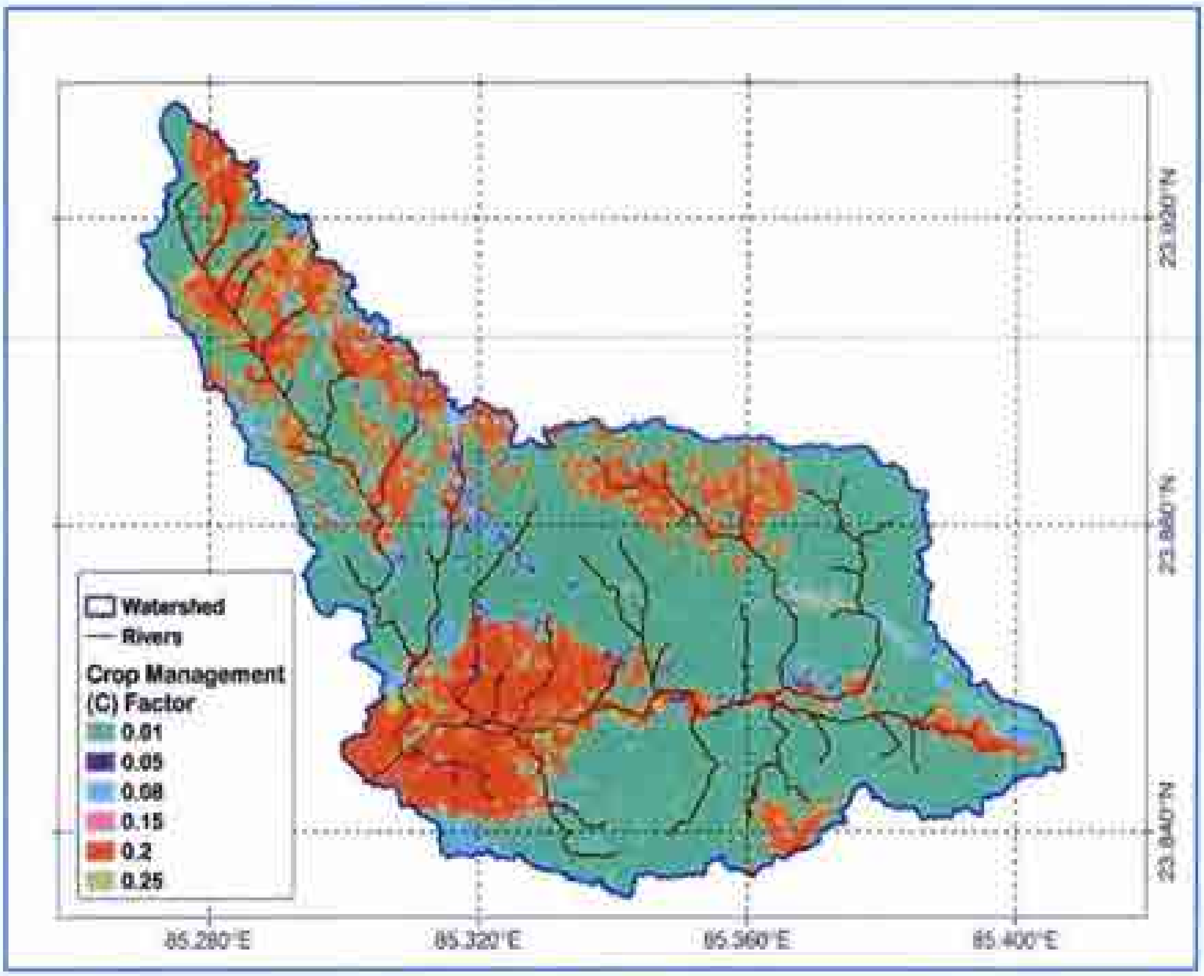


Figure 14: Spatial distribution of crop management (C) factor in the study area

4.4.3 Soil Erodibility (K) Factor

The K factor is an expression of the inherent erodibility of the soil or surface material at a particular site under standard experimental conditions. It is a function of the particle-size distribution, organic-matter content, structure, and permeability of the soil or surface material. Prior to deciding the K values, soil map for the area is a prerequisite. In the present work, the soil type information is obtained from ***global soil data provided by ISRIC world soil information (SoilGrids.org).*** This dataset provides soil type information at 250-meter spatial resolution for multiple soil properties. In the present work, sand silt, clay and organic matter composition in topsoil layer (0-15 cm depth) was used to compute the soil erodibility factor (K). The spatial distribution of soil erodibility factor derived from this information is provided in ***Figure 15*** below.

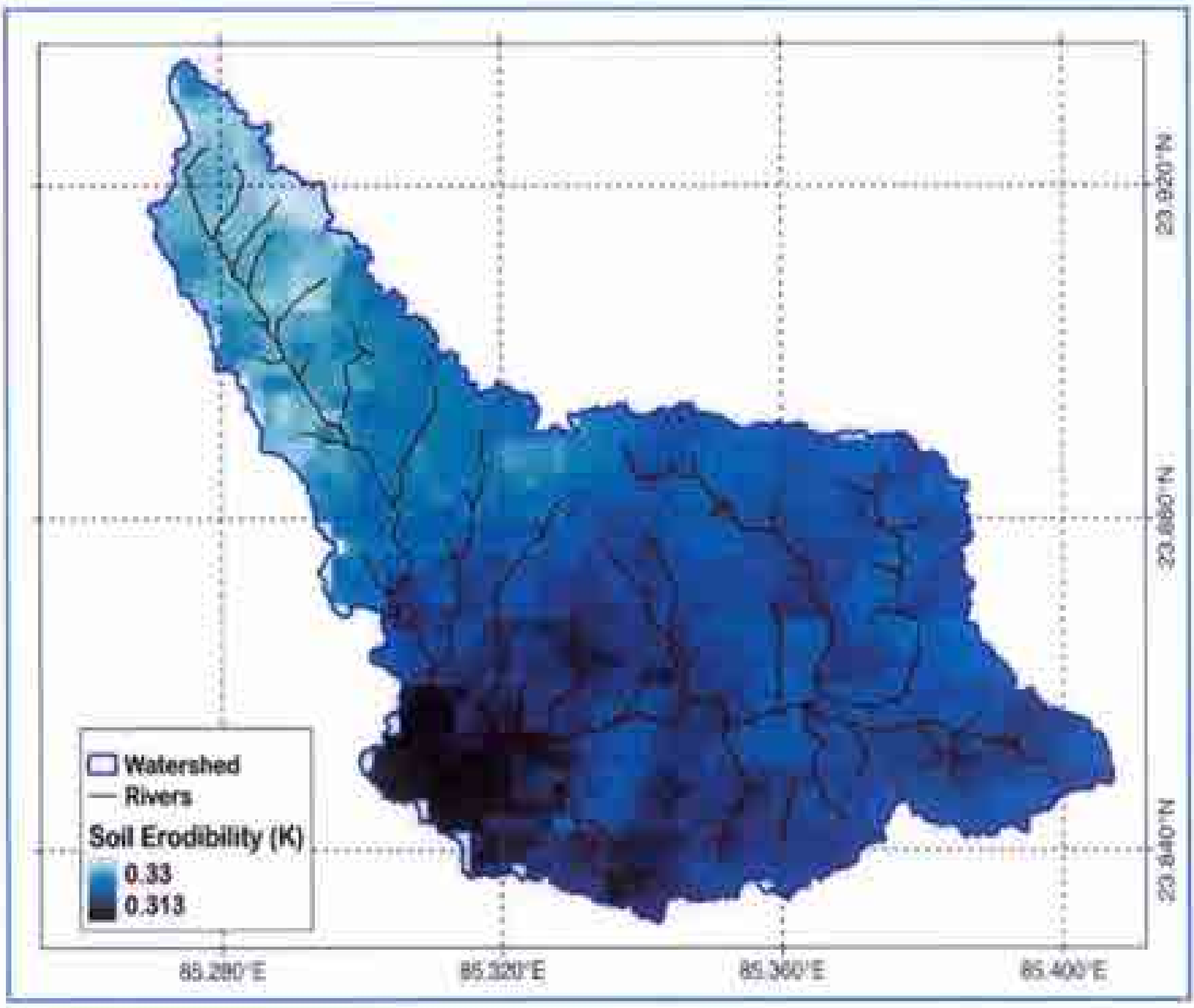


Figure 15: Spatial distribution of soil erodibility factor (K) in the study area

As per the soil map of the catchment area, the soil can be classified in two major categories. Extremely shallow to very shallow with severe to very severe erosion has high K value i.e., from 0.31 to 0.33. Various classes of soil and the values of K are given in in ***Table 10*** below;

Table 10: Soil Erodibility Factor for different Soil Types

Sl No.	Soil Type	Erosion Intensity	K Value
1	Extremely Shallow to Very Shallow	Very Severe	0.33
2	Extremely Shallow to Very Shallow	Severe	0.31

4.4.4 Topographic (LS) Factor

The slope has a great influence on the soil and water loss from the area and thereby influences the landuse capability. The degree slope determines the erosion susceptibility of the soil depending on its nature. This helps in classifying various lands in suitable capability classes which enables us to formulate suitable conservation measures for the prevention ofsoil erosion. 30 m Digital Elevation Data (DEM) Data has been used for preparation of slope map. The data has been downloaded in Georeferenced Tagged Image File Format (GeoTIFF) format and using ArcGIS software a slope (in percent) map has been prepared. The percent slopes have been divided into different slope classes as per SLUSI. As seen from the table (**highlighted cells**) and map, maximum of the catchment area falls under gentle sloping category. The other dominant sloping categories are rolling slope and flat to gentle slope.

Table 11: Slope categories in the study domain and their susceptibility

Class No.	Slope category (%)	Characteristics	Susceptibility	Area (Ha)	Area (Km^2)	Area (%)
1	0-2	Flat to Gentle	High	1285	12.85	19.02
2	2-5	Gentle	Low	2816	28.16	41.68
3	5-10	Rolling	Medium	1730	17.3	25.6
4	10-20	Moderately steep	Very high	760	7.6	11.24
5	>20	Steep	Very low	166	1.66	2.46
Total				**6757**	**67.57**	**100**

AFROZ ... VICE PRESIDENT ... LIMITED

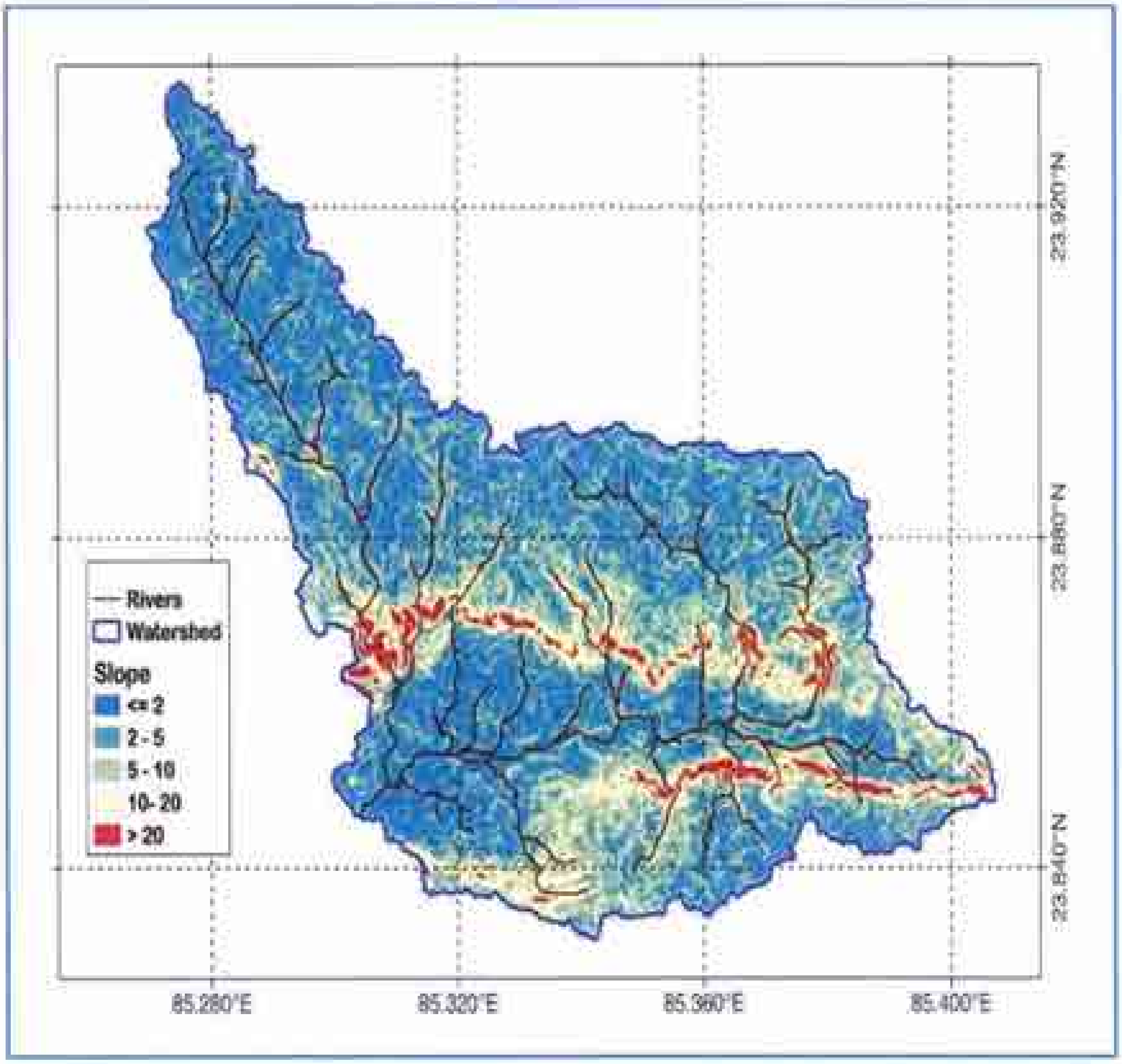


Figure 16: Slope Map for the study area

The LS factor is an expression of the effect of topography, specifically hill slope length and steepness, on rates of soil loss at a particular site. The value of 'LS' increases as hill slope length and steepness increase, under the assumption that runoff accumulates and accelerates in the down-slope direction. Digital Elevation Model (DEM) and Slope of a particular area is a prerequisite for LS factor. The 30 m DEM described above has been utilized to prepare slope length and steepness (LS) factor (shown in ***Figure 17***).

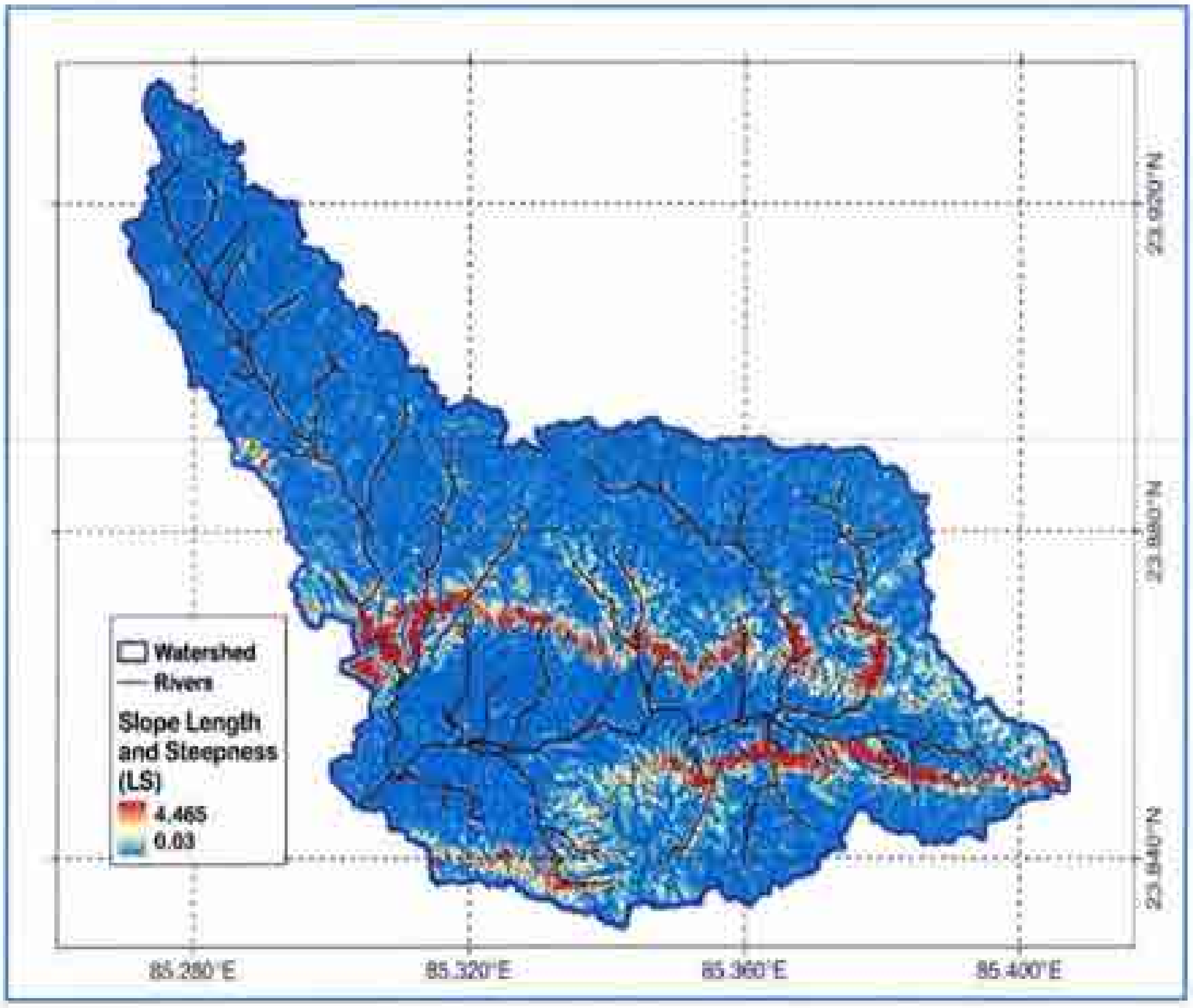


Figure 17: Spatial distribution of slope length and steepness (LS) factor

4.4.5 Conservation Support Practice (P) Factor

The P factor is an expression of the effects of supporting conservation practices, such as contouring, buffer strips of vegetation, and terracing, on soil loss at a particular site. It is the ratio of soil loss with specific support practice to the corresponding loss with up- or down-slope cultivation. In the present study, the P factor has been considered as 1 as no prior conservation support practice is not considered for calculating actual soil loss.

4.4.6 Soil loss and sediment yield

Annual soil loss and sediment yield due to water erosion has been evaluated for Soil Conservation Plan.

Equation of soil loss

The Revised Universal Soil Equation (RUSLE) model is most commonly used method for calculating the soil loss.

AFROZ
VICE PRESIDENT
GONDULPARA ... PROJECT
ADANI ENTERPRISES LIMITED

The soil loss equation is as follows-

$$A = R \times K \times LS$$

Where,

A = Soil loss (tons/ha/year)

R = The he rainfall erosivity factor

K = The soil erodibility factor

L S = Topographic factors representing length and slope

C = The vegetation cover and management factor and

P = The support practices factor.

Despite the USLE's plot-scale spatial focus, the model has often been used to estimate soil erosion on much larger areas, such as watersheds or even whole continents. The relation between gradient (in %) to Soil loss per ha is represented below in Figure

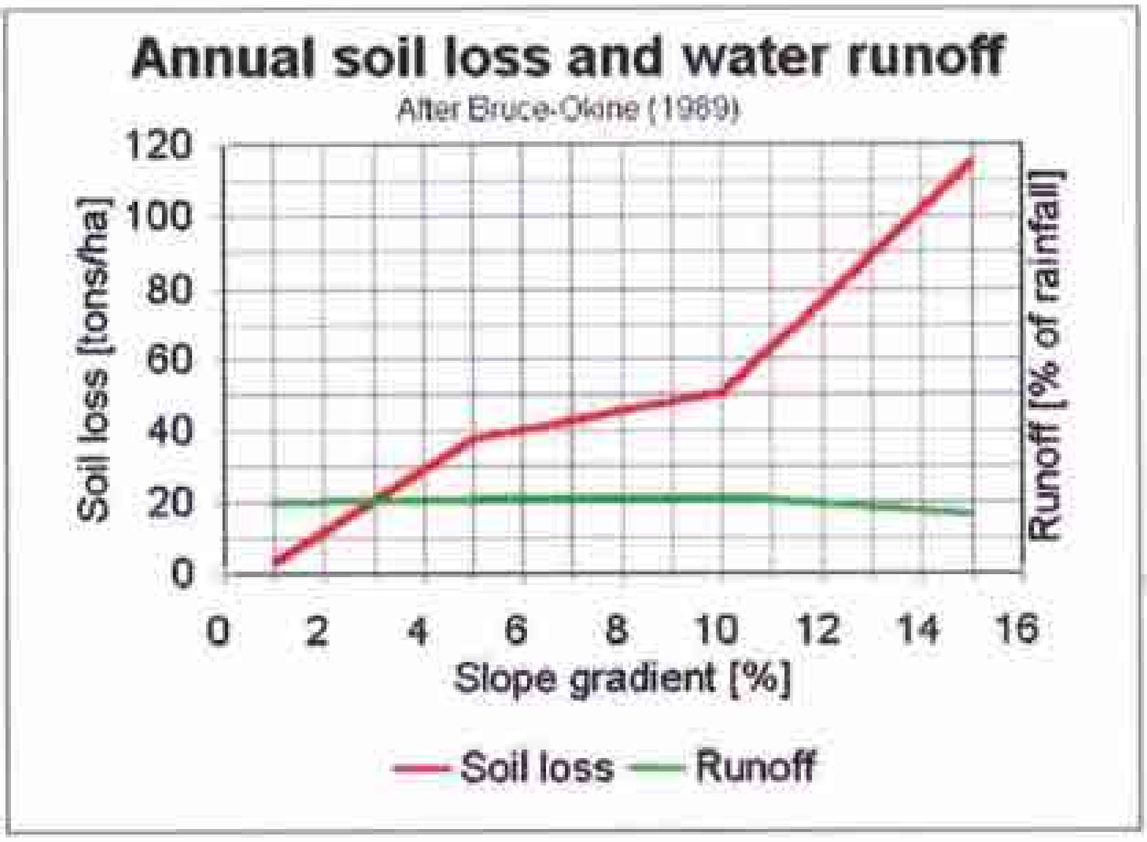


Figure 18: Theoretical Annual Loss and Water Runoff

5.0 RUSLE Model Output

A thematic map for soil loss of the catchment area has been prepared using the RUSLE model mentioned in the above section. The catchment area was then demarcated into different soil erosion intensity mapping units or classes based upon the extent of soil loss (***see Table 12 & Figure 19)***. As can be seen from the figure and table, around 71.2% of the catchment area is prone to less than 5 tons/ha/annum soil erosion, i.e., under low erosion intensity category. On the other hand, almost 9.47 % of its catchment area is prone to very high and severe soil erosion.

Table 12: Different soil loss categories and their area in the study domain

Sl. No.	Soil loss in tons/ha/annum	Erosion Intensity Category	Area (Ha)	Area (Sq. Km.)	Area (%)
1	0 - 5	Low	4784	47.84	71.2
2	5 - 10	Moderate	442	4.42	6.59
3	10 - 20	High	546	5.46	8.13
4	20 - 40	Very High	588	5.88	8.75
5	>40	Severe	359	3.59	5.34

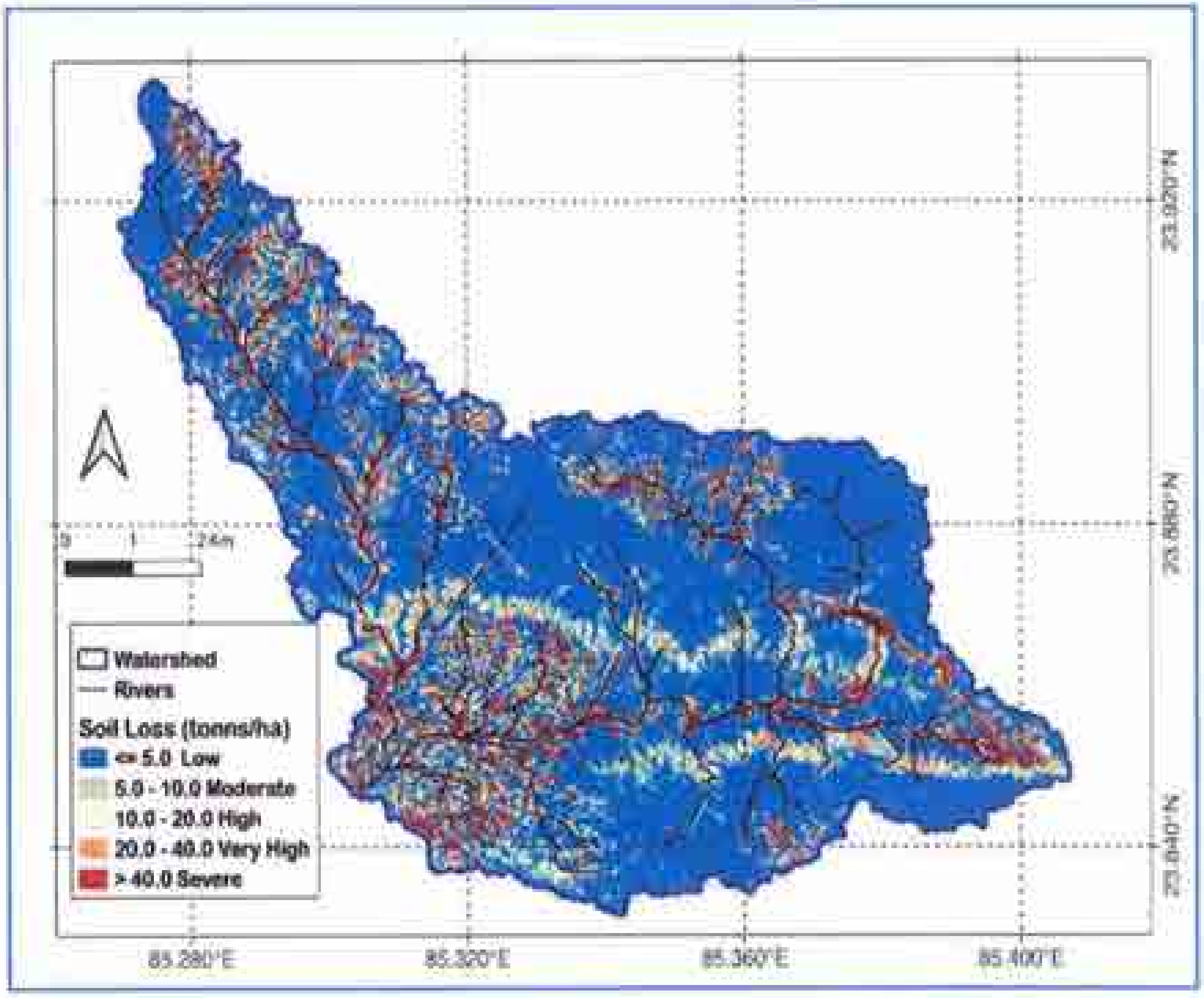


Figure 19: Soil Loss Map for the study area

6.0 The causes of soil erosion and the contributing factors

Soil erosion is a natural phenomenon that affects all landforms. Soil erosion in agriculture refers to the wearing away of the topsoil by natural physical forces such as water and wind, as well as pressures connected with farming activities such as tillage. Erosion, whether caused by water, wind, or tillage, consists of three separate processes: soil detachment, movement, and deposition. Topsoil, which is rich in organic matter, fertility, and soil life, is either moved "on-site" where it accumulates over time or transported "off-site" where it fills drainage channels. Soil erosion affects agriculture productivity while also polluting nearby watercourses, marshes, and lakes. Soil erosion can be a sluggish process that goes unnoticed for a long time, or it can develop at an alarming rate, resulting in significant loss of fertile topsoil. Other major soil degradation characteristics that can exacerbate the soil erosion process include soil compaction, low organic matter, loss of soil structure, poor internal drainage, salinization, and soil acidity.

AFROZ
VICE PRESIDENT
... COAL PROJECT
... ENTERPRISES LIMITED

6.1 Water Erosion

The widespread occurrence of water erosion combined with the severity of on-site and off-site impacts have made water erosion the focus of soil conservation efforts all over the state. The rate and magnitude of soil erosion by water is controlled by the following factors:

6.1.1 Rainfall and Runoff

The greater the intensity and duration of a rainstorm, the higher is the erosion potential. The impact of raindrops on the soil surface can break down soil aggregates and disperse the aggregate material. Lighter aggregate materials such as very fine sand, silt, clay and organic matter are easily removed by the raindrop splash and runoff water; greater raindrop energy or runoff amounts are required to move larger sand and gravel particles.

Soil movement by rainfall (raindrop splash) is usually greatest and most noticeable during short-duration, high-intensity thunderstorms. Although the erosion caused by long-lasting and less-intense storms is not usually as spectacular or noticeable as that produced during thunderstorms, the amount of soil loss can be significant, especially when compounded over time.

Surface water runoff occurs whenever there is excess water on a slope that cannot be absorbed into the soil or is trapped on the surface. Reduced infiltration is due to soil compaction. Runoff from agricultural land is greatest during monsoon months when the soils are typically saturated.

6.1.2 Intensity of rainfall

The rainfall intensity corresponding to a duration and desired probability of exceedance i.e. return period. This is rainfall-frequency duration relationship for the given catchment area.I.M.D. has prepared Isopluvial maps for the different return period for given catchment area. The maximum intensity of one hour rainfall is 30mm.

6.1.3 Runoff coefficient

The runoff coefficient is a dimensionless coefficient relating to amount of runoff to the amount of precipitation received. It is larger value for area with low infiltration and high runoff and lower for permeable well vegetated area (forest, flat land).

Runoff Co-efficient = 20 %

6.1.4 Infiltration test

Infiltration is the flow of water into the ground through the soil surface. Since infiltrated water may contribute to the ground water discharge in addition to soil moisture, the process can be schematically modeled. The infiltration characteristics of a soil at a given location has been estimated by using flooding infiltrometer. The infiltration test data and location map of infiltration site is given in below map.

Table 13: Infiltration Test Data

Time since start		Infiltration rate (cm/hr)			
Minutes	Hour	Test-I (Gondulpara Village)	Test-II (Raidpata Village)	Test-III (Isko Village)	Test-VI (Saheda)
10	0.16	20.28	19.22	9.28	8.91
20	0.33	17.21	15.66	8.54	7.53
30	0.50	15.00	14.22	7.23	5.88
45	0.75	12.21	12.00	4.89	4.55
60	1.00	10.21	10.12	3.88	3.23
90	1.50	5.62	8.67	3.50	1.89
120	2.00	4.31	2.61	2.79	1.75
150	2.50	3.00	1.60	1.58	1.25
180	3.00	2.20	0.90	1.06	0.90
210	3.50	0.92	0.80	0.50	0.31
Constant Infiltration rate cm/hr		*0.72*	*0.80*	*0.50*	*0.31*
Infiltration zone		High	High	Moderate	Low
Recharge/Discharge		Recharge	Recharge	Discharge	Discharge

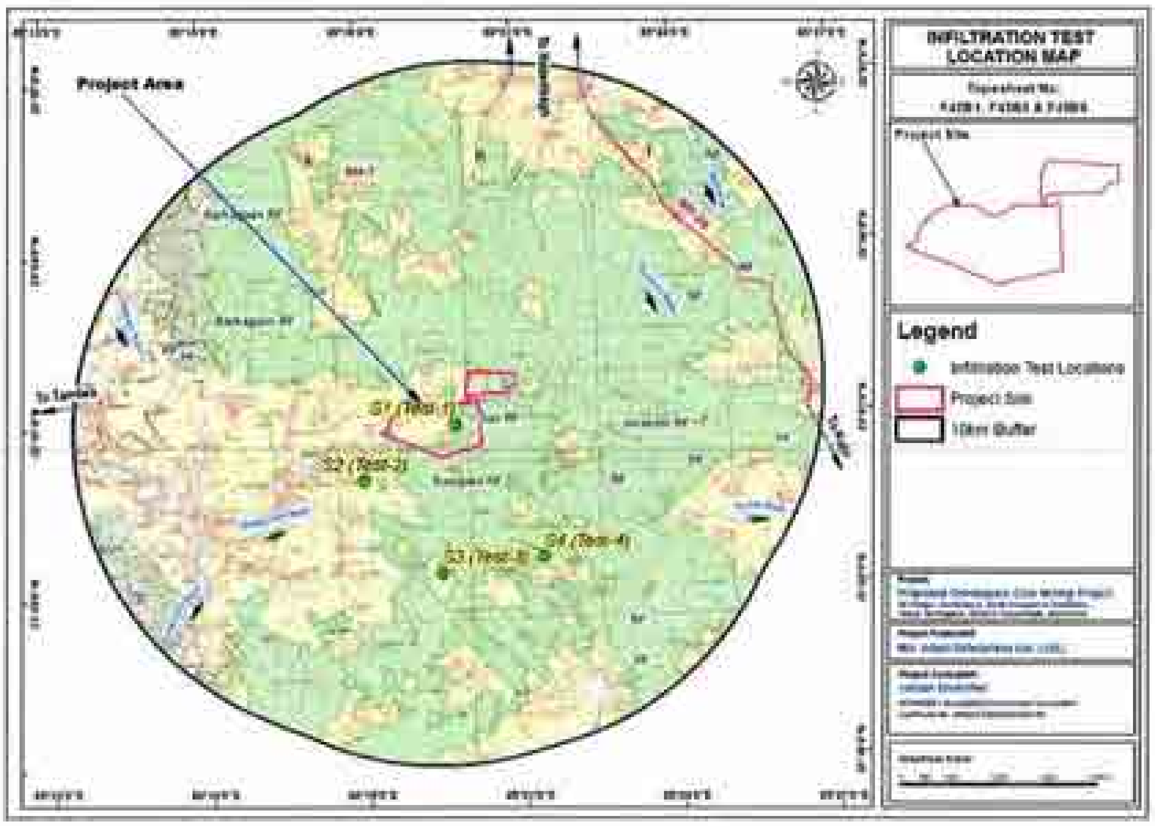


Figure 20: Infiltration Test Location Map

6.1.5 Soil Erodibility

Soil erodibility is an estimate of the ability of soils to resist erosion, based on the physical characteristics of each soil. Texture is the principal characteristic affecting erodibility, but structure, organic matter and permeability also contribute. Generally, soils with faster infiltration rates, higher levels of organic matter and improved soil structure have a greater resistance to erosion. Sand, sandy loam and loam-textured soils tend to be less erodible than silt, very fine sand and certain clay-textured soils.

Tillage and cropping practices that reduce soil organic matter levels, cause poor soil structure, or result in soil compaction, contribute to increases in soil erodibility. As an example, compacted subsurface soil layers can decrease infiltration and increase runoff. The formation of a soil crust, which tends to "seal" the surface, also decreases infiltration. On some sites, a soil crust might decrease the amount of soil loss from raindrop impact and splash; however, a corresponding increase in the amount of runoff water can contribute to more serious erosion problems.

Past erosion also has an effect on a soil's erodibility. Many exposed subsurface soils on eroded sites tend to be more erodible than the original soils were because of their poorer structure and lower organic matter. The lower nutrient levels often associated with sub soils contribute to lower crop yields and generally poorer crop cover, which in turn provides less crop protection for the soil.

6.1.6 GRAIN SIZE ANALYSIS

Grain Size Analysis of Soil

The grain size analysis of the soil in respect of area in and around of study area is given in below table.

Table 14: Grain size Analysis in (%)

Type of Grain	Notation	Mine Area	[illegible]	[illegible]	[illegible]	[illegible]	Average %
		S1 ([illegible] Village)	S2	S3	S4	S5	
Sand	(SAN)	40	31	32	34	33	34
Silt	(SIL)	48	55	53	56	54	53
Clay	(CLN)	12	14	15	10	13	13
Organic	(C)	0.38	0.53	0.50	0.58	0.44	0.49
	%	100	100	100	100	100	100

(Source: Mine plan)

6.1.7 Slope Gradient and Length

The steeper and longer the slope of a field, the higher is the risk for erosion. Soil erosion by water increases as the slope length increases due to the greater accumulation of runoff. Consolidation of small fields into larger ones often results in longer slope lengths with increased erosion potential, due to increased velocity of water, which permits a greater degree of scouring (carrying capacity for sediment).

6.1.8 Cropping and Vegetation

The potential for soil erosion increases if the soil has no or very little vegetative cover of plants and/or crop residues. Plant and residue cover protects the soil from raindrop impact and splash, tends to slow down the movement of runoff water and allows excess surface water to infiltrate. The erosion-reducing effectiveness of plant and/or crop residues depends on the type, extent and quantity of cover. Vegetation and residue combinations that completely cover the soil and intercept all falling raindrops at and close to the surface are the most efficient in controlling soil erosion (e.g., forests, permanent grasses). Partially incorporated residues and residual roots are also important as these provide channels that allow surface water to move into the soil.

The effectiveness of any protective cover also depends on how much protection is available at various periods during the year, relative to the amount of erosive rainfall that falls during these periods. Crops that provide a full protective cover for a major portion of the year can reduce erosion much more than can crops that leave the soil bare for a longer period of time (e.g., row crops), particularly during periods of highly erosive rainfall during Pre- monsoon and monsoon. Crop management systems that favor contour farming and strip-cropping techniques can further reduce the amount of erosion. To reduce most of the erosion on annual row-crop land, leave a residue cover greater than 30% after harvest and over the winter months, or inter-seed a cover crop.

6.1.9 Tillage Practices

The potential for soil erosion by water is affected by tillage operations, depending on the depth, direction and timing of plowing, the type of tillage equipment and the number of passes. Generally, the less the disturbance of vegetation or residue cover at or near the surface, the more effective is the tillage practice in reducing water erosion. Minimum till or no-till practices are effective in reducing soil erosion by water.

Tillage and other practices performed up and down field slopes creates pathways for surface water runoff and can accelerate the soil erosion process. Cross-slope cultivation and contour farming techniques discourage the concentration of surface water runoff and limit soil movement.

6.2 Forms of Water Erosion

6.2.1 Splash erosion

Splash erosion is the first stage of the erosion process. It occurs when raindrops hit bare soil. The explosive impact breaks up soil aggregates so that individual soil particles are 'splashed' onto the soil surface. The splashed particles can rise as high 60cm above the ground and move up to 1.5 meter from the point of impact. The particles block the spaces between soil aggregates, so that the soil forms a crust that reduces infiltration and increases runoff.

6.2.2 Sheet Erosion

Sheet erosion is the movement of soil from raindrop splash and runoff water. It typically occurs evenly over a uniform slope and goes unnoticed until most of the productive topsoil has been lost. Deposition of the eroded soil occurs at the bottom of the slope or in low areas. Lighter-colored soils on knolls, changes in soil horizon thickness and low crop yields on shoulder slopes and knolls are other indicators.

6.2.3 Rill Erosion

Rill erosion results when surface water runoff concentrates, forming small yet well-defined channels. These distinct channels where the soil has been washed away are called rills when they are small enough to not interfere with field machinery operations. In many cases, rills are filled in each year as part of tillage operations. The distinct path where the soil has been washed away by surface water runoff is an indicator of rill erosion.

6.2.4 Gully Erosion

Gully erosion is an advanced stage of rill erosion where surface channels are eroded to the point where they become a nuisance factor in normal tillage operations. There are farms that are losing large quantities of topsoil and subsoil each year due to gully erosion. Surface water runoff, causing gully formation or the enlarging of existing gullies, is usually the result of improper outlet design for local surface and subsurface drainage systems. The soil instability of gully banks, usually associated with seepage of groundwater, leads to sloughing and slumping (caving-in) of bank slopes. Such failures usually occur during monsoon when the soil water conditions are most conducive to the problem.

Gully formations are difficult to control if corrective measures are not designed and properly constructed. Control measures must consider the cause of the increased flow of water across the landscape and be capable of directing the runoff to a proper outlet. Gully erosion results in significant amounts of land being taken out of production and creates hazardous conditions for the operators of farm machinery. Gully erosion may develop in locations where rill erosion has not been managed.

6.2.5 Bank Erosion

Natural streams and constructed drainage channels act as outlets for surface water runoff and subsurface drainage systems. Bank erosion is the progressive undercutting, scouring and slumping of these drainage ways. Poor construction practices, inadequate maintenance, uncontrolled livestock access and cropping too close can all lead to bank erosion problems.

Bank erosion involves the undercutting and scouring of natural stream and drainage channel banks.

Poorly constructed tile outlets also contribute to bank erosion. Some do not function properly because they have no rigid outlet pipe, have an inadequate splash pad or no splash pad at all, or have outlet pipes that have been damaged by erosion, machinery or bank cave-ins.

The direct damages from bank erosion include loss of productive farmland, undermining of structures such as bridges, increased need to clean out and maintain drainage channels and washing out of lanes, roads and fence rows.

6.2.6 Tillage Erosion

Tillage erosion is the redistribution of soil through the action of tillage and gravity. It results in the progressive down-slope movement of soil, causing severe soil loss on upper-slope positions and accumulation in lower-slope positions. This form of erosion is a major delivery mechanism for water erosion. Tillage action moves soil to convergent areas of a field where surface water runoff concentrates. Also, exposed subsoil is highly erodible to the forces of water and wind. Tillage erosion has the greatest potential for the "on-site" movement of soil and in many cases can cause more erosion than water or wind.

The overall effects of Soil erosion are

- Loss of Production Potential,
- Reduction in infiltration rate,
- Reduction in water holding capacity resulting poor forest growth and dryer species.
- Loss of nutrient,
- Increase in tillage operation costs,
- Reduction in water storage capacity of rivers / streams/ reservoirs.

6.3 Soil Types and Characteristics

The composition, moisture, and compaction of soil are all major factors in determining the erosivity of rainfall. Sediments containing more clay tend to be more resistant to erosion than those with sand or silt, because the clay helps bind soil particles together. Soil containing high levels of organic materials are often more resistant to erosion, because the organic materials coagulate soil colloids and create a stronger, more stable soil structure. The amount of water present in the soil before the precipitation also plays an important role, because it sets limits on the amount of water that can be absorbed by the soil (and hence prevented from flowing on the surface as erosive runoff). Wet, saturated soils will not be able to absorb as much rain water, leading to higher levels of surface runoff and thus higher erosivity for a given volume of rainfall. Soil compaction also affects the permeability of the soil to water, and hence the amount of water that flows away as runoff. More compacted soils will have a larger amount of surface runoff than less compacted soils.

7.0 Prioritization using Silt Yield Index (SYI) Method

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

SYI = (Σ (Ai * Wi) * Di * 100)/Aw; where i = 1 to n

where,

Ai	Area of ith unit
Wi	Weightage value of ith mapping unit
n	No. of mapping units
Aw	Total area of sub-catchment
Di	Delivery ratio

7.1 Erosion Intensity Mapping Unit

Erosion Intensity Mapping Units (EIMU) are demarcated and defined as per the soil erosion intensity map prepared above. Various EIMU categories, such as Very Severe, Severe, Moderate, Low, Very Low, and Negligible & Slight (clubbed together), were then used to calculate sub-watershed-wise SYI. Erosion Intensity Mapping Units (EIMU) is a composite expression of physiography, land use, and conservation practices adopted. While computing soil erosion intensity in a catchment all the factors (physiography, land use, and conservation practices) are already taken into consideration. Therefore, EIMUs are assumed as per the soil erosion intensity in the sub-watershed. The sub-watershed wise area under each EIMU class is given in **Table 15**.

Table 15: Sub-watershed wise area under each EIMU class

Sl. No	EIMU Class	Sub- Watershed wise Area (Ha)			Total Area (Ha)
		C1	C2	C3	
1	**Severe**	75	108	176	359
2	**Very High**	87	154	201	442
3	**High**	98	178	270	546
4	**Moderate**	168	167	253	588
5	**Low**	1165	1791	1828	4784

7.2 Weightage Value

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

7.3 Delivery Ratio

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

Table 16: Delivery Ratio

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

7.4 Silt Yield Index

The area of each of the mapping units is computed and silt yield indices of individual sub-watersheds are calculated using the equations mentioned above. The SYI values for classification of various categories of erosion intensity rates are given in ***Table 17***.

Table 17: SYI Classification of Sub-Watersheds in Catchment Area

Sub-Watershed	EIMU	EIMU Area (EA) in ha.	Weightage Factor (WF)	Silt Yield (SY) (EA * WF)	Delivery Ratio (DR)	SYI = (SY*DR*100)/SA
C1	1	75	19	1425	0.9	1321.4
	2	87	18	1566		
	3	98	16	1568		
	4	168	15	2520		
	5	1165	14	16310		
Total		**1593**		**23389**		
C2	1	108	19	2052	0.85	1249.5

	2	154	18	2772		
	3	178	16	2848		
	4	167	15	2505		
	5	1791	14	25074		
Total		**2398**		**35251**		
C3	1	176	19	3344	0.95	1416.3
	2	201	18	3618		
	3	270	16	4320		
	4	253	15	3795		
	5	1828	14	25592		
Total		**2728**		**40669**		

7.5 Prioritization of Sub-Watersheds

The sub-watersheds are subsequently rated into various categories corresponding to their respective SYI values. The criteria followed for priority categorization of sub-watersheds depending upon their SYI values is given *in* ***Table 18*** and the priority classification of individual sub-watershed is given in ***Table 19 and Figure 21***.

Table 18: Criteria for Priority

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

Table 19: Priority Number as per SYI Classification in Catchment Area

Sub-Watershed	SYI Value	Priority	Priority Number
C3	1416.3	Very High	1
C1	1321.4	Very High	2
C2	1249.5	Very High	3

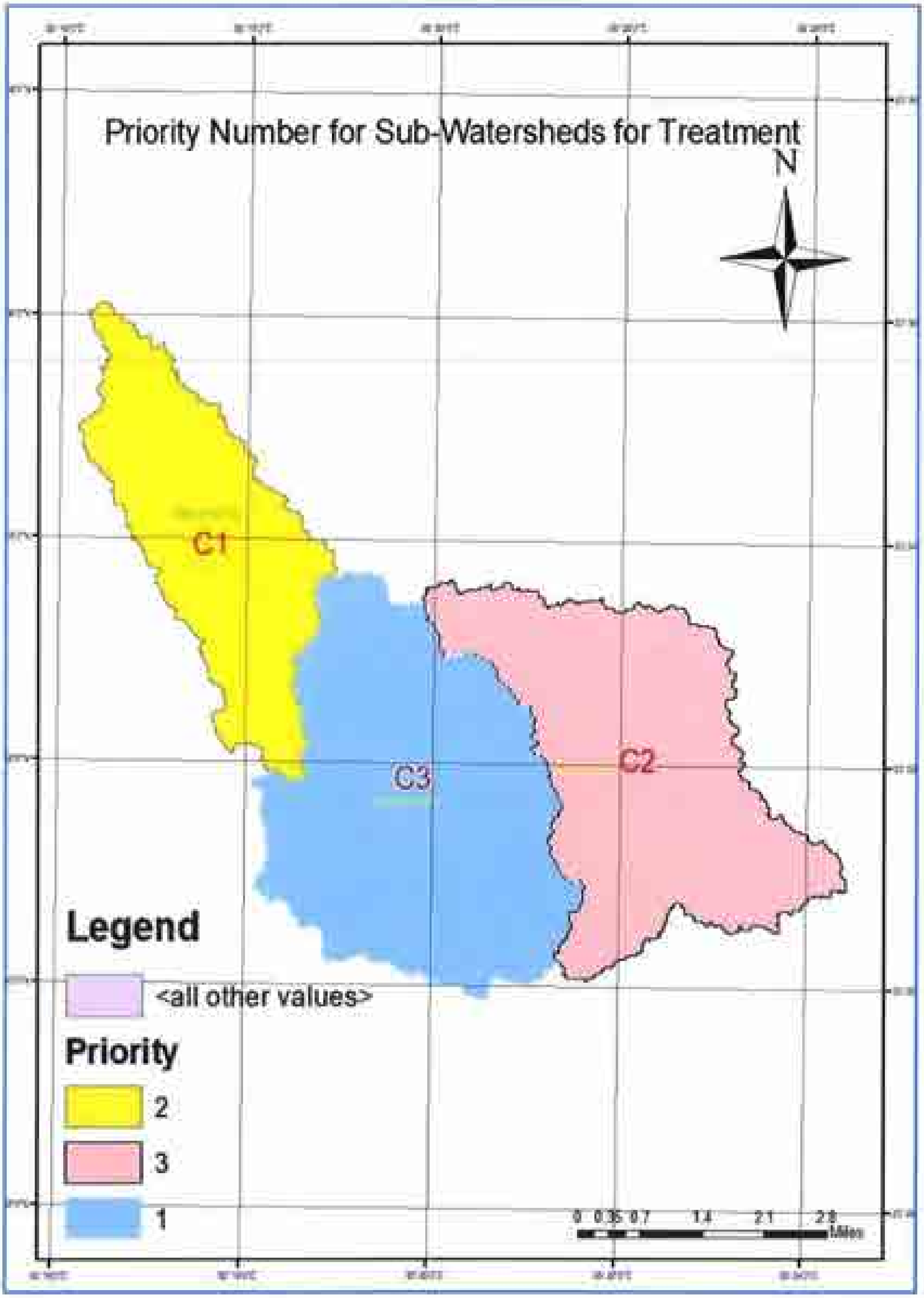


Figure 21: Priority Map for Sub-Watersheds for Treatment

8.0 Treatment Plan

8.1 Area to be taken up for Treatment

As already mentioned, the catchment area of Badamahi river catchment is 6757.15 Ha (67.57 Km²). However, out of this area, 4303 ha (63 %) area falls under the dense forest category which can mainly be considered for biological treatment measures after proper permissions. Therefore, an overall area of 863.84 Ha (12.78 %) will be considered for treatment measures. The land use category wise areas selected for treatment are shown in ***Table 20.***

Table 20: Treatment Area

Sl. No.	LU_Class	Area as per LULC data (Ha)	Actual area found treatable (Ha)	Remark
1	Forest	4303.96	430.40	10% of the area
2	Shrubland	91.06	27.32	30% of the area
3	Grassland	382.68	114.80	30% of the area
4	Agriculture	1686.86	253.03	15% of the area
5	Built-Up	22.88	0.00	Not required
6	Barren/ Sparsely Vegetated	255.32	38.30	15% of the area
7	Open Water	14.39	0.00	Not required
Total		**6757.15**	**863.84**	**12.78%**

8.2 Treatment Measures

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

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

The basis of site selection for different engineering treatment measures under CAT are given in **Table 21**.

AFROZ
VICE PRESIDENT
KONDULI... COAL PROJECT
...ENTERPRISES LIMITED

Table 21: Basis for selection of catchment area treatment measures

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

8.3 Biological Measures

The biological measures would comprise of:

- Afforestation
- Assisted Natural Regeneration

a. Afforestation

A well-stocked forest plays a very important role in control of soil erosion. Thus, it is proposed to increase the vegetal cover in the area. As most of the areas in Hazaribagh have sufficient rainfall and light, the growth of plants is very fast. Afforestation programme would be taken up in open forests and degraded surfaces where slope is less than 45 degrees. It is suggested to undertake plantations of shrubs as well as trees. The area to be brought under afforestation programme and its unit cost is given in ***Table 22.***

b. Assisted Natural Regeneration

It is important to enhancing the establishment of secondary forest from moderately dense forests, degraded grassland and shrub vegetation by protecting and nurturing the mother trees and their wildlings inherently present in the area. Assisted natural regeneration is proposed to accelerate, rather than replace, natural successional processes by removing or reducing barriers to natural forest regeneration such as soil degradation, competition with weedy species, and recurring disturbances (e.g., fire, grazing, and wood harvesting). The area to be brought under assisted natural regeneration programme and its unit cost is given in ***Table 22.***

c. Soil & Moisture Conservation in Forest Area

Besides of afforestation and assisted natural regeneration, it is also necessary to have soil and moisture conservation measures i.e., contour bunds / staggered trenches to check runoff and allow percolation of water to improve quality of vegetation and prevent loss of top soil (Sheet erosion). It is proposed to provide 20MDs per hectare to carryout soil & Moisture Conservation activities in the forest area.

8.4 Engineering Measures

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

a. Brushwood Check Dams

Brushwood check dams are very feasible where vegetative material for construction is abundant. Brushwood check dams can only be constructed in small gullies not deeper than 1m depth. As material required for construction of these types of dams is available locally these can be constructed faster and in very short span of time thereby effectively reducing the erosion in early phase of Project. The numbers of check dams are estimated using number of first order streams in an area under severe and very severe erosion intensity, and constructed at an interval of 100 m. The number of brushwood check dams suggested and its unit cost is given in ***Table 1.16.***

b. Dry Stone Masonry Check Dams

Dry stone masonry check dams/ walls can be made of boulder piled up across the gulley and along the banks if they are locally available. Such structures for damming a gulley or a stream to refine the flow velocity and to control bank erosion are called dry stone masonry/ loose bolder check dams/ walls. The number of dry-stone masonry check dams suggested and its unit cost is given in ***Table 22***.

c. Contour Bunding

Contour Bunding is used for retaining the water by creating obstruction to control erosion. It consists of constructing narrow based trapezoidal bunds on contours to improve runoff rainwater in such a manner that it percolates and recharges the root profile on either side of the bunds. Bunds are simply embankments like structures, constructed across the land slope. The area to be treated under Contour Bunding scheme and its unit cost is given in ***Table 22.***

d. Gabion Check Dams

If dry stone masonry check dams are considered not to be stable in a particular reach of the stream, Gabion structure or stone masonry structures can be installed. The proper judgment as per site condition for construction of these structures may be taken. The number of gabions check dams suggested and its unit cost is given at ***Table 22.***

9.0 Cost Estimates

The estimated cost of implementation of Soil Moisture Conservation plan is Rs. 1.26 Cr. and is given at ***Table 22.*** Year wise phasing of physical and financial outlay has been given in ***Table 23.***

Table 22: Cost Estimates for Soil Moisture Conservation Plan

Sl No.	Item	Rate (Rs)	Unit	Target	
				Quantity	Financial (Rs)
I	**Biological Measures**				
1	Afforestation				
	i) Creation	40,000	Ha	50	2,000,000
	ii) Maintenance for 5 years	20,000	Ha	50	1,000,000
2	Assisted Natural Regeneration				
	i) Creation	30,000	Ha	50	1,500,000
	ii) Maintenance for 5 years	10,400	Ha	50	520,000
3	Soil & Moisture Conservation due to Forest Diversion	300.0	20 MD / Ha	400	2,400,000
4	Wages for plantation watchman i.e., unskilled laborer round the year for 5 years (one watchman for every 50 ha) @ Rs. 9000 p.m. per watchman. Total area:100 ha. Admissible watchman: 2 nos.	9,000	man-month	100	900,000
	Sub Total I (1+2+3)				**8,320,000**
II	**Engineering Measures**				
5	Brushwood Check Dams	20,000	No	25	500,000
	Maintenance Cost @ 5% of the cost				25,000
6	Dry Stone Masonry Check Dams (Nos)	20,000	No	20	400,000
	Maintenance Cost @ 5% of the cost				20,000
7	Gabion Check Dams	26,000	No	15	390,000
	Maintenance Cost @ 5% of the cost				19,500
8	Contour Bunding	15,000	Ha	50	750,000

AFROZ
VICE PRESIDENT GONDULPARA COAL PROJECT ADANI ENTERPRISES LIMITED

	Maintenance Cost @ 5% of the cost				37,500
	Sub Total II (4+5+6+7)				**2,142,000**
A	**Treatment Cost (Sub Total I + II)**				**10,462,000**
III	**Administrative Measures**				
9	Administrative Charges @5% of Treatment Cost				523,100
10	Micro Planning Charges @2% of Treatment Cost				209,240
11	Monitoring & Evaluation Charges @3% of Treatment Cost				313,860
12	Contingencies @10% of Treatment Cost				1,046,200
B	**Sub Total III**				**2,092,400**
	Total Soil Moisture Conservation Pan Cost (A + B)				**12,554,400**
	OR SAY				**1.26 Cr.**

AFROZ
VICE PRESIDENT
GONDULPARA COAL PROJECT
ADANI ENTERPRISES LIMITED

Table 23: Year wise physical & financial targets of treatment measures for Soil Moisture Conservation Plan

S. No.	Treatment Measures	Year I Phy.	Year I Fin. (Rs. In Lakh)	Year II Phy.	Year II Fin. (Rs. In Lakh)	Year III Phy.	Year III Fin. (Rs. In Lakh)	Year IV Phy.	Year IV Fin. (Rs. In Lakh)	Year V Phy.	Year V Fin. (Rs. In Lakh)	Year VI Phy.	Year VI Fin. (Rs. In Lakh)	Year VII Phy.	Year VII Fin. (Rs. In Lakh)	Total Phy.	Total Fin. (Rs. In Lakh)
I	**BIOLOGICAL MEASURES**																
1	**Afforestation (Ha)**			50	20.0											50	20.0
	1st Year maintenance					50	3.20									50	3.20
	2nd Year maintenance							50	2.30							50	2.30
	3rd Year maintenance									50	1.50					50	1.50
	4th Year maintenance											50	1.50			50	1.50
	5th Year maintenance													50	1.50	50	1.50
2	**Assisted Natural Regeneration (Ha)**			50	15.0											50	15.00
	1st Year maintenance					50	1.508									50	1.508
	2nd Year maintenance							50	1.196							50	1.196
	3rd Year maintenance									50	0.832					50	0.832
	4th Year maintenance											50	0.832			50	0.832
	5th Year maintenance													50	0.832	50	0.832
3	**Soil & Moisture Conservation (Ha)**				4.00		4.00		4.00		4.00		4.00		4.00		24.00
4	**Watch & Ward**			2	1.50	2	1.50	2	1.50	2	1.50	2	1.50	2	1.50		9.00
	Sub Total I				40.500		10.208		8.996		7.832		7.832		7.832		83.200
II	**ENGINEERING MEASURES**																
5	Brushwood Check Dams (Nos)			25	5.00											25	5.0
	Maintenance Cost @ 5% of the cost						0.250										0.250
6	Dry Stone Masonry Check Dams (Nos)			20	4.00											20	4.00
	Maintenance Cost @ 5% of						0.200										0.200

	the cost																
7	Gabion Check Dams (Nos)			15	3.90											15	3.90
	Maintenance Cost @ 5% of the cost						0.195										0.195
8	Contour Bunding (Ha)			50	7.50											50	7.50
	Maintenance Cost @ 5% of the cost						0.375										0.375
	Sub Total II				**20.40**		**1.020**										**21.420**
A	**Treatment Cost (Sub Total I + II)**				**60.900**		**11.228**		**8.996**		**7.832**		**7.832**		**7.832**		**104.620**
III	**ADMINISTRATIVE MEASURES**																
9	Administrative Charges @5% of Total		1.046		1.046		1.046		1.046		1.046						**5.231**
10	Micro planning @2% of Treatment Cost		2.092														**2.092**
11	Monitoring & Evaluation Cost @3% of Treatment Cost						1.046				1.046				1.046		**3.139**
12	Contingencies @10% of Treatment Cost				1.744		1.744		1.744		1.744		1.744		1.744		**10.462**
B	**Sub Total III**		**3.139**		**2.790**		**3.836**		**2.790**		**3.836**		**1.744**		**2.790**		**20.924**
	Total Soil Moisture Conservation Cost (A + B)		**3.139**		**63.690**		**15.064**		**11.786**		**11.668**		**9.576**		**10.622**		**125.544**
	OR SAY																**1.26 Cr.**

AFROZ
VICE PRESIDENT
COAL PROJECT
ADANI ENTERPRISES LIMITED

CONCLUSION

- The study area is located in the Hazaribagh District of Jharkhand, with latitudes ranging from 23° 49' 53.04" to 23° 56' 6.72" N and longitudes ranging from 85° 16' 10.2" to 85° 24' 27" E.
- Water level in the study area varies from 2.1 to 9.8 mbgl.
- Catchment area has been divided in to three sub-watershed area and total sub-water shed area of have been calculated as 67.570sq.km.
- Major area of study is coming under the gentle slope having less susceptibility of erosion.
- Infiltration tests have been caried out at four locations namely Gondulpara Village, Rautpara Village, Isko Village and Saheda Village.
- As per grain analysis study majorly sand and silts are dominated about 80% in the soil.
- Cost estimate for Biological Conservation Plan which include green belt and sowing of seeds will cost around Rs. 83,20,000
- Cost estimate for Engineering Conservation Plan which include Catch pits and Check dams or toe walls will cost around Rs. 21,42,000
- The estimated cost of implementation of Soil Moisture Conservation Plan is Rs. 1.26 Cr.

REFRENCE

- *Mine Plan*
- *Ven Te Chow, "Hand Book of Applied Hydrology", (1964).*
- *Santosh Kumar Garg, "Irrigation Engineering and Hydraulic Structures"*
- *Andy Ward, Adrian Smith & Jack Caldwell, Surface Erosion and sediment control at Open Cast Mine in South Africa, (1984) IAHS publication no. 144.*
- *Source-UNEP-DHI Partnership- Soil moisture conservation techniques*
- *Geological Survey of India (GSI)*
- *Survey of India (SOI)*
- *Central ground Water Board (CGWB)*
- *Soil and Land Use Survey of India (https://slusi.dacnet.nic.in/)*
- *For Soil Moisture Conservation Map*
  - I. https://bhukosh.gsi.gov.in/Bhukosh/Public
  - II. https://bhuvan.nrsc.gov.in/
  - III. https://onlinemaps.surveyofindia.gov.in/
  - IV. https://earthexplorer.usgs.gov/

AFROZ
VICE PRESIDENT
PARSA COAL PROJECT
ADANI ENTERPRISES LIMITED

Annexure-I
Field Photographs

Field Photgraphs