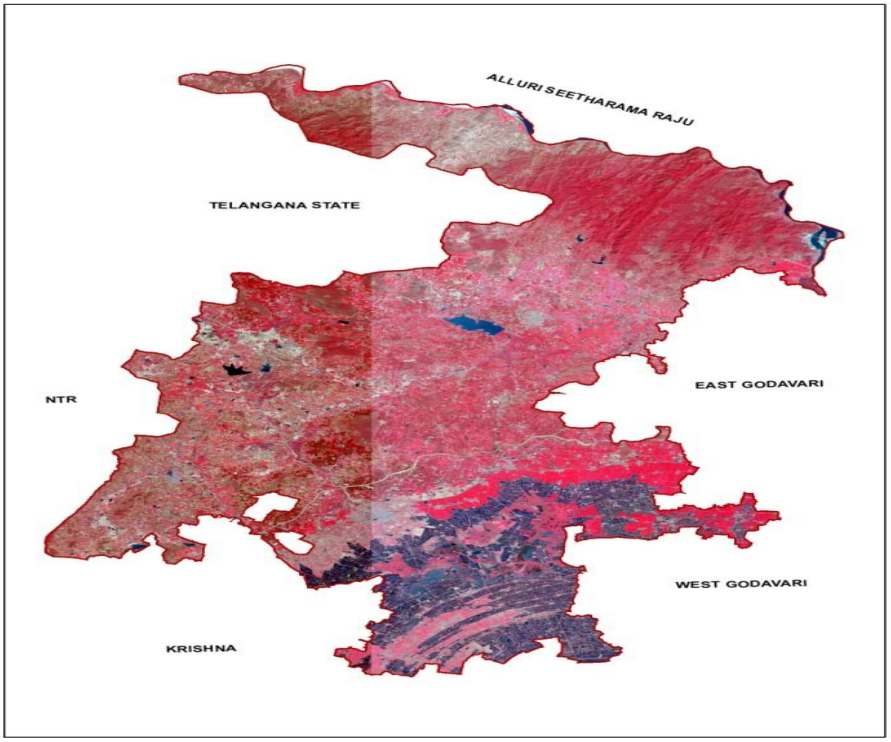
DISTRICT SURVEY REPORT
FOR
SAND AND OTHER MINOR MINERALS
ELURU DISTRICT, ANDHRA PRADESH

(FOR THE DEPARTMENT OF MINES AND GEOLOGY, GOVT. OF AP)

As per Notification No. S.O. 141 (E), 15.01.2016, S.O. 3611(E), 25.07.2018, and Enforcement and Monitoring Guidelines for Sand Mining 2020 of MOEF and CC, GoI



Prepared by

ANDHRA PRADESH SPACE APPLICATIONS CENTRE (APSAC)
ITE and C Department, Govt. of Andhra Pradesh

Submitted to

DEPARTMENT OF MINES AND GEOLOGY
Government of Andhra Pradesh

December 2023

Andhra Pradesh Space Applications Centre
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Report Scrutiny Mechanism

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PREFACE

The Natural resource inventory is the assessment of the status of a given natural resource of an area at a given point in time. Population pressure results in over- exploitation of resources. The baseline information on the resources would help the administration for better planning and decision making. The main purpose of the report is to disseminate data on the natural resource up to the lowest administrative functionary to facilitate micro level planning and development. The efforts have been made to assess and document the information on land use/land cover, crop, surface water resource, soils, slope, groundwater prospects, groundwater quality, geological information, and minerals resources in Eluru district, Andhra Pradesh, based on the satellite remote sensing data and socioeconomic information.

The Department of Mines and Geology (DMG), Government of Andhra Pradesh (AP) requested the Andhra Pradesh Space Applications Center (APSAC) to update the district survey reports with availability of sand mineral information, major and minor mineral details, and river morphology for all the districts in the State. The District Survey report emphasizes and updated the major and minor minerals in the districts of AP. The District Survey reports are updated following the "Sustainable Sand Mining guidelines" issued in 2016 and 2020 and SO 741 of 2016 of the Ministry of Environment, Forests and Climate Change provided by the DMG. The comments received from the public, if found fit, shall be incorporated in the report. A list of leases in the district will be provided by the concerned Assistant Directors of Mines and Geology.

The report is an outcome of the efforts of the Scientists and Project Associates at APSAC. I heartily congratulate the team for compiling the report.

(Dr.Sundar Balakrishna, IFS)
Vice-Chairman
APSAC

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We would like to express our sincere gratitudeto **Dr. Sundar Balakrishna, IFS**, **Special Secretary to Government,** Information Technology, Electronics and Communications (ITEandC), Govt. of Andhra Pradesh and the **Vice-Chairman, APSAC** Govt. of Andhra Pradesh, for his meticulous guidance and supervision.

We are grateful to the **Sri. V.G. Venkata Reddy**, **Director**, Department of Mines and Geology, Govt. of Andhra Pradesh for entrusting the work for the preparation of District Survey Reports of Andhra Pradesh.

We owe a great deal to **Sri. P Raja Babu, Joint Director,** Department of Mines and Geology for his overall support and guidance during the execution of this work.

We are very much thankful to **Dr.M.J.Ratnakanth Babu, Royalty Inspector (Head Office**), Mines and Geology for his support to complete the work successfully.

We are also thankful to the **District Mines and Geology Officer,** Eluru District for their support in providing information

Our sincere thanks are due to the scientific staff of APSAC who has generated all the thematic maps for District Survey Reports.

APSAC

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List of Abbreviations

APSAC	: Andhra Pradesh Space Applications Centre
APMMC	: Andhra Pradesh Minor Mineral Concession
AMSL	: Above Mean Sea Level
AWiFS	: Advanced Wide Field Sensor
APWALTA	: Andhra Pradesh State Water, Land and Trees Authority
APMDC	: Andhra Pradesh Mineral Development Corporation
Bgl	: Below ground level
BT Road	: Bituminous Road
Cl	: Chlorine
CC Road	: Cement concrete
CRZ	: Coastal Regulatory Zone
CPSU	: Central Public Sector Undertaking
CGWB	: Central Ground Water Board
cu.m/day	: Cubic meter per day
DSR	: District Survey Report
DMG	: Directorate of Mines and Geology
DMandGO	: District Mines and Geology Officer
DES	: Directorate of Economics and Statistics
DMF	: District Mineral Fund
DEM	: Digital Elevation Model
dS/m	: Decisiemens per meter
EIA/EMP	: Environmental Impact Assessment
F	: Fluorine
FAC	: Full Additional Charge
FASAL	: Forecasting Agricultural output using Space, Agrometeorology and Land-based observations
Fe	: Iron
Ft	: feet
GD	: Geosciences Division
GIS	: Geographical Information System
GSI	: Geological Survey of India
Ha	: Hactar
Km	: Kilometer
IRS	: Indian Remote Sensing Satellite
ITE and C	: Information Technology Electronics and Communications
LISS	: Linear Imaging Self Scanning
LULC	: Land Use / Land Cover
Lps	: Litres per second

M	: meter
Mi	: mile
mm	: millimetre
MT	: Million Tonne
MoEF	: Ministry of Environment and Forests
MERIT	: Mineral Exploration Research Innovation Trust Fund
MSL	: Mean Sea Level
NIRD	: National Institute of Rural Development
NH	: Natinal Highway
$NaNO_3$	: Sodium nitrate
NRSA	: National Remote Sensing Agency
NRSC	: National Remote Sensing Centre
PESA	: Panchayats Extension to Scheduled Areas
pH	: Power of hydrogen
PSD	: Performance Security Deposit
PSU	: Public sector Undertakings
R2	: ResourceSat-2
RGNDWM	: Rajiv Gandhi National Drinking Water Mission
RWS and S	: Rural Water Supply and Sanitation
SAR	: Synthetic Aperture Radar
SEB	: Special Enforcement Bureau
SO_4	: Sulfate
Sq.Km	: Square Kilometre
Sq.m	: Square metre
TA	: Tantalum
TIN	:Triangular Irregular Network
TGA	: Total Geographical Area
TIS	: Tank Information System
TTD	: Tirumala Tirupati Devasthanams
WBM	: Water Bound Macadam

Chapter I – Introduction andGeneral Profile

1.1 Administrative Setup

Eluru district is one of the coastal districts in the state of Andhra Pradesh. The district is established on 4th April 2022 with the administrative headquarters as Eluru.

Geographically, Eluru district is bounded north by Khammam district and Alluri Sitharama Raju district, south by West Godavari and Krishna districts, on the west by NTR district and on the east by East Godavari district. The total geographical area of the district is 6,679 Sq.km. It is covered with 3 Revenue divisions namely Eluru, Jangareddigudem and Nuzvid and comprising of 28 Revenue mandals and 693 Revenue villages. Buttayagudem mandal is having maximum number of villages (53) and Bhimadole mandal is having minimum number of villages (11). Out of 28 mandals of the district, the maximum area (541.06 Sq.km) is occupied by Buttayagudem mandal and minimum area in Ganapavaram mandal (97.47 Sq.km). The mandals covered in each Revenue division are shown in Table-1 and its spatial distribution is shown in Figure-1. The satellite view of Eluru District is shown in Figure-2.

Table 1 List of Mandals Covered in each Revenue division

Eluru Division	Jangareddigudem Division	Nuzvid Division
Bhimadole	Buttayagudem	Agiripalle
Denduluru	Dwaraka Tirumala	Chatrai
Eluru	Jangareddigudem	Chintalapudi
Ganapavaram	Jeelugu Milli	Lingapalem
Kaikalur	Kamavarapukota	Musunuru
Kalidindi	Koyyalagudem	Nuzvid
Mandavalli	Kukunoor	
Mudinepalle	Polavaram	
Nidamarru	T.Narasapuram	
Pedapadu	Velairpadu	
Pedavegi		
Ungutur		

Data Source: APSAC, Vijayawada.

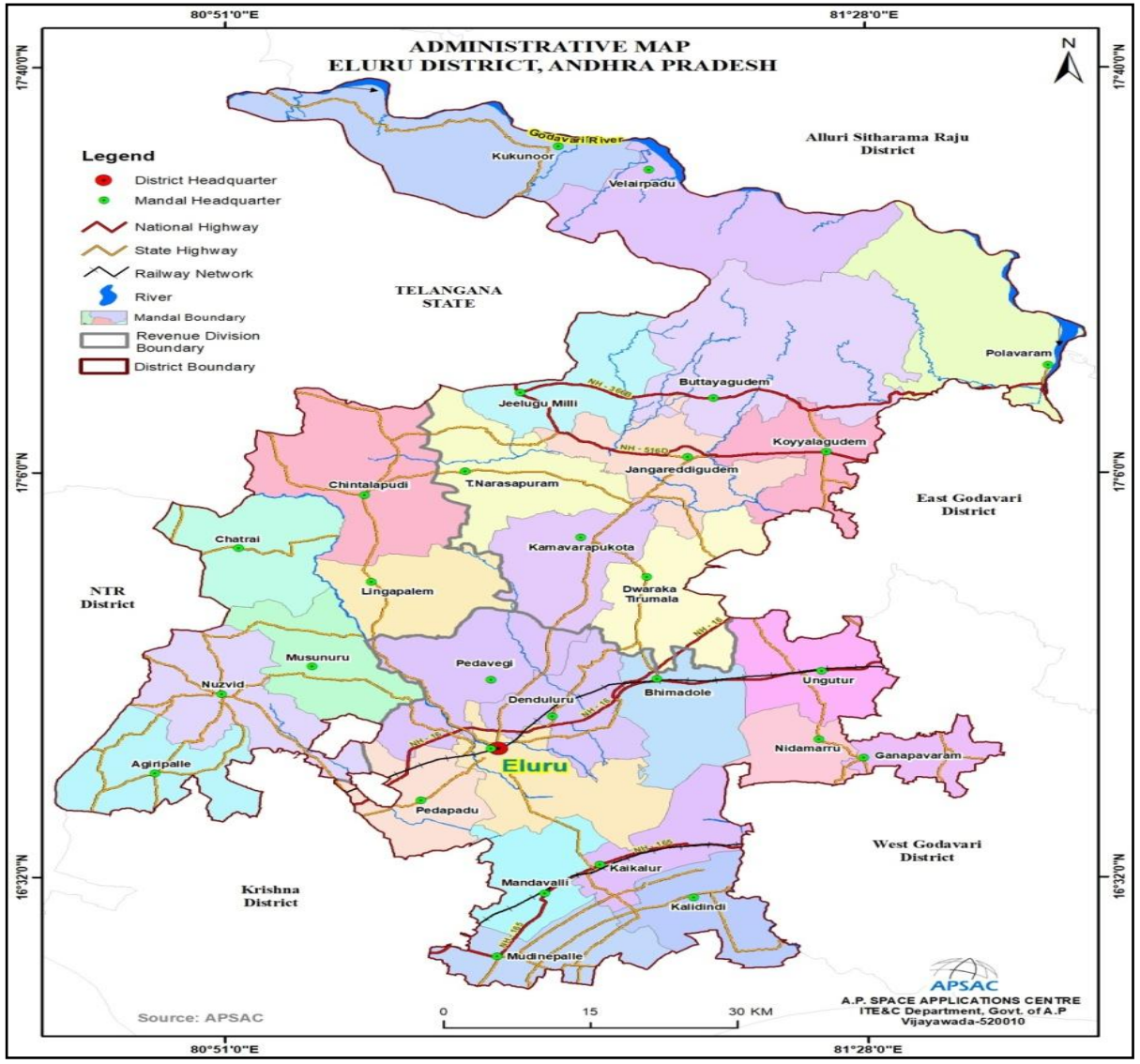


Figure-1: Administrative Map of Eluru district, Andhra Pradesh

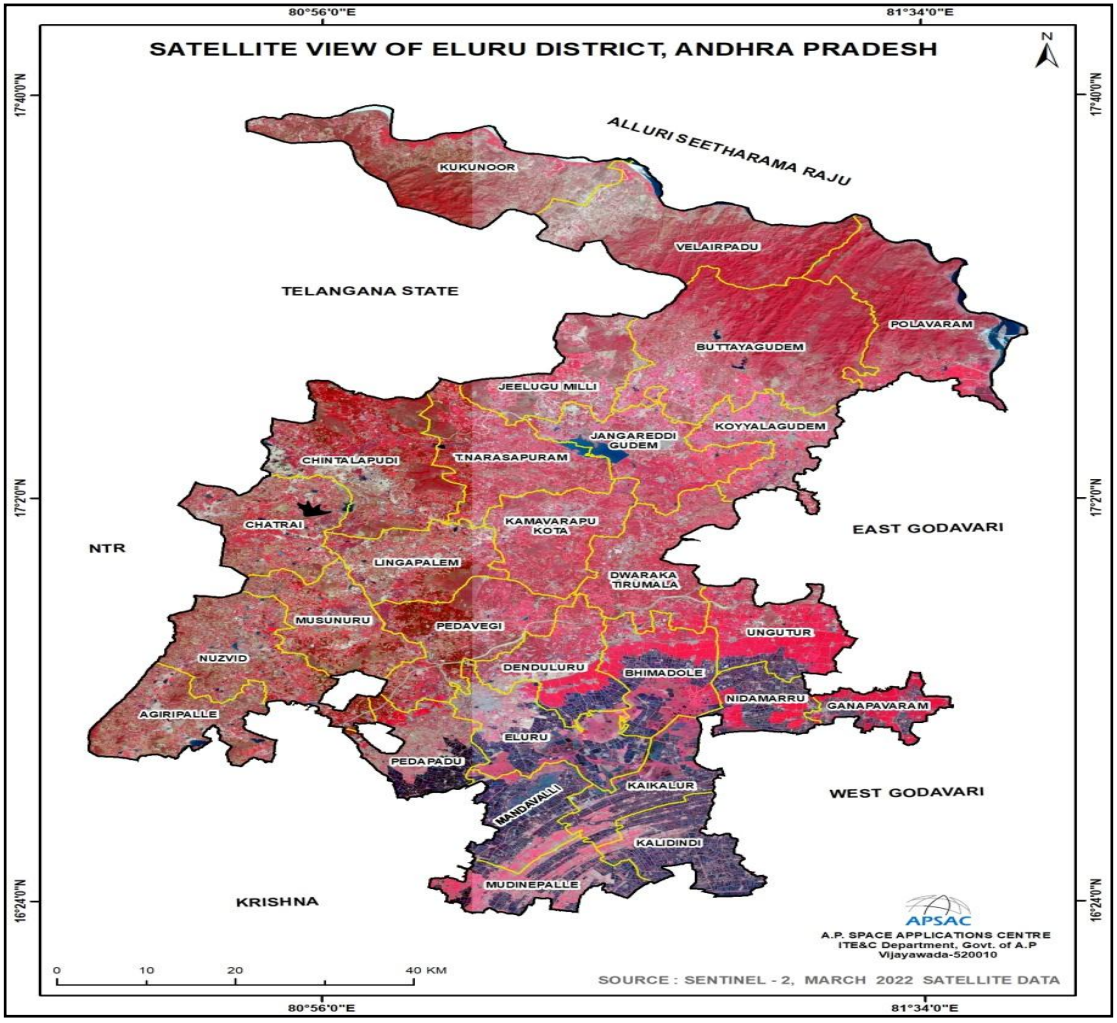


Figure-2: Satellite View of Eluru District

1.2 Physiography

Physiographically Eluru district is a central plain land surrounded by nearly plain and rolling lands to moderately steep to very steep sloping plains. The very steep sloping areas are mostly in the northern and NE parts of the district. The Western and eastern parts of the district are plainlands.

1.2.1 Relief

As per the guidelines of All India Soil and Land Use Planning (AIS and LUP) soil survey manual, the slope distribution of the district is provided in Figure-3. The slope map shows that most of the district land is nearly level, followed by moderately steep to steep sloping. They account for 76% and 15% of the district's total area, respectively. These sloping areas are found along the northern and north-eastern parts of the district. The gently sloping areas (3-5%) are found along the streams and the western and northern parts of the district, which accounts 3.5% of the district geographical area.

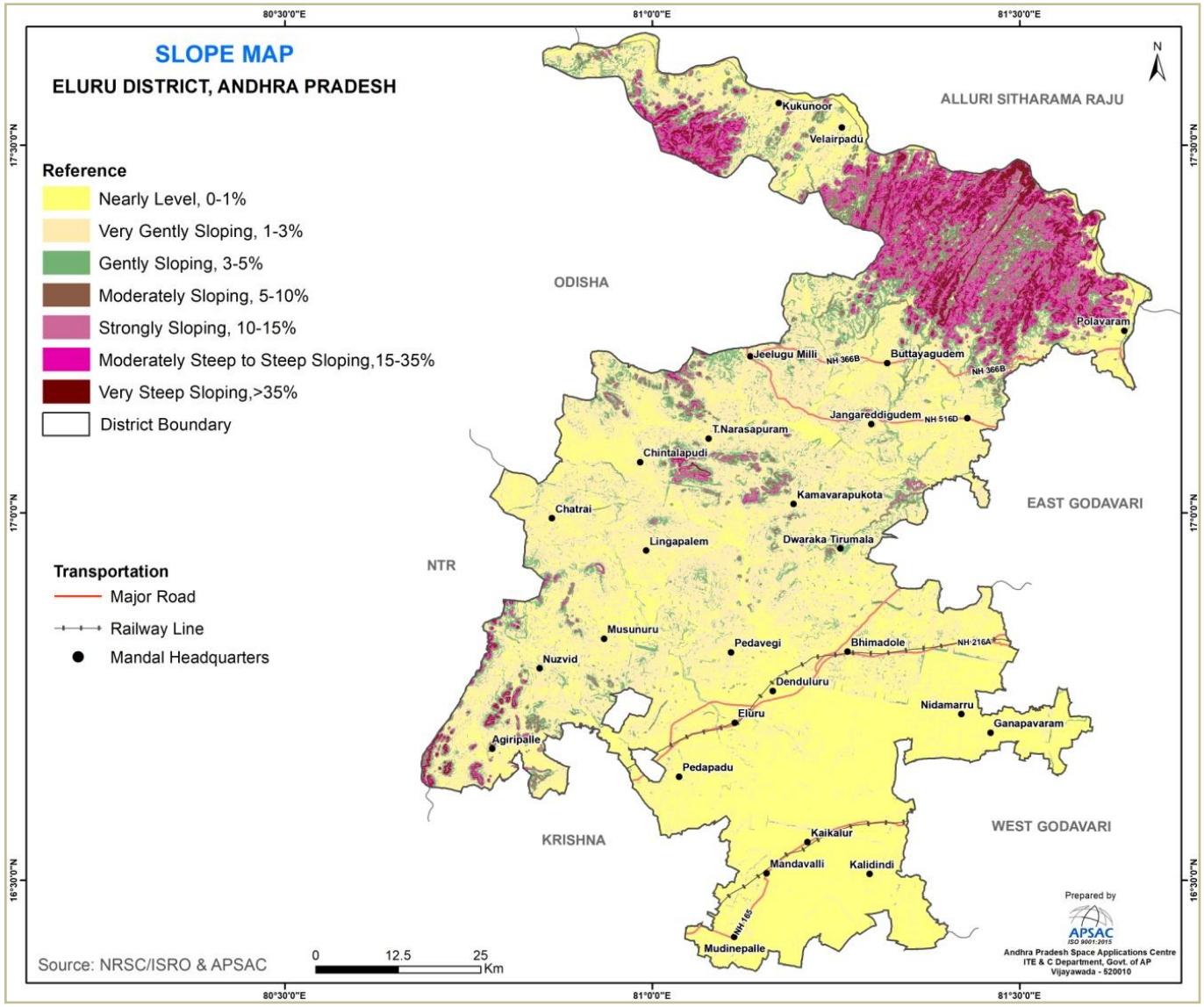


Figure-3: Slope Map of Eluru District

1.2.2 Climate and Rainfall

1.2.3.1. Climate:

Tropical climate conditions with extremely hot summer and cold winter prevail in this District. During the months of April to June is the hottest period with the high temperature in May. The climate of the district is moderate and characterized by a tropical rainy climate with aggressive summer. The period from December to the middle of February month is generally the season of fine weather. The minimum and maximum temperatures recorded in the district are 19°C in the months of January and 36°C in May respectively. The average rainfall for the last 25 years data used for the analysis. The locations of Automatic Weather Stations (AWS) are in Eluru District shown in Figure-4.

1.2.3.2. Rainfall:

The average annual rainfall of the district is 1063.01 mm, of which 784.68 mm falls as South-West (June-September) and 186.54 mm as North-East (October-December) monsoon.The minimum and maximum temperatures recorded in the district are 19°C in January and 36°C in May, respectively. The average rainfall for the last 25 years is used for the analysis. The average annual rainfall is shown in Figure-5 and details are given in Table-2.

Table 2 Average Annual Rainfall (mm) in the district, during the year 1998-2021

S.No	Month	Average Annual Rainfall (mm)
1	January	6.20
2	February	7.87
3	March	11.14
4	April	15.62
5	May	50.96
6	June	137.64
7	July	234.08
8	August	235.42
9	September	177.54
10	October	127.21
11	November	46.50
12	December	12.83
Total		**1063.01**

Data source: AWS and APSDPS, Vijayawada

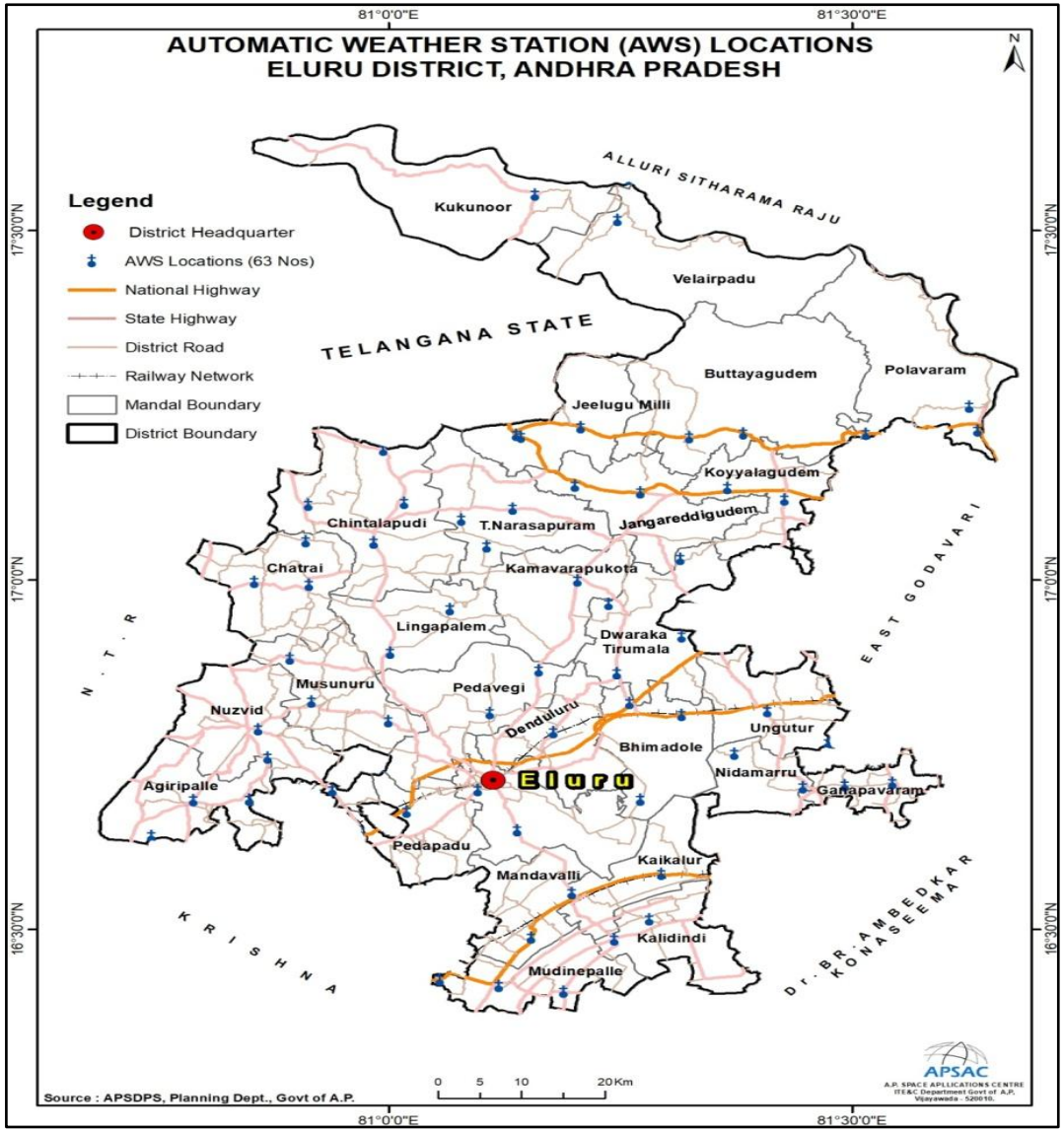


Figure-4: Locations of Automatic Weather Stations (AWS) in Eluru District

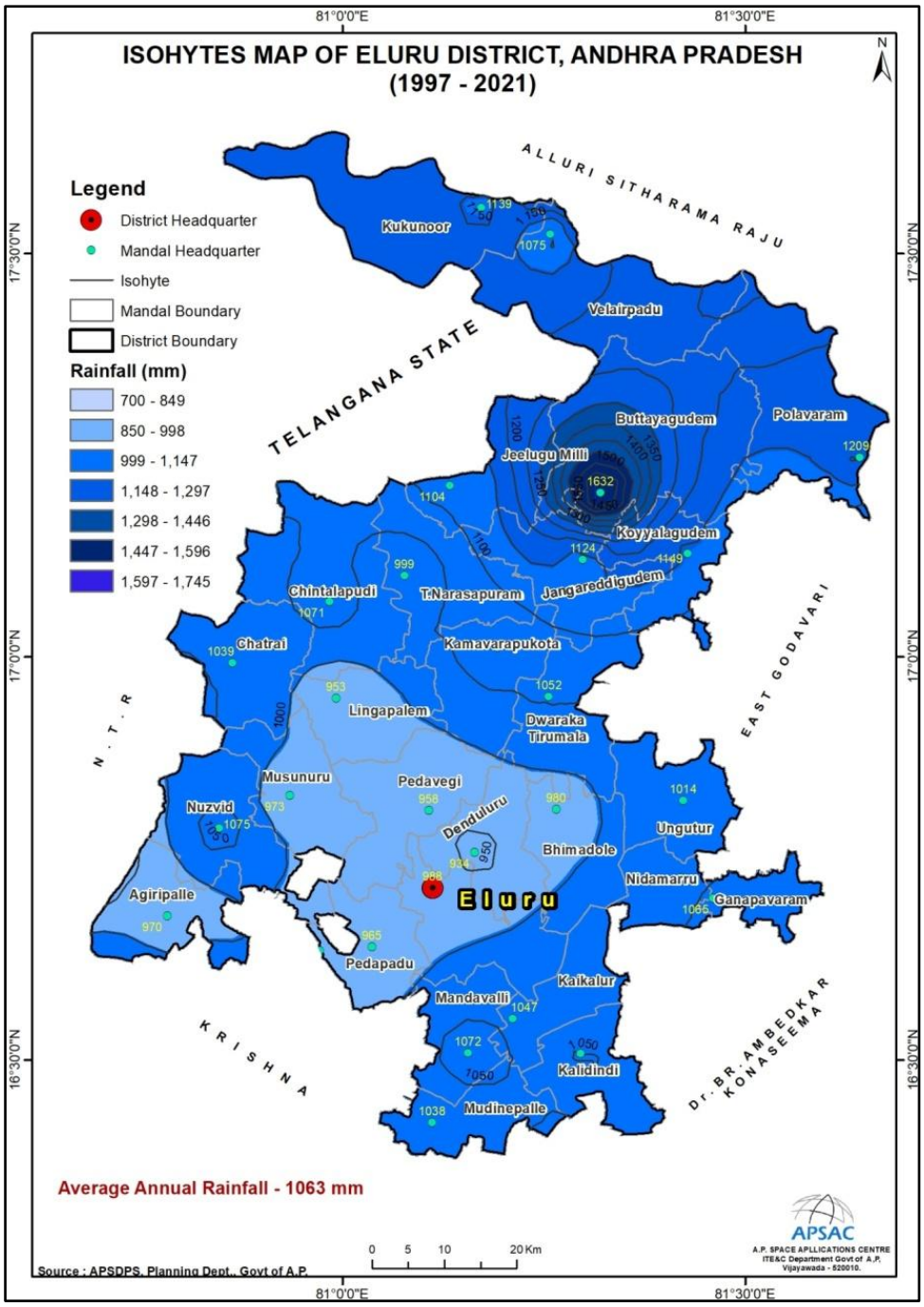


Figure-5: Rainfall distribution in Eluru District

1.2.3 Drainage

The principal rivers flowing in the district are Godavari, Yerrakalva, Kovvada Kalva, Thammileru, Ramileru Vagu and partially covered with Budameru, Upputeru rivers. The Godavari River rises near Trimbakeshwar in the Nashik district of Maharashtra about 80 km from the Arabian Sea at an elevation of 1,067 m and The total length of Godavari from its origin to outfall into the Bay of Bengal is 1,465 km. Itenters into the district near Velair village in Kukunoor mandal and leaves the district near Gutala village in Polavaram mandal.

The Yerrakalva river rises in Khammam district of Telangana and Eluru district of Andhra Pradesh. The Yerrakalva river flows towards south-east direction and leaves the district near Rajavaram. It is merged into Enamadurru drain near Nandamuru Aquduct (Eluru Canal-Godavari). The Kovvada Kalva river rises in Kovvada RF and Chintapalle RF, Buttayagudem mandal in Eluru district and flows towards south-east direction and leaves the district near Pattisam village in Polavaram madnal.

The Thammileru river rises in Dammapeta Mandal, Khammam district in Telangana State and enters into the district near Chinnampet village in Chatrai mandala. It flows towards south direction and joining to Kolleru Lake near Eluru madnal in Eluru district.

Four major drains are covered in southern part of the district, Perantalakanama drain, Polaraju drain, Pedalanka drain and Chandrayya drain. The drains are flows towards east direction and Polaraju, Chandrayya drains are joining to Kolleru Lake and Perantalakanama, Pedalanka drains joining in Upputeru river in Eluru district.

The Kolleru Lake is one of the largest freshwater lakes in the country located southern part of the district and located between the Krishna and Godavari deltas. The Ramileru Vagu and Gunderu rivers are rises in Eluru district, flows towards south direction and joining to Kolleru Lake in Eluru district.

1.3 Population and Literacy

1.3.1. Population: The total population of the district is 20,71,647 as per the 2011 census of India; of which male and female are 10,35,066 and 10,36,581 respectively. Among all the mandals, Eluru Mandal is having maximum population of 3,19,405; whereas Velairpadu Mandal is having minimum population of 22,882.

The total schedule caste(SC) population in the district is 4,65,537; of which male and female are 2,32,112 and 2,33,425 respectively. The schedule tribe (ST) population is 1,22,923; of which male and female are 59,964 and 62,959 respectively. The mandal wise population is shown in Table-3.The mandal wise spatial distribution of total population is depicted in Figure-6.

1.3.2. Literacy: The total literacy in the district is 13,20,228; of which male and female are 6,91,684 and 6,28,544 respectively. The total illiterates are 7,51,419; of which male and female are 3,43,382 and 4,08,037 respectively. The mandal wise Literacy Statistics Summary is shown in Table-4.

1.3.3. Details of the Occupational Health issues in the District (Last five-year data of number of patients of Silicosis): No cases were reported during last 5 years due to mining activity.

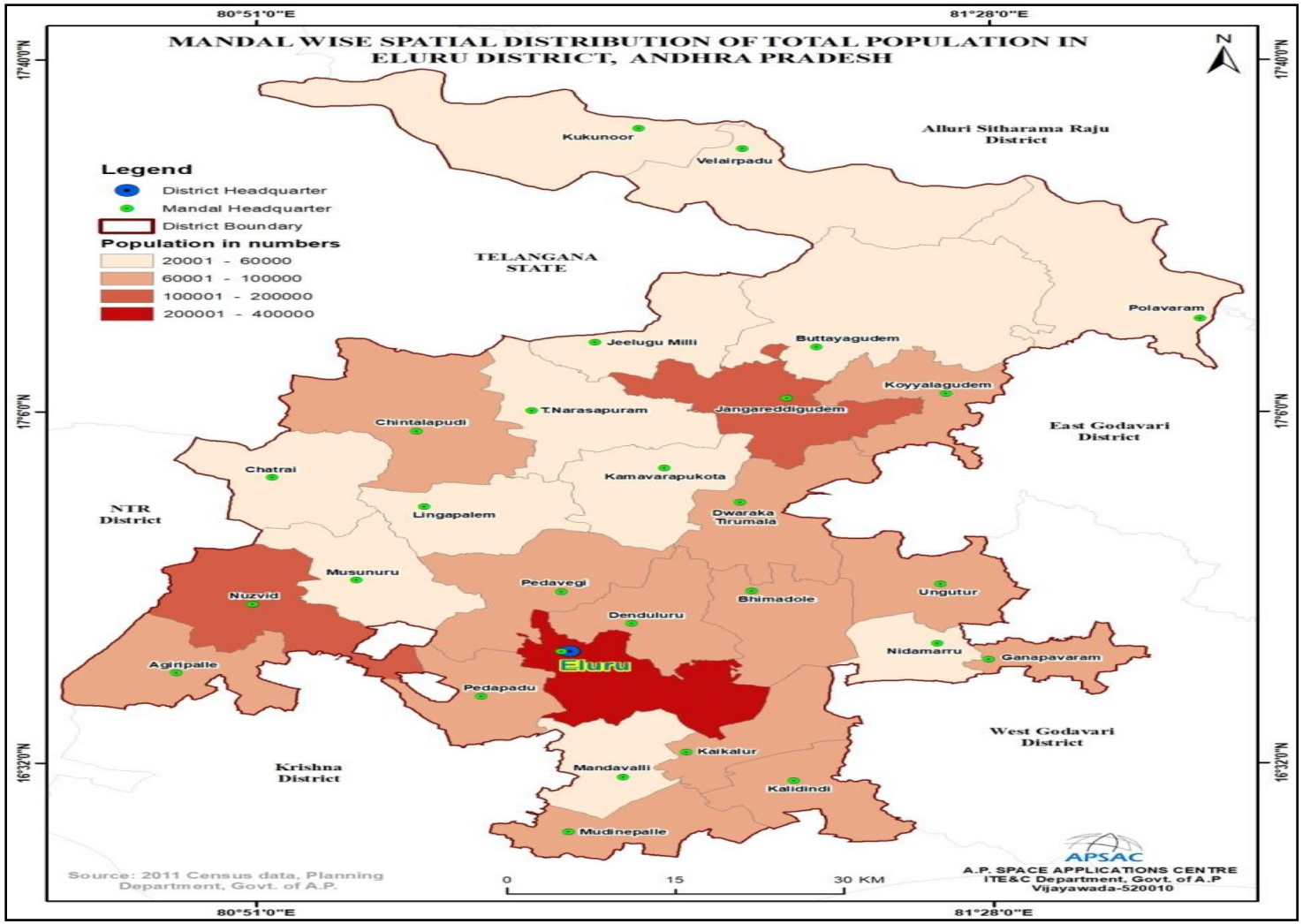


Figure-6: Mandal wise Spatial Distribution of Population in Eluru district, Andhra Pradesh

Table 3 Mandal wise total population in Eluru District

S. No	Mandal Name	Total House Holds	Total Population	Total Male Population	Total Female Population	Total SC Population	Male SC Population	Female SC Population	Total ST Population	Male ST Population	Female ST Population
1	Agiripalle	17055	62098	31780	30318	15757	8098	7659	971	489	482
2	Bhimadole	18193	65216	32392	32824	15614	7505	8109	456	207	249
3	Buttayagudem	14521	53031	25533	27498	4516	2213	2303	34247	16245	18002
4	Chatrai	14425	53493	27080	26413	15481	7820	7661	1823	932	891
5	Chintalapudi	24992	91372	45350	46022	28952	14212	14740	9121	4566	4555
6	Denduluru	18782	66695	33425	33270	19156	9591	9565	478	245	233
7	Dwaraka Tirumala	19180	68989	34797	34192	24820	12319	12501	950	481	469
8	Eluru	82609	319405	157783	161622	44153	21541	22612	2717	1345	1372
9	Ganapavaram	18622	64963	32519	32444	13641	6809	6832	662	340	322
10	Jangareddigudem	29820	109814	54682	55132	25259	12459	12800	2741	1331	1410
11	Jeelugu Milli	8438	30077	15163	14914	5924	3043	2881	8779	4500	4279
12	Kaikalur	21660	77654	38890	38764	8973	4473	4500	468	236	232
13	Kalidindi	19894	70729	35364	35365	6136	2989	3147	521	265	256
14	Kamavarapukota	15701	57636	29248	28388	18767	9559	9208	1552	777	775
15	Koyyalagudem	20785	75694	37755	37939	18629	9261	9368	2816	1353	1463
16	Kukunoor	10606	35894	17822	18072	9550	4757	4793	10899	5445	5454
17	Lingapalem	15626	58360	29546	28814	23897	12155	11742	329	165	164
18	Mandavalli	13900	48627	24342	24285	8997	4473	4524	314	160	154
19	Mudinepalle	18741	64377	32300	32077	12796	6363	6433	1528	764	764
20	Musunuru	15205	57197	28941	28256	18839	9578	9261	627	313	314
21	Nidamarru	13639	47623	24011	23612	6941	3463	3478	134	70	64
22	Nuzvid	32996	129553	65001	64552	30745	15397	15348	6395	3263	3132
23	Pedapadu	18497	69141	33878	35263	17571	8450	9121	1103	543	560
24	Pedavegi	23686	88834	45172	43662	26922	13772	13150	803	393	410
25	Polavaram	13677	45392	22345	23047	5695	2818	2877	12112	5829	6283
26	T.Narasapuram	15293	56179	28523	27656	17204	8780	8424	5079	2443	2636
27	Ungutur	23080	80722	40417	40305	18305	9085	9220	1058	528	530
28	Velairpadu	6785	22882	11007	11875	2297	1129	1168	14240	6736	7504
	Grand Total	**566408**	**2071647**	**1035066**	**1036581**	**465537**	**232112**	**233425**	**122923**	**59964**	**62959**

Data Source: Census - 2011, DES.

Table 4 mandal wise Literacy statistics

S.No	Mandal Name	Total Literacy	Male Literacy	Female Literacy	Total Illiterates	Male Illiterates	Female Illiterates
1	Agiripalle	37806	20387	17419	24292	11393	12899
2	Bhimadole	42256	21803	20453	22960	10589	12371
3	Buttayagudem	32315	16417	15898	20716	9116	11600
4	Chatrai	29378	16031	13347	24115	11049	13066
5	Chintalapudi	55464	29376	26088	35908	15974	19934
6	Denduluru	43198	22707	20491	23497	10718	12779
7	Dwaraka Tirumala	42364	21860	20504	26625	12937	13688
8	Eluru	236156	122104	114052	83249	35679	47570
9	Ganapavaram	44406	23033	21373	20557	9486	11071
10	Jangareddigudem	68788	35629	33159	41026	19053	21973
11	Jeelugu Milli	18419	9942	8477	11658	5221	6437
12	Kaikalur	49672	26048	23624	27982	12842	15140
13	Kalidindi	43594	22977	20617	27135	12387	14748
14	Kamavarapukota	34692	18367	16325	22944	10881	12063
15	Koyyalagudem	45017	23285	21732	30677	14470	16207
16	Kukunoor	17723	9722	8001	18171	8100	10071
17	Lingapalem	35553	19100	16453	22807	10446	12361
18	Mandavalli	31214	16522	14692	17413	7820	9593
19	Mudinepalle	41391	21758	19633	22986	10542	12444
20	Musunuru	33291	17587	15704	23906	11354	12552
21	Nidamarru	30257	15774	14483	17366	8237	9129
22	Nuzvid	84438	44692	39746	45115	20309	24806
23	Pedapadu	46953	24117	22836	22188	9761	12427
24	Pedavegi	55914	29541	26373	32920	15631	17289
25	Polavaram	28301	14536	13765	17091	7809	9282
26	T.Narasapuram	31012	16792	14220	25167	11731	13436
27	Ungutur	50429	26138	24291	30293	14279	16014
28	Velairpadu	10227	5439	4788	12655	5568	7087
	Grand Total	**1320228**	**691684**	**628544**	**751419**	**343382**	**408037**

Data Source: 2011 Census data, Planning Department and DES.

1.4 Land Utilization Pattern

1.4.1 Land Use / Land Cover

The Land Use / Land Cover (LULC) pattern of any region is an outcome of various physical and cultural factors and their utilization by man in time and space. Land use refers to the type of utilization to which man has put the land. It also refers to the evaluation of the land's various natural characteristics. But land cover describes the vegetal attributes of the land. Land use/land cover data is essential for planners, decision-makers, and those concerned with land resource management. For a proper understanding of the influence of the various human-induced land-use practices on environmental change, it is essential to help simulate the land-use changes. Remote sensing technology is considered the most effective as it provides timely and authentic information about the spatial distribution of land use/land cover, while the Geographical Information System (GIS) provides a flexible digital environment for collecting, storing, visualizing, and analyzing spatial data. Rapid evaluation and monitoring of a natural resource are made possible with the help of Remote Sensing (RS). When combined with GIS, it makes it possible to map land use/land cover phenomena in detail for further planning, development, and decision-making, which is essential for meeting the increasing demands and welfare of the ever-growing population.

1.4.2 Spatial Distribution of Land Use / Land Cover

Using satellite data from the three seasons (Kharif, Rabi, and Zaid), various land use and land cover categories have been identified under the level-3 classification. The land use/land cover map has been classified using visual image interpretation techniques such as size, shape, color, tone, texture, association, and pattern (NRSC, 2006). This information is used for general planning purposes at the district/mandal level. The broad land use/land cover categories such as built-up land (240.70 sq. km.), agricultural land (4444.78 sq. km.), forest (1400.30 sq. km.), wastelands (95.56 sq. km..), wetlands (209.18 sq. km.) and water bodies (287.47 sq. km.) were identified. The main food crop grown in the district is paddy. The other major crops grown in this district are tobacco, oil palm, maize, coconut, sugarcane, chillies, and bananas. The spatial distribution of land use/land cover map of Eluru district is presented in Figure-7 and the area statistics are shown in Table-5.

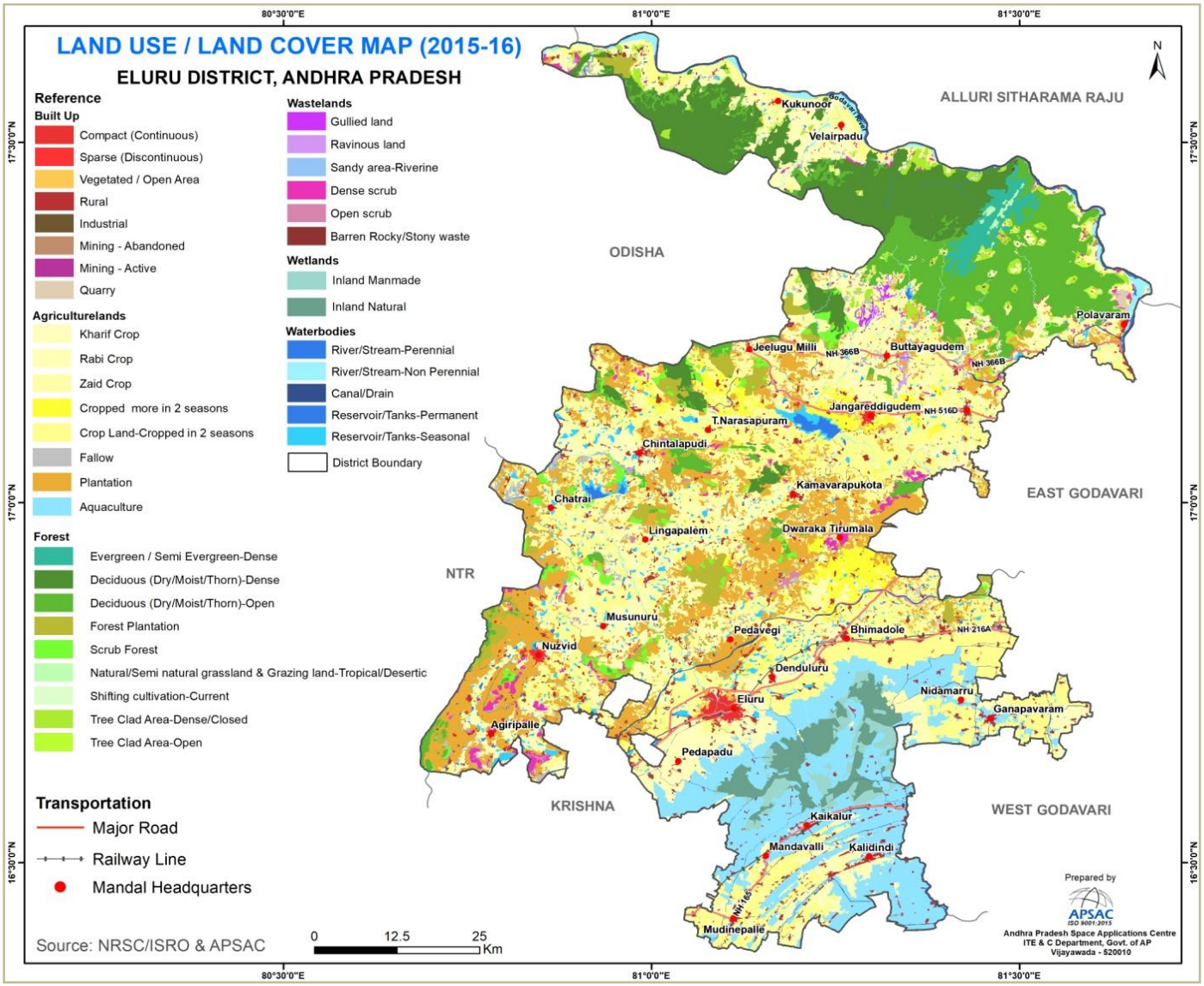


Figure-7: Land use / land cover map of Eluru District 2015-16

Table 5 Category-wise distributions of Land Use/Land Cover during 2015-16

S. No	LULC categories	Area in sq. km	% to total
Built up		**240.70**	**3.60**
1	Compact (Continuous)	23.92	0.36
2	Sparse (Discontinuous)	3.19	0.05
3	Vegetated / Open Area	10.38	0.16
4	Rural	187.85	2.81
5	Industrial	8.04	0.12
6	Mining - Active	0.11	0.00
7	Mining - Abandoned	0.41	0.01
8	Quarry	6.80	0.10
Agricultural land		**4444.78**	**66.55**
9	Kharif Crop	889.55	13.32
10	Rabi Crop	409.81	6.14
11	Zaid Crop	3.11	0.05
12	Cropped in 2 seasons	1464.68	21.93
13	Cropped more in 2 seasons	150.85	2.26
14	Fallow	86.66	1.30
15	Plantation	804.02	12.04
16	Aquaculture	636.09	9.52
Forest		**1400.30**	**20.97**
17	Evergreen / Semi Evergreen-Dense	64.02	0.96
18	Deciduous (Dry/Moist/Thorn)-Dense/Closed	474.77	7.11
19	Deciduous (Dry/Moist/Thorn)-Open/Closed	523.32	7.84
20	Forest Plantation	157.08	2.35
21	Scrub Forest	78.55	1.18
22	Tree Clad Area-Dense	79.41	1.19
23	Tree Clad Area-Open	16.41	0.25
24	Grazing land	6.63	0.10
25	Shifting cultivation-Current	0.11	0.00
Wastelands		**96.56**	**1.45**
26	Gullied land	7.01	0.11
27	Ravinous land	4.47	0.07
28	Dense scrub	60.83	0.91
29	Open scrub	23.50	0.35

30	Sandy area-Riverine	0.20	0.00
31	Barren Rocky/Stony waste	0.55	0.01
Wetlands		**209.18**	**3.13**
32	Wetlands-Inland Manmade	72.41	1.08
33	Wetlands-Inland Natural	136.77	2.05
Water bodies		**287.47**	**4.30**
34	River/Stream-Perennial	32.65	0.49
35	River/Stream-Non Perennial	66.31	0.99
36	Canal/Drain	36.17	0.54
37	Reservoir/Tanks-Permanent	32.00	0.48
38	Reservoir/Tanks-Seasonal	120.34	1.80
Total		**6679.00**	**100.00**

Data source: NR Census 3rd cycle mapping, NRSC/ISRO and APSAC, GoAP

1.4.2.1. Built-up

These are the areas where people live and are supported by infrastructure such as buildings, roads, and other modes of transportation, as well as utilities connected to water, vegetation, and open spaces. It consists of built-up (Compact and Sparse), Vegetated / Open Area, Rural, Industrial, and Mining/Quarry. It covers an area of 240.70 sq. km, accounting for 3.60% of the total geographical area of the district. The built-up category includes district headquarters, some mandal headquarters, industrial areas, and rural settlement areas. Many vacant lands with layouts and fencing are being developed for real estate development on the outskirts of the urban areas of Eluru, Nuzvid, and Jangareddigudem.

1.4.2.2. Built-up - Compact (Continuous)

Most of the land is covered by buildings, roads, and artificially surfaced areas and covers almost all the ground. The built-up-compact class is assigned where impermeable surfaces such as the transportation network and urban structures take up more than 80% of the surface area. This category occupies 23.92 sq. km. and is found in Eluru, Nuzvid, and Jangareddigudem towns.

1.4.2.3. Built-up - Sparse (Discontinuous)

The majority of the land is covered by structures such as buildings, roads, and artificially surfaced areas that are associated with vegetated areas and bare soil, occupying discontinuous but significant surfaces. Between 30 to 80

% of the total surface should be impermeable. This category delineates scattered blocks of residential flats, hamlets, and small villages. It covers an area of 3.19 sq. km. and is located in the peri-urban areas of Eluru, Nuzvid, and Jangareddigudem.

1.4.2.4. Vegetated / Open Area

These are vegetated areas within an urban agglomeration (areas located within or adjacent to urban areas). The vegetation cover of trees, shrubs, and herbs has been delineated and covers the surface area. Open areas used as Parks, sports and leisure facilities, camping grounds, sports grounds, leisure parks, golf courses, and race courses, including formal parks etc, are considered in this category. This category covers an area of 10.38 sq. km and is found in and around the towns of Eluru, Nuzvid, and Jangareddigudem.

1.4.2.5. Built-up – Rural

These are lands used for human settlement of a size comparable to urban settlements, in which more than 80% of the people are engaged in primary agricultural activity, are associated with non-commercial and allied classes, and are classified as built-up (rural). The rural built-up area is the most prevalent of the built-up categories and is spread throughout the district. It contributed an area of 187.85 sq. km (2.81%) of the district's total geographical area.

1.4.2.6. Industrial

Non-linear impervious surfaces are included in this class which is related to trade, manufacturing, distribution, and commerce. These are areas where human activity is observed in the form of manufacturing along with other supporting establishments for maintenance. The industrial area occupies an area of 8.04 sq. km, which is observed in and around towns.

1.4.2.7. Mining – Active

Mining areas encompass areas under surface operations. The recognizable impacts of these activities on the landscape are unmistakable giant pit mines covering vast areas. The active mining areas are presently large-scale surface operations of removal of economically important ores and presently going on. The active mining area contributes an area of 0.11 sq. km.

1.4.2.8. Mining – Abandoned

These are the areas where large-scale surface operations of removal of economically important ores were carried out in the past but presently kept abandoned due to various reasons like economic, operational, viability, disturbances, etc. Only 0.41 sq. km comes under this category.

1.4.2.9. Quarry

These are manifestations of surface mining operations, which involve small-scale land surface excavation for quarries of quartzite, granite, sand, and other materials. They are primarily distinguished by their proximity to cities. It covers 6.80 sq. km of the district's total area.

1.4.2.10. Agricultural Land

Agriculture land is primarily used for the production of food, fiber, and other commercial and horticultural crops. It includes land under crops namely cropland, fallow land, agricultural plantations, and aquaculture. The district's economy is primarily based on agriculture, which was found to account for 4444.78 sq. km (66.55%) of its total area during the period. It is also found that the double-cropped area accounts for about 22% of the district total. Major food crops grown are paddy, jowar, bajra, black gram, Bengal gram, red gram, and sugarcane, cotton, chillies, turmeric, castor, and lemon, banana, sapota, coconut and vegetables.

1.4.2.11. Kharif Crop

The agricultural area cultivated between June/July to September/October coinciding with the southwest monsoon season is considered Kharif crop. It is associated with rain-fed crops under dry land farming with limited or no irrigation and areas of rain-fed paddy and other dry crops. Kharif cropland is the second-largest agricultural category, covering 889.55 sq. km (13.32%). During the Kharif season, a variety of crops including paddy, sugarcane, jowar, maize, red gram, cotton, castor, and others are widely grown in the district.

1.4.2.12. Rabi Crop

These areas are cultivated between November/December to February/March. It is associated with areas under assured irrigation irrespective of the source of irrigation. During the Rabi season, primarily irrigated crops like rice, sugarcane, and vegetables are grown using canals, tanks, and groundwater resources. In the years 2015–16, Rabi cropland covered 409.81 sq. km (6.14%) of the total area.

1.4.2.13. Cropped in two seasons

These are the cropping areas that are commonly associated with irrigated areas during the two cropping seasons. Three combinations are possible in this category viz., - Kharif + Rabi, Kharif + Zaid, and Rabi + Zaid. Cropped areas in any two seasons are mapped under cropped in the two seasons category, occupying an area of 1464.68 sq. km (21.93%). These can be found throughout the district, with reliable irrigation provided by canals and groundwater.

1.4.2.14. Cropped in more than two seasons

These are the areas that have been cultivated over the course of more than two cropping seasons. It includes triple-cropped areas (Kharif, Rabi, and Zaid), as well as areas under multiple cropping. This category includes long-duration crops such as sugarcane, cotton, bananas, and tobacco are considered in this category. This category accounts for 150.85 sq. km (2.26%) of the district's total geographical area.

1.4.2.15. Fallow land

The agricultural land which is being used for cultivation but is temporarily allowed to rest or un-cropped for one or more seasons, but not less than a year and for not more than five years is referred to as fallow land. The fallow land occupies an area of 86.66 sq. km.

1.4.2.16. Agricultural Plantation

These are the areas where agricultural tree crops have been planted using agricultural management techniques. These also include the areas of land use systems and practices wherein the cultivation of herbs, shrubs, and vegetable crops are deliberately integrated with crops mostly in irrigated conditions for ecological and economic reasons. These areas can be distinguished from cropland, especially using data collected during the Rabi/Zaid season. Plantations appear in varying sizes with regular and sharp edges, indicating the presence of a fence around them. Plantations such as mango, banana, eucalyptus, teak, and others are grown in and around the Nuzvid and Dwaraka Tirumala areas of the district. The plantations category accounts for 804.02 sq. km (12.04%) of the district's total geographical area.

1.4.2.17. Aquaculture

These are the locations used for the commercial breeding and rearing of fish and shrimp. Aquaculture ponds are located mostly along the coast or in

lakes, rivers, and estuaries. This also includes the breeding and rearing of freshwater or marine fish in captivity. The category of aquaculture is mostly found along the south with an area of 636.09 sq. km.

1.4.2.18. Forest

The term forest is used to refer to land with a tree canopy cover of more than 30 percent and an area of more than 0.5 ha. Forest is determined both by the presence of trees and the absence of other predominant land uses within the notified forest boundaries. The trees should be able to reach a minimum height of 5 m within the notified forest boundaries. The forest area occupies an area of 1400.30 sq. km (20.97%) and is found along the north and central parts of the district.

1.4.2.19. Evergreen / Semi Evergreen-Dense/Closed

This term as such describes the phonology of perennial plants that are never entirely without green foliage. This category comprises tall trees, which predominantly remain green throughout the year. It includes both coniferous and tropical broadleaved evergreen species. Semi-evergreen is a forest type that includes a combination of evergreen and deciduous species with the former dominating the canopy cover. This category includes all areas where the canopy cover/density is more than 40 %. It occupies an area of 64.02 sq. km of the district total.

1.4.2.20. Deciduous (Dry/Moist/Thorn)-Dense

This category is predominantly composed of species, which shed their leaves once in year, especially during summer. These are mostly broad-leaved tropical forests with a tendency to shed their leaves annually. This category includes all the areas where the canopy cover/density is more than 40 % and contributed 474.77 sq. km in the district.

1.4.2.21. Deciduous (Dry/Moist/Thorn)-Open

This category is predominantly composed of species, which shed their leaves once a year, especially during summer. These are mostly broad-leaved tropical forests with a tendency to shed their leaves annually. This category includes all the forest areas where the canopy cover/density ranges between 10 - 40 percent. In addition to timber, these forests also contain a large variety of fauna like tigers, leopards, wolves, bears, etc. An area of 523.32 sq. km (7.84%) is attributed to this category.

1.4.2.22. Forest Plantation

These are the areas of tree species of forestry importance, raised and managed especially in the notified forest areas. Most of these are located in uplands, coastal areas within notified areas. Many of these can be identified based on the sharp boundaries exhibited by them. Forest plantations, mainly teak, bamboo, casuarinas, etc have been delineated with an area of 157.08 sq. km during the period.

1.4.2.23. Scrub Forest

These are the forest areas that are generally seen on the fringes of dense forest cover and settlements, where there is biotic and abiotic interference. Most times they are located closer to habitations. Forest blanks which are the openings amidst forest areas, devoid of tree cover, observed as openings of assorted sizes and shapes as manifested in the imagery are also included in this category. Most of the scrub forests are found in fringe areas of reserved forests and account for 78.55 sq. km (1.18%), which are generally prone to the conversion of forest plantations and other development activities within the notified forest.

1.4.2.24. Tree Clad Area-Dense

Areas with tree cover lying outside the notified forest area with a woody perennial plant with a single, well-defined stem carrying a more-or-less-defined crown and being at least 3 m tall. Plants essentially herbaceous but with a woody appearance (e.g. Bamboo and ferns) are also classified as trees if the height is more than 5 m and as shrubs if the height is less than 5 m. This category includes all the areas where the canopy cover/density is more than 40%. The dense tree-clad area contributes an area of 79.41 sq. km, which is found along with forest areas.

1.4.2.25. Tree Clad Area-Open

Areas with tree cover lying outside the notified forest area with a woody perennial plant with a single, well-defined stem carrying a more-or-less-defined crown and being at least 3 m tall. Plants essentially herbaceous but with a woody appearance (e.g. Bamboo and ferns) are also classified as trees if the height is more than 5 m and as shrubs if the height is less than 5 m. This category includes all the forest areas where the canopy cover/density ranges between 10 - 40 percent. The tree-clad open category has been mapped with an area of 16.41 sq. km.

1.4.2.26. Grass and Grazing Lands-Tropical

Grasslands are the areas of natural grass along with other vegetation, predominated by the former or grass like plains (Monocotis) and non-grass like herbs (Except lantana species which are to be classified as scrub). They possess irregular shapes with contiguous and non-contiguous appearance. Located in plains, uplands, and hill slopes or close to rivers/streams, they are associated with agricultural lands, drylands fenced from cultivation, riverbeds, and forested areas in high altitudes. Natural grasslands are those in which climate is the prime controlling factor under light to moderate grazing pressure. Semi-natural grasslands occur in normal upland situations that have been deforested by man as in situations in which physical factors are unfavorable to the development of forests. The area under this category is 6.63 sq. km.

1.4.2.27. Shifting cultivation-Current

Shifting cultivation is the name we use for agricultural systems that involve an alternation between cropping for a few years on selected and cleared plots and a lengthy period when the soil is rested. Cultivation consequently shifts within an area that is otherwise covered by natural vegetation. This category occupies an area of 0.11 sq. km. only.

1.4.2.28. Wastelands

Wasteland is described as degraded land which can be brought under vegetative cover with reasonable effort and which is currently underutilized, and land which is deteriorating due to lack of appropriate water and soil management or on account of natural causes. Wastelands can result from inherent/imposed disabilities such as location, environment, chemical and physical properties of the soil, or financial or management constraints. The area under the wasteland category was mapped at 96.56 sq. km (1.45%) during the study, which consists of further subcategories of gullied land, ravinous land, dense scrub, open scrub, riverine land, and barren rocky/stony waste.

1.4.2.29. Gullied land

Gullies are formed as a result of localized surface run-off affecting the unconsolidated material resulting in the formation of perceptible channels causing the undulating terrain. Gullies develop from rills which are tiny water channels a few centimeters deep, formed as a resultant impact of heavy rainfall and the wearing action of runoff generated therefrom. They are

commonly found on sloping lands, developed as a result of concentrated runoff. Further classification of this category is possible based on the depth, width, bed slope, frequency, and morphology of the bed material of the ravines. They appear in light yellow to bluish-green depending on the surface moisture and depth of erosion. They vary in size and shape with irregular broken network patterns. The gullied lands are mapped in the areas of pediment and the foothill zones, accounting for 7.01 sq. km (0.11%).

1.4.2.30. Ravinous land

The word ravine is usually associated not with an isolated gully but an intricate network of gullies formed generally in deep alluvium and entering a nearby river, flowing much lower than the surrounding area. Ravines are basically extensive systems of gullies developed along the river course. It covers an area of 4.47 sq. km.

1.4.2.31. Dense scrub

The scrub is usually confined to topographically elevated areas, on the hill slopes generally surrounded by agricultural lands. These areas possess shallow and skeletal soils, at times chemically degraded, extremes of slopes, severely eroded, and lands subjected to excessive aridity with scrubs dominating the landscape. It is found with varying sizes of small to large areas having a contiguous or dispersed pattern. The dense scrub areas are identified on the hills with moderate slopes. About 61 sq. km of the area was mapped during the period.

1.4.2.32. Open scrub

This category has a similar description as mentioned in the dense scrub except that they possess sparse vegetation or are devoid of scrub and have a thin soil cover. The open scrub areas are found at the foothills and moderate to gentle slopping areas are surrounded by agricultural lands. The area mapped under this category is about 23.50 sq. km.

1.4.2.33. Riverine sand

Riverine sands are those that are seen as accumulations in the flood plain as sheets which are the resultant phenomena of river flooding. The sandy areas occurring within or in continuity to the river course are to be excluded from this category. The riverine sands are mapped at 0.20 sq. km only along the rivers.

1.4.2.34. Barren Rocky/Stony waste

The barren rock exposures are especially confined to hilly terrain with down slopes with rock outcrops, stony waste, and fragments. Barren rocky areas have been observed as rocky outcrops in the forest and scrubland. It is found that most of the barren rocky areas are being quarried for various construction activities in the district. The area under this category is 0.55 sq. km.

1.4.2.35. Wetlands

Wetlands are all submerged or water-saturated lands that unavoidably have a land-water interface, whether they are man-made or natural, inland or coastal, permanent or temporary, static or dynamic. The wetlands category is found to have 209.18 sq. km with two subcategories.

1.4.2.36. Wetland - Inland Natural

These are the areas that include ox-bow lakes, cut-off meanders, playas, swamps, marsh, and peat bogs (with vegetation). This category contributes 136.77 sq. km of the district total.

1.4.2.37. Wetland - Inland Manmade

Waterlogged areas (seasonal and perennial) are created due to the negative effect of human management practices and are present with vegetation. This is attributed to an area of 72.41 sq. km.

1.4.2.38. Water Bodies

This category comprises areas with surface water, either impounded in the form of ponds, lakes, and reservoirs or flowing as streams, rivers, canals, etc are delineated. These can be seen clearly in the satellite image in blue to dark blue or cyan depending on the depth of the water. This category includes rivers, streams, canals, reservoirs, and tanks. The total area of water bodies, including all sub-categories, is about 287.47 sq. km (4.30%).

1.4.2.39. River/Stream-Perennial

Rivers/streams are the natural course of water flowing on the land surface along a definite channel/slope regularly or intermittently towards a sea in most cases or a lake or an inland basin in desert areas or a marsh or another river. The rivers/streams that flow continuously throughout the year are considered as perennial. It contributes an area of 32.65 sq. km. The important river and rivulets in the district are the Godavari. The River Godavari flows through the district in a north-east direction.

1.4.2.40. River/Stream-Non Perennial

When the water covers the surface for less than nine months each year, it is considered non-perennial. This also includes the dry part of the river generally characterized by the presence of sand or exposed rocks. It contributes an area of 66.31 sq. km under this category.

1.4.2.41. Canal/Drain

Canals and drains are artificial watercourses constructed for irrigation, navigation or to drain out excess water from agricultural lands. It is found mostly in the coastal plains with an area of 36.17 sq. km.

1.4.2.42. Reservoir/Tanks-Permanent

The reservoir is an artificial lake created by the construction of a dam across the river specifically for hydel power generation, irrigation, and water supply for domestic/ industrial needs, and flood control, either singly or in combination. Tanks are small lakes of impounded waterways constructed on land surfaces for irrigation. They are associated with croplands, lowlands, and reservoirs surrounded by hills without vegetation. This includes all reservoirs/tanks with water spread seen at least during one season in a year is considered under the permanent category. This category was delineated with an area of 32 sq. km. The Yerra Kalava Reservoir is the major reservoir in the district.

1.4.2.43. Reservoir/Tanks-Seasonal

Dry reservoirs/tanks are those which do not have water spread throughout the year and are considered seasonal. During the mapping period, where the water spread is not found in the three seasons, those areas are mapped in this category. Many of the tanks are found to be seasonal, with a total area of 120.34 sq. km.

1.4.3 Forest Cover Distribution

The forest cover maps were created by interpreting multiple sources of topographical maps and satellite data. Land with a tree canopy cover of more than 10% and a size of more than 0.5 ha is referred to as a forest. The forest is defined by the presence of trees and the absence of other dominant land uses within the notified forest boundaries. The trees should be able to reach a minimum height of 5 m within the notified forest boundaries. The forest cover in the district based on the interpretation of IRS R2 LISS III data of 2015-16 is 1400.30 sq. km, which is 20.97 % of the total geographical area of the district. The majority of the forest cover is found in

the north of the district. The district has a variety of vegetation types rich in flora and fauna. Its varied topography ranging from the hills of Eastern Ghats and plains supports varied ecosystems. Most of the forest cover extends over the north, with scattered patches in the central and western parts of the district. The forest cover vegetation is largely dry deciduous type with a mixture of Teak, Bamboo, Devadharu, etc. The spatial distribution of forest cover and its statistics are presented in Figure-8 and Table-6. As per the Forest Department, Government of Andhra Pradesh the Forest boundary map is presented in Figure-9 and the wildlife sanctuary boundary map shown in Figure-9A.

Table 6 Forest cover distribution in Eluru District

S. No	Type of Forest	Area in sq. km	% to district total
1	Evergreen / Semi Evergreen-Dense	64.02	0.96
2	Deciduous (Dry/Moist/Thorn)-Dense/Closed	474.77	7.11
3	Deciduous (Dry/Moist/Thorn)-Open/Closed	523.32	7.84
4	Forest Plantation	157.08	2.35
5	Scrub Forest	78.55	1.18
6	Tree Clad Area-Dense	79.41	1.19
7	Tree Clad Area-Open	16.41	0.25
8	Grazing land	6.63	0.10
9	Shifting cultivation-Current	0.11	0.00
Total		**1400.30**	**20.97**

Data source: NR Census 3rd cycle mapping, NRSC/ISROand APSAC, GoAP

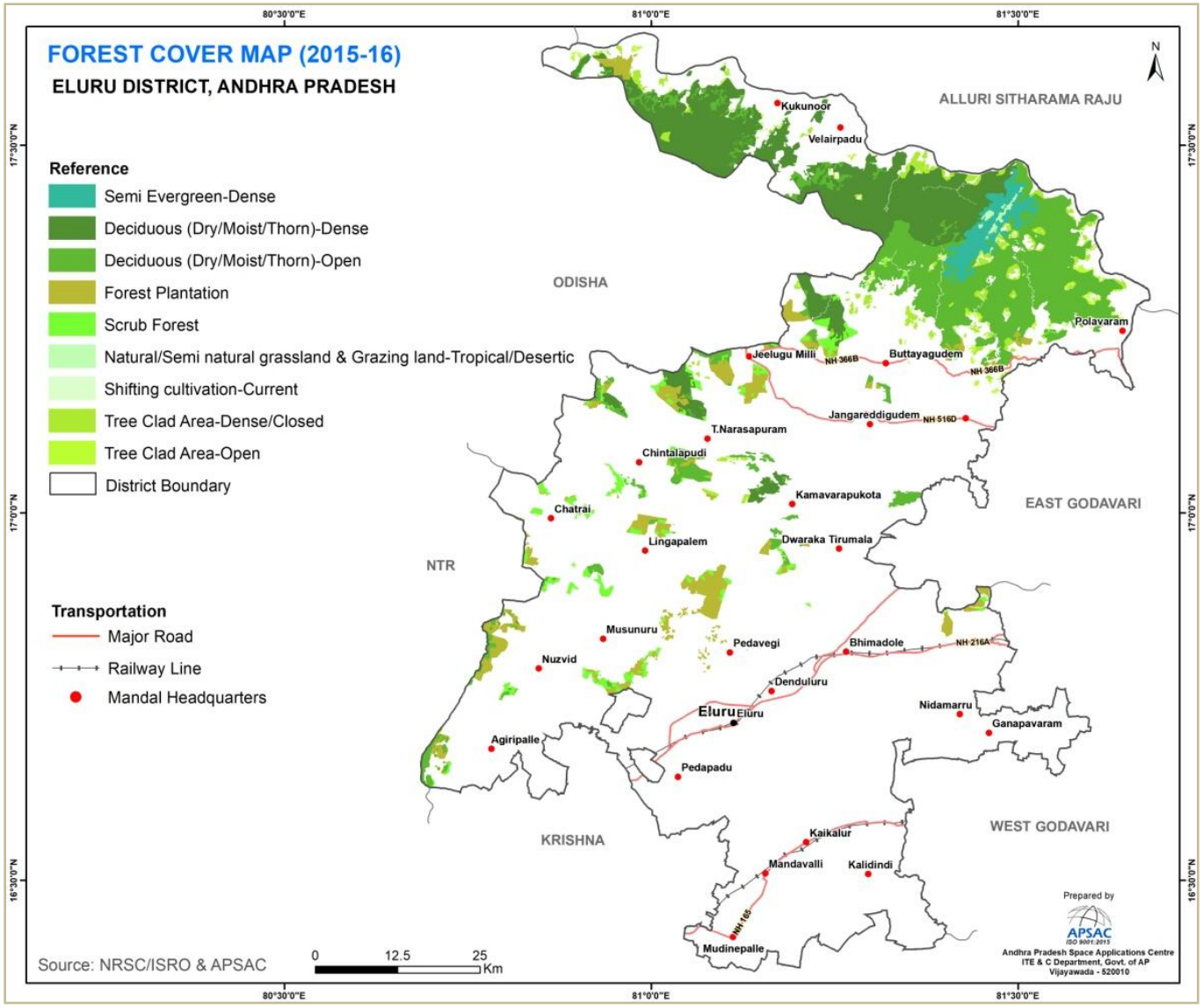


Figure-8: Forest cover map of Eluru District

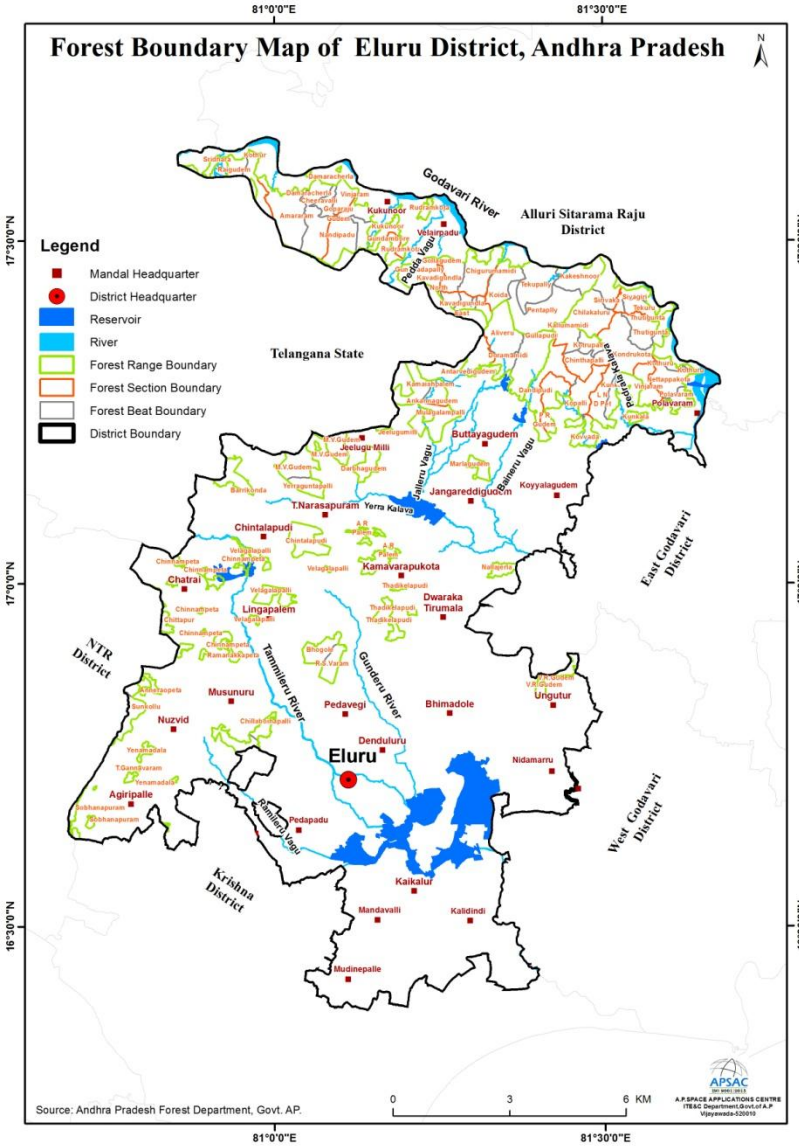


Figure-9: Forest boundary map of Eluru District

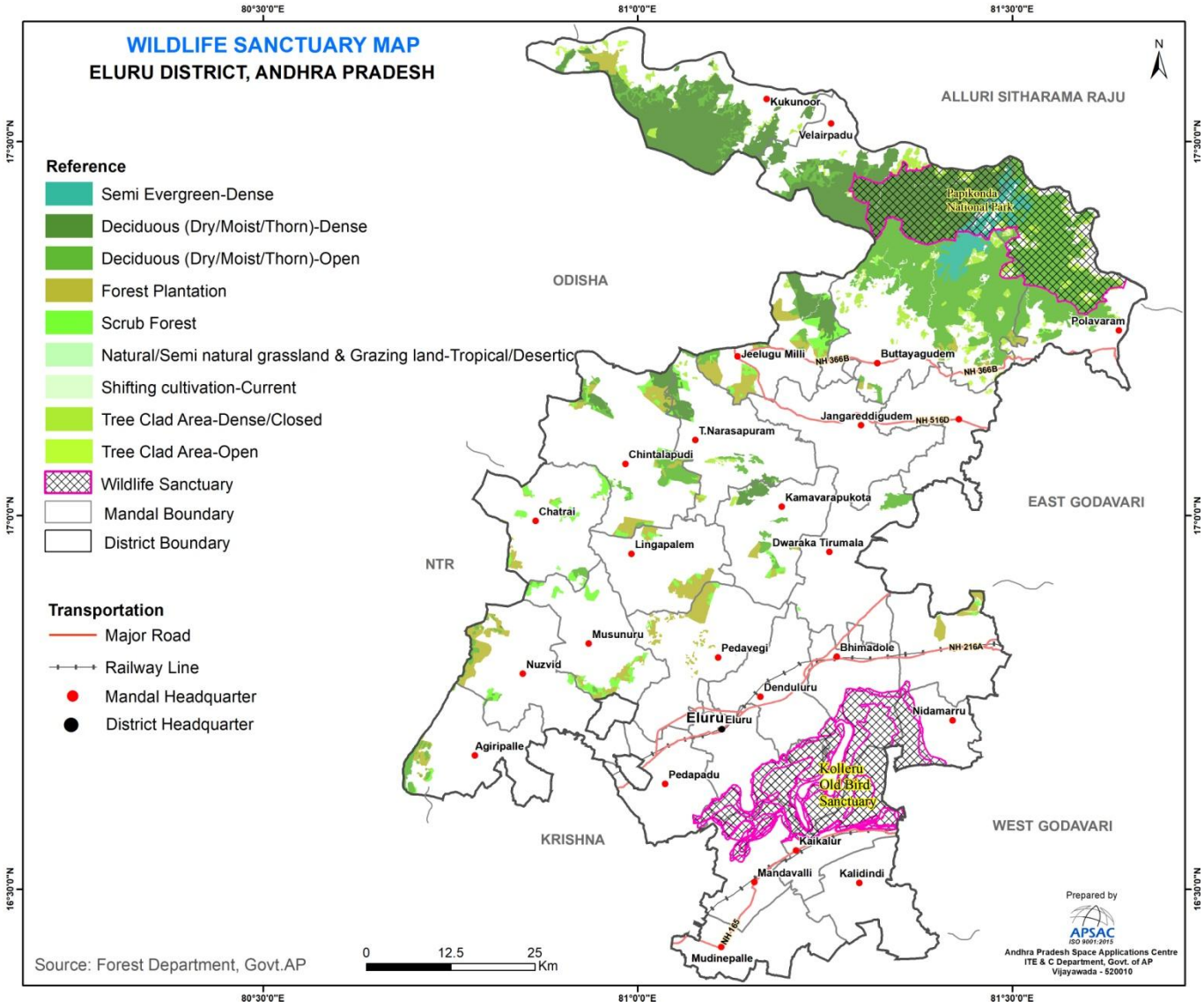


Figure-9A: Wildlife sancturay boundary map of Eluru District

1.4.4 Agricultural Resources in Eluru District

Over the past two decades, APSAC has effectively employed remote sensing technology in agriculture, encompassing both spatial and temporal dimensions across various projects. The continuous evolution of satellite remote sensing technology has facilitated systematic monitoring of crop conditions and vigor across extensive regions. Within the realm of spectral vegetation indices derived from remote sensing data, the Normalized Difference Vegetation Index (NDVI) stands out as the most widely utilized for operational drought assessment. Its popularity stems from its straightforward calculation, ease of interpretation, and the capacity to mitigate the impacts of atmospheric conditions, illumination geometry, and other variables.

APSAC conducted in-season crop condition assessments at the Mandal level in Andhra Pradesh. This initiative aimed to provide administrators and planners with crucial insights for strategic decision-making regarding drought management, import-export policies, and trade negotiations. The NDVI is calculated using the formula (NIR–Red)/(NIR+Red), where NIR and Red represent the reflectance in the visible and near-infrared channels, respectively. Water, clouds, and snow exhibit higher reflectance in the visible region, causing NDVI to assume negative values for these features. Bare soil and rocks, with similar reflectance in both visible and near-infrared regions, yield index values close to zero. NDVI values for vegetation typically range from 0.2 to 0.6, with higher values associated with greater green leaf area and biomass. The Shortwave Infrared (SWIR) band is sensitive to soil and crop canopy moisture. Early in the cropping season, when soil background dominates, SWIR is sensitive to top 12 cm soil moisture. As crop growth progresses, SWIR becomes sensitive to leaf moisture content, providing surface wetness information.

The Normalized Difference Wetness Index (NDWI), computed using SWIR data, complements NDVI for drought assessment, especially in the early cropping season. NDWI is derived as follows: NDWI=(NIR-SWIR)/(NIR+SWIR), where NIR and SWIR represent reflected radiation in the Near-Infrared and Shortwave Infrared channels. Higher NDWI values indicate increased surface wetness.

For satellite-based crop condition anomalies indicating agricultural drought, the Vegetation Condition Index (VCI) of both NDVI and NDWI can be

computed. When combining VCI values of NDVI and NDWI, the minimum of the two can be considered. For instance, if at least one is categorized as severe, the overall category is considered severe. If at least one is moderate, the overall category is taken as moderate. The vegetation conditions and corresponding ranges are detailed in Table-7.

Table 7 Vegetation condition and range in percentage

VCI range (%)	Vegetation Condition	Description
60-100	Normal	Crop condition is Normal
40-60	Moderate	Crop condition is Moderate
0-40	Severe	Crop condition is Severe

1.4.4.1 Kharif Crop Condition Assessment

Andhra Pradesh Space Applications Centre (APSAC) conducted a crop condition assessment in Eluru district during Kharif 2022-23 utilizing MODIS (Moderate Resolution Imaging Spectroradiometer) satellite data. The assessment revealed that out of the total mandals in the district, 19 were categorized as having a normal crop condition, 04 were classified as moderate, and 05 were identified as severe. Notably, urban and forest cover mandals were excluded from the vegetation condition assessment. This comprehensive evaluation provides valuable insights into the agricultural landscape of Eluru district, aiding in targeted interventions and resource allocation to mitigate the impacts of varying crop conditions.

1.4.4.2 Rabi Crop Condition Assessment

During Rabi 2022-23, The assessment identified 06 mandals with normal crop conditions, 04 mandals categorized as moderate, and 18 mandals were classified as severe. Notably, mandals predominantly covered by urban or forest areas were excluded from the vegetation condition assessment. This evaluation provides valuable insights into the agricultural status of Eluru district during the Rabi season, facilitating informed decision-making and resource allocation to support agricultural sustainability and productivity.

1.4.5 Soil Resources of the Eluru District

The Eluru district of Andhra Pradesh exhibits a diverse range of soil types, each contributing distinct characteristics to the region's landscape. The predominant soil category encompasses loamy to clayey skeletal deep

reddish brown soils, covering an extensive area of 2909.64 sq.km, constituting approximately 44.28% of the district's total soil coverage. Following closely are clayey to gravelly clayey moderately deep dark brown soils, occupying 1363.52 sq.km, which accounts for 20.75% of the region's soil composition. Deep black clayey soils sprawl across 1257.9 sq.km, representing 19.14% of the total area, while moderately deep calcareous black soils span 457.75 sq.km, comprising 6.97% of the district's soil diversity. Shallow gravelly red soils extend over 263.46 sq.km, contributing 4.01% to the overall soil makeup, whereas moderately deep calcareous moist clayey soils cover 138.57 sq.km, representing 2.11% of the land. Additionally, gravelly clayey moderately deep grassland soils encompass 101.76 sq.km, making up 1.55% of the area, while loamy to gravelly clay deep dark reddish brown soils occupy 72.04 sq.km, accounting for 1.10%. Lastly, light gray deep sandy soils, although occupying a smaller area of 6.35 sq.km, still play a significant role in the district's soil composition, constituting 0.10%. The soil resource map, depicted in Figure-10, offers a visual representation of the diverse soil landscape present within the Eluru district.

Table 8 Soil classes in the district

S.No.	Classification	Area in Sq.km	Percentage (%)
1	Loamy to clayey skeletal deep reddish brown soils	2909.64	44.28
2	Clayey to gravelly clayey moderately deep dark brown soils	1363.52	20.75
3	Deep black clayey soils	1257.9	19.14
4	Moderately deep calcareous black soils	457.75	6.97
5	Shallow gravelly red soils	263.46	4.01
6	Moderately deep calcareous moist clayey soils	138.57	2.11
7	Gravelly clayey moderately deep grass land soils	101.76	1.55
8	Loamy to gravelly clay deep dark reddish brown soils	72.04	1.10
9	Light gray deep sandy soils	6.35	0.10
		6570.99	100.0

[#]*Excluding the Urban and Water bodies area*

Data Source: APSAC, Vijayawada

1.4.6 Horticulture

Horticulture is a science, as well as, an art of production, utilization and improvement of horticultural crops, such as fruits and vegetables, spices, ornamental, plantation, medicinal and aromatic plants. It also includes plant conservation, landscape restoration, landscape, garden design, construction, maintenance, arboriculture, ornamental treesand lawns.

In the Eluru district, Oil palm is the major horticulture crop, cultivated in an area of 2395.48 ha. followed by Coconut and CocoA (282.42 ha.), Coconut (275.43 ha.), Mangoes (103.52 ha.), Acid lime (85.9 ha.) and Coco (47.43ha.). The total area under horticulture fruit crops is 3321.12 ha. The crop-wise detail is shown in Table-9.

Table 9 Area of horticultural crops in Eluru district

S.No	Crop	Area in ha
1	Lime/Lemon/Citrus	5.07
2	Cherry	2.94
3	Dragon Fruit	1.08
4	Banana	28.03
5	Custard Apple	1.64
6	Arrecanut	1.32
7	Mangoes	103.52
8	Guava	29.42
9	Acid Lime	85.9
10	Coconut	275.43
11	Coco	47.43
12	Coconut and Cocoa	282.42
13	Oil Palm	2395.48
14	Arecanut	35.63
15	Cashew Nut	24.68
16	Mulberry	1.13
	Total Area	**3321.12**

Source: Rashtriya Krishi Vikas Yojana-2022-23, GoAP

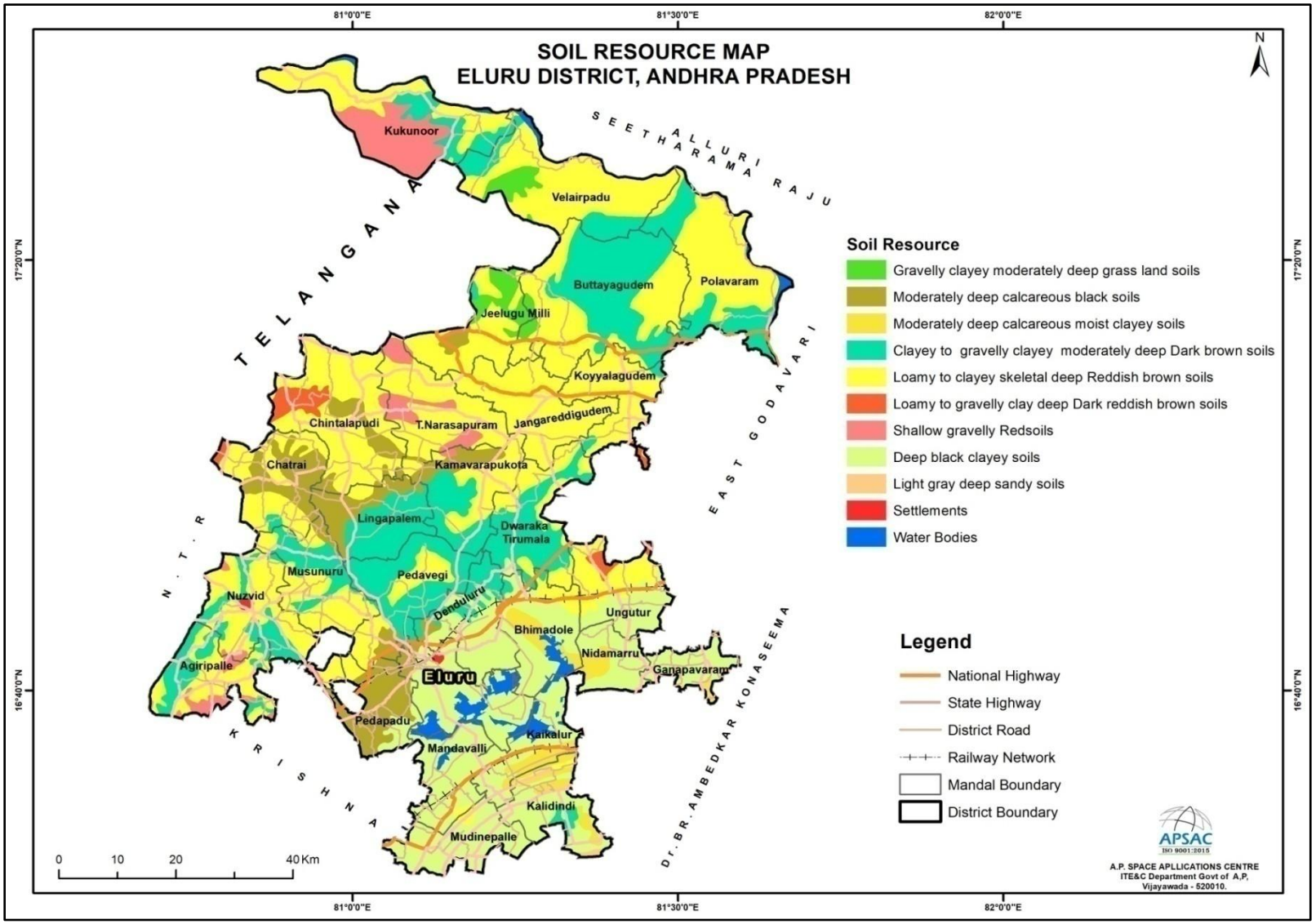


Figure-10: Soil resource map of Eluru District

1.5 Ground Water Prospects in the District:

Groundwater occurs in almost all geological formations, and its potential depends on the nature of geological formations, geographical setup, rainfall incidence, recharge, and other hydrogeological characteristics of the aquifer. In consolidated formations, groundwater occurs under unconfined to semi-confined conditions. It is developed in these formations by dug wells, dug cum bore wells, and bore wells tapping weathered and fractured zones. Deep exploration has revealed the occurrence of aerially extensive multiple aquifer systems. The Chintalapudi, Gollapalli, and Tirupati sandstones of the Gondwana Super Group, along with the Rajahmundry sandstones of Tertiary age, form important aquifers. The Tertiary Rajahmundry formation has a minimum thickness of 9m at Decherla and a maximum thickness of 442m at Tanuku, while the Gondwana formation has a maximum thickness of 600m at Achuthapuram. The thickness of coarse granular zones tapped in wells ranges from 24 to 107m in Chintalapudi, 12-71m in Gollapalli, 20-224m in Tirupati, and 42-355m in Rajahmundry outcropped areas. The principal aquifer zones available vary from one to six. The percentage of granular zone thickness ranges from 14 to 93 down to 300m, while the same varies from 25 to 77 beyond 300-600m depth. The depth of Gondwana encounter ranges from 46 to 383m below ground level (bgl). The yield of wells ranges from 3,700 to 60,000 liters per minute (lpm) for drawdowns of 19 to 25m. The average permeability is of the order of 10m per day. The transmissivity of aquifers ranges from 25 to 3540 square meters per day. The Groundwater prospects map of Eluru District is shown in Figure-11.

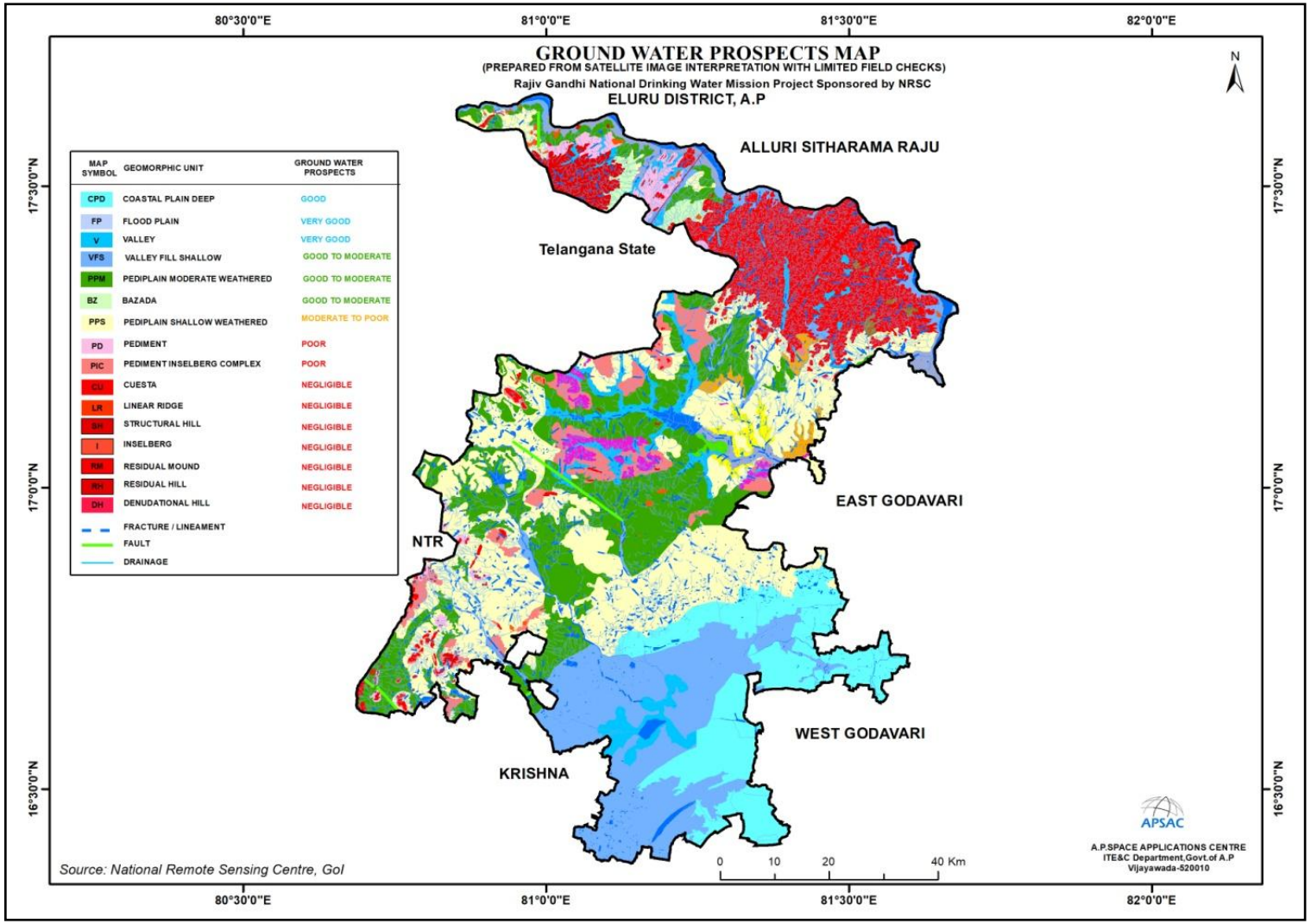


Figure-11: Ground Water prospects in Eluru District, Andhra Pradesh

1.6 Infrastructure

1.6.1 Transport Network

Eluru district is well-connected by various modes of transportation such as road and rail. The connectivity of each category is also depicted in Figure-12. The details of each transport network distribution in the district is given below.

1.6.1.1. Road Transport: The road network of the district has been delineated by using high resolution satellite data under Space Based Information Support for Decentralized Planning (SIS-DP) project and arrived the lengths of each type of road network. It can be observed that Eluru district has a well-developed road network that facilitates connectivity to all towns within the district, and to other major cities and towns of nearby districts. The major road network includes National Highways (NH), State Highways (SH), and District Roads (DR).The rural areas of the district also good connectivity by Panchayat Raj roads / village roads.

Thetotal length of the road network in the district is about 11295 km of which, the length of the National Highways is about 223.81 km, State Highways is having a length of about 745.35 km. The district roads connecting all towns and mandals are having a length of 1304.95 km. The length of each road category covered in the district are shown in Table-10.

Table 10 Road Category wise Lengths.

S.No	Road Type	Length in Km
1	National Highway	121.62
2	State Highway	443.30
3	District Road	1122.64
4	Village Road	2045.93
5	Cart Track	292.19
6	Foot Path	177.79
7	City Road	106.30
Total Length		**4309.81**

Data Source: RandB Department and APSAC, Vijayawada.

Eluru is traversed by Five National Highways. The traverse and description of each highway is as given below:

1.6.1.1.1. National Highway 365BB (NH 365BB): National Highway 365BB is a secondary route of National Highway 65. NH 365BB traverses the states of Telangana and Andhra Pradesh. It starts at Suryapet and ends at Kovvur. it starts at Telangana border in Eluru district and passes through the mandals Jeelugumilli, Buttayagudem, Polavaram, Tallapudi and terminates at the junction of NH 16 near Kovvur (Rajahmundry).

1.6.1.1.2. National Highway 16 (NH 16): The NH16 is a major National Highway in India that runs along east coast of West Bengal, Odisha, Andhra Pradesh and Tamil Nadu states. The NH starts at Odisha border which passes through the coastal districts in Andhra Pradesh via Srikakulam, Vizianagaram, Visakhapatnam, Anakapalli, Kakinada, East Godavari, Eluru, Krishna, NTR, Guntur, Palnadu, Bapatla, Prakasam, S.P.S. Nellore and Tirupati districts. It traverse through Eluru district and passes through the mandals Bapulapadu, Eluru, Denduluru and Bhimadole which connects to Tamil Nadu Border at Tada in Tirupati district.

1.6.1.1.3. National Highway 516D (NH 516D): National Highway 516D is a spur road of National Highway 16. It traverses the state of Andhra Pradesh. The NH starts at Devarapalle in East Godavari district passes through the mandals Gopalapuram, Koyyalagudem, Jangareddigudem and terminates at Jeelugumilli in Eluru district.

1.6.1.1.4. National Highway 165 (NH 165): It is commonly named as PP road, traverses the state of Andhra Pradesh. It starts at Pamarru in Krishna district and terminates at Palacole in West Godavari district. The NH traverses through Eluru district passes through the mandals Mudinepalle, Mandavalli, Kaikalur, and terminates at Palacole.

5.National Highway 216A (NH 216A): NH 216A is a National Highway in the Indian state of Andhra Pradesh. It starts from Rajahmundry in East Godavari district and ends at Eluru. It traverse through Eluru district passes through the mandals Ungutur, Bhimadole and terminates at Eluru.

Some important State Highway segments covered in the district are given below.

Eluru - Medisettivaripalem (SH020)

Eluru - Jangareddigudem road (SH026)

Boorgampadu - Aswaraopet road (SH212)

Nuzvid – Eluru road (SH209)

Machilipatnam – Nuzvid – Kalluru Road (SH028)

Chintalapudi - Ravikampadu road (SH175)

Vijayawada – Nuzvidu road (SH236)

Bhimavaram - Gudiwada road via Kalidindi (SH019)

1.6.1.2. Railways: The Indian Railway line traversing from various stations to cater the transportation needs of the people. The length of Rail network in the district is about 89.4 km covering 15 railway stations. Among these Eluru is the Main Railway Station; the important Railway stations are Bhimadolu, Kaikaluru, Mandavalli, Powerpet; and the train stations are Badampudi, Chebrole, Denduluru, Mokhasa Kalavapudi, Pallevada, Pasalapudi, Pulla, Putlacheruvu, Unguturu and Vatlur.

Eluru district is traversed by a significant railway line that connects various parts of the district and provides connectivity to neighbouring regions. Howrah-Chennai Main Line which is a major trunk route that connects Howrah (Kolkata) in West Bengal to Chennai in Tamil Nadu and also facilitating passenger and freight transportation across the region. It passes through Eluru district, serving important railway stations such as Bhimadole, Eluru and Powerpet.

In addition to the main line, there are various branch lines and spur lines namely Bhimavarm-Gudivada junction branch line which connects Bhimavaram of West Godavari district and Gudivada of Krishna district, that extend from the main line to connect specific towns with in Eluru district serving important railway stations such as Kaikaluru and Mandavalli. These lines provide local connectivity and transportation services to different parts of the district.

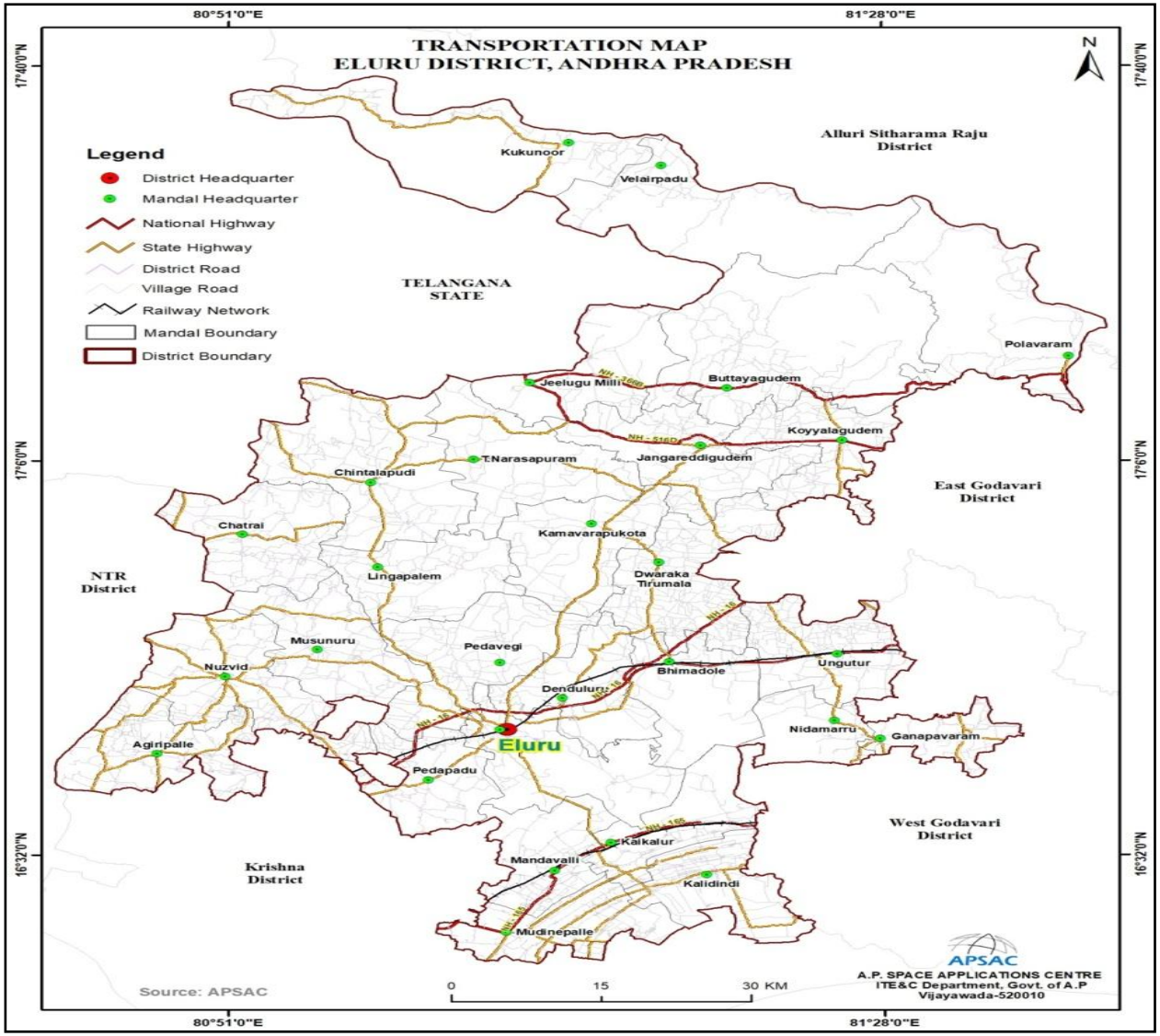


Figure-12: Transport Network of Eluru District, Andhra Pradesh

1.6.2 Irrigation

1.6.2.1. Major and Medium Irrigation Projects in Eluru district:

Irrigation has assumed an increasing significance in agriculture in the context of new technology, where high yielding varieties and multiple cropping are being practiced. The main reasons for low yields are inadequate rainfall, uneven and uncertain rains during the period of crop growth. It is generally found that the introduction of irrigation is associated with changes in the cropping pattern. The shift from a traditional cropping pattern to the most advantageous cropping pattern is possible only in the presence of irrigation facilities. The new agricultural technology is highly based on sufficient moisture conditions. Thus, the development of irrigation is crucial for increasing agricultural production. The irrigation projects are classified as major, medium and minor irrigation details are shown Table-11 and Figure-13.

1.6.2.1.1. Major Irrigation Projects:

In Eluru district there are six major irrigation projects i.e., Sir Author Cotton Barrage (Godavari Delta System-Western Delta), Polavaram Right Main Canal, Pattisam Lift Irrigation Scheme, Tadipudi Lift Irrigation Scheme, Chintalapudi Lift Irrigation Scheme and Krishna Delta System (Krishna Eastern Delta). The Polavaram Right Main Canal is Diversion of 80 TMC of Godavari Waters into the Krishna River and provides drinking water facilities. The Tadipudi LIS also provides drinking water facilities to 5.40 lakh population enroute the canal system.

1.6.2.1.2. Medium Irrigation Projects:

In Eluru district there are five medium irrigation projects i.e., Yerrakalva Reservoir Project, Thammileru reservoir Project, Vijayarai Anicut, Peddavagu Project, Kovvada Kalva Reservoir Project and the minor irrigation projects are Jalleru Reservoir and Pogonda reservoir Project.

There are 18Nos Completed and 17Nos On-going minor lift irrigation schemes in the district under Andhra Pradesh State Irrigation Development Corporation Limited (APSIDC), an ayacut of 16,841 Ac and 16,341 Ac. The Water Resources Department 220Nos of minor irrigation tanks covered in the district an extent of 63,219 Ac. And also 1144Nos of minor irrigation tanks (bellow 100 Ac ayacut) covered in the district an extent of 32,501 Ac of combined West Godavari district.

Table 11 Major and Medium Irrigation Projects in Eluru District

S.No	Project Type	Name of the Project	Status	Ayacut in Ac
1	Major	Krishna Delta System (Eastern Delta)	Completed	58,448
2		Sir Author Cotton Barrage (Godavari Delta System)		1,01,946
3		Polavaram Right Main Canal *(80 TMC of water divertion to Krishna River and Stabilize ayacut of 10.13 lakh acres Krishna Delta)* ***(Combined District)***	Ongoing	2,58,000
4		Pattisam Lift Irrigation Scheme *(Stabilization ayacut of 1,20,000 acres Polavaram RMC)* ***(Combined District)***		-
5		Chintalapudi Lift Irrigation Scheme ***(Combined District)***		1,78,000
6		Tadipudi Lift Irrigation Scheme *(Providing drinking water facilities to 5.40 lakh population)* ***(Combined District)***		2,06,600
7	Medium	Yerrakalva Reservoir Project ***(Combined District)***	Completed	34,360
8		Thammileru reservoir Project		9,169
9		Vijayarai Anicut		3,857
10		Peddavagu Project		13,640
11		Kovvada calva Reservoir Project ***(Combined District)***	Ongoing	17,739
12	Minor	Jalleru Reservoir	Completed	4,200
13		Pogonda reservoir Project	Ongoing	4,000
14		Lift Irrigation Schemes under APSIDC (18 Nos)	Completed	16,841
15		Lift Irrigation Schemes under APSIDC (17 Nos)	Ongoing	16,341
16		Minor Irrigation Tanks - 220 Nos *(Ayacut above 100 Acres)*	Completed	63,219
17		Minor Irrigation Tank-1144 Nos *(below 100 Acres ayacut)* ***(Combined District)***		32,501
			Total	**10,18,861**

Data source: WRD, APWRIMS, Govt. of A.P.

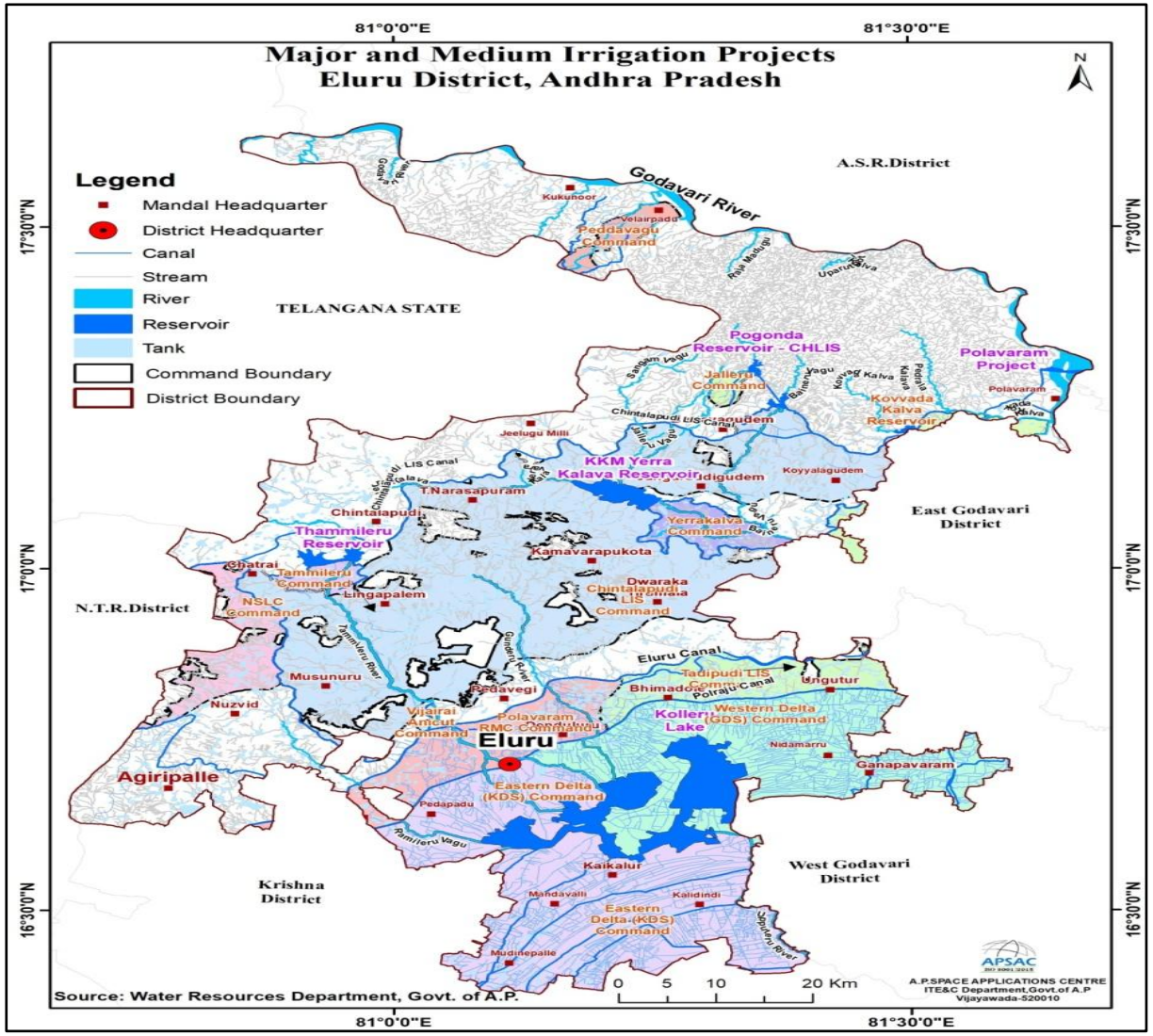


Figure-13: Major and Medium Irrigation Projects of Eluru District

1.6.2.2. Tank Information System

As per the information of Water Resources Departmental portal, Andhra Pradesh Water Resources Information and Management System (APWRIMS) and the URL:https://apwrims.ap.gov.in/ in Eluru district has 1,513 minor irrigation tanks. The Designed Storage Capacity of minor irrigation tanks in Eluru district 9,903.23mcft and Current Storage Capacity is 7,811.18mcft. The mandal wise minor irrigation tanks details of Eluru district are shown in Table-12.

Table 12 Mandal wise Minor Irrigation Tanks details of Eluru district

S.No	Mandal	No.of MI Tanks	Designed Storage Capacity (mcft)	Current Storage Capacity (mcft)
1	AGIRIPALLE	87	526.42	389.14
2	BHIMADOLE	38	131.97	100.25
3	BUTTAYAGUDEM	64	1,048.59	869.17
4	CHATRAI	112	1,962.97	1,772.14
5	CHINTALAPUDI	157	776.85	583.21
6	DENDULURU	99	364.21	364.21
7	DWARAKA TIRUMALA	80	332.08	98.12
8	ELURU(M)	3	20.87	15.65
9	JANGAREDDIGUDEM	46	185.36	122.6
10	JEELUGUMILLI	39	143.55	142.81
11	KAMAVARAPUKOTA	172	272.98	203.45
12	KOYYALAGUDEM	64	235.43	174.27
13	LINGAPALEM	90	420.19	315.14
14	MUSUNURU	84	846.29	630.99
15	NUZVID	85	927.58	838.7
16	PADAVEGI	99	667.26	419.9
17	PEDAPADU	24	110.26	82.7
18	POLAVARAM	24	185.29	173.03
19	T NARASAPURAM	88	532.82	370.97
20	UNGUTURU	58	212.25	144.72
	TOTAL	**1,513**	**9,903.23**	**7,811.18**

Data source: WRD, APWRIMS, Govt. of A.P.

1.6.3 Eco-sensitive areas and Important places

Eluru district has acquired special historic importance popular tourist, religious and culturalplaces to visit in the Eluru district are shown in the Table-13 and the geographical location of each place is depicted in Figure-13 and brief discussion is given below:

Table 13 Important places of Tourism in Eluru district.

S.No	Name	Village	Mandal
1	Abhaya budda Statue	Eluru	Eluru
2	Guntupalli buddhist caves	Guntupalli	Kamavarapukota
3	Maddi Anjaneya Swamy Temple	Guravaigudem	Jangareddigudem
4	Papikondalu	Eluru(R)	Eluru
5	Pattiseema	Pattisam	Polavaram
6	Polavaram Project area	Polavaram	Polavaram
7	Sri BhuniLa Sameta Sri Janardhana Swamy Kanyakumara Parameshwari Ammanala Temple	Chataparru	Eluru
8	Sri Gubbalamangamma Ammavari Temple	Forest	Buttayagudem
9	Sri Parijathagiri Venkateshwaraswamy Temple	Jangareddigudem	Jangareddigudem
10	Syed Baji Hazarat Dargah	Eluru	Eluru
11	Vengi Monuments	Pedavegi	Pedavegi

Data Source: Tourism Department, Government of Andhra Pradesh

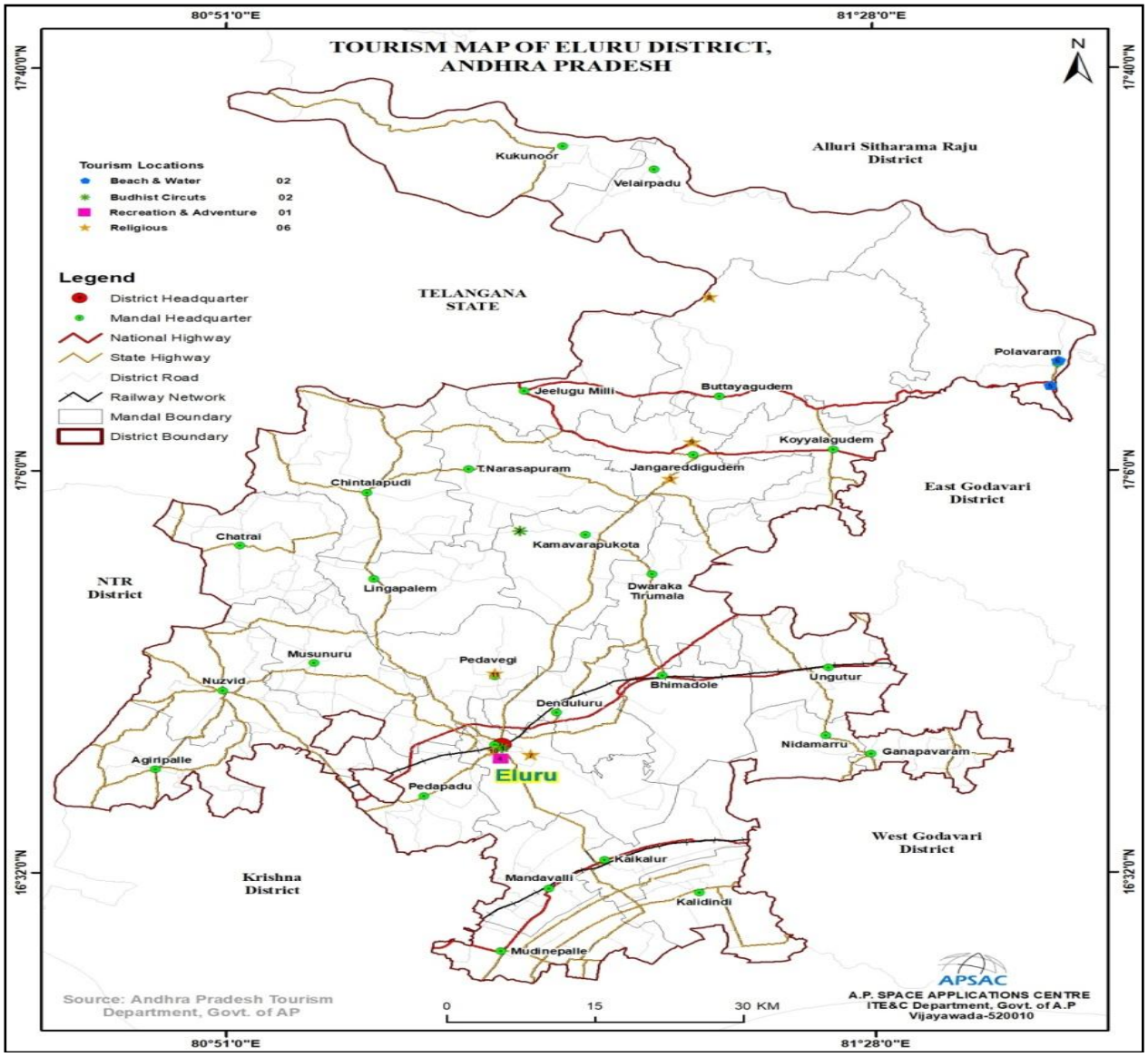


Figure-14: Tourist Map of Eluru District, Andhra Pradesh

1.6.3.1. Papikondalu: Papikondalu is located at a distance of about 4.6 km from the district headquarter Eluru. The entrance of Papi kondalu can be seen from Koruturu. "Papi kondalu" or the "Papi Hills" are series of mountain range that are located Rajahmundry in Eluru District of Andhra Pradesh. Papikondalu Mountain range runs along River Godavari, one of the largest and vivacious rivers in India. Papikondalu mountain range spreads over a vast area, the ups and downs of the river water, the drifting sand, the cool breeze and the fresh air from the Papikondalu Hills, give you one of the best experiences to travel.

1.6.3.2. Guntupalli buddhist caves: Guntupalli buddhist caves are located at a distance of about 40 km from the district headquarter Eluru.These caves are significant archaeological and religious sites that date back to the ancient Buddhist period. The caves are carved into a hillside and are a fine example of rock-cut architecture. The caves are accessible to visitors and have been preserved as archaeological sites of historical importance. They offer a glimpse into the ancient Buddhist way of life and are an interesting destination for history and archaeology enthusiasts.

1.6.3.3. Pattiseema: Pattiseema is located at a distance of about 90 km from the district headquarter Eluru. It is notable for its location near the confluence of the Godavari River and the Krishna River, two of the major rivers in South India. One of the key engineering projects associated with Pattiseema is the Pattiseema Lift Irrigation Project. Pattiseema is also a place of pilgrimage for devotees who come to witness the confluence of the Godavari and Krishna rivers and to offer prayers at the nearby temples. The region's natural beauty and the cultural and religious attractions draw tourists and visitors throughout the year.

1.6.3.4. Polavaram Project area: Polavaram Project areais located at a distance of about 110 km from the district headquarter Eluru. The Polavaram Project, officially known as the Polavaram Irrigation Project, is a major multi-purpose river development project in the Indian state of Andhra Pradesh. It is one of the largest and most significant river projects in India. The project aims to provide irrigation water to vast agricultural areas in the Godavari delta region, which is known for its fertile soil. The polavaram project itself showcase the regions natural beauty, cultural heritage and the significance of the project.

1.6.3.5. Vengi Monuments: Vengi Monuments are located at a distance of about 14 km from the district headquarter Eluru. The Vengi

Monuments, also known as Vengi Stupas, are historical Buddhist stupas located in Pedavegi, a village in the Eluru district of the Indian state of Andhra Pradesh. These monuments are significant archaeological sites that date back to ancient times. The Eastern Chalukyas were known for their patronage of Buddhism and Jainism, and these monuments reflect their support for Buddhist culture.

1.6.4 Places of Religious and Cultural importance

1.6.4.1. Sri Parijathagiri Venkateswaraswamy Temple: Sri Parijathagiri Venkateswaraswamy Temple is located at a distance of about 2.8 km from the district headquarter Eluru. Sri Venkateswara Swami temple located in Jangareddygudem is also called parijathagiri temple. This is a very beautiful place to visit and worship. It is a common belief that Jangareddygudem is the only town in Andhra Pradesh where there is a collection of seven mountains other than Tirumala Tirupathi. This temple was recently restructured due to increased number of pilgrims.

1.6.4.2. Sri Gubbalamangamma Ammavari Temple: Sri Gubbalamangamma Ammavari Temple is located at a distance of about 4.4 km from the district headquarter Eluru. The Temple is located in Buttayigudem, a town in the Eluru district of Andhra Pradesh, India. This temple is dedicated to the goddess Gubbalamangamma Ammavaru and is a place of worship and devotion for local residents and devotees. Like many Hindu temples in India, it likely hosts various religious and cultural festivals and rituals throughout the year, attracting devotees from the surrounding areas. A small water stream which flows near the main temple is something that you shouldn't miss taking a view.

1.6.4.3. Sri Bhunila Sameta Sri Janardhana Swamy Kanyakumara Parameshwari Ammanala Temple: The Temple is located at a distance of about 6.8 km from the district headquarter Eluru. The significance of the temple is that, the creator of this creation, who created the Trinity, wanted to make himself mature and said that Brahma wanted the shankar to accept the Vishnu and agreed to accept the third and the same. The rest of the fourth part of the 101 portions of the rest of the village was asked to live and give each village a village for grammar. These were the ones who were born to Nokkalamma, Polaremma, Sattemma and Mahavishnu as the name Pothuraju.

1.6.4.4. Maddi Anjaneya Swamy temple: Maddi Anjaneya Swamy temple is located at a distance of about 51 km from the district headquarter Eluru. The temple is at 3 KM distance from Janareddigudem town. The name of the village is Gurvaigudem. The architectural style and design of the temple may vary, but many Hanuman temples feature vibrant colours and intricate sculptures and carvings depicting scenes from Lord Hanuman's life. Lord Hanuman is known for his unwavering devotion to Lord Rama, a central figure in the Hindu epic, the Ramayana.

1.6.4.5. Syed Baji Hazarat Dargah: Syed Baji Hazarat Dargah is located at a distance of about 2 km from the district headquarter Eluru. The Dargah is a revered Sufi shrine located in Eluru of the Indian state of Andhra Pradesh. The specific architectural style of the Syed Baji Hazarat Dargah may reflect the cultural and architectural traditions of the region. Devotees visiting the dargah may engage in various devotional practices, including offering floral tributes, lighting candles or lamps, and reciting prayers or verses from the Quran.

1.6.4.6. Abhaya budda Statue: Abhaya budda Statue is located at a distance of about 3 km from the district headquarter Eluru. A magnificent 74 feet Buddha statue was constructed in the middle of the pond and a painting gallery was also created to spread the Buddha's teachings. The Statue is one of the tallest monolithic Buddha statues in India. It stands at an impressive height and is known for its grandeur. The statue is not only a symbol of Buddhism but also a representation of peace, compassion, and spirituality. It serves as a point of pilgrimage and tourism for visitors seeking a spiritual experience or an appreciation of art and culture.

1.7 Drainage Pattern

1.7.1 Drainage

The principal rivers flowing in the district are Godavari, Yerrakalva, Kovvada Kalva, Thammileru, Ramileru Vagu and partially covered with Budameru, Upputeru rivers. The Godavari River rises near Trimbakeshwar in the Nashik district of Maharashtra about 80 km from the Arabian Sea at an elevation of 1,067 m and The total length of Godavari from its origin to outfall into the Bay of Bengal is 1,465 km. It enters into the district near Velair village in Kukunoor mandal and leaves the district near Gutala village in Polavaram mandal.

The Yerrakalva river rises in Khammam district of Telangana and Eluru district of Andhra Pradesh. The Yerrakalva river flows towards south-east direction and leaves the district near Rajavaram. It is merged into

Enamadurru drain near Nandamuru Aquduct (Eluru Canal-Godavari). The Kovvada Kalva river rises in Kovvada RF and Chintapalle RF, Buttayagudem mandal in Eluru district and flows towards south-east direction and leaves the district near Pattisam village in Polavaram madnal.

The Thammileru river rises in Dammapeta Mandal, Khammam district in Telangana State and enters into the district near Chinnampet village in Chatrai mandala. It flows towards south direction and joining to Kolleru Lake near Eluru madnal in Eluru district.

Four major drains are covered in southern part of the district, Perantalakanama drain, Polaraju drain, Pedalanka drain and Chandrayya drain. The drains are flows towards east direction and Polaraju, Chandrayya drains are joining to Kolleru Lake and Perantalakanama, Pedalanka drains joining in Upputeru river in Eluru district.

The Kolleru Lake is one of the largest freshwater lakes in the country located southern part of the district and located between the Krishna and Godavari deltas. The Ramileru Vagu and Gunderu rivers are rises in Eluru district, flows towards south direction and joining to Kolleru lake in Eluru district. Figure-15 illustrates the drainage system and the surface water bodies.

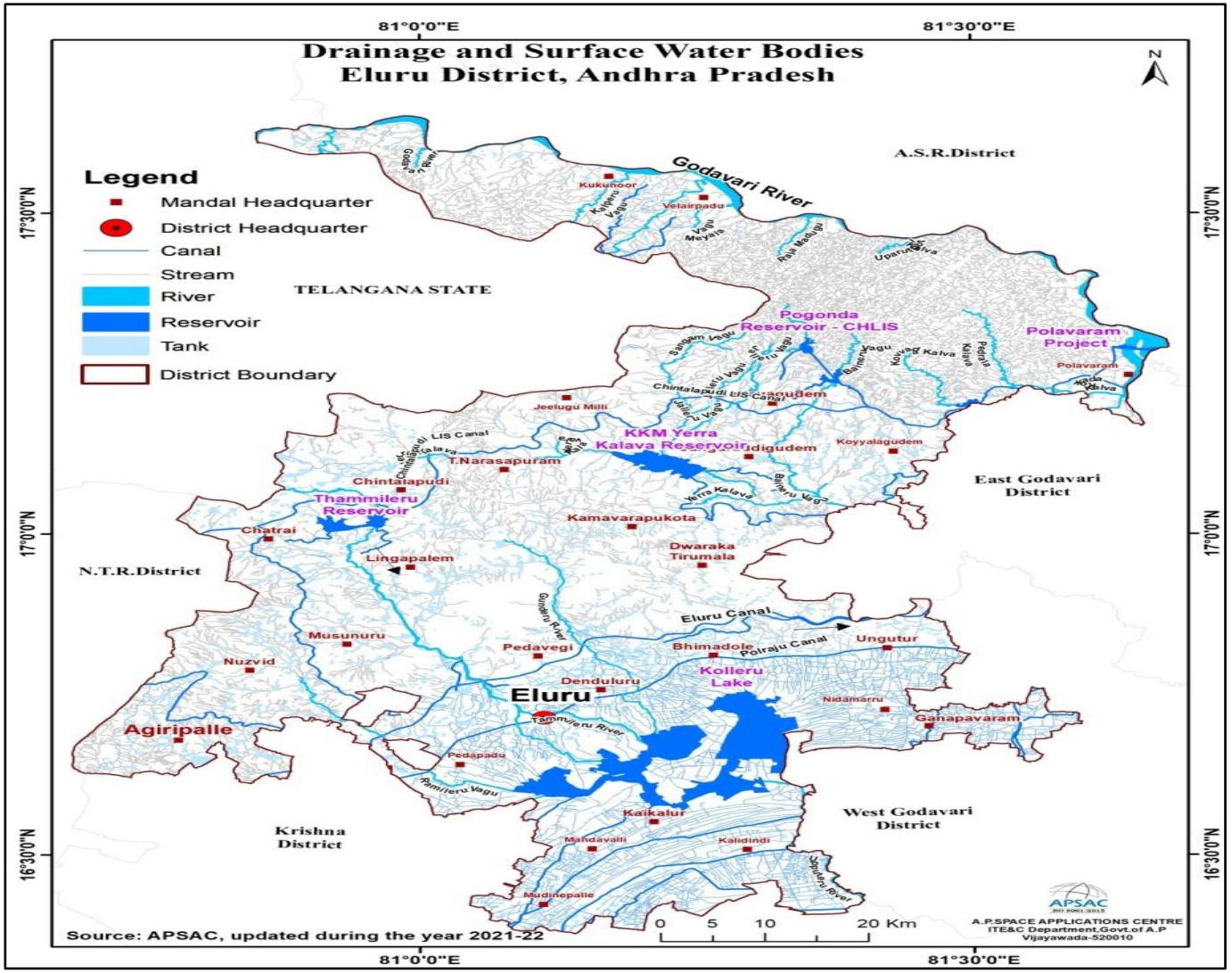


Figure-15: Drainage Network and Surface Water Bodies of the Eluru District

1.7.2 Geomorphology of the District:

Using IRS satellite data and GIS, a detailed geomorphological and structural map of Eluru District was generated according to the guidelines of the Rajiv Gandhi National Drinking Water Mission (RGNDWM) on a 1:50,000 scale. The objective of this endeavor is to map lithology, geomorphology, and structural characteristics of an area at a 1:50,000 scale and to integrate this information to identify potential groundwater prospect zones and recommend suitable structures for groundwater recharge. Various hydrogeomorphic units are delineated, and suitable recharge structures are proposed for villages affected by drinking water issues under this project. The Geomorphology map of Eluru District, Andhra Pradesh, is shown in Figure-16.

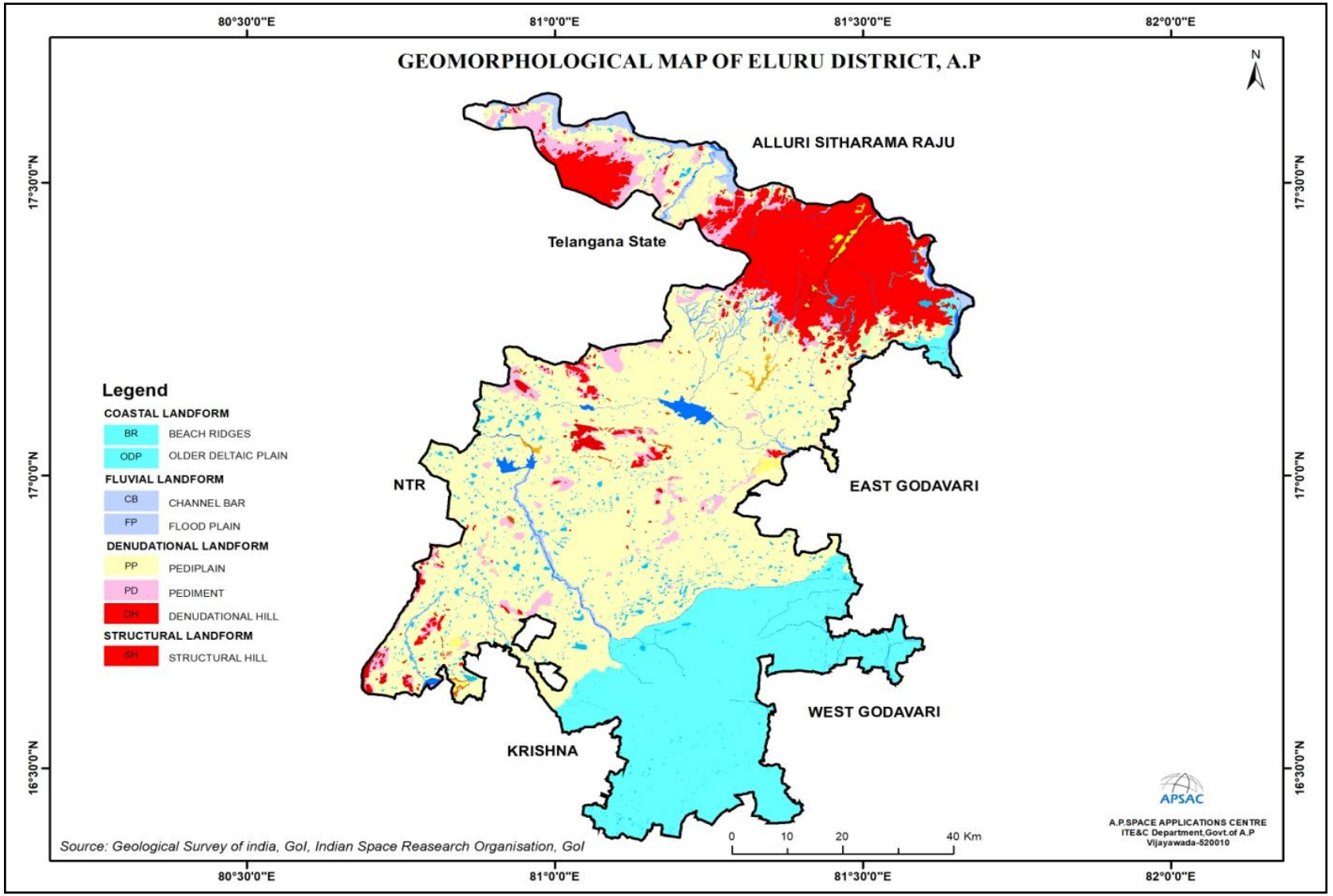


Figure-16: Geomorphology of Eluru District, Andhra Pradesh

1.7.3 Landforms of Fluvial origin

The word "fluvial" is used in Earth science to refer to processes and landforms produced by running water. Like other surface processes, running water can either erode material from the earth's landscape or deposit layers of sediment. The resulting landforms can thus be classified as either erosional or depositional. The incredible power of running water in carving various erosional and depositional landforms is well known. Although the quantity of water in the stream is small at any given time during the year, very large volumes of water move through the channel, forming an important component of the hydrological cycle. The fluvial dissection of the landscape consists of valleys and their included channelways organized into a system of connections known as a drainage network. Drainage networks display many types of quantitative regularities that are useful in analyzing both the fluvial systems and the terrains that they dissect (NRSA, 2007).

1.7.3.1. Alluvial plain: A level or gently sloping tract, or a slightly undulating land surface produced by extensive deposition of alluvium, usually adjacent to a river that periodically overflows its banks. It may be situated on a floodplain, a delta, or an alluvial fan. This landform is predominantly seen in the southern part of the district.

1.7.3.2. Palaeo-channel: Deep valleys cut into the bedrock terrain and now largely filled with alluvium, glacial outwash gravels, sands, or tills. These are a good source of underground water.

1.7.3.3. Floodplain: The surface or strip of relatively smooth land adjacent to a river channel constructed (or in the process of being constructed) by the present river in its existing regimen and covered with water when the river overflows its banks during times of high water. It is built of alluvium carried by the river during floods and deposited in the sluggish water beyond the influence of the swiftest current.

1.7.3.4. Valley fill: The unconsolidated sediment deposited by any agent to fill or partly fill a valley.

1.7.4 Landforms of Coastal origins

Coasts are also the loci of a unique assemblage of erosional and depositional processes. The various landforms of coastal areas are almost exclusively the result of the action of ocean waves. Wave action creates some of the world's most spectacular erosional landforms. Where wave

energy is reduced, depositional landforms like beaches are created. The source of energy for coastal erosion and sediment transport is wave action. A wave possesses potential energy as a result of its position above the wave trough, and kinetic energy caused by the motion of the water within the wave. This wave energy is generated by the frictional effect of winds moving over the ocean surface. The higher the wind speed and longer the fetch, or distance of open water across which the wind blows and waves travel, the larger the waves and the more energy they possess. Long open ocean waves or swells travel faster than short, locally generated sea waves. They also have longer wave periods, distinguishing them from the short sea waves upon reaching the coast. Long swells, which have traveled hundreds of kilometers, may have wave periods of up to 20 seconds. Smaller sea waves have wave periods of 5 to 8 seconds. Where ocean depths are greater than the length of the waves, wave motion does not extend to the ocean floor and therefore remains unaffected by it. As the ocean depth falls below half the wavelength, the bottom increasingly affects wave motion. As the depth of water decreases, wave height increases rapidly and wavelength decreases rapidly. Thus, the wave becomes more and more peaked as it approaches the shore, finally curling over as a breaker and breaking on the shore. As the wave breaks, its potential energy is converted into kinetic energy, providing a large amount of energy for the wave to work along the shoreline. Transportation by waves and currents is necessary to move rock particles eroded from one part of a coastline to a place of deposition elsewhere. One of the most important transport mechanisms results from wave refraction. Since waves rarely break onto a shore at right angles, the upward movement of water onto the beach (swash) occurs at an oblique angle. However, the return of water (backwash) is at right angles to the beach, resulting in the net movement of beach material laterally. This movement is known as beach drift. The endless cycle of swash and backwash and resulting beach drift can be observed on all beaches.

Frequently, backwash and rip currents cannot remove water from the shore zone as fast as it is piled up there by waves. Consequently, there is a buildup of water that results in the lateral movement of water and sediment just offshore in the direction of the waves. The currents produced by the lateral movement of water are known as longshore currents. The movement of sediment is known as longshore drift, which is distinct from the beach drift described earlier, operating on land at the beach. The combined movement of sediment via longshore drift and beach drift is known as littoral drift. Tidal currents along coasts can also

be effective in moving eroded material. While incoming and outgoing tides produce currents in opposite directions daily, the current in one direction is usually stronger than the other, resulting in a net one-way transport of sediment. Longshore drift, longshore currents, and tidal currents in combination determine the net direction of sediment transport and areas of deposition. Utilizing multi-temporal satellite data can elucidate the dynamics of the coast (NRSA, 2007).

1.7.4.1. Palaeo Beach Ridges: A paleo beach ridge is a raised, elongated landform or ridge-like structure located parallel to the modern coastline but situated inland. It is composed primarily of sand, gravel, shell fragments, or other sediments deposited by wave and tidal action during past periods of higher sea levels. These ridges often represent former shorelines or beachlines that existed during periods of higher sea levels or different environmental conditions, typically during the Pleistocene epoch or other geological eras.

1.7.4.2. Coastal Plain: A low, generally broad but sometimes narrow plain that has its margin on the shore of a large body of water (especially the ocean) and its strata either horizontal or very gently sloping toward the water. It generally represents a strip of recently emerged seafloor or continental shelf.

1.7.4.3. Dune and Swale Complex: This is a large complex of parallel wetland swales and upland beach ridges (dunes) found in a coastal embayment and on large sand spits along the shorelines of the Great Lakes. The upland dune ridges are typically forested, while the low swales support a variety of herbaceous or forested wetland types, with open wetlands more common near the shoreline and forested wetlands more prevalent further from the lake.

1.7.5 Landforms of denudational origins

A landform of denudational origin is formed where the denudation process dominates over other processes. Most landforms resulting from this process are the combined effect of mechanical and chemical weathering. Denudation is the process of material removal by erosion and weathering, which directly influences the relief of the area, especially in reducing relief to the base level. The agents involved are mostly water, ice, and wind. The major factors affecting denudation include geology, climate, tectonics, and anthropogenic effects. All rocks and minerals at or near the surface are subject to attack by physical and chemical processes. The

effect of this process varies because rocks have differing resistance to change. Consequently, weathering and erosion yield several landforms with typical shapes and forms. Weathering is an essential part of the rock cycle. The parent material or rock-weathered material is disaggregated to form smaller fragments, and some minerals are dissolved and removed by water. This removal of material is erosion, which is accomplished by running water, wind, and glaciers. Weathering provides the raw material for sedimentary rock and soil (NRSA, 2007).

1.7.5.1. Pediplain: An extensive, multi-concave, rock-cut erosion surface formed by the coalescence of two or more adjacent pediments and occasional desert domes, representing the result (the "peneplain") of the mature stage of the erosion cycle. Based on the thickness of weathering, they are further classified as shallow, moderate, and deep pediplains.

1.7.5.2. Denudational Hill: A highly dissected hill that has obliterated the structures.

1.7.5.3. Residual Hill: A small remnant hill that has witnessed all forms of denudation.

1.7.5.4. Inselberg: A prominent, isolated, steep-sided, usually smoothed and rounded, residual knob, hill, or small mountain of circumdenudation rising abruptly from and surrounded by an extensive and nearly level, lowland erosion surface in a hot, dry region (such as the deserts of southern Africa or Arabia). It is generally bare and rocky, although partly buried by the debris derived from and overlapping its slopes. It is characteristic of an arid or semiarid landscape in a late stage of the erosion cycle.

1.7.5.5. Pediment: A broad, flat, or gently sloping, rock-floored erosion surface or plain of low relief, typically developed by subaerial agents (including running water) in an arid or semiarid region at the base of an abrupt and receding mountain front or plateau escarpment. It is underlain by bedrock (occasionally by older alluvial deposits) that may be bare but more often partly mantled with a discontinuous veneer of alluvium derived from the upland masses and in transit across the surface.

1.7.5.6. Pediment-Inselberg Complex: The pediments are dotted by numerous inselbergs of small sizes, making it difficult to distinguish from the pediments. Hence, it is called a complex of pediment and inselberg.

1.7.6 Landforms of Structral Origin

Landforms of structural origin are intricately linked to the structural aspects of an area. The genesis of most landforms in this category is closely tied to the underlying structure, wherein the structure plays a pivotal role in reducing rock resistance, leading to various geomorphic forms. These forms range from minor variations to mega-scale features, the latter of which significantly influence landform genesis and indirectly reflect the structural composition of the area through mapping. Mega-scale structural features such as faults and folds, depending on their type, profoundly affect the formation of structural landforms. The impact of geologic structures on landscape development and appearance is pronounced, spanning from large features that dominate entire landscapes to small features influencing individual landforms and associated geomorphic processes. Structural control may stem from active structures, directly shaping modern landscapes, or from ancient structural features whose influence on contemporary landscapes is primarily due to differential erosion (NRSA, 2007).

1.7.6.1. Structural Hills: Hills and valleys that originate due to tectonic processes and are extensively dissected by drainage lines. These can be further classified as having high, moderate, or low dissection depending on the density of joints and drainage. This classification is mostly interpreted from planimetric satellite data and is highly subjective.

1.7.7 Structural Features of Eluru District

The oldest rock types are of Archaean age, belonging to the Eastern Ghats Supergroup, represented by Khondalite, Charnockite group, and granite gneiss (migmatite). Talchir, Barakar, and Kamthi formations of the Lower Gondwana, and Kota and Gangapur formations of the Upper Gondwana represent Gondwana sediments of the U. Carboniferous to L. Cretaceous age. Gollapalli, Raghavapuram, and Tirupati formations represent the East Coast Gondwanas. The Deccan Traps overly these Gondwana rocks. Deposition of Rajahmundry Sandstone indicates marine transgression during the Mio-Pliocene. Laterite cappings on Khondalite and Charnockite are seen on hilltops. Quaternary sediments occur along the rivers and the beach.

Khondalite and Charnockite groups with patches of granite gneiss occur to the NE of Jangareddygudem and around Polavaram. The Khondalite Group is represented by garnet-sillimanite-graphite biotite gneiss, forming strike ridges, steep scarp sections, hillocks, or conical mounds, and also as bands of varying dimensions within the Migmatitic terrain. Calc-granulite

and quartzite occur as persistent, narrow bands conformable to the sillimanite gneiss. The Charnockite Group comprises basic, intermediate, and acid variants. Quartzo-feldspathic injections are common within the acid Charnockite. The lower topographic levels are occupied by migmatite rocks and are characterized by variations in lithology, texture, and mineralogy. They include leptynite and various products of migmatization of Khondalite, Charnockite, and pyroxene granulite.

The Gondwana formations are seen in the central part, around Jilugumilli-Chintalapudi and Dwaraka-Tirumala. The Talchir Formation comprises green shale and siltstone, occurring as small lensoidal bodies near Chintalapudi. The Barakar Formation comprising sandstone, shale, and coal occurs near Bedadanur on the western margin of the Gondwana basin. Ferruginous sandstone and shale of the Kamthi Formation occur north of Chintalapudi and east of Gokavaram. The Kota Formation, represented by sandstone and limestone, occurs over a considerable area around Jangareddigudem. The Gangapur Formation is represented by white sandstone, characterized by horizontal beds. The coastal Gondwanas, a marine and fluvio-marine sequence, are found as discontinuous outcrops along the east coast. They are designated as the Gollapalli Formation, Raghavapuram Formation, and Tirupati Formation and predominantly comprise sandstone, shale, and sandstone, respectively. The Tirupati Formation contains plant remains and fossils of brachiopods, cephalopods, and foraminifera.

The traps are disposed of as horizontal to sub-horizontal basaltic lava flows near Duddukuru and Devarapalli. Infratrappean sediments are exposed near Pangadi. The traps are overlain by Rajahmundry Sandstone occurring as disconnected outcrops between Bhimadolu and Chagallu and comprise ferruginous sandstone, clay, pebble beds, and lignite. Laterite occurs on hilltops, invariably overlying the white clay and friable sandstone of Rajahmundry Sandstone. Bauxitic laterite occupies several flat-topped and gently sloping hills at elevations of 1000m and above, the basement rock of which is mostly Khondalite and Charnockite.

Quaternary sediments of both fluvial and marine regimes occur in the south. The fluvial areas consist of floodplain, levee, and active channel formations, while the marine areas include palaeo-beach ridges, palaeo-tidal flats, and active beaches. Kolleru Lake is situated to the southwest. The floodplain occupies the major part of the delta and is mainly composed of black silt clay, while the levee is made of brown silt. The

active channel comprises coarse sand with rock fragments. The palaeo-channels are composed of 2.5m to 3.00m thick black clay on top, underlain by coarse sand. Palaeo-beach ridges rise about 2m above the present surface and are made of highly oxidized brown, fine sand, with inter-ridge lows or tidal flats composed of an alternating sequence of brown silt clay and sand. The present-day beach is made of grey to cream, fine sand. Evidence of movements during the Quaternary is recorded along the east-northeast to west-southwest trending Narsapur-Yanam fault. The Structural Map of Eluru District, Andhra Pradesh, is shown in Figure-20. The northern part of the area is mainly covered by Chintalapudi sandstones, and boreholes are not drilled beyond the Chintalapudi sandstones. In the central part of the district, more than one geological formation is encountered, while in the southern part, boreholes could not be drilled beyond the alluvium due to its considerable thickness. Granites are encountered at shallow depths near Gopalapuram in the northeastern part of the area and near Jeelakarragudem and Pragadavaram in the western part of the district. From the panel diagram, five faults could be inferred between (1) Achutapuram and Gopalapuram, (2) Bhimadolu and Kaikaram, (3) Gopalapuram and Chityala, (4) Dharmajigudem and Kallacheruvu, and (5) T. Nyampalle and Denduluru.

Groundwater occurs under unconfined, semi-confined, and confined conditions in different formations of the area. In the crystalline formation, the yield of open wells ranges from 20 to 50 m^3/day, and the discharge of bore wells varies from 17.28 to 648 m^3/day. The Chintalapudi formations are relatively hard on the surface and form good aquifers, with granular zone thickness varying from 24 to 107 m. The yield of wells ranges between 604.8 and 2419.2 m^3/day, and the transmissivity values are in the order of 50 to 1338 m^2/day. In Gollapalli sandstone, the thickness of granular zones varies from 12.0 to 71.0 m, and the depth of the wells ranges between 75 and 120 m, with discharges of 691.2 to 1382.4 m^3/day. Raghavapuram shales have a maximum thickness of 10 m and are poor aquifers. In the Tirupati sandstone formation, the depth of the wells ranges between 99 and 250 m, with yields varying from 345.6 to 1555.2 m^3/day, and the thickness of the granular zone is in the order of 20 to 93 m. The depth of the wells in Rajahmundry sandstones ranges between 32 and 611 m, and the discharge varies from 1296 to 3024 m^3/day, with a thickness of the granular zone in the order of 18 to 175 m. Groundwater development is limited in alluvium, and in general, the deeper zones are brackish to saline in nature. The piezometer observation wells in Eluru District are shown in Figure-17.

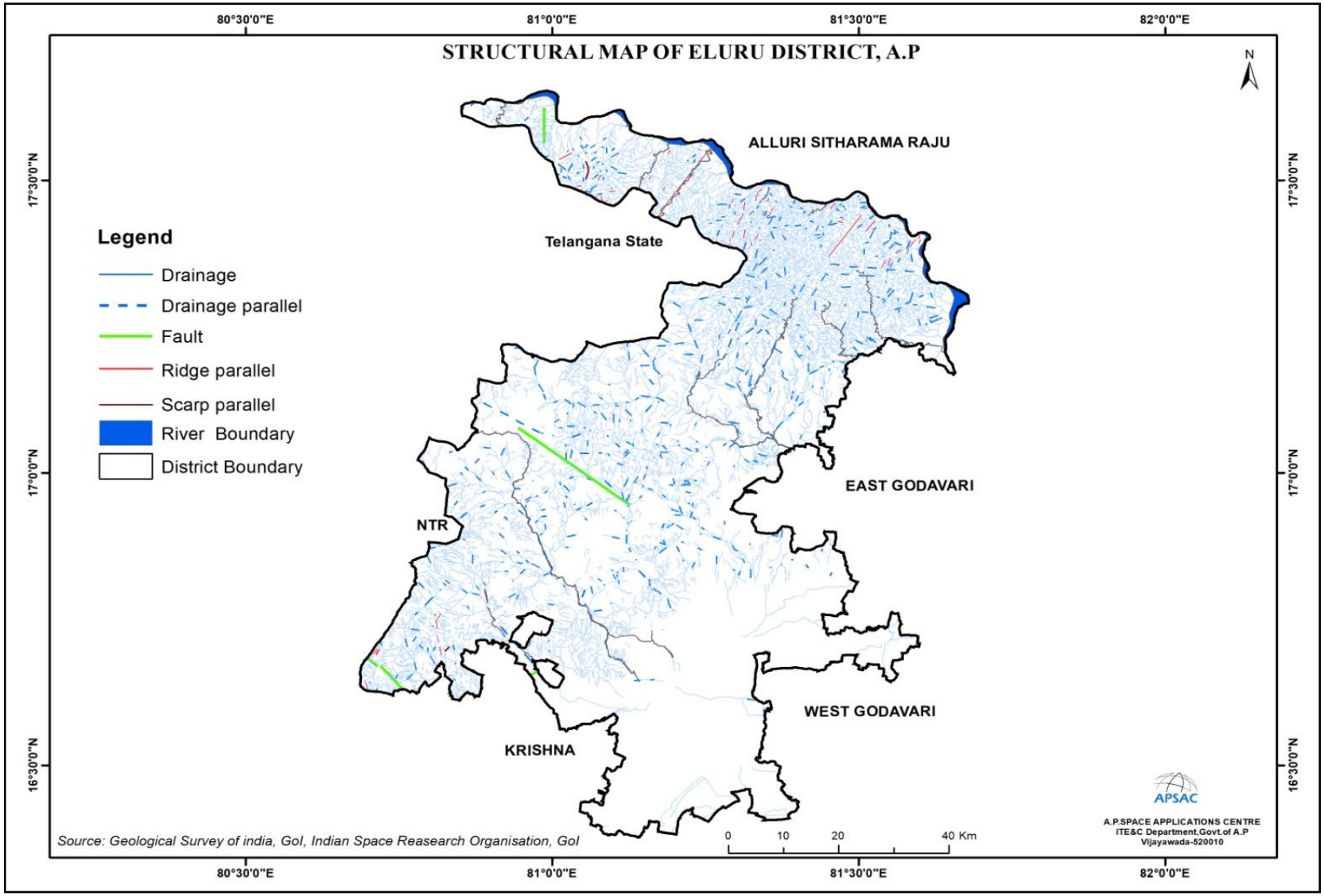


Figure-17 : Structural Map of Eluru District, Andhra Pradesh

1.7.8 Ground Water Quality in the Eluru District

The district is mainly drained by the Godavari, Yerrakalava, Tammileru, and Ramileru rivers. The river Godavari enters the district near the northeastern corner and, after flowing a distance of 72 km, bifurcates into the Gautami and Vasishta rivers at Vijeshwaram. The Gautami River, which marks the district boundary, debouches into the Bay of Bengal at Antervedi, draining about 20% of the district area. The other prominent rivers/streams in the district are Yerrakalava, Tammileru, Ramileru, and Guvvaleru. Yerrakalava joins the Godavari River while Tammileru and Guvaleru join Kolleru Lake. Kolleru Lake, the biggest freshwater lake in the country, is situated in the southwestern part of the district. The drainage is mainly dendritic in the northern part of the district and appears to be controlled by structure. Drainage density is higher in the northern part and sparse in the southern part. The delta area is served by the Godavari canal system and numerous other drains.

The region mostly has a tropical climate like the rest of the Coastal Andhra region. The summer (March–June) is very hot and humid, while the winter is pleasant. The rainy season (July–December) is the best time to visit the district, with fields brilliantly green with paddy crops, rivers flowing with water, and a relatively cool climate. The geology of the Eluru District forms a part of the Indian Peninsular Shield, which remained more or less a stable landmass and comprises different types of igneous and metamorphic rocks such as Granite, Gneiss, Quartzite, Granulite, Amphibolite, Khondalite, and Charnokite.

Laboratory analysis for groundwater quality on physicochemical parameters like Total Dissolved Solids, Total Hardness, Chlorides, Nitrate, pH, Fluoride, Iron, Alkalinity, and Sulphate using standard techniques. Groundwater quality samples were collected for two seasons, i.e., post-monsoon and pre-monsoon, from December 2017 to June 2019 from the Rural Water Supply and Sanitation Department (RWSandS) and compared with the BIS (2015) standards in terms of desirable, permissible, and non-potable classes. Blue, yellow, and red colors indicate pre-monsoon quality, and +, ., - symbols indicate post-monsoon quality for desirable, permissible, and non-potable classes, respectively.

From the analysis, it has been observed that the groundwater is polluted in both pre-monsoon and post-monsoon seasons, with about 5% of the area falling under the non-potable category due to high concentrations of

Nitrate, Iron, and Total Hardness. Approximately 85% of the area falls under the potable category, while the remaining 10% of the area is covered by hills and water bodies throughout the district. The occurrence and movement of groundwater in an area are governed by several factors such as topography, lithology, geological structure, depth of weathering, extent of fractures, drainage pattern, climate conditions, and the interrelationship between these factors. The Groundwater quality map of the Eluru District is shown in Figure-18.

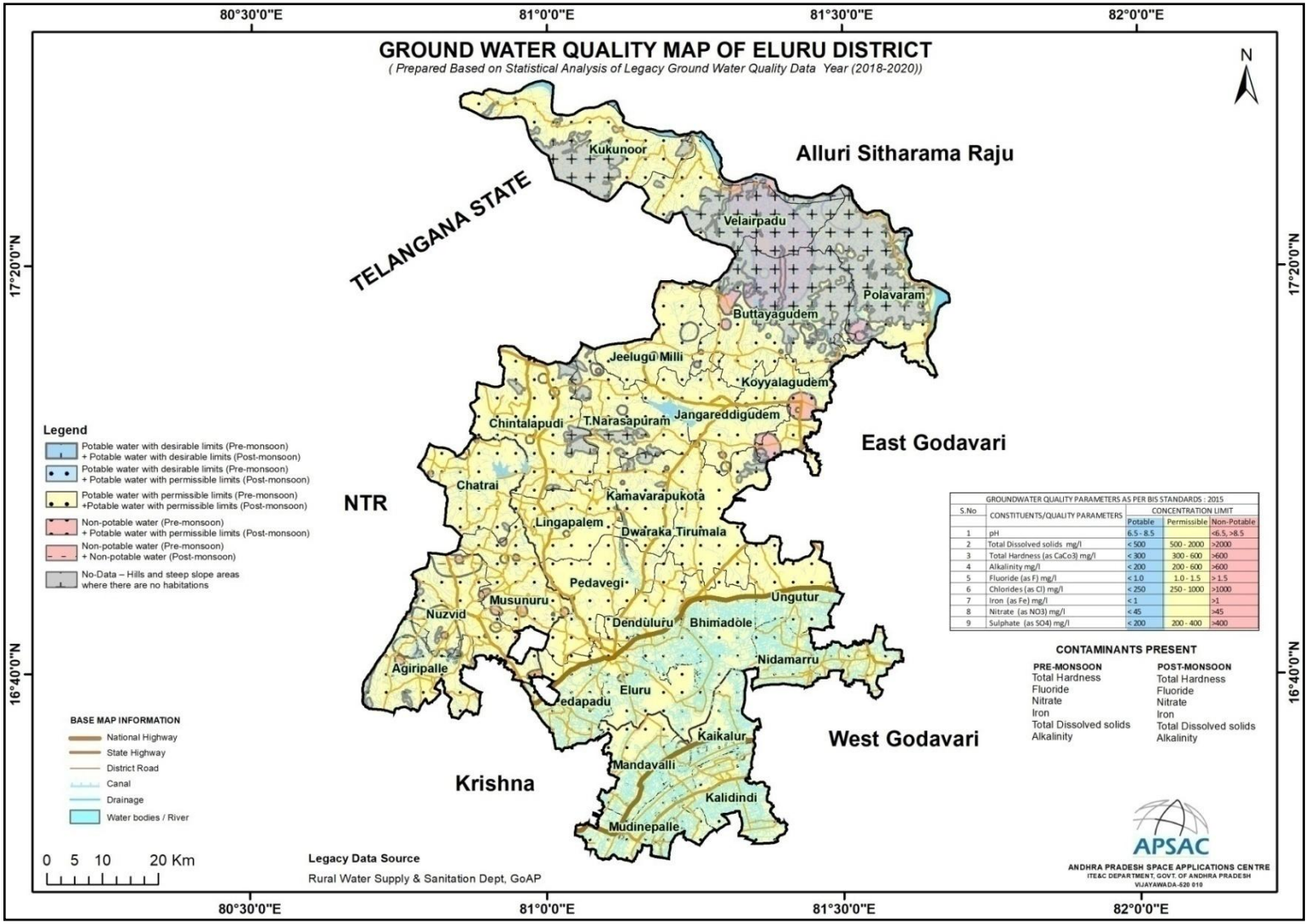


Figure-18: Ground Water Quality Map of Eluru District

Chapter – II Minor Minerals

2.1 Overview of Mining Activity

The following leases exist in this Eluru office jurisdiction. Mineral Regulatory, the important functioning of this office in these aspects are:-

i. Achievement of Targets of Mineral Revenue collections being fixed to this office annually
ii. Receiving and processing of the Mineral Concession Applications duly conducting the technical inspection, Survey and demarcation of the Mineral bearing applied areas
iii. Execution and Regulation of the operations of the Mining / Quarry leases in accordance with the Acts and Rules
iv. Issuing of dispatch permits duly collecting the Advance Royalty / Seig.fee from the lease holders on the minerals produced and intend to dispatch from their leased areas through online permit system
v. Controlling the illegal Mining / Quarrying and transportation by conducting the periodical inspections of the Mines and Quarries and also conducting the surprise vehicular checking and imposing the penalties
vi. Finalisation of Demand, Collection and Balance statements of the leases on annual basis

Eluru District endowed with rich and varied minor mineral resources such as Ball Clay, Gravel, Ordinary Earth and Road Metal.

There are 72 mineral leases in force in Eluru district. It is estimated that during the year 2022-23, 5,25,638 CuM of Ordinary Earth, 3,36,369 CuM of Gravel, 2,10,930 MT of Ball Clay and 56,158 CuM of Road Metal are produced in Eluru in 2022-23

2.2 Geology of the District

Genaralized Litho-stratigraphic Succession of Andhra Pradesh

Geological Time (a)	Supergroup (b)	Group (c)	Formation (d)
Holocene	-	-	Alluvium, river terraces, beach sands and soils
Pleistocene	-	-	Laterite and Gravel
Mio-Pilocene	-	-	Rajahmundry Fm.
Late Cretaceous Eocene	-	-	Deccan Trap with infra-and inter-trappeans

Lower Cretaceous to Upper Carboniferous	Gondwana	Upper Gondwana	Godavari Valley (Fluviatile) Chikiala Fm. Gangapur Fm.	Coastal Area (Fluvio-marine) Tirupati Fm. (Vejendla Fm) Raghavapuram Fm. (Vemavaram), Kandukuru, Sriperambadur Fms)
		Lower Gondwana	Kota Fm. Maleri Fm.	Gollapalle Fm. (Satyavedu Fm.) Kamthi Fm. Barren Measures, Barakar Fm. Talchir Fm.

		Cuddapah Basin	**Pakhal Basin**
			Sullavai Sandstone
Middle to Upper Proterzoic (980-500 m.y)	Kurnool	Nandyala Shale Koilakuntla Limestone Panyam Quarzite Owk Shale Narji Limestone Banaganapalli Quartzite	Putnur Limestone Penganga Group Takalapalle Arkose

			Srisailam Quartzite	**Alabaka Sandstone**
		Nallamalai	Cumbum Fm.	Lankavaram Shale Pattipalle Quartzite
			Mulug Group	Polavaram Fm. Jakaram Arkose
Middle Proterozoic (1600-1300 m.y.)	Cuddapah	Chitravathi	Bairankonda Quartzite Gandikota Quartzite	Pandikunta Shale
			Tadipatri Fm.	Gunjeda Dolomite
			Pulivendula Quartzite Mallampalli Group	
		Papaghni	Vempalle Fm. Gulcheru Quartzite	Bayyaram Quartzite Bolapalle Fm.
EPARCHAEAN INTERVAL				
Middle Proterozoic to Late Archean (2600-970 m.y)	Eastern Ghats		Charnockite	Charnockite with megacrystic k-feldspar charnockite
			Khondalites	Two pyrozene granulite / amphibolite Calc-silicate / granulite, Garnet-sillimanite-quartz-graphite gneiss (biotite-k-feldspar (Khondalite) Quartzite (gernet, sillimanite)
Late Archaean (2700 m.y)	Dharwar	Ramagiri-Penakacherla, Kolar, Kadiri, Gadwal-Narayanpet, Jonnagiri, Veligallu Peddavuru Schist Belts and W.Part of		Pyroclastic Rocks, local conglomerate / event conglomerate Metabasalt (Pillowed), Acid volcanics, minor andesite, dacite, rhyodacite, amphibolites, metaultramafics, minor quartzite, calcsilicates, phyllites, intrusives of basic

		Nellore Belt.	rocks and granites, rare lamprophyres.
Middle Archaean (3100-2900 y.m)	Older Supracrustals (Sargur)	Eastern and Southern parts of Nellore.	High Grade schists include include garnet, staurolite, kyanite, sillimanite, cordierite (rarely sapphirine-kornuropine as in Karimnagar) Mica schists, calcilicate rocks, crystalline limestone (minor). BIF, fuchsite quartzite, hornblende granulite, amphibolite, migmatite streaky biotite gneiss.
Gneissic Complex			Banded Tonalite-Trondhjemite Gneiss.

Geologically, the State of Andhra Pradesh forms a part of peninsular India and is one of the most ancient land masses. The geological formations of Andhra Pradesh range from the oldest to the recent.

The Sargur Supracrustals are the oldest rocks in Southern India, mostly present as enclaves within the migmatitic gneiss. These supracrustals are exposed in the eastern and southern parts of the Nellore schist belt. The lithology of Sargur mostly comprises garnet, staurolite, kyanite schists, BIFs, quartzites, granulites, and amphibolites. The gneissic complex comprises banded tonalite trondhjemite gneiss, which forms the basement rock of the study area, along with migmatitic gneiss and biotite granite gneiss. TTGs are sodic, quartz-bearing granitic (plutonic) rocks with plagioclase as the most common feldspar, and K-feldspar ranging from subordinate to nearly absent. The Dharwarian rocks in Andhra Pradesh are exposed in the western part of the Nellore belt and in many other areas like Anantapur, Ramagiri-Penakacherla, Kolar, Kadiri, Gadwal-Narayanpet, Jonnagiri, Veligallu Peddavuru Schist Belts, and the western part of the Nellore Belt. The lithology mostly comprises Metabasalt (Pillowed), Acid volcanics, minor andesite, dacite, rhyodacite, amphibolites, metaultramafics, minor quartzite, calcsilicates, phyllites, intrusives of basic rocks and granites, rare lamprophyres, as well as some Pyroclastic Rocks and local conglomerate/event conglomerate, defining a hiatus in stratigraphy observed in the study area. Rocks of middle Proterozoic to late Archaean age are exposed in the Eastern Ghats Mobile

Belt, characterized by extremely high-grade metamorphism, falling under the granulite facies. They mostly include khondalites and charnockites. Charnockite with megacrystic K-feldspar, two pyroxene granulite/amphibolite, calc-silicate/granulite, garnet-sillimanite-quartz-graphite gneiss (Biotite-K-feldspar), quartzite (garnet, sillimanite), and other rocks are exposed throughout the state

The Cuddapah basin is part of the Dharwar craton and is the second-largest Purana basin of Peninsular India. It marks the profound unconformity known as the Eparchaen unconformity in early literature. The Cuddapah basin formation exposes rocks from the late Proterozoic to the upper Proterozoic. The Cuddapah basin is divided into four groups: Nallamalai, Chitravathi, Papaghni, and Kurnool. Papaghni comprises dolomite and limestones, Chitravathi comprises shale, dolomite, and quartzites, Nallamalai comprises shale, quartzites, and arkosic sandstones, and Kurnool comprises shales, quartzites, and limestones. The Cuddapah basin is characterized by a rhythmic pattern of quartzite-shale-carbonates cycle. Uraniferous limestone is also reported from the Cuddapah basin. The major exposures of Purana rock formations are in Prakasam, Kurnool, Cuddapah, Chittoor, and Nellore. The Deccan traps are found in East and West Godavari districts, with exposures near Rajahmundry. Outcrops of Tertiary formations are found in East and West Godavari and Visakhapatnam districts, and Quaternary sediments occur as thick blankets of alluvium in the river valleys, deltas, and along the East coast.

Eluru district is underlain by a variety of geological formations, ranging from the oldest Archeans to Recent Alluvium. The oldest rock types are of Archean age, belonging to the Eastern Ghats Supergroup, represented by Khondalite, the Charnockite group, and granite gneiss (migmatite). Talchir, Barakar, and Kamthi formations of the Lower Gondwana, and Kota and Gangapur formations of the Upper Gondwana represent Gondwana sediments ranging from the U. Carboniferous to L. Cretaceous age. Gollapalli, Raghavapuram, and Tirupati formations represent the East Coast Gondwanas. The Deccan Traps overlie these Gondwana rocks. Deposition of Rajahmundry Sandstone indicates marine transgression during the Mio-Pliocene. Laterite cappings on Khondalite and Charnockite are seen on hilltops. Quaternary sediments occur along the rivers and the beach. Khondalite and Charnockite groups with patches of granite gneiss occur to the NE of Zangareddygudem and around Polavaram. The Khondalite Group is represented by garnet-sillimanite-graphite biotite

gneiss, forming strike ridges, steep scarp sections, hillocks, or conical mounds, and also as bands of varying dimensions within the Migmatitic terrain. Calc-granulite and quartzite occur as impersistent, narrow bands conformable to the sillimanite gneiss. The Charnockite Group comprises basic, intermediate, and acid variants. Quartzo-feldspathic injections are common within the acid Charnockite. The lower topographic levels are occupied by migmatite rocks and are characterized by variations in lithology, texture, and mineralogy. They include leptynite and various products of Migmatisation of Khondalite, Charnockite, and pyroxene granulite

The Gondwana formations are seen in the central part, around Jilugumilli-Chintalapudi and Dwaraka-Tirumala. The Talchir Formation comprises green shale and siltstone, occurring as small lensoidal bodies near Chintalapudi. The Barakar Formation, comprising sandstone, shale, and coal, occurs near Bedadanur on the western margin of the Gondwana basin. Ferruginous sandstone and shale of the Kamthi Formation occur north of Chintalapudi and east of Gokavaram. The Kota Formation, represented by sandstone and limestone, occurs over a considerable area around Zangareddygudem. The Gangapur Formation is represented by white sandstone, characterized by horizontal beds. The coastal Gondwanas, a marine and fluvio-marine sequence, are found as discontinuous outcrops along the east coast. They are designated as the Gollapalle Formation, Raghavapuram Formation, and Tirupati Formation and dominantly comprise sandstone, shale, and sandstone, respectively. The Tirupati Formation contains plant remains and fossils of brachiopods, cephalopods, and foraminifera.

The Deccan Traps are manifested as horizontal to sub-horizontal basaltic lava flows near Duddukuru and Devarapalli. Infratrappean sediments are exposed near Pangani. These traps are overlain by Rajahmundry Sandstone, occurring as disconnected outcrops between Bhimadolu and Chagallu, comprising ferruginous sandstone, clay, pebble beds, and lignite. Laterite occurs on hilltops, invariably overlying the white clay and friable sandstone of the Rajahmundry sandstone. Bauxitic laterite occupies several flat-topped and gently sloping hills at elevations of 1000m and above, the basement rock of which is mostly khondalite and charnockite.

Quaternary sediments of both fluvial and marine regimes occur in the south of the district. The fluvial sediments include floodplains, levees, and

active channels, while the marine sediments consist of the palaeo-beach ridge, palaeo-tidal flat, and active beach. Kolleru Lake is situated to the southwest. The floodplain occupies the major part of the delta and is primarily composed of black silt clay, while the levee is made of brown silt. The active channel comprises coarse sand with rock fragments. The palaeo-channels consist of 2.5m to 3.00m thick black clay on top, underlain by coarse sand. The palaeo-beach ridges rise about 2m above the present surface and are composed of highly oxidized brown, fine sand, with inter-ridge lows or tidal flats consisting of alternating sequences of brown silt clay and sand. The present-day beach is composed of grey to cream, fine sand. Evidence of movements during the Quaternary is recorded along the east-northeast-west-southwest trending Narsapur-Yanam fault. The geological map and a detailed legend with the stratigraphic sequence of Eluru District, Andhra Pradesh, are shown in Figure-19, along with a detailed legend showing the stratigraphic sequence.

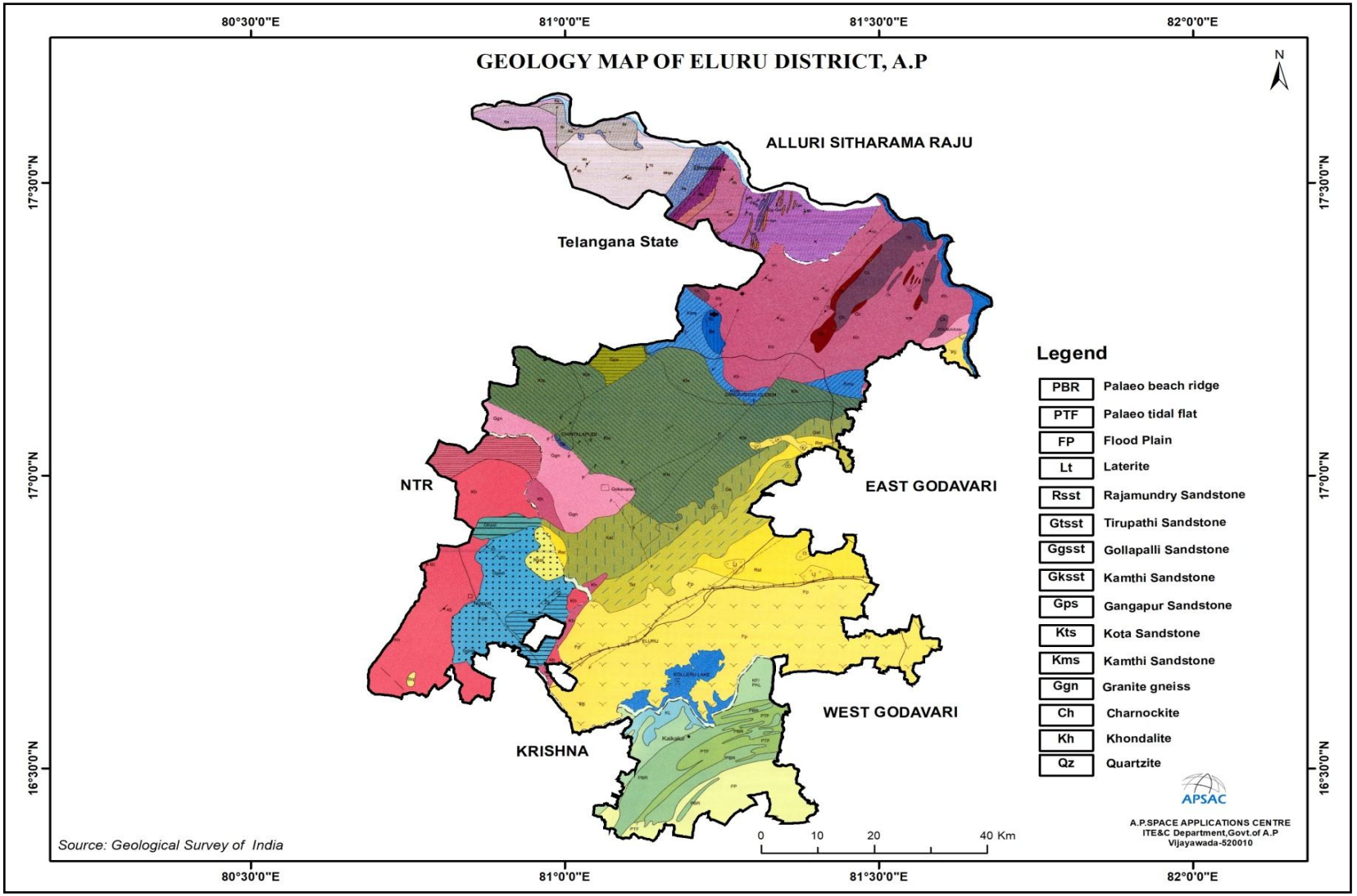
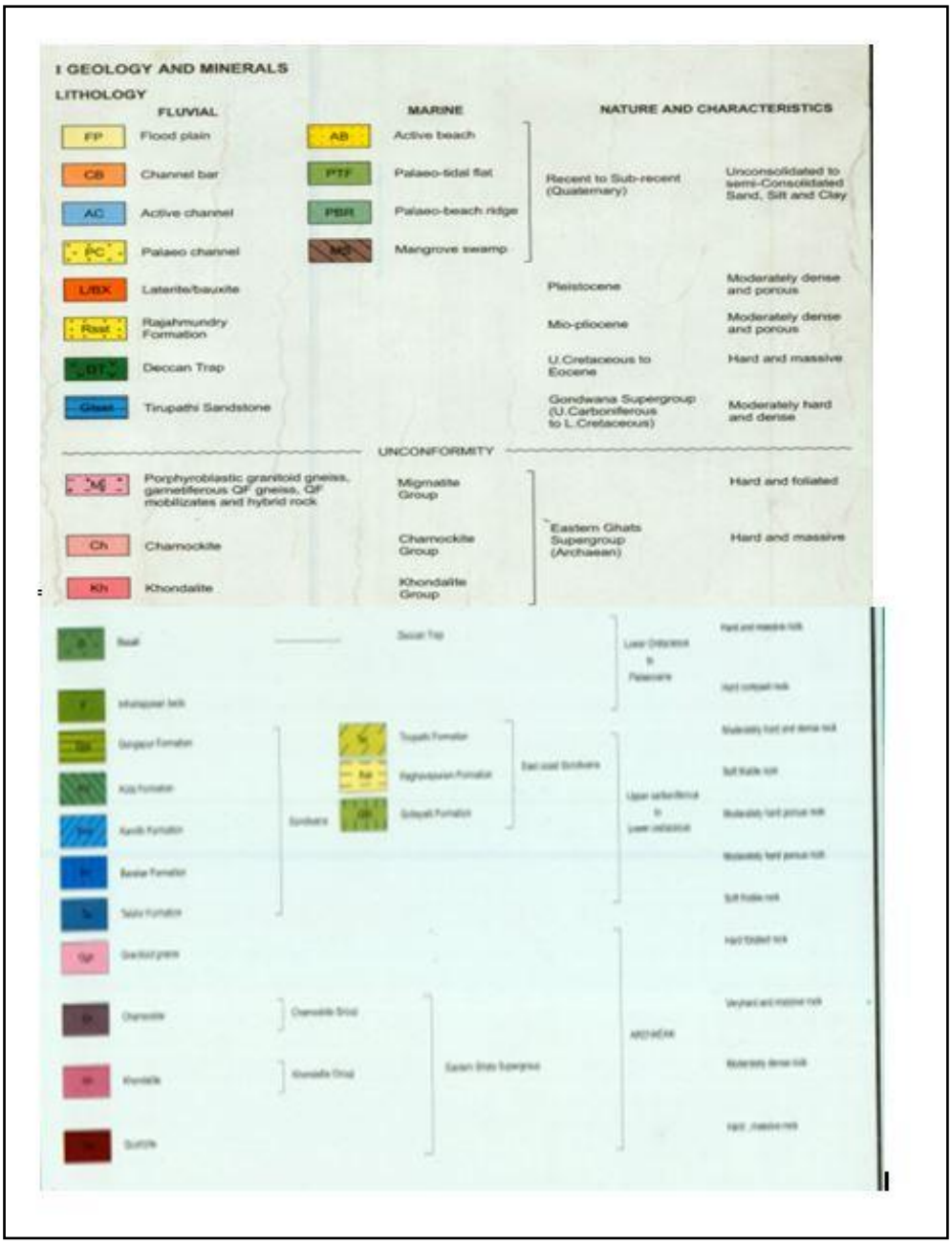


Figure 19: Geology of Eluru District, Andhra Pradesh (Source: GSI, 2000)



Detailed Legend with Stratigraphic Sequence of Eluru District

2.3 Minor Mineral Resources of Eluru District:

As per literature (GSI, 2000) the following minerals are available in Eluru District. (Data Source: Assistant Director of Mines and Geology, Eluru District, Andhra Pradesh) and showing in Figure-20

2.3.1. Gravel: Gravel is used for road construction, mixed with asphalt, as construction fill, and in the production of construction materials such as concrete blocks, bricks, and pipes. This mineral is available in Boddanapalle, Kanasanapalle, Narasingapalem, and Thotapalle villages in Agiripalle Mandal, Amberpeta villages in Bhimadole Mandal, Pothanapalle Village in Chatrai Mandal, Chillaboinapalle village in Musunuru Mandal, Ravicherla village in Nuzvid Mandal, and Kaikaram, Unguturu village in Unguturu Mandal.

2.3.2. Ball Clay (Crude): Ball clay is used for manufacturing ceramic whiteware and sanitary ware and is available in Dwarakatirumala, Gundugolanukunta, Kommugudem, and Venkatakrishnapuram villages in Dwaraka Tirumala Mandal.

2.3.3. Ordinary Earth: Ordinary earth is used for filling embankments, roads, railways, and buildings, and is available in Amberpeta village in Bhimadole Mandal and Parimpudi village in Koyyalagudem Mandal.

2.3.4. Road Metal: Road metal is utilized for construction purposes, as well as railway ballast. It is available in Pothanapalle village in Bhimadole Mandal, Pothanapalle village in Chatrai Mandal, Pragadavaram village in Chintalapudi Mandal, and Parimpudi village in Koyyalagudem Mandal.

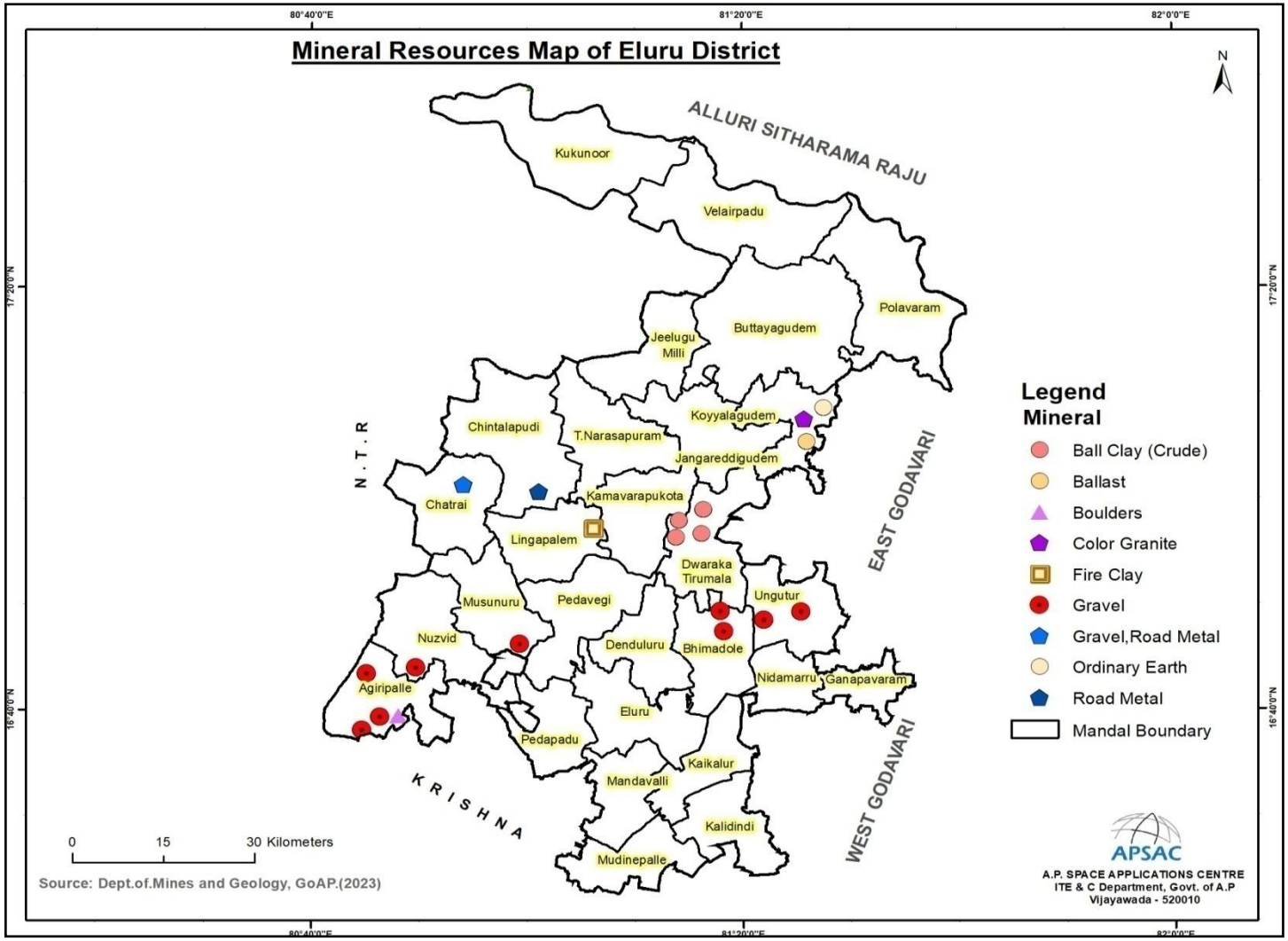


Figure-20: Mineral Resource Map of Eluru District

The Details List of statement showing the Leases wise for Minor Minerals during the period described in Table-14 and letter of intest details are showin in Table-15:

Table 14 Statement showing the List of details Leases wise for Minor Minerals during the Period (Present Status)

S. NO	Name of the Mineral	Name of the Lessee	Address and Contact No. of the Lessee	Mining Lease Grant Order No. and Date		Area of mining lease (ha)				Period of Mining Lease (Initial)		Period of Mining Lease (1st and 2nd ...renewal)		Date of commencement of Mining Operation	Status (Working /non-working/ Temp.working for dispatch etc.,)	Captive/Non-captive	Obtained environmental clearance (YES/No), if Yes Letter No. with date of grant of EC	Location of the Mining Lease (Latitude and Longitude)	Method of Mining (Opencast/Underground)
				Govt.Order NO.	Govt.Order Date	Extent	Sy.No	Village	Mandal	From	To	From	To						
1	Gravel	V. PRAVEEN	8096585859	4235/Q3/2016	9/15/2017	4.859	101/22(p)	Vadlamanu	Agiripalle	9/25/2017	3/31/2024	--	--	9/25/2017	Non Working	Non-captive	DEIAA/AP/574/VJA/2017, , dt:13.05.2017	16°42' 58.8"N 80°48' 14.2"E	Open Cast
2	Gravel	Moram Bhavana Rushi	9393511320	31/Q3/2018	2/4/2020	4.497	117/P	Kanasanapalle	Agiripalle	2/11/2020	2/10/2025	--	--	2/11/2020	Non Working	Non-captive	SEIAA/AP/KRI/MIN/05/2019/1006 dt:06.8.2019	16°36' 08.50027"N 80°45' 21.22624"E	Open Cast
3	Gravel	L V V R V Prasad	9490909096	326/Q3/2017	1/23/2019	12.318	2-Jan	Thotapalle	Agiripalle	4/20/2019	3/31/2024	--	--	4/20/2019	Non Working	Non-captive	SEIAA/AP/KRI/MIN/10/2018/711 dt:06.12.2018	16°38' 39.9900"N 80°46' 01.5600"E	Open Cast
4	Boulders, Gravel,Rough Stone	Galaxy Minerals	9440281443	2077/Q3/2017	3/29/2019	3.387	131	Narasingapalem	Agiripalle	6/21/2019	6/20/2029	--	--	6/21/2019	Non Working	Non-captive	DEIAA/AP747/VJA/2017, dt:23.01.2018	16°39' 40.32" N 80°48' 28.47" E	Open Cast
5	Gravel	Rudra Satyanarayana	9866936789	3980/Q2/2016	1/10/2019	1.797	502/1and2	Amberpeta	Bhimadole	1/25/2019	3/31/2024	--	--	1/25/2019	Non Working	Non-captive	DEIAA/AP/16749/WG/2018-17, dt:02.10.2018	16°49' 55.86" N 81°17' 25.57" E	Open Cast

S.NO	Name of the Mineral	Name of the Lessee	Address and Contact No. of the Lessee	Mining Lease Grant Order No. and Date		Area of mining lease (ha)				Period of Mining Lease (Initial)		Period of Mining Lease (1st and 2nd ...renewal)		Date of commencement of Mining Operation	Status (Working /non-working/ Temp.working for dispatch etc.,)	Captive/Non-captive	Obtained environmental clearance (YES/No), if Yes Letter No. with date of grant of EC	Location of the Mining Lease (Latitude and Longitude)	Method of Mining (Opencast/Underground)
				Govt.Order NO.	Govt.Order Date	Extent	Sy.No	Village	Mandal	From	To	From	To						
6	Gravel,Murram,Ordinary Earth	Gummadi Srinivasa Rao	9666426136	391/Q/2021	10/15/2022	1.254	478	Amberpeta	Bhimadole	10/22/2022	6/30/2025	--	--	10/22/2022	Working	Non-captive	SEIAA/AP/WG/MIN/6/2022/4406/193.36/190.31 dt:18.08.2022	16°49' 55.21303"N 81°17' 00.12304"E	Open Cast
7	Gravel,Road Metal	Sri Balaji Stone Infratech	7093450969	440/Q1/2022	6/23/2022	4.225	7-1C, 7-2B, 7-3, 11-2B and 15-1	Pothanapalle	Chatrai	8/2/2022	8/1/2032	--	--	8/2/2022	Non Working	Non-captive	SEIAA/AP/KRI/MIN/04/2022/4166/186.24/183.26, dt:28.05.2022	17°02’ 01.12024" N 80°53' 40.80228" E	Open Cast
8	Road Metal	Sri Balaji Granites and Metals	9441966441	1956/Q2/2015	4/23/2015	2.1	169/4	Pragadavaram	Chintalapudi	5/13/2015	5/12/2025	--	--	5/13/2015	Working	Non-captive	DEIAA/AP/3881/W.G/2017-9, Dt:17.02.2018	17°01' 02.80283"N 80°59' 52.32320"E	Open Cast
9	Ball Clay	Sri Venkateswara Ceramic Industries	8897630667	49	1/27/2006	17.494	115, 117	Gundugolanukunta	Dwaraka Tirumala	6/3/2006	3/31/2024	--	--	6/3/2006	Non Working	Non-captive	-	16°57' 03.99" N 81°14' 13.32" E	Open Cast
10	Ball Clay	M/s. East Coast Minerals	9502646396	163	4/17/1993	3.644	109/1	Gundugolanukunta	Dwaraka Tirumala	5/17/1993	3/31/2024	1st Renwal	--	5/17/1993	Non Working	Non-captive	-	16°57' 11.06379"N 81°14' 17.12728"E	Open Cast
11	Ball Clay	G.V.B. Gopala Murthy	9989818273	444	11/22/1994	1.92	63/1	Dwarakatirumala	Dwaraka Tirumala	3/28/1995	3/27/2045	--	--	3/28/1995	Non Working	Non-captive	-	16°57' 02.00" N 81°15' 09.00" E	Open Cast

S.NO	Name of the Mineral	Name of the Lessee	Address and Contact No. of the Lessee	Mining Lease Grant Order No. and Date		Area of mining lease (ha)				Period of Mining Lease (Initial)		Period of Mining Lease (1st and 2nd ...renewal)		Date of commencement of Mining Operation	Status (Working /non-working/ Temp.working for dispatch etc.,)	Captive/Non-captive	Obtained environmental clearance (YES/No), if Yes Letter No. with date of grant of EC	Location of the Mining Lease (Latitude and Longitude)	Method of Mining (Opencast/Underground)
				Govt.Order NO.	Govt.Order Date	Extent	Sy.No	Village	Mandal	From	To	From	To						
12	Ball Clay	Sri M.Venkateswara Rao	9440539817	266	5/12/2000	4.573	11	Dwarakatirumala	Dwaraka Tirumala	3/24/1996	3/22/2036	--	--	3/24/1996	Working	Non-captive	-	N 16o 57'' 19.36" E 81o 15'' 02.44"	Open Cast
13	Ball Clay	M/s.APMDC Ltd	9441586287	124	9/3/1985	13.93	15/4	Dwarakatirumala	Dwaraka Tirumala	12/4/2010	12/3/2030	--	--	12/4/2010	Working	Non-captive	SEIAA/AP/WG-05/2009, dt:19.08.2016	16°57' 06.76" N 81°14' 38.49" E	Open Cast
14	Ball Clay	Sri O.G.Raja Kumar	9989323415			3.67	18/2,66/P	Dwarakatirumala	Dwaraka Tirumala	2/22/1991	2/21/2031	--	--	2/22/1991	Non Working	Non-captive	-	-	Open Cast
15	Ball Clay	Sri O.K.Visweswara Rao	9440871213	187	5/13/1992	4.383	18/2,66	Dwarakatirumala	Dwaraka Tirumala	2/2/1992	3/31/2024	--	--	2/2/1992	Non Working	Non-captive	SEIAA/AP/WG-73/2015, dt:18.01.2016	16°57' 06.19" N 81°14' 38.53" E	Open Cast
16	Ball Clay	Sri M.Satyanarayana	9440234668	309	11/17/2008	2.081	22/3,28/1	Dwarakatirumala	Dwaraka Tirumala	8/14/2009	10/30/2024	--	--	8/14/2009	Non Working	Non-captive	-	16-57-18.31589''N 81-14-55.99040''E	Open Cast
17	Ball Clay	Sri.M.Venkateswara Rao	9440539817	218	9/30/2004	4.85	76	Dwarakatirumala	Dwaraka Tirumala	1/6/2004	3/31/2024	--	--	1/6/2004	Working	Non-captive	SEIAA/AP/WG-72/2015, dt:18.01.2016	16°56' 42.4"N 81°14' 50.2"E	Open Cast
18	Ball Clay	M.VENKATESWARA RAO	9440539817	13495/D5-ELR/2018	1/31/2023	1.031	65/1,65/3A(P),65/3b(P)	Kommugudem	Dwaraka Tirumala	2/8/2023	2/7/2043	--	--	2/8/2023	Working	Non-captive	SEIAA/AP/WG/MIN/10/2022/4667/203.06 and200.06, dt: 07.12.2022	16°57' 03.03528"N 81°14' 50.505	Open Cast

S.NO	Name of the Mineral	Name of the Lessee	Address and Contact No. of the Lessee	Mining Lease Grant Order No. and Date		Area of mining lease (ha)				Period of Mining Lease (Initial)		Period of Mining Lease (1st and 2nd ...renewal)		Date of commencement of Mining Operation	Status (Working /non-working/ Temp.working for dispatch etc.,)	Captive/Non-captive	Obtained environmental clearance (YES/No), if Yes Letter No. with date of grant of EC	Location of the Mining Lease (Latitude and Longitude)	Method of Mining (Opencast/Underground)
				Govt.Order NO.	Govt.Order Date	Extent	Sy.No	Village	Mandal	From	To	From	To						
																		02"E	
19	Ball Clay	M/s.Satya Sai Mines and Minerals	9440539817	49	5/29/2010	2.43	75/1	Kommugudem	Dwaraka Tirumala	5/29/2010	7/22/2030	--	--	5/29/2010	Working	Non-captive	SEIAA/AP/WG-71/2015, dt:18.01.2016	16°56' 51.03" N 81°14' 45.85" E	Open Cast
20	Ball Clay	Smt. M.Lakshmi Ramani	9849766666	311	11/20/2007	7.14	69/1	Kommugudem	Dwaraka Tirumala	4/15/2008	4/14/2028	--	--	4/15/2008	Working	Non-captive	SEIAA/AP/WGD-02/08, Dt:09.04.2008	16-56-58.59189''N 81-14-32.40455''E	Open Cast
21	Ball Clay	M/s Dwaraka Mineral Works	9849766666	363	7/31/1987	5.45	70/2,74	Kommugudem	Dwaraka Tirumala	9/29/1987	9/28/2028	--	--	9/29/1987	Working	Non-captive	SEIAA/AP/KDP/MIN/7/2021/3497/170.46/166.34, dt:06.01.2022	16°56' 51.66501"N 81°14' 36.91937"E	Open Cast
22	Ball Clay	M/s. Vijaya Bharathi Corporation Ltd.	9440875457	167	5/20/1998	12.95	1	Venkatakrishnapuram	Dwaraka Tirumala	3/23/1998	3/31/2030	--	--	3/23/1998	Working	Non-captive	SEIAA/AP/WG/MIN/07/2016/174, dt:27.02.2017	16°57’ 01.60” N 81°14' 11.20" E	Open Cast
23	Ballast,Boulders,Road Metal	M/s BEKEM Infra Projects Pvt.Ltd	9644100555	3240/Q2/2021	5/4/2022	1	944/1A	Parimpudi	Koyyalagudem	5/11/2022	5/10/2032	--	--	5/11/2022	Working	Non-captive	SEIAA/AP/WG/MIN/01/2022/3907/177.89/174.52, dt:18.03.2022	17°08’ 42.34851”N 81°28' 21.81093"E	Open Cast
24	Ordinary Earth,Road Metal	M/s BEKEM Infra Projects Pvt	9644100555	200/Q2/2021	5/9/2022	1.542	938/1,939/1,2,3and4	Parimpudi	Koyyalagudem	5/18/2022	5/17/2032	--	--	5/18/2022	Working	Non-captive	SEIAA/AP/WG/MIN/3/2022/3999/180.81/178.68 , dt:29.03.2022	17°08' 55.74320"N 81° 28'40.1	Open Cast

S.NO	Name of the Mineral	Name of the Lessee	Address and Contact No. of the Lessee	Mining Lease Grant Order No. and Date		Area of mining lease (ha)				Period of Mining Lease (Initial)		Period of Mining Lease (1st and 2nd ...renewal)		Date of commencement of Mining Operation	Status (Working /non-working/ Temp.working for dispatch etc.,)	Captive/Non-captive	Obtained environmental clearance (YES/No), if Yes Letter No. with date of grant of EC	Location of the Mining Lease (Latitude and Longitude)	Method of Mining (Opencast/Underground)
				Govt.Order NO.	Govt.Order Date	Extent	Sy.No	Village	Mandal	From	To	From	To						
		Ltd																7983"E	
25	Ballast,Ordinary Earth,Road Metal	M/s BEKEM Infra Projects Pvt.Ltd	9644100555	2820/Q2/2021	5/4/2022	2.29	944/1C and 944/2C	Parimpudi	Koyyalagudem	5/11/2022	5/10/2032	--	--	5/11/2022	Working	Non-captive	SEIAA/AP/WG/MIN/01/2022/3912/177.90/174.5, dt:18.03.2022	17°08'34.38030"N 81°28'26.60582"E	Open Cast
26	Color Granite	Koduru Venkata Ratnam	9494233324	6416/R2-2/2018	12/3/2018	1.482	943	Parimpudi	Koyyalagudem	1/23/2019	1/22/2039	--	--	1/23/2019	Non Working	Non-captive	DEIAA/AP/500/W.G/2018/EC-18, Dt:02.10.2018	17°08'43.64"N 81°28'31.13"E	Open Cast
27	Fire Clay	Smt. O.S.K. Maha Lakshmi	9440871213	220	5/28/2001	14.529		Asannagudem	Lingapalem	4/22/1994	4/21/2034	--	--	4/22/1994	Non Working	Non-captive	-	16-56-26.41902''N 81-07-15.15053''E	Open Cast
28	Gravel	Annamreddy Nagaraju	9912266669	1709/Q3/2020	9/29/2021	3.36	208	Chillaboinapalle	Musunuru	12/24/2021	12/23/2026	--	--	12/24/2021	Working	Non-captive	SEIAA/AP/KRI/MIN/12/2020/2650/158.88 and 153.108-365, dt: 28.06.2021	16°45'48.35.330"N 81°00'16.03.309"E	Open Cast
29	Gravel	Ch.Saraswathi	9866105929	1626/Q3/2016	7/2/2019	5	21	Ravicherla	Nuzvid	8/6/2019	8/5/2024	--	--	8/6/2019	Non Working	Non-captive	DEIAA/AP/3279/VJA/2018, dt: 12.06.2018	16°39'39.69"N 80°48'17.72"E	Open Cast
30	Gravel	K.SAGAR	7288840419	288/Q/2022-1	12/24/2022	4.5	1	Kothavaram	T Narasapuram	2/6/2023	2/5/2033	--	--	2/6/2023	Non Working	Non-captive	SEIAA/AP/WG/MIN/06/2022/4339/193.20/190.19, Dt:17.08.2022	17°04'31.80885"N 81°07'30.99378"E	Open Cast

S. NO	Name of the Mineral	Name of the Lessee	Address and Contact No. of the Lessee	Mining Lease Grant Order No. and Date		Area of mining lease (ha)				Period of Mining Lease (Initial)		Period of Mining Lease (1st and 2nd ...renewal)		Date of commencement of Mining Operation	Status (Working /non-working/ Temp.working for dispatch etc.,)	Captive/Non-captive	Obtained environmental clearance (YES/No), if Yes Letter No. with date of grant of EC	Location of the Mining Lease (Latitude and Longitude)	Method of Mining (Opencast/Underground)
				Govt.Order NO.	Govt.Order Date	Extent	Sy.No	Village	Mandal	From	To	From	To						
31	Gravel	K.V.V.B.M. KRISHNAM RAJU	9866936789	33/Q/2019	11/29/2019	3	649	Ungutur u	Ungu turu	2/25/2020	2/24/2025	--	--	2/25/2020	Non Working	Non-captive	SEIAA/AP/WG/MIN/05/2019/1005, dt: 06.08.2019	16°50' 33.58" N 81°24' 50.80" E	Open Cast
32	Gravel	K VEERA VENKATA BALA MURALI KRISHNAM RAJU	9866936789	378/Q/2019	6/9/2020	4.395	111/10	Kaikaram	Ungu turu	7/1/2020	6/30/2025	--	--	7/1/2020	Working	Non-captive	SEIAA/AP/WG/MIN/10/2019/1375221, dt: 11.02.2020	16°49' 28.99596"N 81°22' 33.48954"E	Open Cast

Data Source: District of Mines and Geology, Eluru District, Andhra Pradesh

Table 15 List of Letter of Intent (LOI) Holders in the District along with its validity as per the following format

Sl. No.	Name of the Mineral	Name of the Lessee	Address and Contact No. of Letter of Intent Holder	Letter of Intent Grant Order No. and date	Area of Mining Lease to be allotted				Validity of LoI	Use (Captive/ Non-Captive)	Location of the Mining Lease (Latitude and Longitude)
1	2	3	4	5	Survey Nos.	Village	Mandal	Extent in Hect	7	8	9
					6						
1	Ball Clay	Sri Rajendra Babu Mallipeddi	9642234545	3308/D5-ELN2023, dt:20.07.2023	66/2	Kommugudem	Dwarakatirumala	1.619	03 Years	Non Captive	16°56'59.19905"N 81°14'49.24381"E
2	Quartz, Feldspar and Mica	Sri Manapati Abbulu	6281211677	7099/D5/2019, Dt:07.10.2020	401/2, 402/1, 402/2 and 402/3	Pragadapalli	Polavaram	4.96	01 Year	Non Captive	17°12'53.41263"N 81°34'53.00190"E
3	Quartz, Feldspar and Mica	Sri Manapati Abbulu	6281211677	7100/D5/2019, Dt:07.10.2020	407	Pragadapalli	Polavaram	4.95	01 Year	Non Captive	17°12'53.41263"N 81°34'53.00190"E
4	Gravel and Ordinary Earth	Sri Ponnam Praveen	7799992745	3284/QL/2022, Dt:13.04.2023	91-2, 90-2A1, 90-2B1	Chebrolu	Unguturu	1.78	03 Years	Non Captive	16°50'05.55578"N 81°23'46.19465"E
5	Morrum/Gravel and Ordinary Earth	M/s MBL Minerals, Mg:P Sri M.Venkata Rama Rao	9705162222	502/Q1/2023, Dt:28.04.2023	15, 16/2A,16/2C	Thotapalli	Agiripalli	2.74	03 Years	Non Captive	16°38'59.52525"N 80°45'36.51079"E

Data Source: District of Mines and Geology, Eluru District, Andhra Pradesh

2.4 Details of Royalty in last 3 years

The royalty of last three years in the Eluru district detailed list is given in Table-16.

Table 16 Details of Royalty in last 3 years

Royalty for 2022-23

S. No.	Mineral	Royalty (in Rs. Lakhs)	Consideration Amt. (in Rs. Lakhs)	DMF (In Rs. Lakhs)	MERIT (in Rs. Lakhs)
1	Ball Clay	158	158	47.5	3.1
2	Gravel	151.3	151.3	45.4	3
3	Ordinary Earth	236.5	236.5	71	4.7
4	Road Metal	50.5	50.5	15	1
Total		**596.3**	**596.3**	**179**	**11.8**

Royalty for 2021-22

S. No.	Mineral	Royalty (in Rs. Lakhs)	Consideration Amt. (in Rs. Lakhs)	DMF (In Rs. Lakhs)	MERIT (in Rs. Lakhs)
1	Ball Clay	164.5	82.5	49.3	3.3
2	Gravel	130.5	65.25	39.2	2.6
3	Ordinary Earth	207.4	103.7	62.2	4.2
4	Road Metal	6.6	3.3	2	0.13
Total		**509**	**254.7**	**152.7**	**10.23**

Royalty for 2020-21

S. No.	Mineral	Royalty (in Rs. Lakhs)	DMF (In Rs. Lakhs)	MERIT (in Rs. Lakhs)
1	Ball Clay	104.33	31.3	2
2	Gravel	123	37	2.5
3	Murram	13.5	4	0.27
4	Ordinary Earth	175.6	52.7	3.5
5	Road Metal	35	10.5	0.7
Total		**451.43**	**135.5**	**8.97**

Data Source: District Mines and Geology Officer, Eluru District, Andhra Pradesh

2.5 Details of Production in last 3 years

Production of last three years in the Eluru district details is given in Table-17.

Table 17 Details of Production in last 3 years

Production for 2022-23

S. No.	Mineral	Unit	Production (in MT)
1	Ball Clay	MT	2,10,930
2	Gravel	Cubic Meter	3,36,369
3	Ordinary Earth	Cubic Meter	5,25,638
4	Road Metal	Cubic Meter	56,158

Production for 2021-22

S. No.	Mineral	Unit	Production (in MT)
1	Ball Clay	MT	2,19,370
2	Gravel	Cubic Meter	2,89,819
3	Ordinary Earth	Cubic Meter	4,60,905
4	Road Metal	Cubic Meter	7,340

Production for 2020-21

S. No.	Mineral	Unit	Production (in MT)
1	Ball Clay	MT	1,39,116
2	Gravel	Cubic Meter	2,73,131
3	Murram	Cubic Meter	30,000
4	Ordinary Earth	Cubic Meter	3,90,271
5	Road Metal	Cubic Meter	38,840

Data Source: District Mines and Geology Officer, Eluru District, Andhra Pradesh

2.6 Impact on environment

The extraction and utilization of minor minerals have become integral to our modern way of life, fueling infrastructure development, construction, and various industries. However, the impact of these activities on the environment cannot be underestimated. Minor minerals, which include granite, road metal, gravel, clay, and more, play a significant role in shaping the natural landscape and ecosystems. The various environmental consequences associated with the extraction and use of minor minerals are:

2.6.1. Habitat Destruction: The mining of minor minerals often entails the removal of topsoil and vegetation, leading to habitat destruction. This can disrupt ecosystems, displace wildlife, and threaten the survival of numerous species. Loss of biodiversity is a significant concern in regions with extensive mining operations.

2.6.2. Land Degradation: Mining activities can lead to land degradation, including soil erosion and compaction. This not only reduces the land's fertility but also affects its ability to support agriculture and vegetation growth. Moreover, land degradation can contribute to increased vulnerability to natural disasters like floods.

2.6.3. Water Pollution: Mining operations can contaminate nearby water bodies through the discharge of sediments, chemicals, and heavy metals. This pollution can have detrimental effects on aquatic life, disrupt local hydrology, and compromise the quality of water available for human consumption.

2.6.4. Air Quality: Dust emissions from mining sites can deteriorate air quality in surrounding areas. The fine particles and pollutants released during excavation and transportation of minor minerals can pose health risks to both workers and nearby communities.

2.6.5. Regulatory Challenges: Enforcing regulations and monitoring mining activities in remote or unregulated areas can be challenging, allowing illegal and unsustainable practices to persist.

The extraction and utilization of minor minerals are essential for economic development, but they come at a cost to the environment. Recognizing the environmental impacts of these activities is crucial for sustainable resource management.

2.7 Remedial Measures

The provisions of Rule 12 (1) and Rule 12 (5) and of Andhra Pradesh Minor Mineral Concession Rules, 1966 allows the State Government to issue the Letters of Intent with the stipulated conditions to submit Approved Mining Plan (AMP), Environment Clearance (EC) and Consent for Establishment (CFE) for grant of lease.

Mine Plan stipulate the maximum permissible annual production of the mineal from the designated lease area and also includes

estimated quantum of solid waste generation and its method of disposal, etc. Based on the Approved Mine Plan projections, Environment Management Plan shall be prepared and SEIAA makes the decision to grant the EC based on the EMP.

Leaseholders commit to all the remedial measures in the Mining Plan and the State Environment Impact Assessment Authority (SEIAA) ensures the remedial measures are being adhered to during the tenure of the Environmental Clearance.

Leaseholders in the district have adopted various remedial measures to mitigate the impact of mining on the environment. These measures aim to reduce the environmental footprint of mining operations and address the associated challenges. Some common practices include:

2.7.1. Environmental Impact Assessments (EIAs): Leaseholders conduct comprehensive EIAs to evaluate the potential environmental consequences of mining projects. They shall use this information to develop mitigation strategies.

2.7.2. Reclamation and Rehabilitation: Leaseholders work to restore mined areas by recontouring landscapes, replanting native vegetation, and stabilizing soils to promote ecosystem recovery.

2.7.3. Water Management: Proper management of water resources is crucial. Leaseholders use techniques like sedimentation ponds, water recycling, and water treatment facilities to minimize water pollution and ensure responsible water use.

The following preventive measures are being followed for minimizing adverse effects on water regime:

- Small Gully checks, gully check dams, silt settling tanks, silt traps, etc. shall be constructed.
- Along all discharge points leaving the mining lease, into the surrounding area, suitable number of filter walls of sufficient lengths shall be erected across the flow, at intervals, all along the length to prevent suspended solids entering the surrounding streams/ drains/ water courses, to confine the discharge water quality to the permissible limits.

- Regular monitoring may be carried out and further remedial steps as may be necessary may be taken.

2.7.4. Waste Management: Effective management of mining waste, such as tailings and slag, involves containment in secure facilities to prevent soil and water contamination. Advances in waste disposal technologies are also being explored.

Steps being followed for effective waste management:

- Implementation of practices to minimize waste generation at the source. This involves optimizing extraction techniques, reducing overburden removal, and improving resource utilization.
- Encouraging recycling and reuse of waste materials wherever possible within the mining operation.
- Selection of an appropriate disposal methods based on waste characteristics and environmental considerations. Common methods include landfilling, controlled dumping, and backfilling.
- Treatment of contaminated water and effluents using appropriate technologies before discharge.

2.7.5. Afforestation: Leaseholders carry out a year-wise afforestation plan for the initial years with detailed costing of each plant, its maintenance per piece, etc.

While these measures represent positive steps toward mitigating environmental impact, it's important to note that the effectiveness of these practices can vary widely depending on factors such as the location, scale, and specific mineral being mined. Continuous improvement and adaptation are essential in the mining industry's ongoing efforts

2.8 Reclamation Measures

As per Rule 7A (ii) of Andhra Pradesh Minor Mineral Concession Rules, 1966, Mine Closure Plan shall be submitted by the leaseholder before 6 months of expiry of the lease in the proforma as prescribed by the Director. The Deputy Director concerned shall approve the mine closure

plan and ensure compliance of conditions of the approved mine closure plan before expiry of the lease period.

Financial assurance of Rs.50,000/-(Rupees Fifty Thousand) for the quarry lease granted below five(5) hectares and Rs.10,000/- (Rupees Ten Thousand) per Hectare or part thereof for the quarry lease granted five (5) hectares and above, shall be submitted in the form of deposit. If the leaseholder does not reclamate the area as mentioned in the Mine Closure Plan, the deposit shall be forfeited and the Department of Mines and Geology ensure the proper implementation of the Mine Closure Plan.

2.9 Risk Assessment and Disaster Management Plan

Leaseholders conduct comprehensive risk assessment, prepare a model disaster management plan and submit in the Mining Plan.

The leaseholders maintain and arrange following resources at the mine site:

a) Firefighting equipment

b) Ambulance services with location

c) List of volunteer organizations

d) List of Civil, Police and other authorities to be informed in case of an accident

e) Last of mobile crane operators (Government, Public Sector, and Private Sector).

f) List of mines, contacts, facility available nearby

g) List of first aiders and contacts.

h) List of Officers of DGMS to be informed in case of serious accidents Concerned DGMS officers concerned is displayed at the mine head.

The leaseholders shall monitorthe total execution of the disaster management plan. The resources of all departments including men and material are being promptly made available. They are also conducting regular mock rehearsals with their staff to update the risk register and accordingly, disaster management plan

2.9.1. Mineral Regulatory:

The important functioning of District Mines and geology Officer, Eluru are:-

- Achievement of Targets of Mineral Revenue collections being fixed to this office annually

- Receiving and processing of the Mineral Concession Applications duly conducting the Technical inspection, Survey and demarcation of the Mineral bearing applied areas

- Execution and Regulation of the operations of the Mining / Quarry leases in accordance with the Acts and Rules

- Issuing of dispatch permits duly collecting the Advance Royalty / Seig.fee from the lease holders on the minerals produced and intend to dispatch from their leased areas through online permit system

- Controlling the illegal Mining / Quarrying and transportation by conducting the periodical inspections of the Mines and Quarries and also conducting the surprise vehicular checking and imposing the penalties

- Finalisation of Demand, Collection and Balance statements of the leases on annual basis

2.10 Planation and Green Belt Development

Leaseholders are complying with the plantation and green belt development programmes as committed in their Mining Plans.

CHAPTER III: SAND

3.1 Sand Mineral Resources of the Eluru District

3.1.1 General Sand Mineral Details Eluru District

(Prepared as per Sustainable Sand Mining Management Guidelines 2016 and 2020)

The Eluru District is primarily drained by the Godavari, Yerrakalava, Tammileru, Jalleru, Baineru, and Pamuleru rivers, collectively spanning a total length of 645 km. These rivers are mostly seasonal, flowing primarily during the rainy season. Existing check dams and reservoirs are located along these rivers, including the Dawalaiswaram Barrage and the Polavaram Project across the Godavari River, as well as the Karatam Krishna Murthy Reservoir across the Yerrakalva River. Additionally, the Nagireddygudem Dam is situated across the Thammileru River. Following the district's recent bifurcation, the Eluru District Mines Office was established. Consequently, information on sand production has not been available for the past three years, as indicated in Table-18.

Table 18 Details of Production of Sand in Last three years in the District

Year	Production (In MTs)	Revenue Generated (in Rs)
2020-21	--	--
2021-22	78,332	68,93,216
2022-23	17,918	15,76,784

Data Source: District Mines and Geology Officer, Eluru District

3.1.2 River Basins in Eluru District

In Eluru district there are 08 major river basins i.e, Godavari, Yerrakalva, Tammileru, Kovvada Kalva, Minor Drainages in Krishna Delta Joining Sea in Krishna District, Ramileru Vagu, Gunderu, Budameru. The Godavari, Yerrakalva and Thammileru major river basins are covered 80% of the total area in the district and partially covered with Gunderu, Ramileru Vagu, Kovvada Kalva, Munneru and Minor Drainages in Krishna Delta Joining Sea in Krishna District basins.

The catchment area of each river basin is delineated by using master plan records and updated with survey of India toposheets (1:50K). The Yerrakalva river basin and Godavari river basin catchment areas are 2,372.40 Sq.km and 1,319.62 Sq.km in the district. The district having total number of tanks including ponds and minor irrigation tanks 3,578. The hydrological units of Palnadu district shown in Table-19, Drainage system with description of main rivers shown in the Table-20,

Table 19 Hydrological units of Eluru District

S.No	Major Basin	Minor Basin	Catchment Area Sq.km	No of. Tanks
1	Budameru	Budameru	329.86	161
2	Gunderu	Gunderu	679.66	441
3	Godavari	Kovvada Kalva	355.82	32
4		Lower Godavari	963.8	122
5	Minor Drainages in Krishna Delta Joining Sea in Krishna District	Minor Drainages in Krishna Delta Joining Sea in Krishna District	630.85	485
6	Krishna	Munneru	32.24	22
7	Ramileru Vagu	Ramileru	263.2	137
8	Tammileru	Tammileru	1,112.65	633
9	Yerrakalva	Drinages in West Godavari Delta	106.08	107
10		Yerrakalva	1,622.97	916
11		Other Drainages Joining Kolleru Lake	643.35	522
Total			**6,740**	**3,578**

Data source: APSAC, Vijayawada

Table 20 Drainage system with description of main rivers

S.No	Name of the Minor Basin	Area Drained (Sq.Km)	% of Area Drained in the district
1	Yerrakalva	1608.71	23.87
2	Tammileru	1112.54	16.51
3	Lower Godavari	978.73	14.52
4	Gunderu	679.66	10.08
5	Other Drainages Joining Kolleru Lake	638.25	9.47
6	Minor Drainages in Krishna Delta Joining Sea in Krishna District	628.35	9.32
7	Kovvada Kalva	355.80	5.28
8	Budameru	329.97	4.90
9	Ramileru Vagu	263.12	3.90

10	Drinages in West Godavari Delta	113.04	1.68
11	Munneru	32.32	0.48

Data source: APSAC, Vijayawada

As per the WALTA Rules 2004, the sand mining is permitted in the III Order Streams such as Gundlakamma river, Vogeru Vagu, Romperu Vagu, only if the deposition of sand is more than 5,000 Cum. The sand excavated in these areas are only allowed for local use and not for commercial purposes. Therefore, undertaking replenishment studies for the streams of III and below orders are not required. River's lengths of Palnadu district are shown in Table-21 and.Salient features and altitudes origin of rivers shown in the Table-22.

Table 21 River Lengths in Eluru District

S. No	Name of the Major Basin	Name of the Minor Basin	Name of the River	River Length in Km
1	Budameru	Budameru	Budameru River	130.02
2	Godavari	Kovvada Kalva	Kovvada Kalva	18.69
3		Lower Godavari	Godavari	1.86
4			Godavari River	9.81
5			Kalperu Vagu	14.42
6			kinnarasani River	3.83
7			Meyala Vagu	7.58
8			Pamuleru River	10.60
9			Pedda Vagu	22.57
10			Raja Madugu	9.25
11			Ralla Vagu	1.93
12			Uparutgoti Kalva	6.38
13	Ramileru Vagu	Ramileru Vagu	Ramileru Vagu	36.03
14	Tammileru	Tammileru	Tammileru River	90.24
15	Yerrakalva	Drinages in West Godavari Delta	Upputeru River	62.57
16		Gunderu	Gunderu River	47.19
17		Minor Drainages in Krishna Delta Joining Sea in Krishna District	Upputeru River	3.61
18		Yerrakalva	Baineru Vagu	42.35
19			Jalleru Vagu	74.52
20			Sangam Vagu	16.26
21			Yerra Kalava	35.63
Total				**645.35**

Data source: APSAC, Vijayawada

Table 22 Salient Features of Important Rivers in Eluru District

S.No	Name of the River	Place ofOrigin	Altitude at Origin (m)
1	Godavari	Nasikatrayambkam, Maharastra State	1,067
2	Yerrakalva	Khammam district of Telangana State and Eluru district of Andhra Pradesh	375
3	Kovvada Kalva	Kovvada RF and Chintapalle RF, Buttayagudem mandal in Eluru District	652
4	Thammileru	Dammapeta Mandal, Khammam district in Telangana State	423
5	Ramileru Vagu	Annaravupeta RF, Nuzvid mandal in Eluru District	428
6	Gunderu	Bandamcherla RF, Chintalapudi mandal in Eluru District	340

Data source: APSAC, Vijayawada

3.1.2.1. The Godavari River: The Godavari River is India's second longest river after the Ganga River and drains into the third largest basin in India, covering about 10% of India's total geographical area. Its source is in Trimbakeshwar, Nashik, Maharashtra. It flows east for 1,465 kilometres (910 mi), draining the states of Maharashtra (48.6%), Telangana (18.8%), Andhra Pradesh (4.5%), Chhattisgarh (10.9%) and Odisha (5.7%). The river ultimately empties into the Bay of Bengal through an extensive network of distributaries.[6] Measuring up to 312,812 km2 (120,777 sq mi), it forms one of the largest river basins in the Indian subcontinent, with only the Ganga and Indus rivers having a larger drainage basin.[7] In terms of length, catchment area and discharge, the Godavari is the largest in peninsular India, and had been dubbed as the Dakshina Ganga (Southern Ganges).

3.1.2.2. Yerrakalva River: Yerrakaluvaa is a river that forms boundary between Khammam district of Telangana and West Godavari district of Andhra Pradesh. This river and nearby Kolleru lake drain into the Upputeru river before joining the Bay of Bengal near Mogultur in the West Godavari district. Yerrakalva passes near Konguvarigudem village in Jangareddigudem mandal of West Godavari district.

Yerra Kaluva Reservoir was constructed in 1976. The Yerrakalva Reservoir Project consisted of an earthen dam formed across the river. The ayacut proposed to be irrigated by this project is 9,996 ha benefiting 22 villages in Jangareddigudem, Kamavarapukota, Dwaraka Tirumala, Nallajerla and Tadepalligudem mandals. Flood moderation is provided for safeguarding

about 8,094 ha of fertile lands between Anantapalli and Nandamuru Aqueduct.

3.1.2.3. Budameru River: Budameru River in Krishna district which originates in the hills surrounding Mylavaram and empties itself into Kolleru Lake. Budameru is also known as The Sorrow of Vijayawada. In order to control the floods, the river was dammed at Velagaleru village, and a diversion channel named, Budameru Diversion Channel (BDC) was constructed from Velagaleru to join Krishna River upstream of Prakasam Barrage. This is the first water diversion to the main Krishna river from another river basin.

3.1.3 Process of Deposition of Sediments in the Rivers of the District

Sediment transport is a natural process, and many have argued that the point of rivers is to move sediment downstream. However, with land use changes, e.g., deforestation and construction; agricultural practices; and development activities, accelerated erosion rates is ubiquitous. Sediment in the water column reduces transparency and can be deposited downstream and exacerbate flooding. Three principal sources of sediment are the following:

Sediment transport is the movement of organic and inorganic particles by water. In general, the greater the flow, the more sediment that will be conveyed. Water flow can be strong enough to suspend particles in the water column as they move downstream, or simply push them along the bottom of a waterway. Transported sediment may include mineral matter, chemicals and pollutants, and organic material. Another name for sediment transport is sediment load. The total load includes all particles moving as bedload, suspended load, and wash load.

3.1.3.1. Bedload

As the name suggests, this element of sediment movement consists of loose, granular particles at the sediment-water interface (such as a stream bed or tidal flat). Air or water that moves across the bed will being to move grains if the flow velocity is great enough to overcome the force of gravity and any resistance at grain contacts. This is the **threshold velocity**. The details are shown in Figure-21.

The bedload contains two main components:

- the **traction load**, or traction carpet, and
- the **saltation loads**.

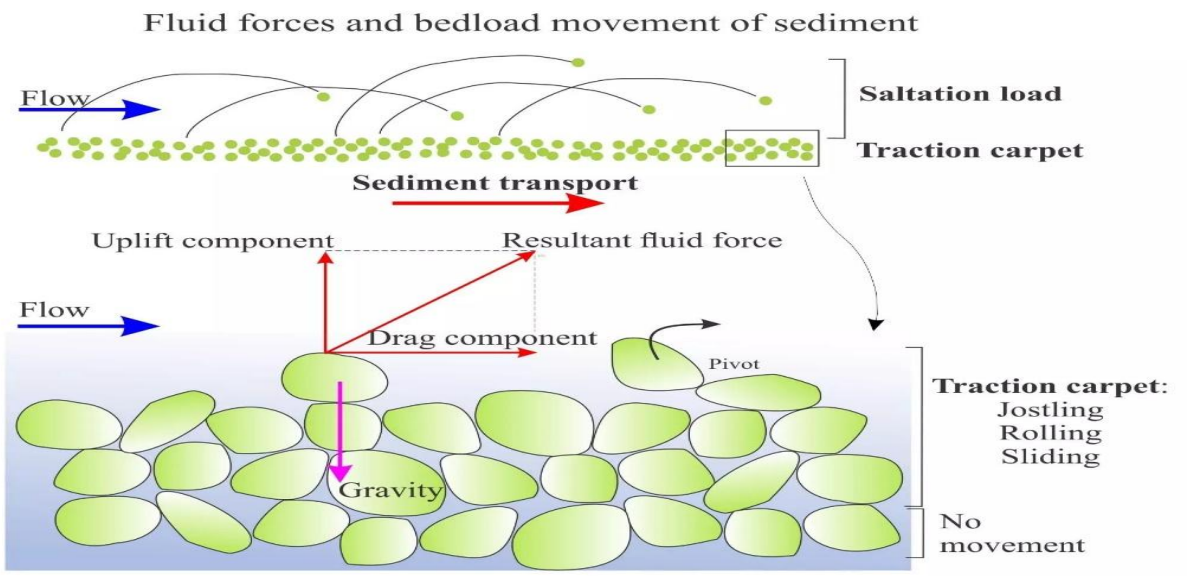


Figure-21: Bedload Movement of Sediment

The various components of force involved in initiation of grain movement are shown above. Here, fluid flowing over a sediment bed produces shear stresses that can be resolved into a component of drag (parallel to the bed) and a lift component normal to the bed. At the threshold velocity when the resultant fluid force on grains is greater than gravity, grains begin to roll, slide and jostle along the bed like a moving carpet – the **traction carpet**.

3.1.3.2. Suspended Load Most natural flows in rivers, shallow marine settings and air are turbulent. Even at low-flow velocities, the speed and trajectories of flow can vary considerably – witness the eddies and boils in seemingly tranquil streams. Very fine particulate sediment (particularly clays) can be kept in suspension for long periods by turbulence; the stresses generated by turbulent flow balance or overcome the gravitational force acting on the particles.

If turbulence decreases significantly, for example when a river empties into a lake, then most particles will gradually settle to the sediment bed. The rate at which a particle settles out of suspension is called the **settling velocity**, where the force of gravity (downwards) exceeds the combined effects of upward-directed **buoyancy forces** acting on a grain and the drag on a particle caused by **fluid (viscous) resistance**. Thus, the rate of settling depends on the size, shape and density of particles, and the viscosity of the fluid. In general, settling through air is much more rapid than through water (Figure-22).

Both bedload and suspension load are important processes in the generation of sedimentary structures. In particular, bedload transport of loose sand is the critical process for growth of bedforms and their internal cross-stratification (crossbedding). The description of **bedforms** (crossbeds) and the flow conditions (**flow regime**) under which they form have been described in other posts.

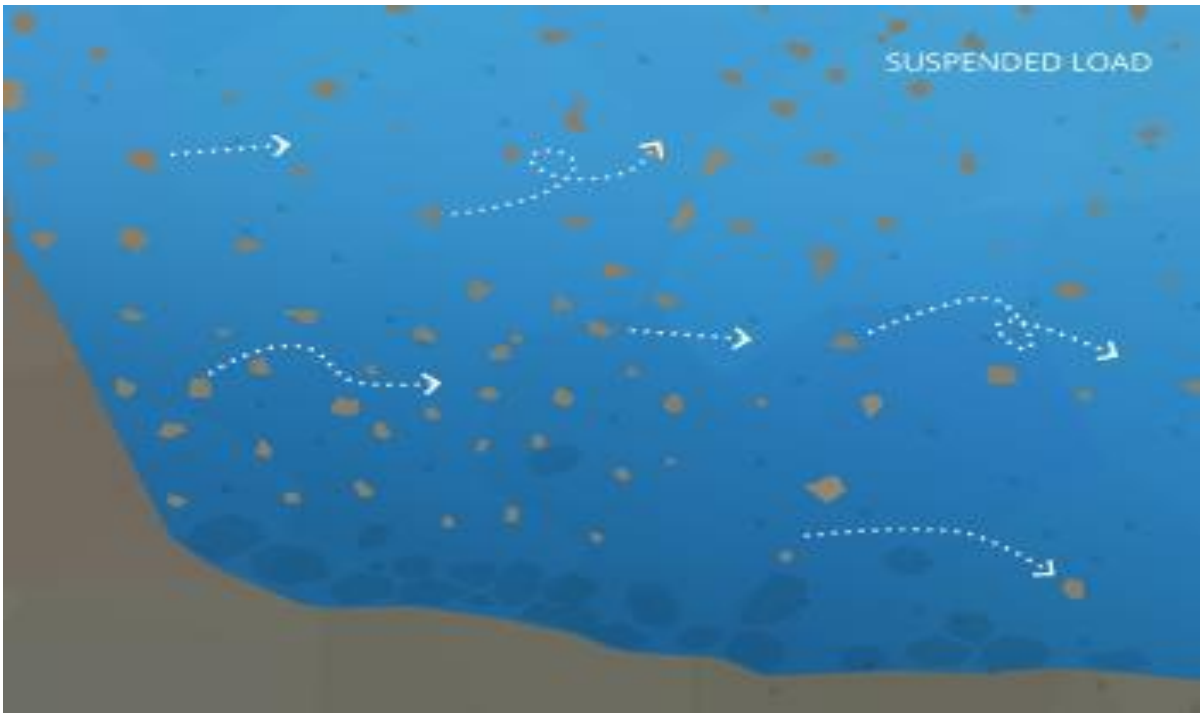


Figure-22: Sediment Load

3.1.3.3. Wash Load

The wash load is the portion of sediment that will remain suspended even when there is no water flow. The wash load is a subset of the suspended load. This load is comprised of the finest suspended sediment (typically less than 0.00195 mm in diameter). The wash load is differentiated from the suspended load because it will not settle to the bottom of a waterway during a low or no flow period. Instead, these particles remain in permanent suspension as they are small enough to bounce off water molecules and stay afloat. However, during flow periods, the wash load and suspended load are indistinguishable. Turbidity in lakes and slow-moving rivers is typically due the wash load 8. When the flow rate increases (increasing the suspended load and overall sediment transport), turbidity also increases. While turbidity cannot be used to estimate sediment transport, it can approximate suspended sediment concentrations at a specific location (Figure-23).

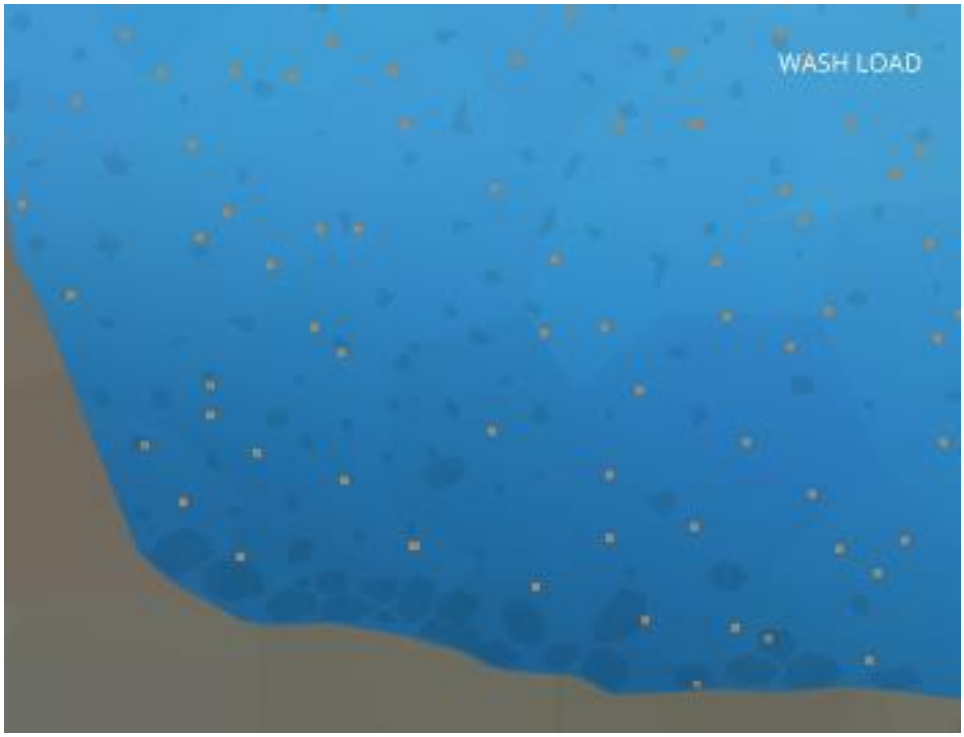


Figure-23: Wash Load

3.1.3.3. Settleable Solids

The suspended particles that fall to the bottom of a water body are called settleable solids. As they are found in riverbeds and streambeds, these settled solids are also known as bedded sediment. The size of settleable solids will vary by water system – in high flow areas, larger, gravel-sized sediment will settle out first. Finer particles, including silt and clay, can be carried all the way out to an estuary or delta (Figure-24).

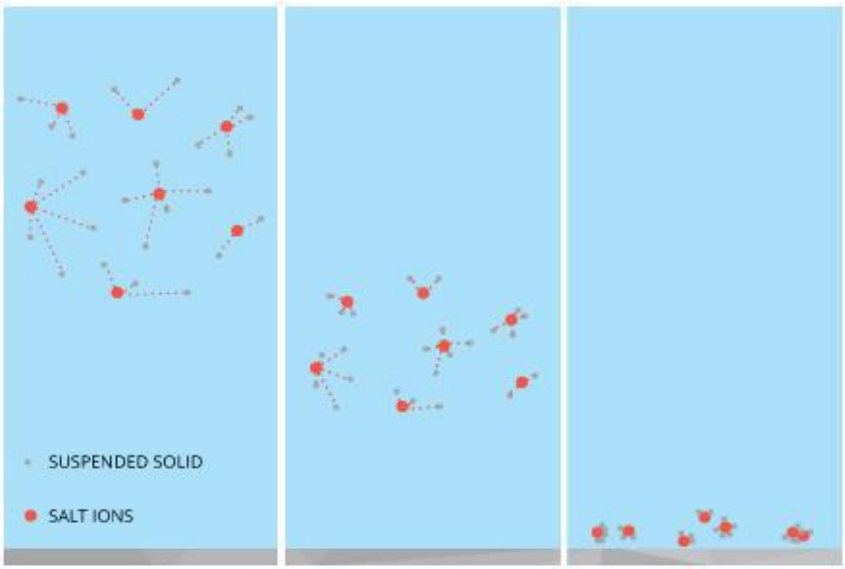


Figure-24: Settleable Solids

3.1.3.4. Sediment Deposition

Sediment is necessary to the development of aquatic ecosystems through nutrient replenishment and the creation of benthic habitat and spawning areas. These benefits occur due to sediment deposition – when suspended particles settle down to the bottom of a body of water. This settling often occurs when water flow slows down or stops and heavy particles can no longer be supported by the bed turbulence. Sediment deposition can be found anywhere in a water system, from high mountain streams, to rivers, lakes, deltas and floodplains. However, it should be noted that while sediment is important for aquatic habitat growth, it can cause environmental issues if the deposition rates are too high, or too low. Sediment transportation and Deposition depends upon various factors like Slope of the Area, Annual Rainfall, Lithology, flow intensity of River, Geomorphology, Soil, Geology and Land use.

In sediment transport a distinction is generally made between fine and coarse sediment, because the transport mechanisms differ. Coarse sediment (grain size >63 μm) tends to be characterised by particles that remain separate and are chemically inert; fine sediments (<63 μm) on the other hand tend to come together as flocculated populations (flocs) and have the tendency to attract organic material and contaminants to their surface. A great deal has been researched and written about the break up and flocculation of these primary particles under turbulence and subsequent settling (e.g., Uncles et al., 2010). These differences imply important variations in the rate of transport and settling characteristics for the same flow conditions for different sediments. The nature of the physical environment also has an important bearing on this, in that fine sediment tend to be found in sheltered environments (shallow, enclosed estuarine systems), while beaches on open coasts are characterised by coarser materials. This reflects the energy of the water in which the particles become suspended and their subsequent fate (Figure-25).

Rates of transport of material are generally expressed in terms of a flux, as kg/s for example, where this figure is generally obtained by considering the product of the flow rate (in m^3/s) and the concentration of material in suspension (kg/m^3). This does not necessarily imply a requirement for the material to be suspended; it is equally possible to express a bed load using the same units, for example, but it does imply that to obtain an estimate of the sediment flux it is necessary to know both the concentration and the flow rate over a given cross section. Both

these quantities can be measured and there are a variety of techniques available to do this, using insitu collection or sampling, in situ optical or acoustic methods, or remote sensing from aircraft or satellites (Uncles and Mitchell, 2017)

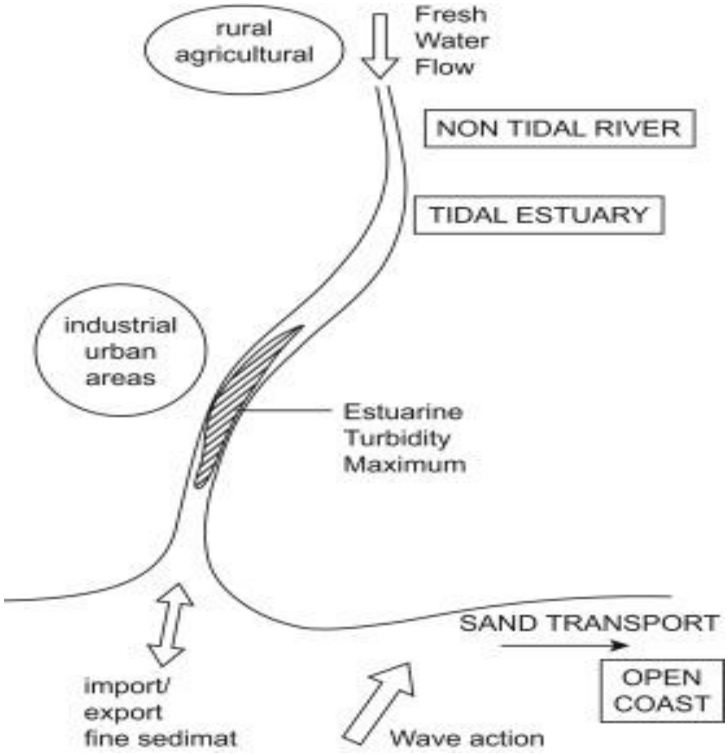


Figure-25: Sediment Deposition Process

Process of Deposition of Sediments in the Rivers of the District Sand is deposited because of the following reasons: (a) Floods: The surface or strip of relatively smooth land adjacent to a river channel constructed (or in the process of being constructed) by the present river in its existing regimen and covered with water when the river overflows its banks at times of high water. It is built of alluvium carried by the river during floods and deposited in the sluggish water beyond the influence of the swiftest current (b) Valley fill: The unconsolidated sediment deposited by any agent so as to fill or partly fill a valley.

3.1.4 Replenishment Study

A replenishment study for riverbed sand is required in order to nullify the adverse impacts arising due to excessive sand extraction. Mining within or near the riverbed has a direct impact on the stream's physical characteristics, such as channel geometry, bedelevation, substratum composition and stability, in-stream roughness of the bed, flow velocity, discharge capacity, sediment transport capacity etc. For sustainable river

sand mining, it is necessary that the mine pits formed as a result of sand excavation are refilled with sand by the natural process of replenishment in a reasonable period so that the area is again available for mining. The rate of gross erosion is dependent upon many physical factors like climatic conditions, the nature of the soil, the slope of the area, topography and land use. The effect of any of these variables may vary greatly from one geographic location to another, and the relative importance of controlling factors often varies within a given land resource area (Dendy, 1976).

There is no denial of the fact that bed load changes from hour to hour, day to day, and year to year; estimating annual bed load rates is a dynamic process involving careful examination. Therefore, proper care has been taken before applying the empirical model to calculate the sediment yield from the watershed.

The estimation of sand replenishment is based on empirical and analytical approaches. There are many sediment transport equations as well as models which are suitable for use in the prediction of the replenishment rate of rivers/watersheds. The sedimentation models include SWAT, HEC-HMS etc. These models are developed based on the fundamental hydrological and sedimentological processes. They may provide detailed temporal and spatial simulation but usually require extensive data input. Hourly/daily input values of meteorological and radiation variables are required for continuous simulations. Some of the empirical equations for estimating sediment transport are as follows.

Annual Replenishment Rate for sand for Major Sand Resource Area is determined using emperial mathematical expression Dendy Bolton Equation and reproduced below:

- Einstein (1950)
- Laursen (1958)
- Bagnold (1966)
- Engelund-Hansen equation (1967)
- Yang equations (1973)
- Dendy- Bolton equation (1976)
- Modified Universal Soil Loss Equation (MUSLE) developed by Williams and Berndt (1977)
- Van Rijn (1984)
- Zanke (1987)

To estimate the transport capacity or the sediment load being conveyedby a waterstream, one of the many transport equations that are available in

the literature is frequentlyused. Einstein (1950) introduced statistical methods to represent the turbulent behaviour ofthe flow. Bagnold (1966) introduced an energy concept and related the sediment transportrate to work done by the fluid. Engelund and Hansen (1967) presented a simpleand reliableformula for the total load transport in rivers. The Yang equation makes use of the total bedhydraulic radius, and studies show that it is good for estimating the sediment transport in thechannel for the condition of dunes on the bed. MUSLE includes only one type of sediment yield (sheet and rill Erosion). Van Rijn (1984) solved the equations ofmotions of anindividual bed-load particle and computed the saltation characteristics and the particlevelocity as a function of the flow conditions and the particle diameter for plane bedconditions. The equations of Zanke and Van Rijn seem to be only moderately satisfactory inestimating the sediment transport in the channel for the condition of dunes on the bed.However, it appears that no single equation could provide reliable estimates of a total load ofsediment transport for all ofthe bed forms that could occur sequentially or randomly inalluvial channels or natural water courses. The comparison of the equations for estimatingsediment rate is given below Table 23 –

Table 23: Types of Sediment Transport Equation

Sl.No.	**Sediment Transport Equation**	**Remarks**
1	Einstein (1950)	Bed load function was determined for many but not all types of stream channels
2	Laursen (1958)	Laursen equation outperforms other transport equations in the silt range
3	Bagnold (1966)	Bagnold related the sediment transport rate to work done by the fluid
4	Engelund-Hansen equation (1967)	The original Engelund-Hansen relation (OEH) is based on a single characteristic grain size, which limits its applicability in sand-bed rivers with a wide GSD
5	Yang equations (1973)	It makes use of a total bed hydraulic radius

Sl.No.	Sediment Transport Equation	Remarks
6	Dendy- Bolton equation (1976)	It uses both drainage area and means annual runoff for estimation of sediment yield. It calculates all types of sediment yield like sheet and rill erosion, gully erosion, channel bed and bank erosion and mass movement
7	Modified Universal Soil Loss Equation (MUSLE) developed by Williams and Berndt (1977)	MUSLE includes only one type of sediment yield (sheet and rill Erosion)
8	Van Rijn (1984)	Calculated equations of motions of an individual bed-load particle for plane bed conditions
9	Zanke (1987)	Zanke was found to be moderately satisfactory for the condition of the dunes on the bed.

In this study, the rate of gross silt production in the watershed and the ability of thestream system to transport the eroded material in a river have been carried out by the Dendy-Bolton equation. Dendy-Bolton formula is often used to calculate the sedimentation yield asit uses both drainage area and mean annual runoff as key parameters to give a yield value.Also, Dendy-Bolton equation calculates all types of sediment yield like sheet and rillerosion, gully erosion, channel bed and bank erosion and mass movement.

The drainage area of Godavari River in Eluru district is situated in upstream of the SAC Barrage. For calculation of sediment yield, the total realization of the SAC Barrage for water year 2022-23 (June 2022 to May 2023) of 6,250.56 TMC is taken as run-off.

Rest of the rivers in Eluru district are of 3rd Order streams. The Sand extraction in Eluru District shall be as per Rule 23(1)(a) of AP Water Land and Tree Rules, 2004 where the transportation of sand shall be by means of bullock carts/ Tractors for the local use.

In case, if the sand deposition exceeds 5,000 Cu.M in a part of the stretch, then manual mining shall be permitted after obtaining Statutory Clearances. the District Collector shall put in place proper administrative

mechanism for enforcement of WALTA regulations in extraction and transportation of sand in I, II and III order streams.

Sand extraction is permitted for commercial usage in sand reaches of III Order streams having sand deposition of more than 5,000 Cum, after obtaining AMP, EC, CFE and CFO (G.O. Ms. No. 2, PRandRD Dept, dated 06.01.2022).

Annual Replenishment Rate for sand for Major Sand Resource Area is determined using emperial mathematical expression Dendy Bolton Equation and the data obtained from Water Resources Dept., GoAP was used and reproduced below:

For Average Annual Run-off less than 2"

S = 1280 x Q0.46 [1.43 – 0.26 log(A)]-------- FORMULA (A)

For Average Annual Run-off more than 2"

S = 1965 x ($e^{-0.055 \times Q}$) [1.43 – 0.26 log(A)]-------- FORMULA (B)

Q = Mean Annual Run-off in mm

A = Net drainage Area in Sq. km

S = Sediment yield (tons/Sq. km/yr)

The sedimentation yield for Godavari River in Palnadu District is arrived based on the above Dendy Bolton Equation or Formula (B). The Sedimentation yield for Krishna River in Eluru District is showin Table-24.

Table 24 Sedimentation yield from Godavari River (upstream) in Eluru District

Name of the River	Area Drained (sq. km)	Mean Annual Run-off (in mm)	Rate of Annual Deposition in the River (tons / sq. km /year)	Annual Deposition (tonne)
Godavari	1,319.62	367.46	225.62	2,97,738*

Data Source: District Mines and Geology Officer, Eluru District, Andhra Pradesh

***Note**: The sedimentation yield was calculated manually by APSAC and the value is **3,28,494 Tones/ year.** The details are provided as an Annexure at page number 1171-118.

In this report, the sediment yield was calculated using the standard records of Department of Water Resources. To ensure systematic and scientific studies, Department of Mines and Geology is in the process of selection of NABET Accredited agency for conducting detailed and regular replenishment studies for potential sand bearing areas.

3.1.5 Details of Sand Mining Leases:

The river Godavari is the main source of sand in the district flowing in the eastern side of the Eluru district through following mandals.

Name of the river	List of Mandals
The River Godavari	Kukunuru
	Velairpadu
	Polavaram

Data Source: District Mines and Geology Officer, Eluru District, Andhra Pradesh

The Proposed potential Sand Mining Leasesin Eluru district shown in Table-25.

Table 25 The detail of Potential Sand Mining Leases

S No	New District Name	Name of the Sand Reach	Location and Extent	Qty. (in Cum)	Qty. (in Tons)	Geo Co-ordinates	
1	Eluru	Ibrahimpeta-Ganapavaram	4.93 Ha Ibrahimpeta-Ganapavaram (V) Kukunoor (M)	49389	74084	17° 38' 47.30'' N	80° 59' 14.64'' E
						17° 38' 50.58'' N	80° 59' 14.54'' E
						17° 38' 51.09'' N	80° 59' 31.05'' E
						17° 38' 47.74'' N	80° 59' 31.04'' E
2	Eluru	Dacharam	4.16 Ha Dacharam (V) Kukunoor (M)	41685	62528	17° 33' 54.04'' N	81° 11' 45.79'' E
						17° 33' 57.40'' N	81° 11' 46.55'' E
						17° 33' 56.08'' N	81° 11' 59.93'' E
						17° 33' 52.74'' N	81° 11' 59.22'' E
3	Eluru	Ganapavaram	4.97 Ha, Ganapavaram (V), Kukunoor (M)	47905	71858	17° 38' 52.57'' N	80° 58' 48.22'' E
						17° 38' 52.13'' N	80° 58' 41.77'' E
						17° 38' 44.03'' N	80° 58' 41.32'' E
						17° 38' 44.52'' N	80° 58' 48.18'' E
4	Eluru	Ibrahimpeta	4.865 Ha, Ibrahimpeta (V), Kukunoor (M)	42853	64280	17° 38' 50.44'' N	80° 59' 51.62'' E
						17° 38' 49.44'' N	80° 59' 58.38'' E
						17° 38' 41.69'' N	80° 59' 56.90'' E
						17° 38' 42.55'' N	80° 59' 50.40'' E
5	Eluru	Ramachandrapuram-1	4.810 Ha Ramachandrapuram (V), Kukunoor (M)	48132	72198	17° 33' 57.41'' N	81° 12' 55.70'' E
						17° 33' 57.39'' N	81° 13' 01.40'' E
						17° 33' 48.09'' N	81° 13' 00.71'' E
						17° 33' 48.15'' N	81° 12' 54.94'' E
6	Eluru	Dacharam-II	4.94 Ha Dacharam (V), Kukunoor (M)	49408	74112	17° 33' 59.78'' N	81° 12' 20.50'' E
						17° 34' 00.04'' N	81° 12' 11.71'' E
						17° 33' 53.96'' N	81° 12' 12.40'' E
						17° 33' 53.33'' N	81° 12' 21.14'' E

S No	New District Name	Name of the Sand Reach	Location and Extent	Qty. (in Cum)	Qty. (in Tons)	Geo Co-ordinates	
7	Eluru	Rudramkota-I	4.96 Ha Rudramkota (V), Velairpadu (M)	49600	74400	17° 33' 40.71'' N	81° 15' 23.83'' E
						17° 33' 43.57'' N	81° 15' 27.96'' E
						17° 33' 51.61'' N	81° 15' 20.16'' E
						17° 33' 48.76'' N	81° 15' 16.21'' E
8	Eluru	Rudramkota-II	4.90 Ha Rudramkota (V), Velairpadu (M)	49000	73500	17° 33' 26.89'' N	81° 15' 36.43'' E
						17° 33' 28.37'' N	81° 15' 41.23'' E
						17° 33' 18.95'' N	81° 15' 48.15'' E
						17° 33' 16.88'' N	81° 15' 44.22'' E
9	Eluru	Vinjaram	4.91 Ha Vinjaram (V), Kukunorr (M)	49100	73650	17° 36' 37.06'' N	81° 06' 51.98'' E
						17° 36' 38.87'' N	81° 06' 57.30'' E
						17° 36' 48.35'' N	81° 06' 56.19'' E
						17° 36' 46.55'' N	81° 06' 50.63'' E

Data Source: District Mines and GeologyOfficer, Eluru District, Andhra Pradesh

Probable Sand Mining reaches in Palnadu district shown in Table-26. Name of the sand bearing index are given from North to South direction. The Probable Sand bearing areas were identified through field survey with the help of hand held GPS (Global Positional System) and the help of existing literature.

Table 26: Probable Sand bearing in the Eluru District

S.No	Name of the River	Sand Bearing Area	Central Coordinates		Area in Ha.
			Latitude	Longitude	
1	Godavari River	A	17° 37' 21.768" N	80° 51' 9.329" E	20.603058
2	Godavari River	B	17° 37' 47.820" N	80° 51' 42.854" E	56.704228
3	Godavari River	C	17° 37' 57.766" N	80° 56' 39.537" E	59.360638
4	Godavari River	D	17° 38' 40.931" N	80° 58' 34.400" E	77.758057
5	Godavari River	E	17° 38' 48.439" N	80° 59' 20.609" E	74.539301
6	Godavari River	F	17° 38' 35.762" N	81° 0' 4.311" E	85.248362
7	Godavari River	G	17° 37' 37.383" N	81° 0' 17.475" E	18.559908
8	Godavari River	H	17° 36' 45.564" N	81° 6' 41.789" E	133.89148
9	Godavari River	I	17° 35' 36.714" N	81° 7' 35.201" E	20.149668
10	Godavari River	J	17° 33' 58.075" N	81° 11' 40.546" E	68.064947
11	Godavari River	K	17° 33' 58.564" N	81° 12' 19.496" E	36.824604
12	Godavari River	L	17° 33' 53.616" N	81° 12' 46.505" E	40.463438
13	Godavari River	M	17° 34' 2.835" N	81° 15' 28.304" E	13.916169
14	Godavari River	N	17° 33' 37.507" N	81° 15' 28.511" E	28.169217
15	Godavari River	O	17° 33' 18.352" N	81° 15' 52.349" E	70.184955
16	Godavari River	P	17° 32' 43.644" N	81° 16' 31.582" E	47.857561
17	Godavari River	Q	17° 31' 0.401" N	81° 17' 17.005" E	59.721036
18	Godavari River	R	17° 29' 49.285" N	81° 21' 40.879" E	20.192991
19	Godavari River	S	17° 28' 58.327" N	81° 23' 1.026" E	14.967486
20	Godavari River	T	17° 26' 10.895" N	81° 33' 47.818" E	14.214062
21	Godavari River	U	17° 24' 16.785" N	81° 36' 37.768" E	21.365008
22	Godavari River	V	17° 22' 43.357" N	81° 36' 3.035" E	35.164186
23	Godavari River	W	17° 20' 48.975" N	81° 36' 27.245" E	63.847285
24	Godavari River	X	17° 17' 59.157" N	81° 40' 1.502" E	115.946492

Data Source: District Mines and Geology Officer, Eluru District, Andhra Pradesh

3.1.6 Details of De-Siltation Location: (Lakes/Ponds/Dams etc.)

The details of potential of de-siltation location are in Eluru Distict shown in Table-27.

Table 27 List of Potential De-Siltation Location: (Lakes/Ponds/Dams etc.) (Existing and proposed)

S. No.	New District Name	Name of the sand reach	Ramp Point	Society's Name
1	Eluru	Gutala-1, Polavaram Mandal	Km.33.400 to 33.600 of AGRB	Sand Quarry Boatsmen and Fishermen Co-Op Society Ltd.
2	Eluru	Pattiseema Polavaram Mandal	Km.34.700 to 34.800 of AGRB	1) Sri Veerabhadra Boatsmen and Sand Quarry Workers Co-Operative Society 2) Sri Visweswara Boatsman and Sand Workers Co-Operative Society Ltd.,

Data Source: District Mines and Geology Officer, Eluru District, Andhra Pradesh

3.1.7 Details of Patta Lands in the District:

The list of Patta Lands in the Eluru distict is shown in Table-28.

Table 28 Details of Patta Lands.

Owner	Sy. No.	Area (Ha)	District	Tehsil	Village	Total Reserve (MT)	Total Mineral to be mined (MT)	Existing/ Proposed
Nil								

Data Source: District Mines and Geology Officer, Eluru District, Andhra Pradesh

3.1.8 Details of M-Sand Plants in the District:

The details of Manufacturing Sand in Eluru district shaon in Table-29.

Table 29 Shown Details of Details of M-Sand Plants

Plant Name	Owner	District	Tehsil	Village	Geo-location	Quantity Tonnes/Annum
NIL There are no existing M - Sand units under this Eluru office jurisdiction						

Data Source: District Mines and GeologyOfficer, Eluru District, Andhra Pradesh

3.1.9 Details of Cluster of Sand Mining Leases

The area of Cluster of Mining Leases in Eluru jurisdiction is shown in Table-30.

Table 30 Details Cluster of Mining Leases in Eluru District

Sl.No	Name of the Cluster	Location (Latitude and Logitude)	Extent (in Ha)	Total No. of Mining Leases in the Cluster	No.of Leases working	Extent of the working leases (in Ha)
NIL						

Data Source: District Mines and Geology Officer, Eluru District, Andhra Pradesh

3.1.10 Details of Contiguous Clusters

The area of Contiguous Cluster of Sand Reaches in Eluru jurisdiction is shown in Table-31.

Table 31 Details of Contiguous Cluster of Sand Reaches in Eluru District

Sl.No	Name of the Cluster	Location (Latitude and Logitude)	Extent (in Ha)	Total No. of Mining Leases in the Cluster	No.of Leases working	Extent of the working leases (in Ha)
NIL						

Data Source: District Mines and Geology Officer, Eluru District, Andhra Pradesh

3.1.11 Sand Reaches Details in Palnadu District

The Department of Mines and Geology has identified sand reach points in the Eluru district, with many additional points also identified, as shown in Figure-26.

Probable sand-bearing areas were identified through field surveys with the assistance of handheld GPS devices and existing literature, and these areas within the Eluru District are depicted in Figure-27.

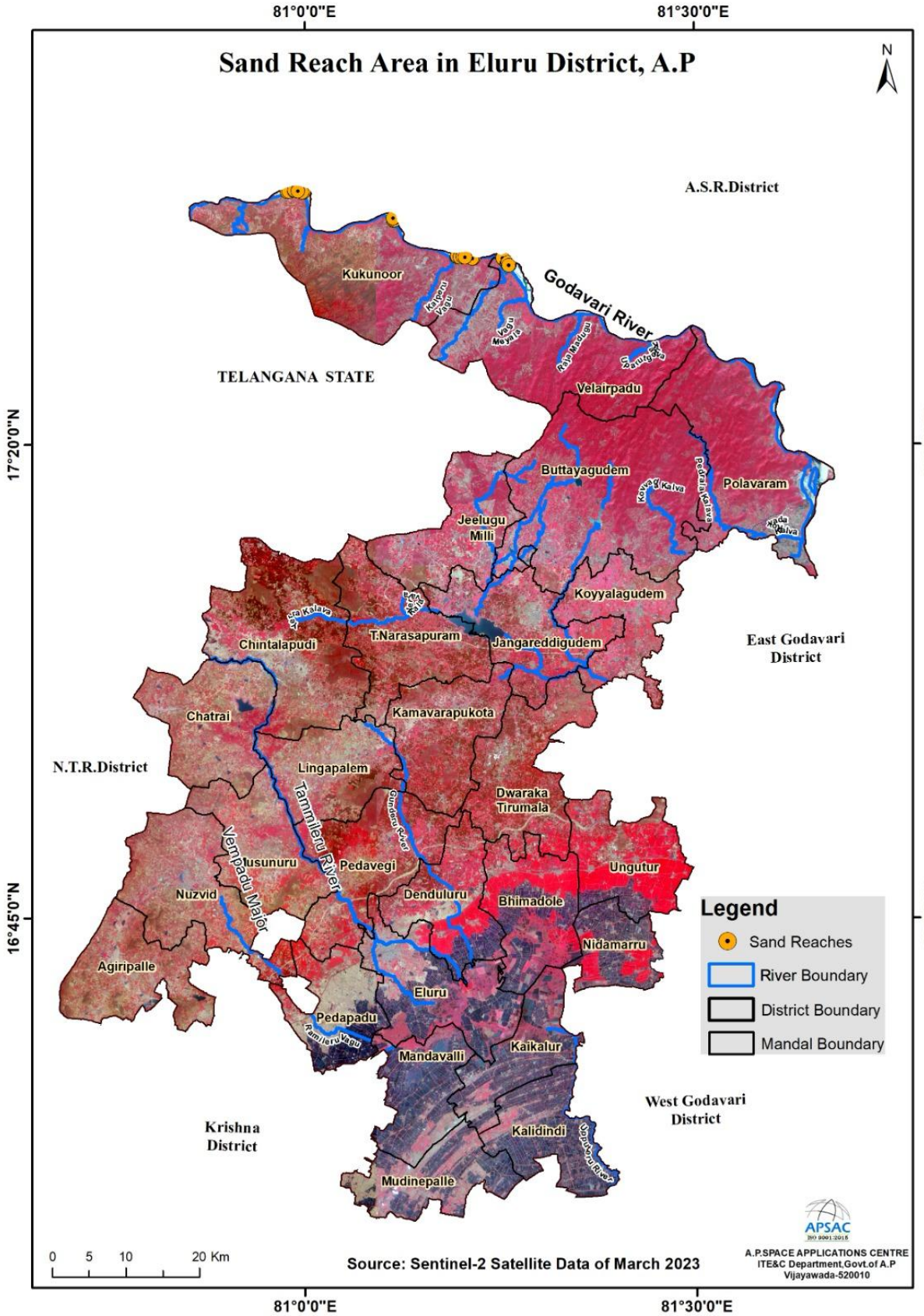


Figure-26: Satellite View of Godavari River sand reach map in Eluru District

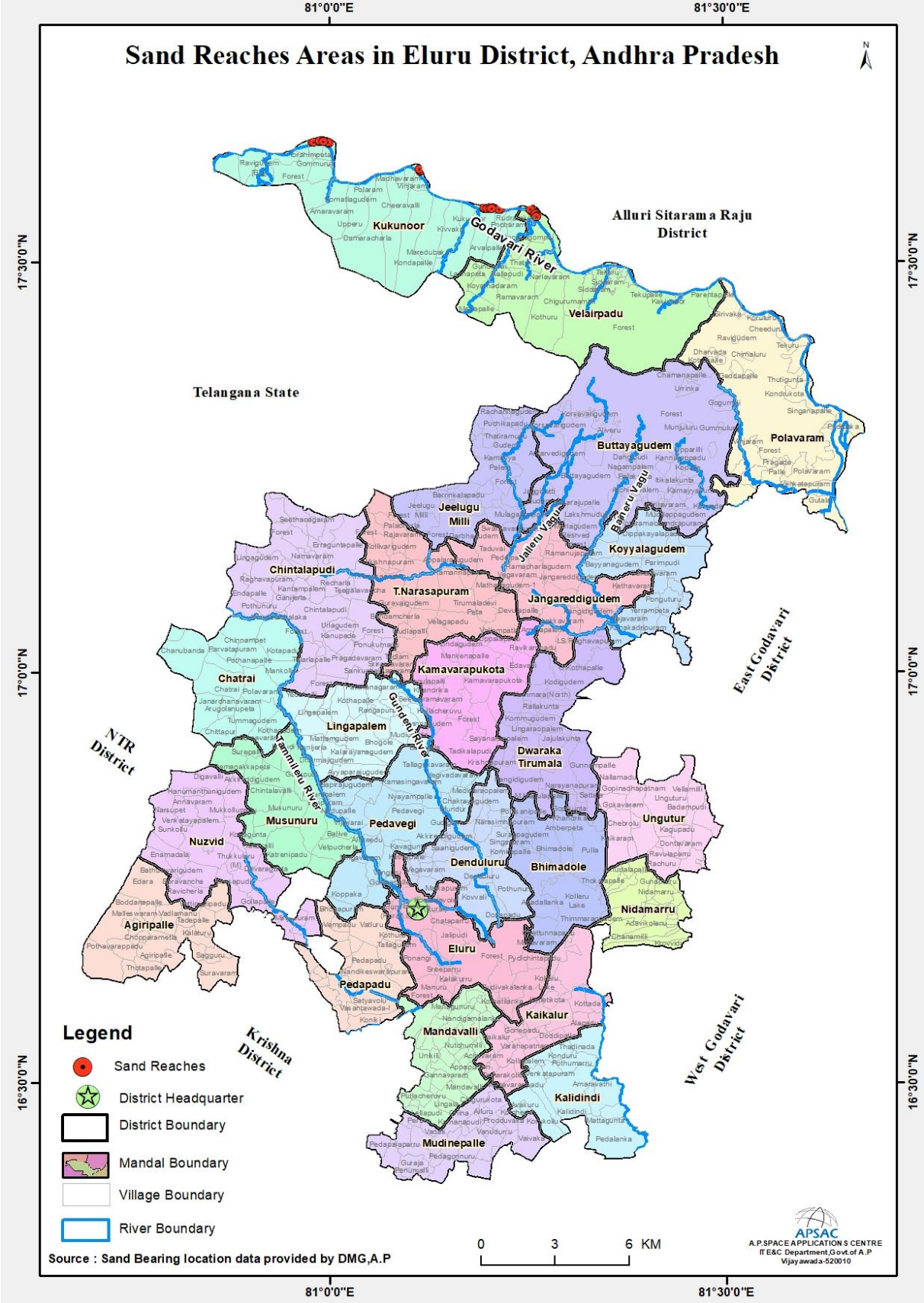


Figure-27: Administrative map of sand reachs in Eluru District

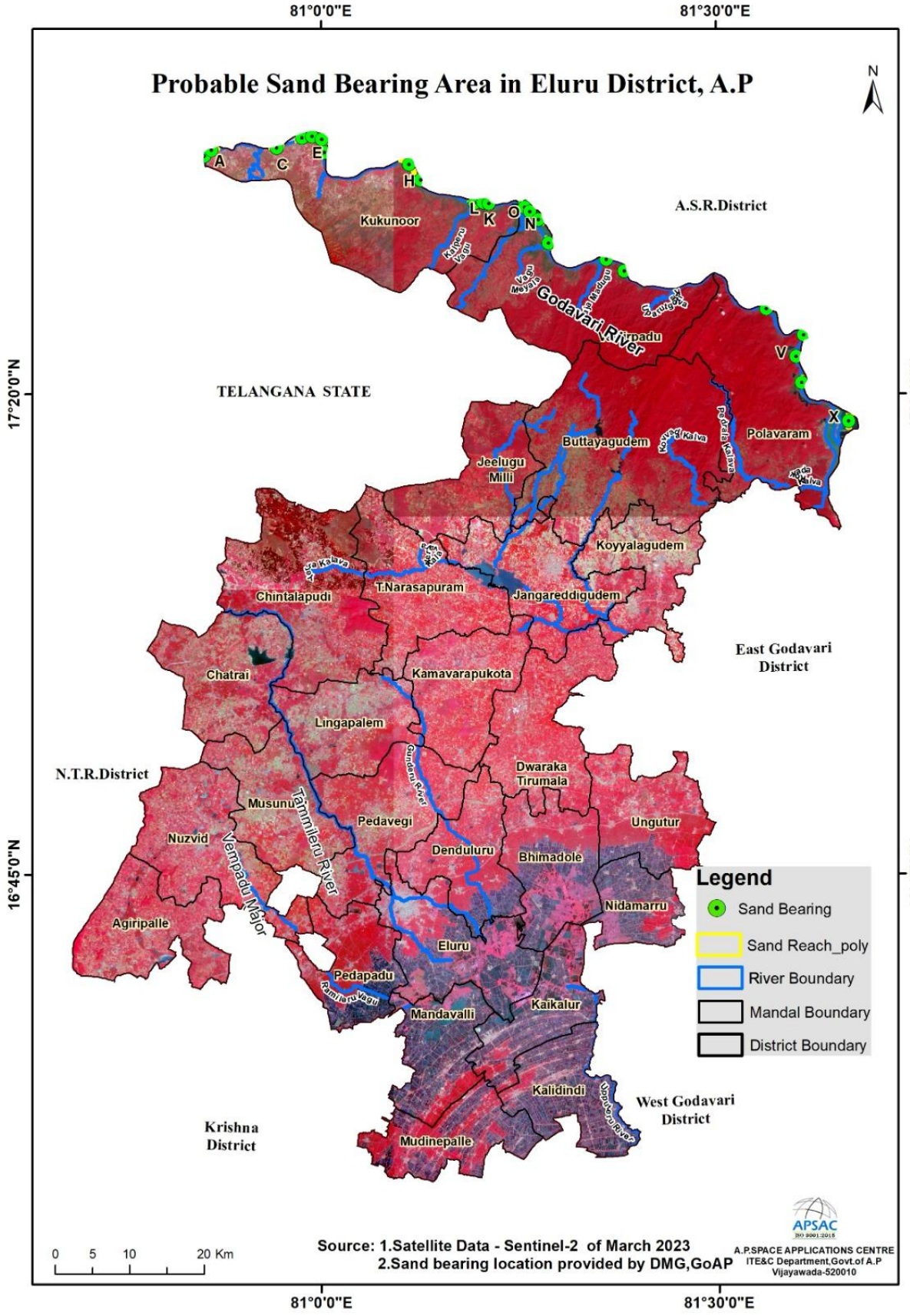


Figure-28: Probable Sand bearing areas in the Eluru District

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ANNEXURE

As the average annual run-off more than 2" in the Eluru District, the sedimentation yield for Godavari River in Eluru District, APSAC manually arrived the value based on the Dendy Bolton Equation or Formula and is given below.

$$S = 1965 \times (e^{-0.055 \times Q}) [1.43 - 0.26 \log (A)]$$

Q = Mean Annual Run-off in mm
A = Net drainage Area in Sq. km
S = Sediment yield (tons/Sq. km/yr)

Sedimentation yield for the Godavari River in Eluru District

Name of the River	Area Drained (sq. km)	Mean Annual Run-off (in mm)
Godavari	1,319.62	367.46

Data Source: District Mines and Geology Officer, Eluru District, Andhra Pradesh and APSAC, Vijayawada

The given drained area value converted from Sq.Km to Sq.mile and the mean annual run-off converted from mm to inches for the calculations.

$$S = 1965 \times (e^{-0.055 \times Q}) [1.43 - 0.26 \log(A)]$$ **Tones/sq.mile/year**

Drainage Area (A) = 1,319.62sq. Km (1 Sq.km = 0.386 Sq.mile)
= 1,319.62 x 0.386
A = 509.373 Sq.mile ----------(1)

Mean Annual Run-off (Q) = 367.46 mm (1 mm = 0.0393 inches)
= 367.46x 0.0393
Q = 14.44118 inches ----------(2)

e is Euler's number and the value is =2.718 ----------(3)

$$S = 1965 \times (e^{-0.055 \times Q}) [1.43 - 0.26 \log (A)]$$ **Tones/sq.mile/year**

$S = 1965 \times (2.718^{-0.055 \times 14.44118}) [1.43 - 0.26 \log (509.373)]$

Log 50 of 9 = 0.7067
0.3 = 3
As per base, the value = 2.0000
_____(+)
Log 509.373 = 2.7070 ----------(4)

$= 1965 \times (2.718^{-0.055 \times 14.44118}) [1.43 - 0.26 \times 2.7070]$

$= 1965 \times (2.718^{-0.79426}) [1.43 - 0.70383]$

$= 1965 \times (2.718^{-0.79426}) [0.72617]$

The value of $2.718^{-0.79426}$
$1/2.718^{0.79426}$ = 0.451951 ----------(5)

$= 1965 \times 0.451951 \times 0.72617$

$= 644.8997$

$S = 644.8997$ **Tones/sq.mile/year** ----------(6)

For total district Sedimentation Yield =

Per Sq.mile Sedimentation Yield (6) x Total Drainage Area (1)

644.8997 x 509.373 = 3,28,494

As the Sedimentation yield calculated manually,

The sedimentation in the total River

in the Eluru District = **3,28,494 Tones/ year**