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केंद्रीय भूमि जल बोर्ड

GOVERNMENT OF INDIA
MINISTRY OF JAL SHAKTI
DEPARTMENT OF WATER RESOURCES, RIVER DEVELOPMENT AND GANGA REJUVENATION
CENTRAL GROUND WATER BOARD

REPORT ON
AQUIFER MAPPING FOR SUSTAINABLE MANAGEMENT OF GROUND WATER RESOURCES IN KAKINADA DISTRICT, ANDHRA PRADESH

CENTRAL GROUND WATER BOARD
AP SUO, VISAKHAPATNAM
NOVEMBER, 2023

REPORT ON
AQUIFER MAPPING FOR SUSTAINABLE MANAGEMENT OF GROUND WATER RESOURCES KAKINADA DISTRICT, ANDHRA PRADESH
(AAP-2023-2024)

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REPORT ON
AQUIFER MAPPING FOR SUSTAINABLE MANAGEMENT OF GROUND WATER RESOURCES IN KAKINADA DISTRICT, ANDHRA PRADESH

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REPORT ON
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AT A GLANCE

S. No.	Item		Particulars
1	District	:	Kakinada
2	Mandals	:	21
3	Revenue villages	:	412
4	Geographical area	:	3020 km^2
5	Geographic Extent	:	North Latitude 17^o 15' and 19^o 15' East Longitude 83^o 0' to 83^o 45'
6	Population (2011 Census)	:	~20.92 lakhs The density of population is 693 persons/ km^2
7	Rainfall (Normal)	:	839.7 mm (Gollaprolu) to 1412.6 mm (Tallarevu) (avg: 1140 mm) (The South west monsoon contributes 65% of the rainfall and northwest monsoon and others contributes 35% of the rainfall in the district.
8	Geomorphology	:	Pediplains, Structural hills, Denudational hills, pediment, Coastal & alluvial, deltaic plains are the major geomorphological units in the district.
9	Major Rivers	:	Godavari and Pushkara and its tributaries.
10	Forests	:	11% (327 Km^2)
11	Soils	:	Red soils, sandy loams and sandy clay constitute 96% of the total area. The soils in the district are predominantly loamy with medium fertility
12	Land Utilization (Ha)	:	Net area sown: 155143 (51%), Barren & uncultivable land: 14069 (5%); Land put to non-agricultural use: 60595 (20%).
13	Total cropped area (Ha)	:	245345
14	Irrigation	:	The district is mainly irrigated by both surface and ground water. Out of total Net area sown of 155143 ha, the net area irrigated is 116477 ha (75%). Out of 116477 ha, the Irrigation through surface water sources is 89911 ha (77.19%). Out of the 89911 ha irrigated by surface water, Canals irrigate 77057 ha (85%), Tanks irrigate 7440 ha (8.2%), irrigation through LIS is 5289 ha (<6%) and irrigation by other sources is 125 ha (0.13%). Irrigation through Ground Water is 26566 ha (22.8%).

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24	Management Strategies	:	○ Scope for GW extraction: Identified feasibility of construction of 4433 bore wells in 215 villages in all 13 mandals, for bringing an additional area of 7478 ha in under GW irrigation. ○ Recommended for construction of 177 additional Percolation Tanks. ○ Existing ARS like percolation tanks and check dams can be de-silted through convergence of schemes ○ Desiltation and cascading of existing MI tanks. This can result in increased ayacut, sustainability of bore wells. ○ Roof top rain water harvesting in Government buildings (new and existing) as per the existing post monsoon depth to water levels, provisions of AP WALTA. ○ Participatory groundwater management (PGWM) approach. ○ In urban and rural area, the sewerage line should be constructed to arrest leaching of nitrate.

ABBREVATION:

2D	:	2 Dimensional
3D	:	3 Dimensional
ARS	:	Artificial Recharge Structures
Avg	:	Average
BW	:	Bore Well
CD	:	Check dam
CGWB	:	Central ground water board
Cr	:	Crore
DTW	:	Depth to water
DW	:	Dug well
EC	:	Electrical conductivity
EL	:	East Longitude
F	:	Fluoride
FP	:	Farm Pond
GEC	:	Ground Water Estimation committee
GW	:	Ground Water
Ha	:	Hector
Ha.m	:	Hector meter
ID	:	Irrigated dry
IMD	:	Indian Meteorological Department
Km2	:	square kilometre
LPS	:	Litres per second
M	:	meter
M^3	:	Cubic meter
max	:	Maximum
mbgl	:	Mitres below ground level
MCM	:	Million cubic meter
Mg/L	:	Milligram per litre
MI	:	Micro irrigation
min	:	Minimum
MPT	:	Mini percolation tank
NL	:	North Latitude
NO_3	:	Nitrate
OE	:	Over Exploited
PGWM	:	Participatory ground water management
PT	:	Percolation tank
SGWD	:	State Ground Water Department
S	:	Storativity
T	:	Transmissivity

EXECUTIVE SUMMARY

The Kakinada district, Andhra Pradesh having geographical area of 3020 sq kms, lies between 16.672423 to 17.534855 of the Northern Latitude and 81.903124 to 82.604773 of the Eastern Longitude. The district is reorganized on 4th April, 2022 from the erstwhile East Godavari district with Headquarters at Kakinada. There are 412 villages with a population of ~20.92 lakhs (2011 census). The average normal annual rainfall is 1140 mm.

The district can be divided into two distinct natural physical divisions i.e., plain and hilly regions. The hilly region is mostly covered with dense to sparse wooded forests with elevation ranging from 130 to 730 m amsl spreading in Prathipadu, Sankhavaram and Routhulapudi mandals. The plain portion of the district is a well cultivated tract with an elevation varying from 0 -120 m amsl. Pediplains, Structural hills, Denudational hills, pediment, Coastal & alluvial, deltaic plains are the major geomorphological units in the district. The district is drained by the rivers of Godavari and Pushkara. The Yeleru, Thandava and Pampa Rivers also flow in the district.

The total cropped area in the district is 245345 ha, out of which net area sown is 155143 ha and area irrigated more than once is 73213 ha. The district is mainly irrigated by both surface and ground water. Out of total Net area sown of 155143 ha, the net area irrigated is 116477 ha (75%). Out of 116477 ha, the Irrigation through surface water sources is 89911 ha (77.19%). Out of the 89911 ha irrigated by surface water, Canals irrigate 77057 ha (85%), Tanks irrigate 7440 ha (8.2%), irrigation through LIS is 5289 ha (<6%) and irrigation by other sources is 125 ha (0.13%). Out of 116477 ha, the Irrigation through Ground Water is 26566 ha (22.8%). The major/Medium irrigation projects in the district are Central Godavari Delta, Chagalnad LIS, Eastern Godavari Delta, ISRMC Polavaram, Pushkara and Yeleru projects. A total of 994 artificial recharge structures (40 Percolation Tanks, 28 Mini Percolation Tanks, 854 Check Dams and 72 Check Walls and Others) are constructed under IWMP and MGNREGS.

The district is underlain by Eastern Ghat Mobile Belt of Precambrian age, Basalts of Mesozoic age, Sandstones of Tertiary age and Alluvium of Recent age. The Eastern Ghat Mobile Belt of Precambrian age include Khondalites and Charnockites. The Mesozoic basalts, Tertiary sandstones and recent alluvium overlie the Precambrian.

The Central Ground Water Board had drilled 15 no's bore wells, carried out 65 Vertical Electrical Soundings (VES) so far. The ground water regime is being monitored form 54 GWM stations and ground water quality data from 54 GW quality monitoring stations. The density of the data calculated as, 1 data points per 56 sq kms for understanding the spatial and temporal variation in ground water regime and 1 data point per 56 sq.kms for understanding the spatial and temporal variation in ground water quality.

The Depth to Water Levels (DTWL) of 10 years (2012 to 2022) for both pre and post-monsoon seasons were analysed for understanding the spatio-temporal variation of ground water regime. The DTWL varies from 1.2 to 68.3 meter below ground level (m bgl) (average: 8.5 m bgl) and 0.5 to 61.9 m bgl (average: 5.8 m bgl) during pre-monsoon and post-monsoon seasons respectively. Trend analysis for the last 10 years (2012-2022) is studied from 55 hydrograph stations of CGWB and SGWD for pre-monsoon and post-monsoon season respectively. It is observed that during pre-monsoon season 23 wells shows falling trend ranging from 0.01 m to 7.20 m/year (Avg: 0.62 m/yr) and 32 wells shows rising trends ranging 0.01 m to 1.41 m/yr (Avg: 0.29 m/yrs). During post-monsoon season 27 wells shows falling trend ranging 0.004 to 1.128 m/yr (Avg: 0.212 m/yr) and 28 wells shows rising trend ranging 0.001 to 3.530 m/yrs (Avg: 0.31 m/yrs). During pre-monsoon season (May), the water-table elevation ranges from <1 to 139 m amsl.

Ground Water from the area is mildly alkaline to alkaline in nature with pH in the range of 6.8 to 8.99 (avg: 8.05). Electrical conductivity varies from 110 to 7111 (avg: 1726) µ Siemens/cm. In majority of area 2644 sq.km (80 %) EC is within 750 to 2250 µ Siemens/cm; in 1244.34 sq. kms (41%) area, it is in the range of 750 to 1500 and in 1173.64, it is in the range of 1500 to 2250 µ Siemens/cm (39%). In 137.5 sq. kms (4.5 %) area, it is <750 µ Siemens/cm and in 353 sq kms (11.7 %) area is 2250 to 3000 µ Siemens/cm and in 111.58 sq kms (3.7 % area), the EC is more than 3000 µ Siemens/cm.

The area underlain by khondalites and Charnokites in the district is about 768 sq. kms. The weathering occurrence is confined to these formations. The Thickness of weathered zone varies from <3 m to 10 m with an average thickness range of 5 m. Thickness of weathering < 3 m occurs in ~6.5 % of the area, 3 to 6 m occurs in ~83 % of area, 6 to 9 m occurs in 10 % of area and >9 m occurs in 0.5% area. The depth of fracturing varies from 10 to 100 m. From the data, it is inferred that fractures in the range of 30 to 60 m depth are more predominant (78 % of the area), 60 to 90 m occur in 14 % area; < 30 m occurs in 6% of the district. The yield ranges from <1.0 to 5 lps. In majority of the area, the ground water yield in the range of 5 lps (72% area) followed by 3 to 5 lps and <1 lps.

As per Ground Water Resource Assessment – 2023, the net annual extractable groundwater resources in the district are 974.80 MCM, gross ground water draft for all uses 171 MCM, provision for domestic utilisation for the year 2025 is 22 MCM and Net Ground Water Availability for future use is 805 MCM. The stage of ground water extraction varies from 7 % in Kakinada (Rural) to 66% in Kakinada (Urban) with an overall stage of ground water extraction is of 21%. Based on the stage of ground water development, all mandals in the district are categorized as Safe.

The Ground Water Assessment – 2023 indicates, there is a scope for further ground water development in the district. Based on criterion of Depth to Water levels (<15 m), Rainfall (>750

mm) and stage of ground water extraction (<60%) and net annual availability of ground water for future use (805 MCM), a judicious enhancement of ground water extraction is recommended in the district by constructing 4433 bore wells in 215 villages in all 13 mandals which can be taken up under YSR Jala Kala/convergence of schemes which can bring an additional area of 7478 ha is under ground water irrigation in the district.

The supply side management include artificial recharge of available surplus runoff through construction of check dams and percolation tanks in rural areas and roof top rainwater harvesting in urban areas. More over repair renovation & restoration of existing tanks in rural and urban areas will also help in ground water recharge. The recharge potential of the aquifers in the district is 108 MCM. The District Water Management Agency (DWMA), Rural Development Department, Govt. of Andhra Pradesh had constructed 486 artificial recharge structures (31 Percolation Tanks, 455 Check Dams) and 42668 Water conservation structures (8715 Farm Ponds and 33953 other WCS) are constructed under IWMP and MGNREGS

In addition to the existing structures, it is recommended to construct 177 Percolation Tanks in the district (Table- 6.3). Further, it is recommended that the existing check dams and percolation tanks may be de-silted involving convergence of schemes and people's participation through the Mahatma Gandhi National Rural Employment Guarantee Scheme. This will also help in sustainable management of ground water resources. In addition, it is recommended for desiltaion of existing MI tanks and cascading of tanks. This can result in increase in Ayacut/Irrigation area, sustain the bore well yields and decrease the ground water irrigation. Roof top rainwater harvesting in Government buildings, proper waste water management, participatory groundwater management (PGWM), lining of sewerage to arrest leaching of nitrate and effective implementation of the existing 'Water, Land and Trees Act' of 2002 (WALTA-2002) are other recommended measures in the district.

REPORT ON
AQUIFER MAPPING FOR SUSTAINABLE MANAGEMENT OF GROUND WATER RESOURCES IN KAKINADA DISTRICT, ANDHRA PRADESH

1. INTRODUCTION

Aquifer mapping is a process wherein a combination of geologic, geophysical, hydrologic and chemical analyses is applied to characterize the quantity, quality and sustainability of ground water in aquifers. In recent past, there has been a paradigm shift from "**groundwater development**" to "**groundwater management**". As large parts of India particularly hard rock have become water stressed due to rapid growth in demand for water due to population growth, irrigation, urbanization and changing life style. Therefore, in order to have an accurate and comprehensive micro-level picture of groundwater in India, aquifer mapping in different hydrogeological settings at the appropriate scale is devised and implemented, to enable robust groundwater management plans. This will help in achieving drinking water security, improved irrigation facility and sustainability in water resources development in large parts of rural and many parts of urban India. The aquifer mapping program is important for planning suitable adaptation strategies for sustainable development and management of ground water resources of the country. As a part of NAQUIM in Andhra Pradesh, the Kakinada district has been selected and completed during AAP 2022-2023.

1.1 Objectives: In view of the above challenges, an integrated hydrogeological study was taken up to develop a reliable and comprehensive aquifer map and to suggest suitable groundwater management plan on 1: 50,000 scale.

1.2 Scope of study: The main scope of study is summarised below.

1. Compilation of existing data (exploration, geophysical, groundwater level and groundwater quality with geo-referencing information and identification of principal aquifer units.
2. Periodic long-term monitoring of ground water regime (for water levels and water quality) or creation of time series data base and ground water resource estimation.
3. Quantification of groundwater availability and assessing its quality.
4. To delineate aquifer in 3-D along with their characterization on 1:50, 000 scale.
5. Capacity building in all aspects of ground water development and management through information, education and communication (IEC) activities, information dissemination, education, awareness and training.

6. Enhancement of coordination with concerned central/state govt. organizations and academic/research institutions for sustainable ground water management.

1.3 Area details: The Kakinada district is reorganized on 4th April, 2022 from the erstwhile East Godavari district with a geographical area of **3020 sq kms** lies between 16.672423 to 17.534855 of the Northern Latitude and 81.903124 to 82.604773 of the Eastern Longitude. (**Fig.1.1**). Administratively, the district is being governed **with 2 revenue divisions (**Kakinada, Peddapuram**), 21 mandals and 412 villages with population of 20.92 lakhs.** Kakinada District is one of the most populous district in the State with a density of 693 persons/Sq. Km, whereas it is 304 persons/Sq. Km in the State. **The district shares** boundary with Anakapalli and AlSR district on the north, East Godavari on the south, Konaseema in the South and Bay of Bengal in the East. The basic details of the district are provided in Table-1.

S. No.	Mandal	Revenue Division	Area (Sq Kms)	No. of Villages	No. of Households
1	GANDEPALLI	Peddapuram	165.44	13	15933
2	GOLLAPROLU	Kakinada	121.54	12	22008
3	JAGGAMPETA	Peddapuram	160.59	19	22181
4	KAKINADA (U)	Kakinada	31.95	4	82333
5	KAKINADA(R)	Kakinada	74.23	15	46322
6	KARAPA	Kakinada	104.03	19	21905
7	KIRLAMPUDI	Peddapuram	87.33	17	20133
8	KOTANANDURU	Peddapuram	114.84	16	13197
9	PEDAPUDI	Kakinada	106.62	17	21176
10	PEDDAPURAM	Peddapuram	144.82	22	35101
11	PITHAPURAM	Kakinada	125.24	27	36276
12	PRATHIPADU	Peddapuram	180.94	40	21571
13	RANGAMPETA	Peddapuram	145.10	15	16129
14	ROUTHALAPUDI	Peddapuram	185.40	44	14728
15	SAMALKOTA	Kakinada	146.64	19	38889
16	SANKHAVARAM	Peddapuram	137.41	32	15593
17	TALLAREVU	Kakinada	414.75	13	22375
18	THONDANGI	Peddapuram	176.62	15	23667
19	TUNI	Peddapuram	187.95	22	36769
20	U. KOTHAPALLI	Kakinada	115.46	16	23575
21	YELESWARAM	Peddapuram	121.30	13	20242
				410	570103

Table-1.1: Details of the Kakinada District, Andhra Pradesh

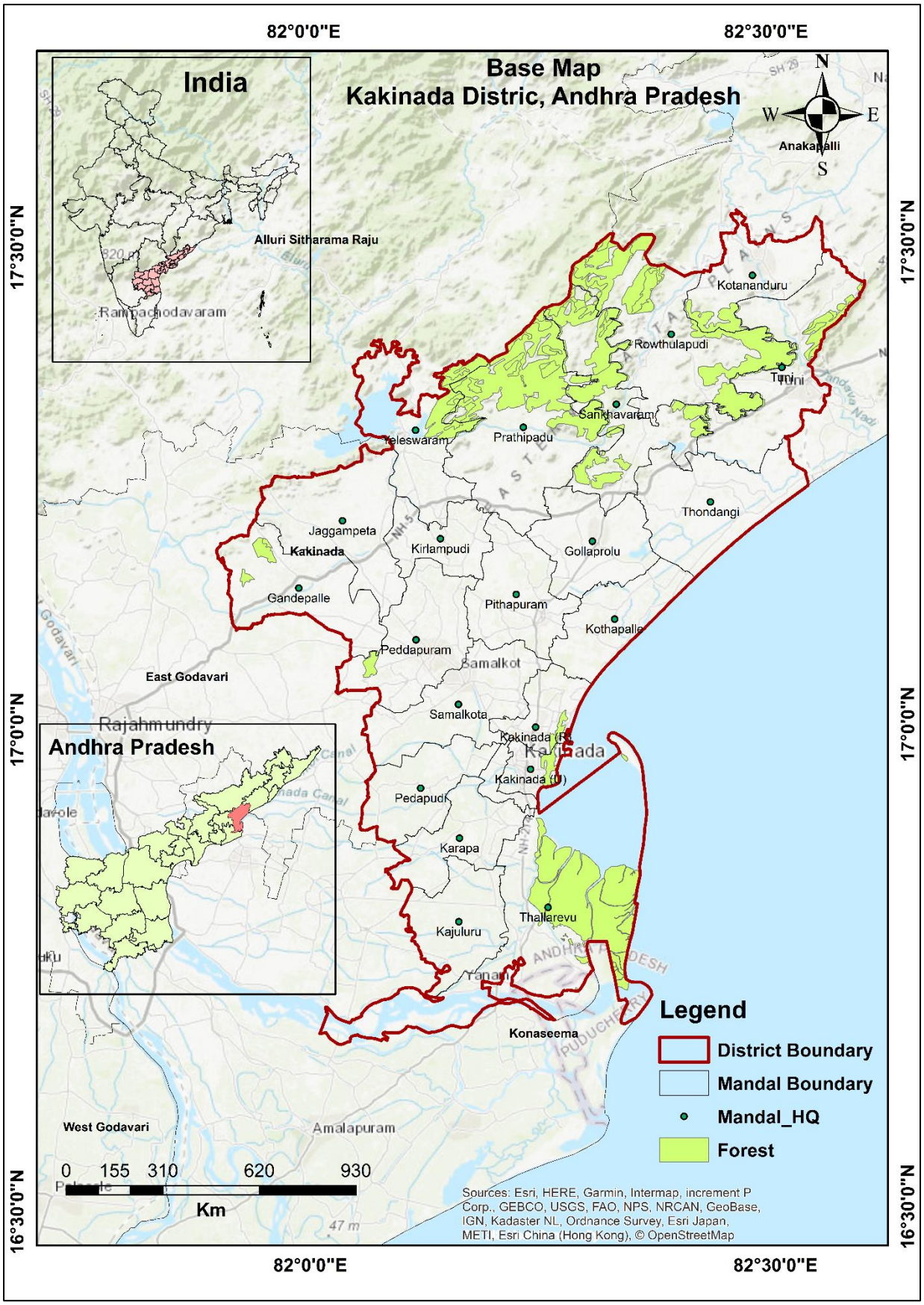


Fig.1.1: Location map of Kakinada district.

1.4 Climate and Rainfall: The district is characterised by hot summer and generally dry weather except during S-W monsoon season. The normal maximum and minimum temperatures recorded in the district are 37.7°c and 28.5°c respectively. The Maximum temperature is usually recorded in the months April, May and June. The average normal annual rainfall of the district is 1140 mm. This varies between 839.7 mm (Gollaprolu) to 1412.6 mm (Tallarevu) (Fig. 1.2). The South west monsoon contributes 65% of the rainfall and northwest monsoon and others contributes 35% of the rainfall in the district. The normal and actual rainfalls are provided in Table-1.2.

Table: 1.2 Rainfall of Kakinada District, AP

S. No.	Mandal	Normal	2014-15	2015-16	2016-17	2017-18	2018-19
1	Gandepalle	1095.5	411.2	760.8	869.5	941.0	866.8
2	Gollaprolu	839.7	469.3	909.8	565.1	729.6	714.8
3	Jaggampeta	1138.0	829.9	844.7	868.2	886.7	801.8
4	Kakinada Rural	1182.3	558.1	1091.2	664.9	657.0	877.2
5	Kakinada Urban	1186.9	511.8	973.7	653.0	713.0	699.3
6	Karapa	1167.3	481.1	1177.2	795.5	518.0	761.1
7	Kirlampudi	1105.5	676.2	781.9	919.5	981.0	785.3
8	Kotananduru	886.5	879.9	1026.1	995.2	1281.4	907.0
9	Kothapalle	1070.8	602.3	898.4	681.1	895.7	596.6
10	Pedapudi	1115.9	522.8	1018.5	814.2	622.6	718.7
11	Peddapuram	1208.6	454.8	932.5	734.8	693.1	723.8
12	Pithapuram	1167.9	528.3	922.9	726.6	729.4	624.2
13	Prathipadu	1182.3	370.8	574.4	921.8	1147.6	812.2
14	Rotulapudi	1164.4	729.3	929.1	859.4	1651.9	820.4
15	Samalkota	1143.7	458.5	1004.5	790.5	628.9	848.0
16	Sankhavaram	1164.4	792.8	807.5	693.9	1191.3	953.9
17	Thallarevu	1412.6	485.4	1261.9	725.7	625.4	910.2
18	Thondangi	1202.8	692.5	987.9	747.2	1136.7	799.2
19	Tuni	1153.3	624.4	962.5	875.1	1041.0	655.1
20	Yeleswaram	1168.3	713.6	958.6	943.7	1182.0	1077.2

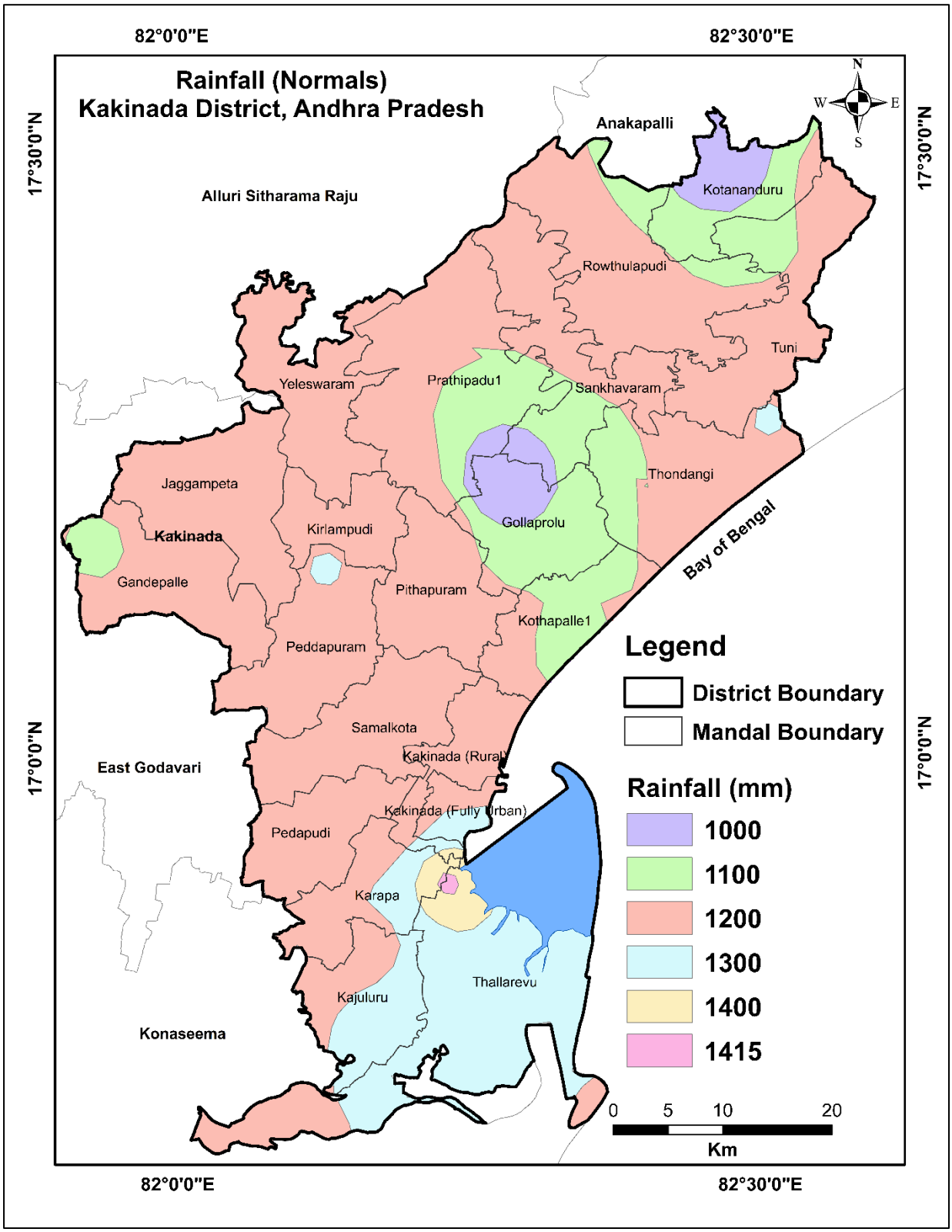


Fig.1.2: Normal Rainfall of Kakinada district

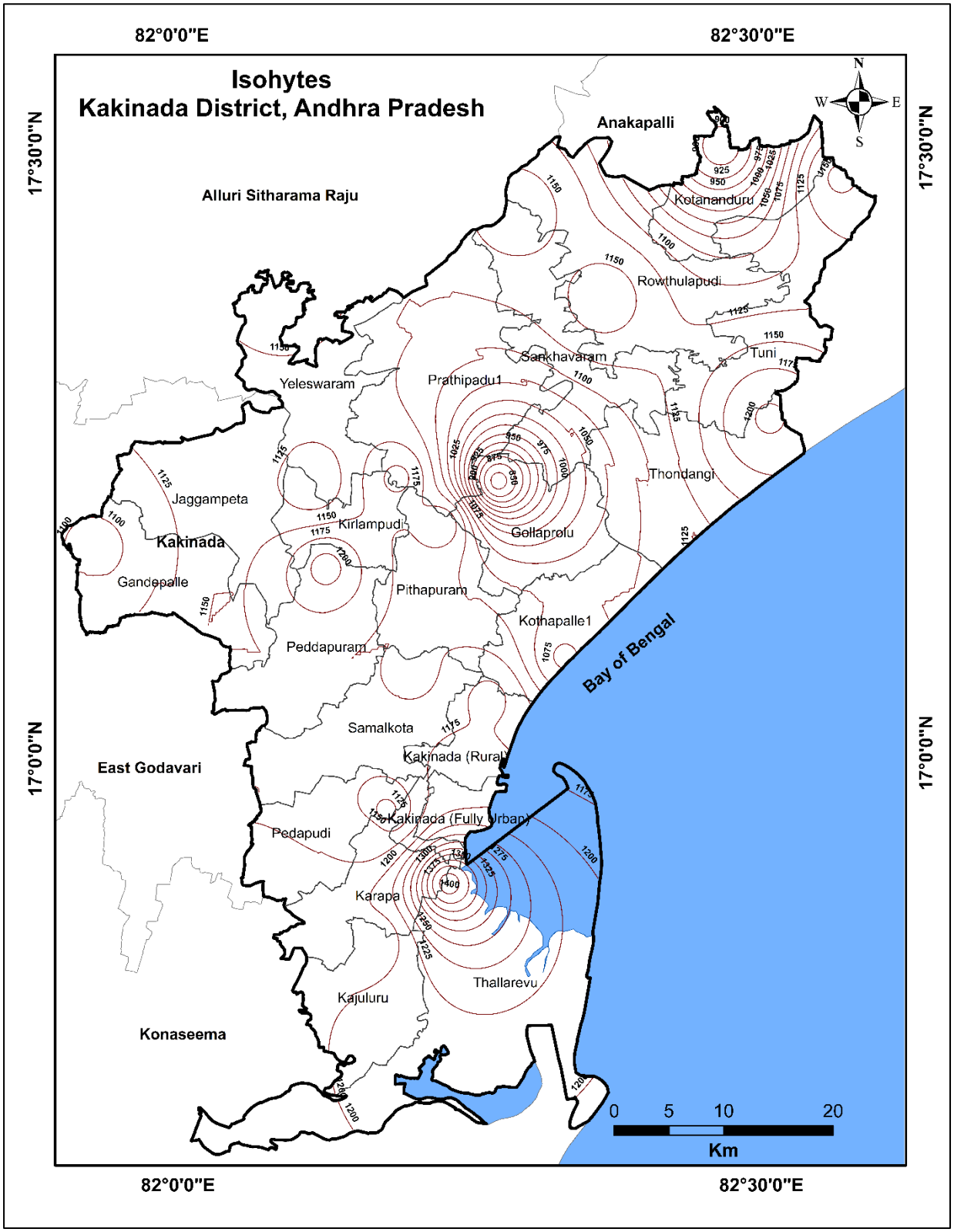


Fig.1.3: Isohytes of Kakinada district

1.5 Geomorphology: Pediplains, Structural hills, Denudational hills, pediment, Coastal & alluvial, deltaic plains are the major geomorphological units in the district. The details and percentage of geomorphological features of the district is given in the table 1.3 and depicted in **Fig.1.4.**

Table-1.3: Geomorphology of Kakinada District

S.No.	Description	Area (Sq. kms)	Percentage
1	Pediplain	913.0	30.2
2	Structural hill	250.0	8.3
3	Pediment	248.0	8.2
4	Structural valley	97.0	3.2
5	Flood plain	45.0	1.5
6	Residual hills	37.0	1.2
7	Denudational hills	130.0	4.3
8	Coastal plain	664.0	22.0
9	Beach	109.0	3.6
10	Alluvial plain	189.0	6.3
11	Salt flat	40.0	1.3
12	Channel fill	13.0	0.4
13	Tidal flat	58.0	1.9
14	Mud flat	17.0	0.6
15	Deltaic plain	85.0	2.8
16	Spit	9.0	0.3
17	Mangrove	110.0	3.6
18	Creek	6.0	0.2
	Total	**3020.0**	**100**

1.6 Physiography:

The district can be divided into two distinct natural physical divisions i.e., plain and hilly regions. The hilly region is mostly covered with dense to sparse wooded forests with elevation ranging from 130 to 730 m amsl spreading in Prathipadu, Sankhavaram and Routhulapudi mandals. The plain portion of the district is a well cultivated tract with an elevation varying from 0 -120 m amsl. In majority potion of the district, the elevation varies from 0-120 m amsl. The elevation map of the district is provided in **Fig-1.5**

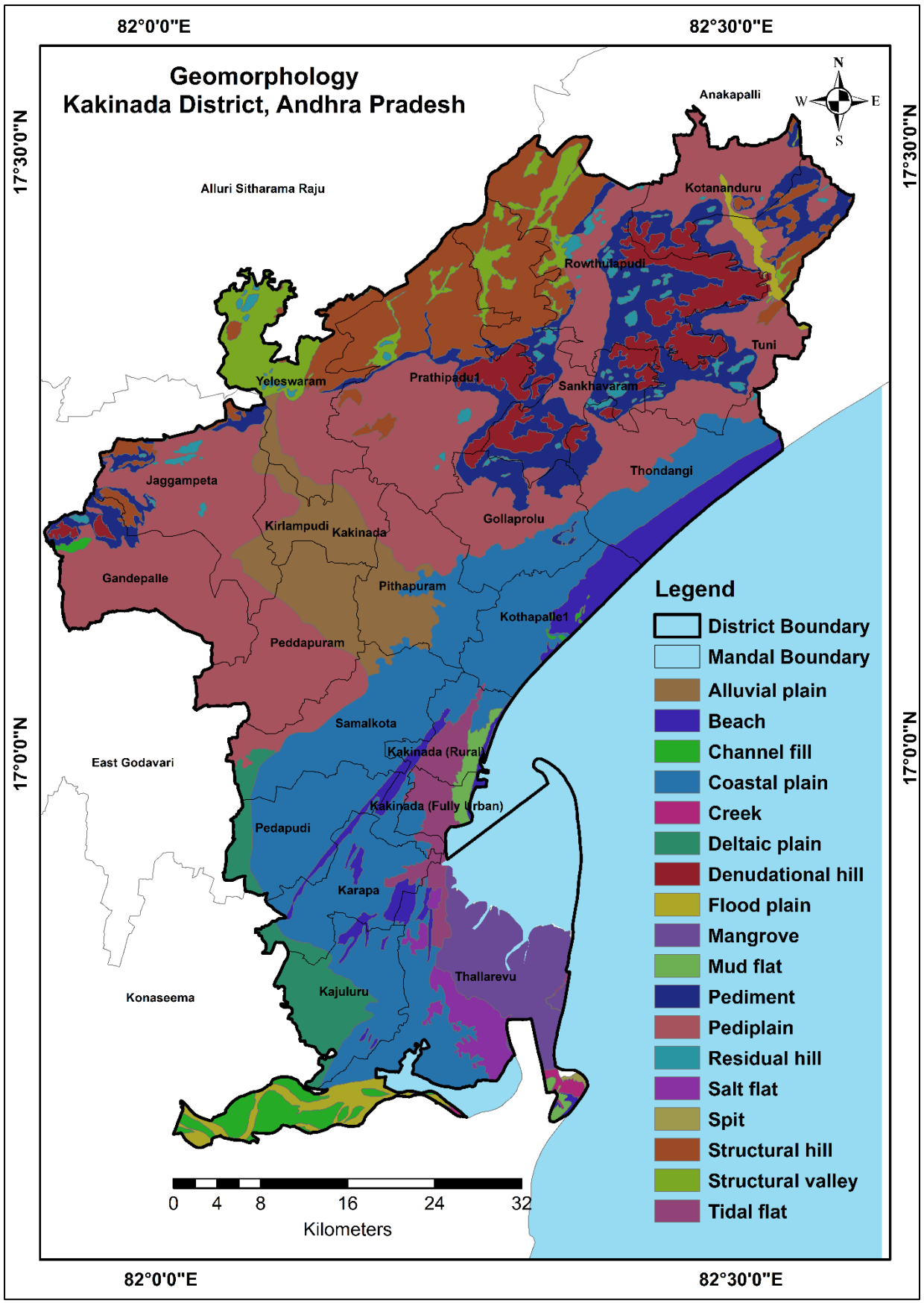


Fig-1.4 Geomorphology of Kakinada District

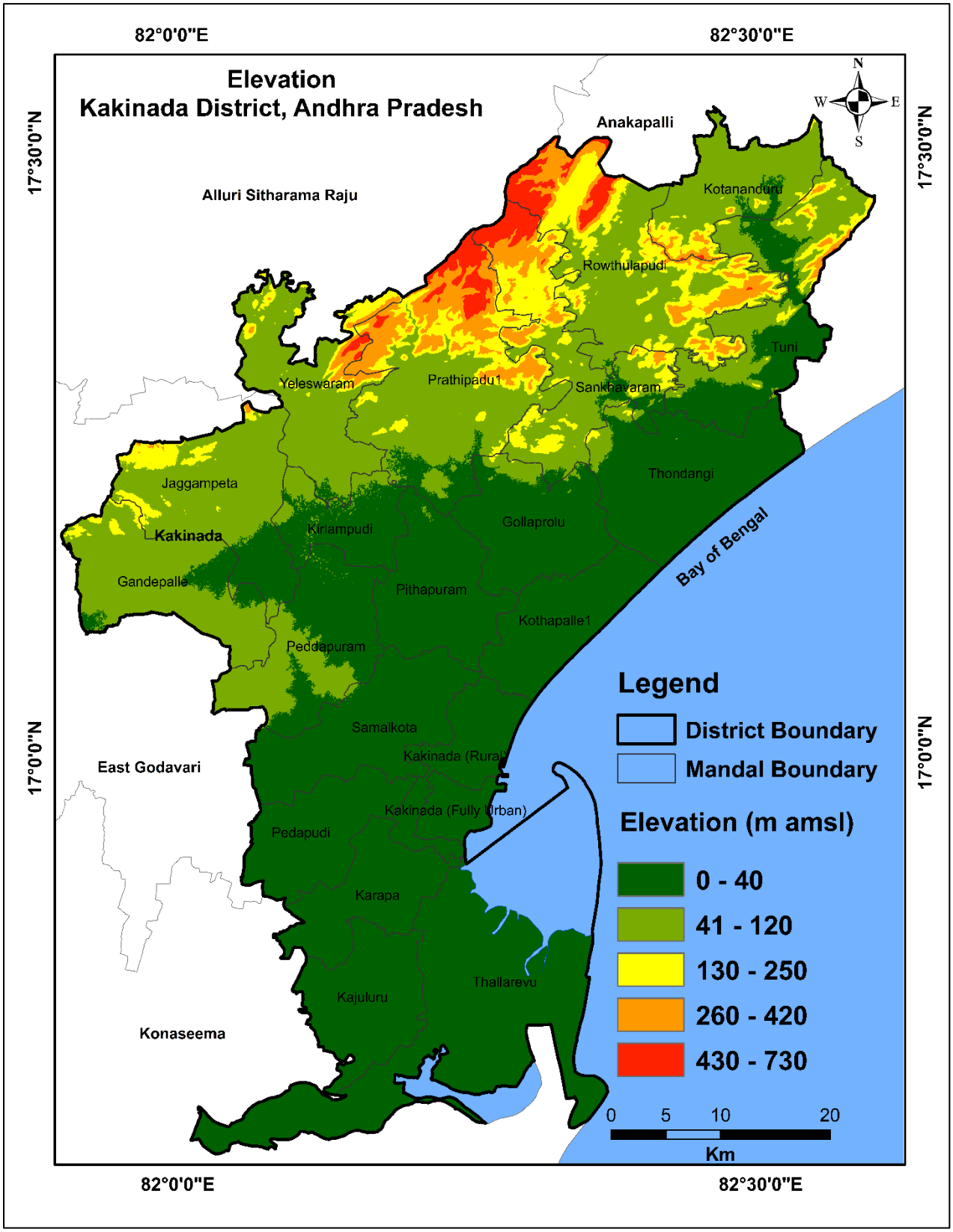


Fig-1.5: Physiography of the Kakinada district, Andhra Pradesh

1.7 Drainage: The district is drained by the rivers of Godavari and Pushkara. The Yeleru, Thandava and Pampa Rivers flows in the district. The general drainage pattern is dendritic to sub-dendritic. The map depicting river, drainage and water bodies is presented in **Fig.1.6.**

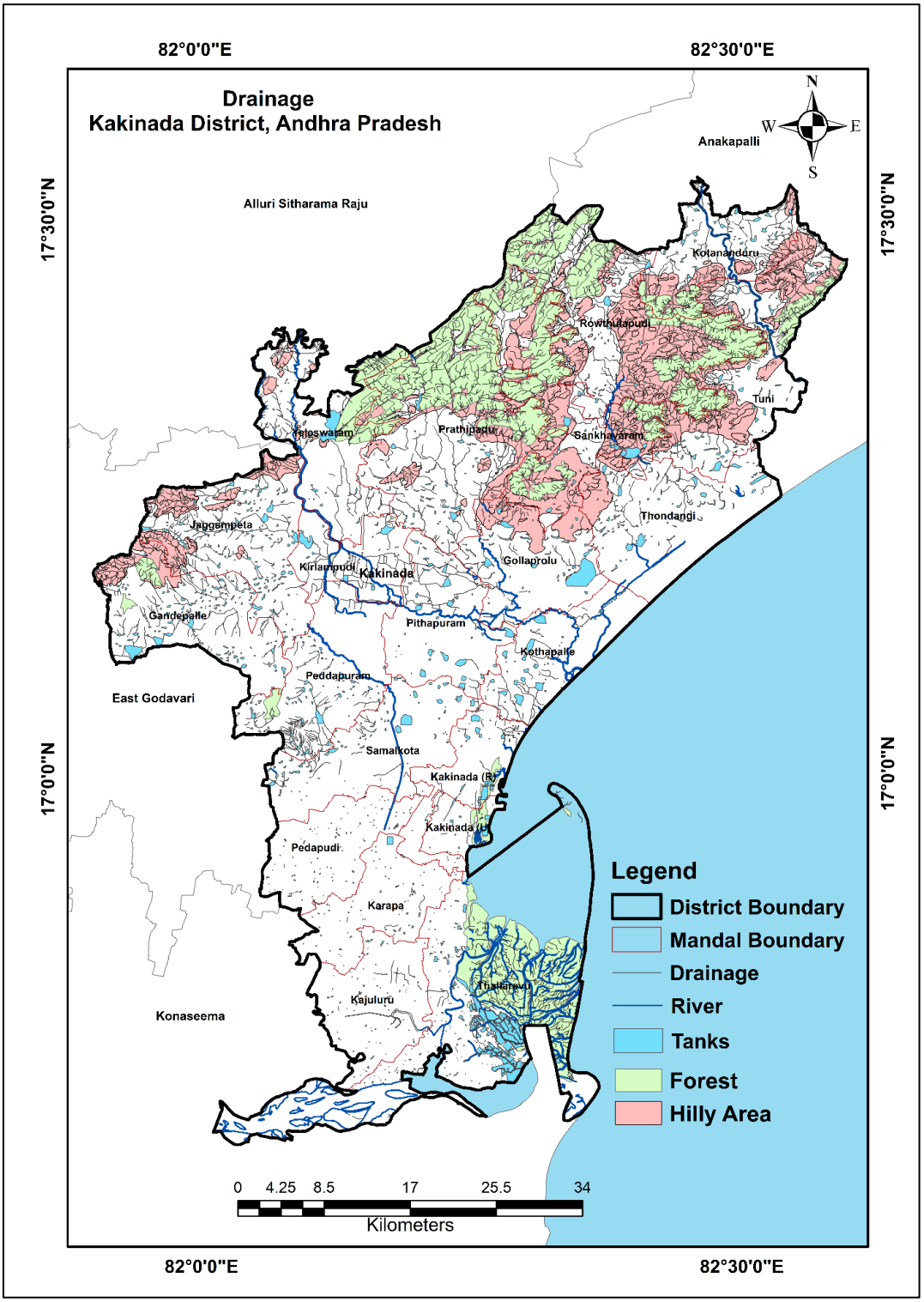


Fig – 1.6: Drainage of Kakinada District, AP

1.8 Land Use: Out of total geographical area of 3019.79 km2, forest occupies 326.65 km2 (~11%), The net area sown is 1551.43 sq kms (51%), land put to non-agricultural uses is 605.95 sq. kms (20%)etc. The details of land use pattern in the district are provided in Table-1.4. The maps depicting Land use and land cover of the district is provided in Fig. 1.7 and 1.8.

Table – 1.4: Land Use Pattern in Kakinada District, Andhra Pradesh

S. No.	Description	Area (Sq. kms)	Percentage
	Total Geographical Area	3019.79	
1	Forest	326.65	10.817
2	Barren Uncultivable Land	140.69	4.659
3	Land put to Non. Agricultural uses	605.95	20.066
4	Cultivable waste	6.02	0.199
5	Permanent Pastures & other grazing lands	56.19	1.861
6	Misc. Tree crops	27.03	0.895
7	Other Fallows	65.54	2.170
8	Current Fallows	187.17	6.198
9	Net Area Sown	1551.43	51.375
10	Fish & Prawn Culture	53.12	1.759
	Total	**3019.79**	**100**

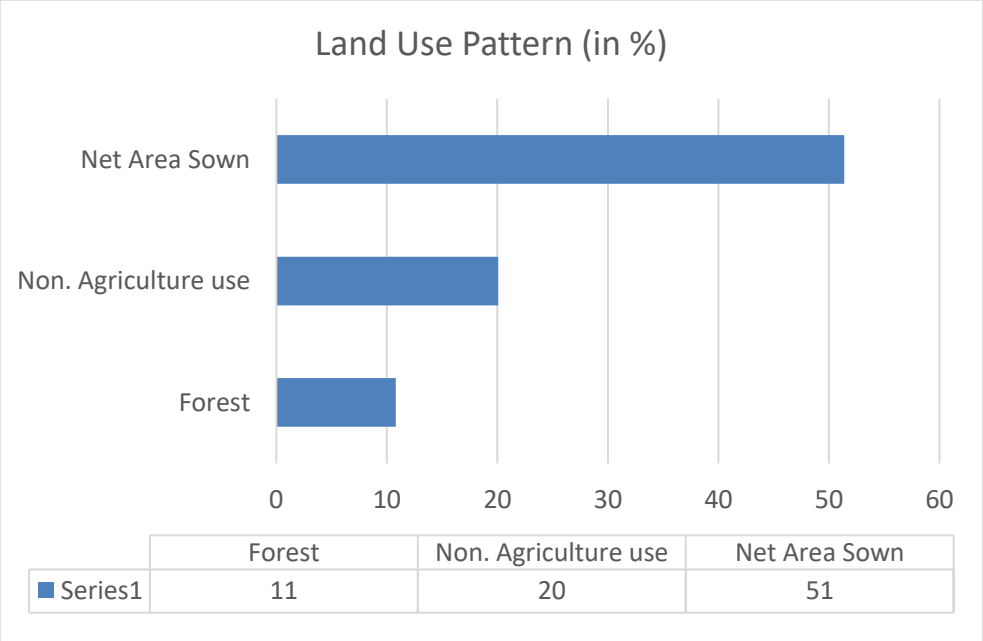


Fig – 1.7: Graphical presentation of Land Use in Kakinada District, AP

Table-1.5: Mandal wise Land Use Pattern in Kakinada District

S. No.	Nandal	Total Geographic Area	Forest	Net Area Sown	Area Sown More than Once	Total Cropped Area	Fish & Prawn Culture	Barren Uncultivable Land	Land put to Non. Agri uses	Cultivable waste	Permanent Pastures & other grazing lands	Misc. Tree crops	Other Fallows	Current Fallows
1	GANDEPALLE	16544	451	11105	2840	13945	0	0	2358	0	393	0	128	2109
2	GOLLAPROLU	12154	0	8159	4514	12673	2	167	2317	0	127	68	539	775
3	JAGGAMPETA	16059	0	9604	2036	11640	33	0	1935	224	94	0	628	3541
4	KAJULURU	11669	0	7938	8005	15943	1276	0	2455	0	0	0	0	0
5	KAKINADA (R)	7423	0	1937	1943	3880	44	0	4921	0	0	0	255	266
6	KAKINADA (U)	3195	0	222	222	444	2	0	2747	0	0	0	90	134
7	KARAPA	10403	0	6322	6877	13199	993	0	2711	0	0	0	111	266
8	KIRLAMPUDI	8733	0	6409	4956	11365	17	216	1499	0	60	0	61	471
9	KOTANANDURU	11484	486	6899	2394	9293	0	786	2666	0	231	225	27	164
10	KOTHAPALLE	11546	0	5315	5488	10803	220	0	3295	0	1838	39	698	141
11	PEDAPUDI	10662	0	7938	8482	16420	755	0	1824	0	0	0	0	145
12	PEDDAPURAM	14482	0	10216	4145	14361	0	71	3126	0	462	41	291	275
13	PITHAPURAM	12524	0	9411	8400	17811	6	56	2595	0	79	0	240	137
14	PRATHIPADU	18094	990	10995	2561	13556	9	1068	1399	22	572	330	142	2567
15	ROTULAPUDI	18540	0	7797	1716	9513	0	3808	1987	133	676	1089	1915	1135
16	SAMALKOTA	14664	0	9810	10086	19896	103	0	3763	0	0	0	338	650
17	SANKHAVARAM	13741	843	6240	1173	7413	0	3456	1703	0	472	456	0	571
18	THALLAREVU	41475	28968	4747	4547	9294	1734	0	5652	0	0	0	370	4
19	THONDANGI	17662	0	9081	4436	13517	96	1191	4234	0	127	80	86	2767
20	TUNI	18795	732	8915	1843	10758	0	2515	2654	218	486	375	433	2467
21	YELESWARAM	12130	195	6083	3538	9621	22	735	4754	5	2	0	202	132

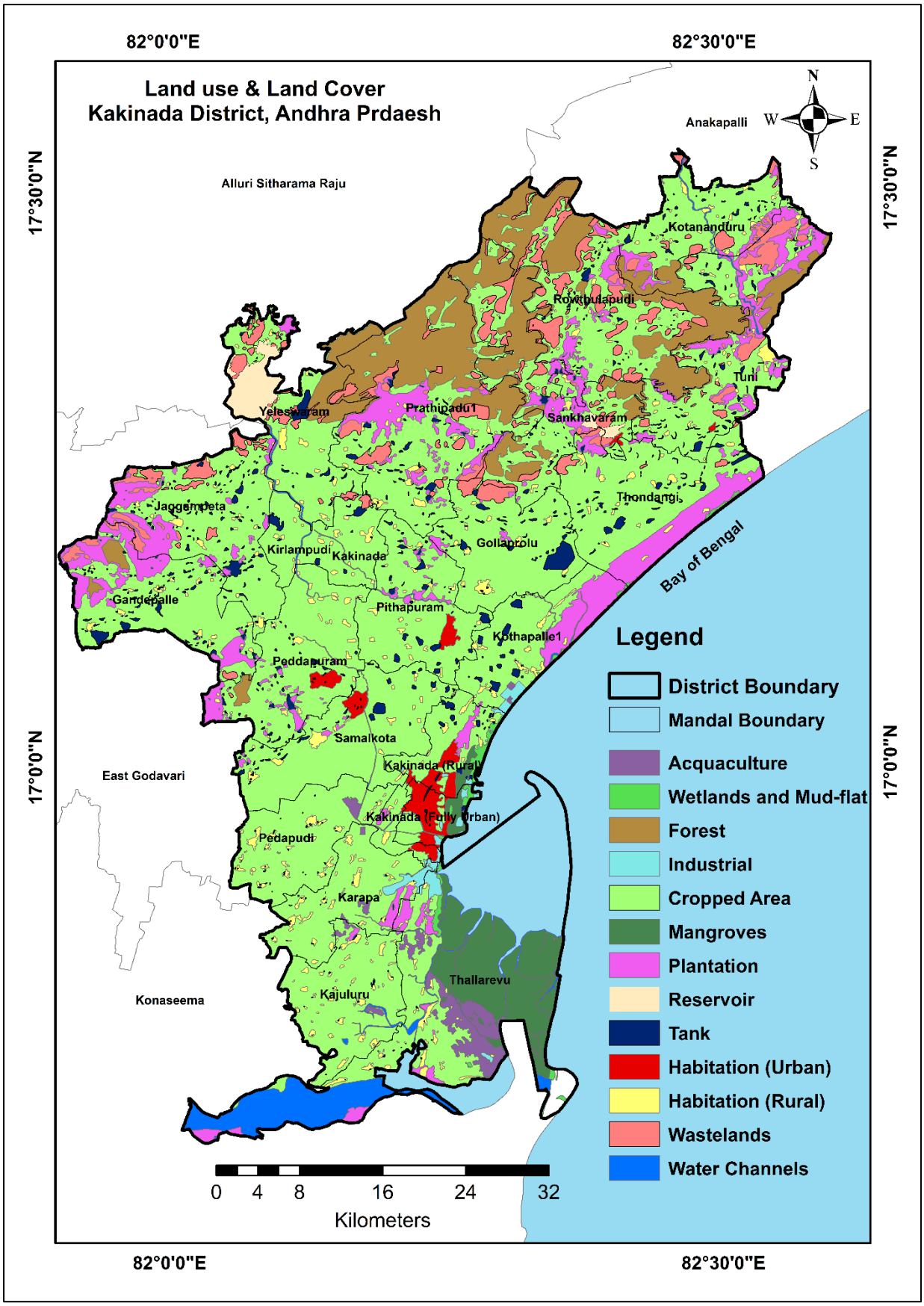


Fig-1.8: Land Use in Kakinada district, AP

1.9 Soils: The main soils in the district are Loamy Soils, Clay soils, sandy and silty soil. The soils in the district are predominantly loamy with medium to high fertility. The soils at some places are as thick as 4 Metres in alluvial tracts and valleys. The map depicting the soils are provided in **fig-1.9**

1.10 Agriculture and Irrigation:

The total cropped area in the district is 245345 ha, out of which net area sown is 155143 ha. The net area irrigated is 116477 ha and area irrigated more than once is 73213 ha. The details of cropped area and irrigation area are provided in Table-1.5. The district is mainly irrigated by both surface and ground water. Out of total Net area sown of 155143 ha, the net area irrigated is 116477 ha (75%). Out of 116477 ha, the Irrigation through surface water sources is 89911 ha (77.19%). Out of the 89911 ha irrigated by surface water, Canals irrigate 77057 ha (85%), Tanks irrigate 7440 ha (8.2%), irrigation through LIS is 5289 ha (<6%) and irrigation by other sources is 125 ha (0.13%). Out of 116477 ha, the Irrigation through Ground Water is 26566 ha (22.8%). The Major/ Medium Irrigation Projects in Kakinada district is shown in fig 1.10.

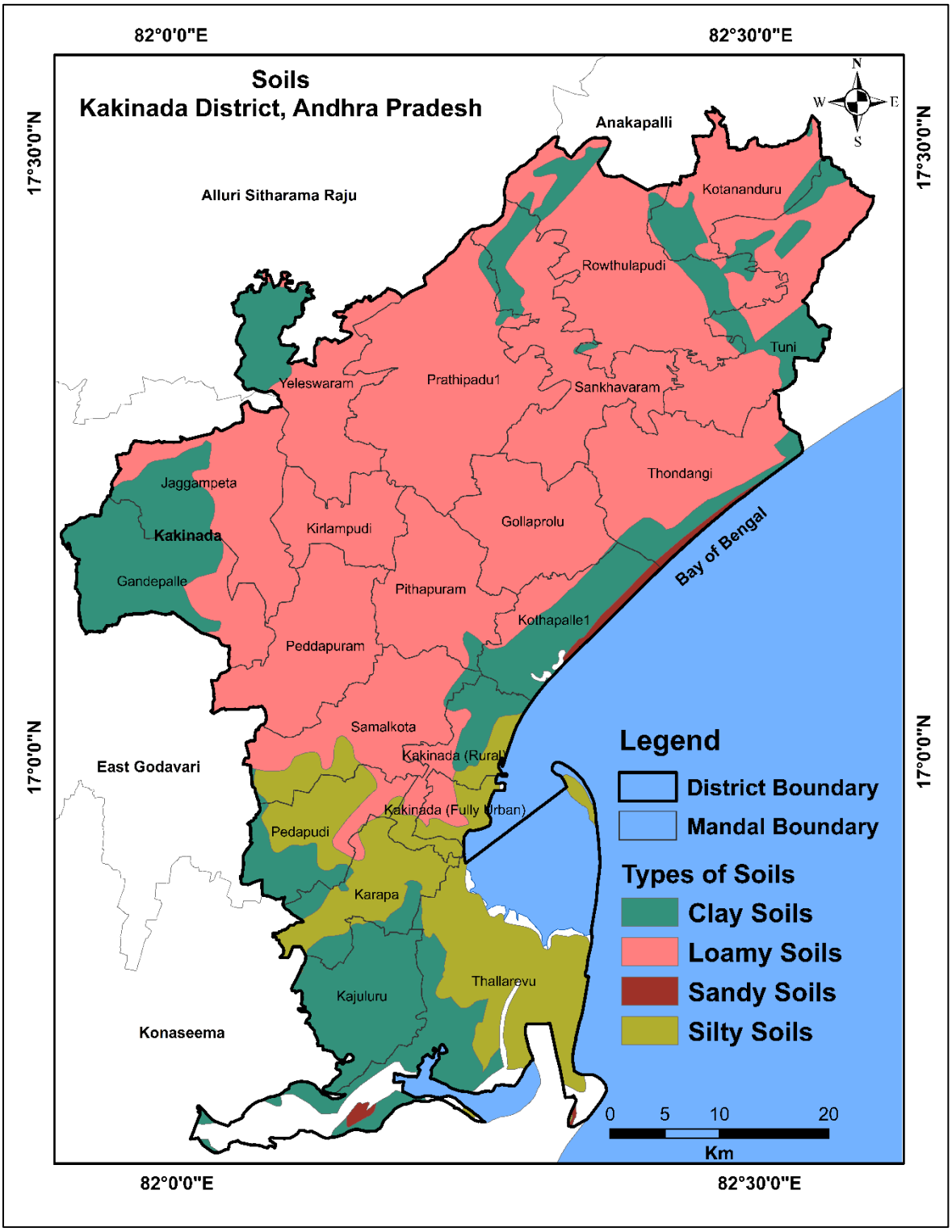


Fig-1.9: Soils of Kakinada District, AP

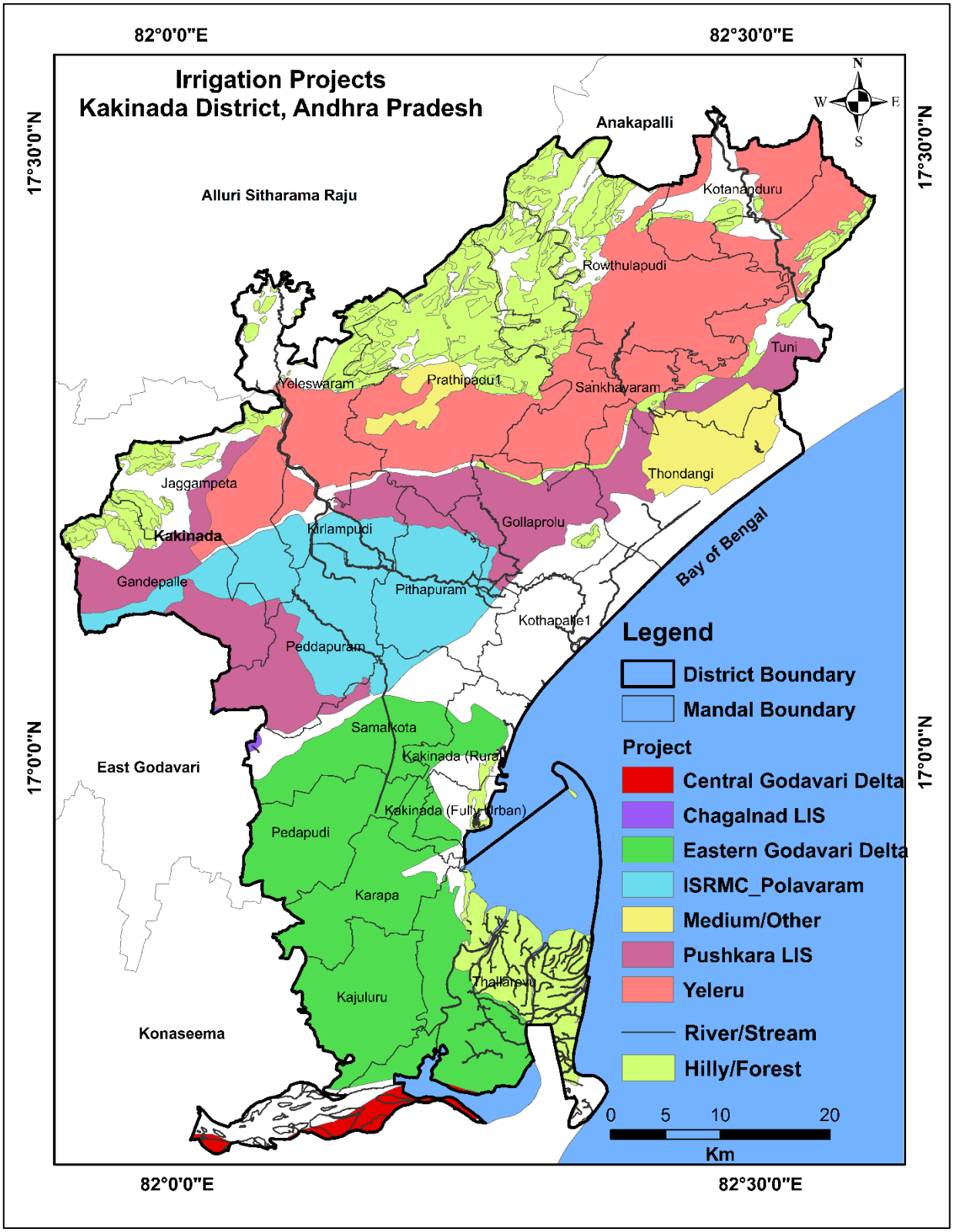


Fig-1.10: Major/ Medium Irrigation Projects, Kakinada district (Source: WRD)

Table – 1.6 : Agriculture and Irrigation Scenario of Kakinada District

S. No.	Mandal	Net Area Sown (ha)			Gross Area Sown (ha)			Net area irrigated (ha) under							Area irrigated more than once (ha)	Gross area Irrigated (ha)
		Kharif	Rabi	Total	Kharif	Rabi	Total	Canals	Tanks	TWs	DWs	LIS	Others	Total		
1	GANDEPALLE	11105	0	11105	11105	2840	13945	0	852	5387	0	1588	0	7827	1687	9514
2	GOLLAPROLU	8159	0	8159	8159	4514	12673	3876	333	1705	0	0	0	5914	3432	9346
3	JAGGAMPETA	9604	0	9605	9604	2036	11640	2831	847	2591	0	40	0	6309	1474	7783
4	KAJULURU	7938	0	7938	8099	7844	15943	7702	0	0	0	0	0	7702	7720	15422
5	KAKINADA (RURAL)	1937	0	1937	1937	1943	3880	1856	0	32	0	0	0	1888	1841	3729
6	KAKINADA (URBAN)	222	0	222	222	222	444	222	0	0	0	0	0	222	222	444
7	KARAPA	6322	0	6322	6322	6877	13199	6097	0	15	22	0	0	6134	6145	12279
8	KIRLAMPUDI	6409	0	6409	6409	4956	11365	3937	0	2270	0	0	0	6207	4535	10742
9	KOTANANDURU	6899	0	6899	6899	2394	9293	2695	773	849	0	0	0	4317	425	4742
10	KOTHAPALLE	5315	0	5315	5315	5488	10803	4998	0	4	0	0	0	5002	4656	9658
11	PEDAPUDI	7938	0	7938	7938	8482	16420	7911	0	0	0	0	0	7911	7822	15733
12	PEDDAPURAM	10216	0	10216	10216	4145	14361	4204	349	2315	0	484	0	7352	3810	11162
13	PITHAPURAM	9411	0	9411	9411	8400	17811	8372	0	915	0	0	0	9287	7739	17026
14	PRATHIPADU	10995	0	10995	10995	2561	13556	2750	950	1618	0	0	0	5318	1165	6483
15	ROTULAPUDI	7797	0	7797	7813	1700	9513	113	1241	1657	0	0	0	3011	644	3655
16	SAMALKOTA	9810	0	9810	9810	10086	19896	8546	195	474	3	592	0	9810	9580	19390
17	SANKHAVARAM	6240	0	6240	6240	1173	7413	82	916	735	0	332	125	2190	509	2699
18	THALLAREVU	4747	0	4747	4747	4547	9294	3977	0	4	7	28	0	4016	4028	8044
19	THONDANGI	9081	0	9081	9142	4375	13517	4030	65	1431	0	1024	0	6550	1555	8105
20	TUNI	8915	0	8915	8915	1843	10758	366	550	2095	0	1039	0	4050	788	4838
21	YELESWARAM	6083	0	6083	6083	3538	9621	2492	369	2437	0	162	0	5460	3436	8896
	Total	**155143**	**0**	**155144**	**155381**	**89964**	**245345**	**77057**	**7440**	**26534**	**32**	**5289**	**125**	**116477**	**73213**	**189690**

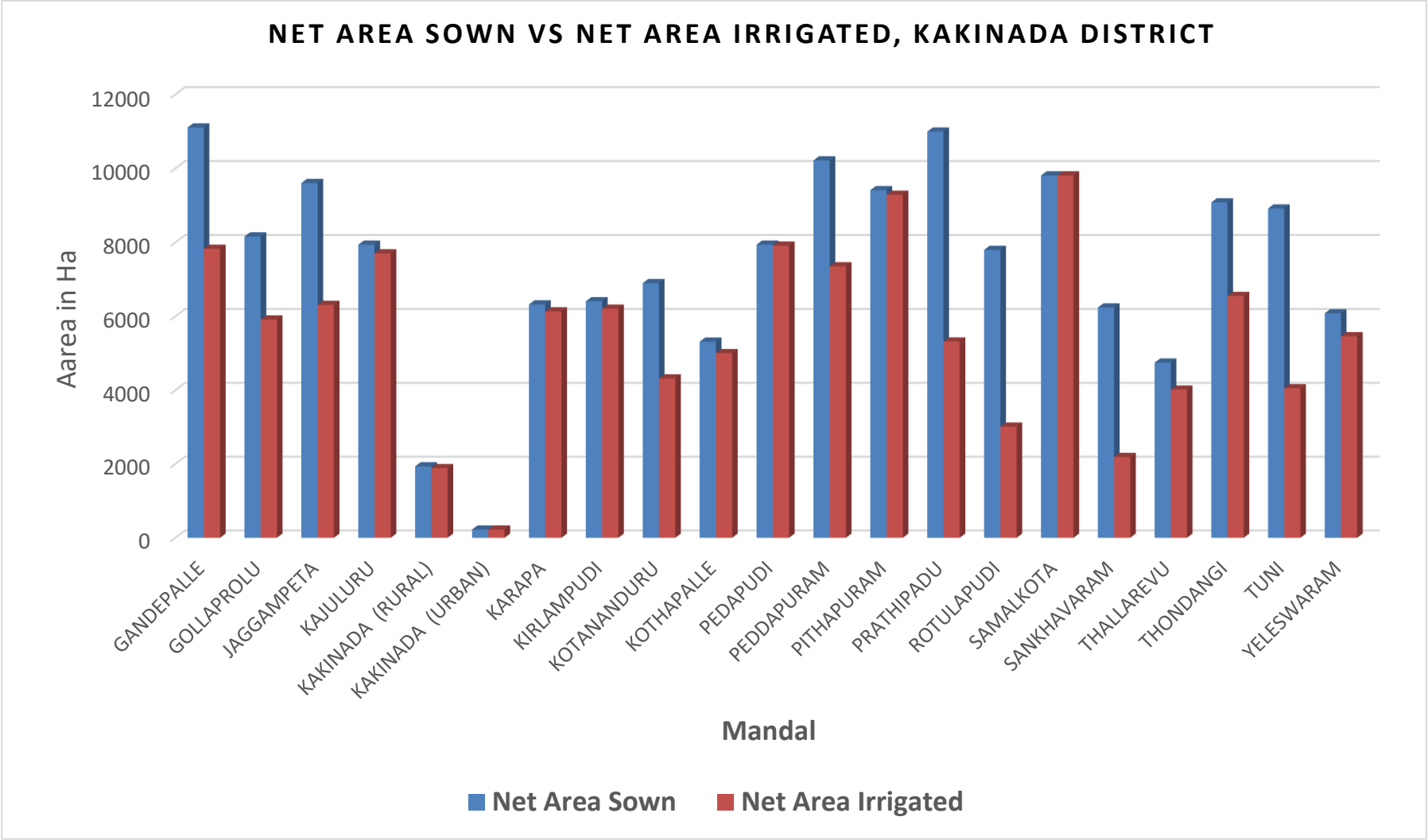


Fig- 1.10.1: Net Area Sown Vs Net Area Irrigated in Kakinada District

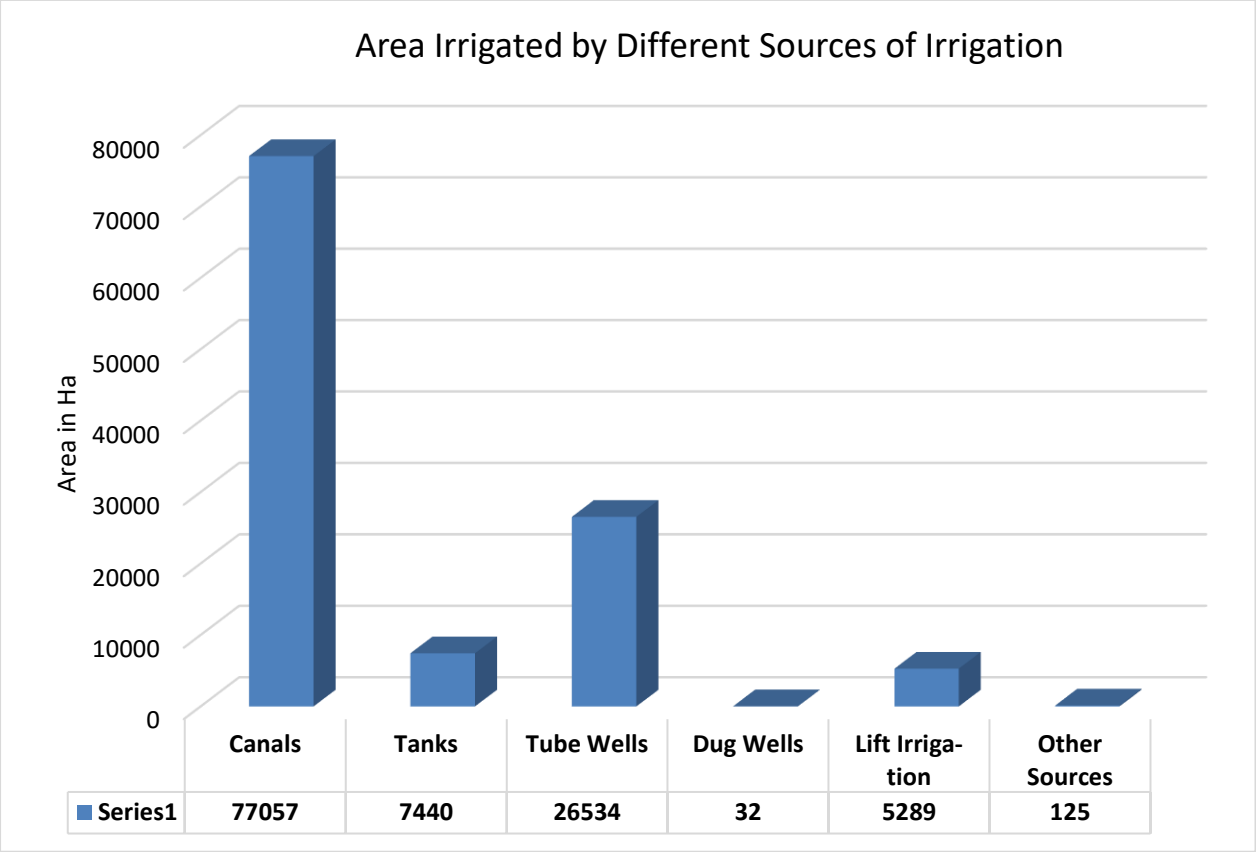


Fig. 1.10.2: Area irrigated under different sources.

Table-1.7: Percentage of Irrigation by different sources in the district

S.No.	Source	Area Irrigated in Ha	Percentage of Irrigation
1	Canals	77057	66.16
2	Tanks	7440	6.39
3	Tube Wells	26534	22.78
4	Dug Wells	32	0.03
5	Lift Irrigation	5289	4.54
6	Other Sources	125	0.11
	Total	116477	100

In the district, there are 10900 Minor Irrigation Tanks having a registered ayacut of 64185.47 ha and actual irrigated area is 58469.11 ha. **(Table-1.7 and Fig.1.8)**.

Table-1.8: Details of Minor Irrigation tanks and its Ayacut, Kakinada District

Sl. No.	Mandal	No. of Sources	Regd. Ayacut (ha)	Actual Area Irrigated (ha)	Percentage of Irrigation
1	Gandepalle	95	1389	1341	96.54428
2	Gollaprolu	498	2976	2038	68.49039
3	Jaggampeta	611	14698	13251	90.15512
4	Kajuluru	175	775	756	97.54839
5	Kakinada (Urban)	0	0	0	
6	Kakinada (Rural)	42	118	32	27.03616
7	Karapa	109	0	33	
8	Kirlampudi	757	2573	1675	65.09911
9	Kotananduru	830	7097	4314	60.78505
10	Kothapalle	48	0	43	
11	Pedapudi	354	2907	8102	278.7066
12	Peddapuram	910	772	658	85.29206
13	Pithapuram	533	2239	850	37.96338
14	Prathipadu	958	7081	6847	96.69411
15	Rotulapudi	1003	5039	3010	59.73407
16	Samalkota	349	4596	2811	61.15679
17	Sankhavaram	435	1877	2189	116.6422
18	Thallarevu	51	130	89	68.29867
19	Thondangi	2	296	65	21.96465
20	Tuni	1577	4040	5019	124.225
21	Yeleswaram	1563	5583	5346	95.76884
	Total	10900	64185.47	58469.11	

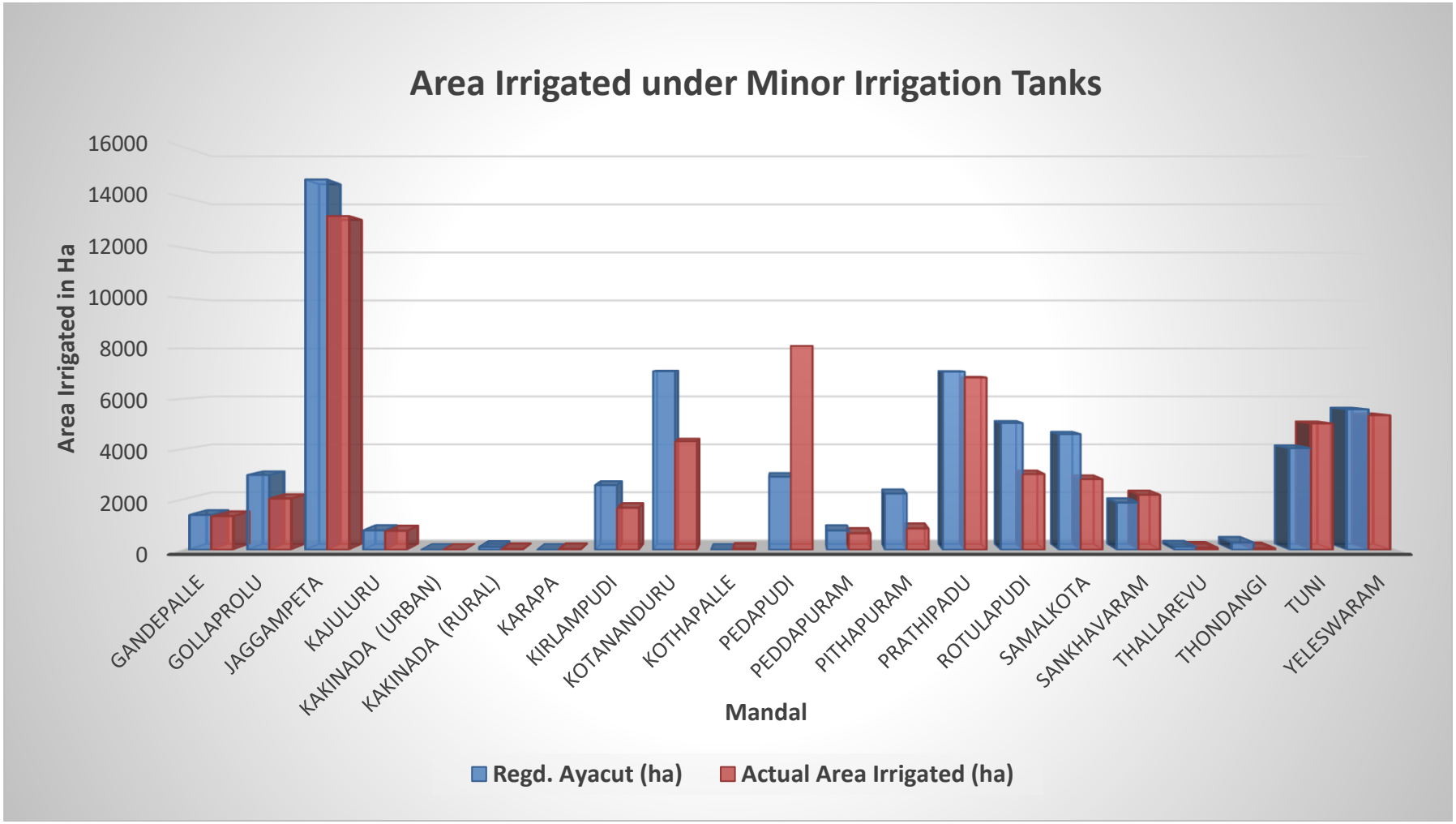


Fig. 1.10.3: Area Irrigated under Minor Irrigation

1.11 Prevailing water conservation/Recharge practices: In the district, a total of 994 artificial recharge structures (40 Percolation Tanks, 28 Mini Percolation Tanks, 854 Check Dams and 72 Check Walls) are constructed under IWMP and MGNREGS. The mandal wise distribution of the ARS is provided in Table-1.9

Table-1.9: Mandal wise details of Existing ARS in Kakinada District, AP

S. No.	Mandal	Check Dam	Check Wall	MPT	PT	Grand Total
1	Gandepalle	30	2	26		58
2	Gollaprollu					
3	Gollaprolu	46				46
4	Jaggampeta	40			26	66
5	Kakinada (Rural)					
6	Karapa					
7	Kirlampudi					
8	Kotananduru	118	20		2	140
9	Pedapudi					
10	Peddapuram					
11	Pithapuram					
12	Prathipadu	190	26		4	220
13	Rangampeta					
14	Rowthulapudi	202	14		4	220
15	Samalkota					
16	Sankhavaram	68	2		2	72
17	Thallarevu					
18	Thondangi					
19	Tuni	114	2			116
20	U. Kothapalli					
21	Yeleswaram	46	6	2	2	56
	Grand Total	**854**	**72**	**28**	**40**	**994**

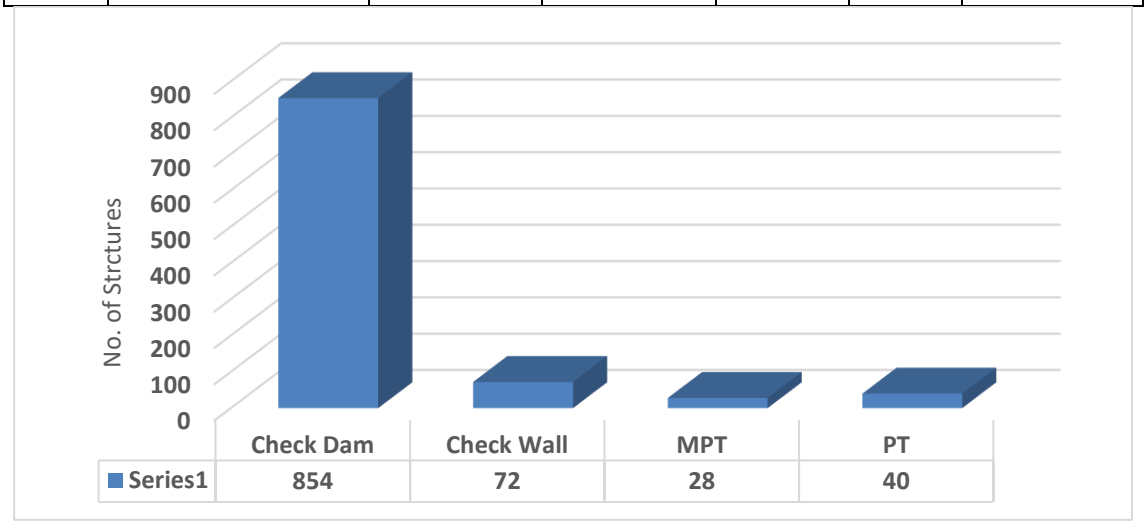


Fig. 1.11: Existing AR Structures in Kakinada District

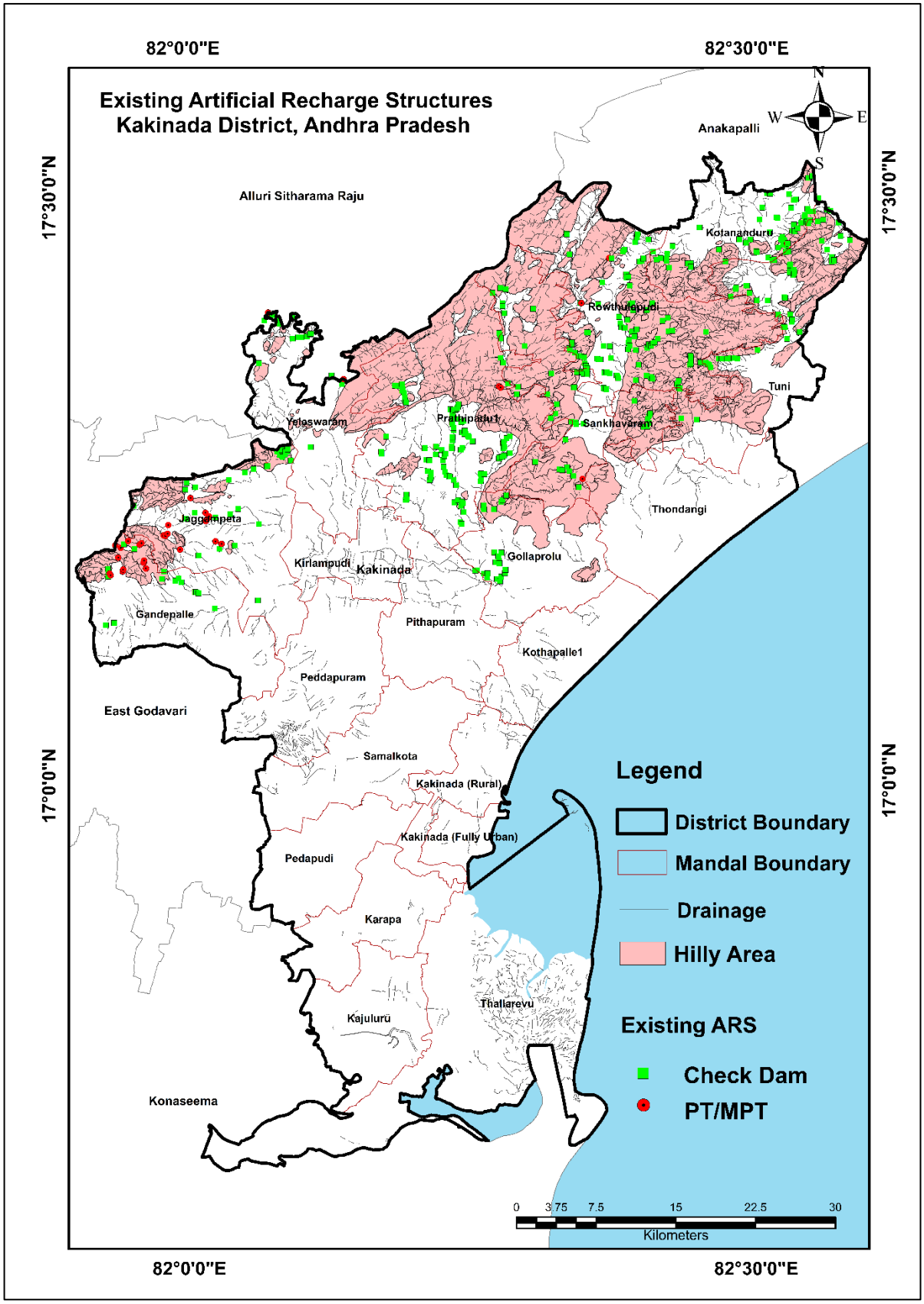


Fig – 1.11.1: Existing AR Structures, Kakinada District

2. DATA COLLECTION AND GENERATION

Collection and compilation of data for aquifer mapping studies is carried out in conformity with Expenditure Finance Committee (EFC) document of XII plan of CGWB encompassing various data generation activities (Table-2.1).

Table-2.1: Brief activities showing data compilation and generations.

S. No.	Activity	Sub-activity	Task
1	Compilation of existing data/ Identification of Principal Aquifer Units and Data Gap	Compilation of Existing data on groundwater	Preparation of base map and various thematic layers, compilation of information on Hydrology, Geology, Geophysics, Hydrogeology, Geochemical etc. Creation of data base of Exploration Wells, delineation of Principal aquifers (vertical and lateral) and compilation of Aquifer wise water level and draft data etc.
		Identification of Data Gap	Data gap in thematic layers, sub-surface information and aquifer parameters, information on hydrology, geology, geophysics, hydrogeology, geochemical, in aquifer delineation (vertical and lateral) and gap in aquifer wise water level and draft data etc.
2.	Generation of Data	Generation of geological layers (1:50,000)	Preparation of sub-surface geology, geomorphologic analysis, analysis of land use pattern.
		Surface and sub-surface geo-electrical and gravity data generation	Vertical Electrical Sounding (VES), bore-hole logging, 2-D imaging etc.
		Hydrological Parameters on groundwater recharge	Soil infiltration studies, rainfall data analysis, canal flow and recharge structures.
		Preparation of Hydrogeological map (1:50, 000 scale)	Water level monitoring, exploratory drilling, pumping tests, preparation of sub-surface hydrogeological sections.
		Generation of additional water quality parameters	Analysis of groundwater for general parameters including fluoride.
3.	Aquifer Map Preparation (1:50,000 scale)	Analysis of data and preparation of GIS layers and preparation of aquifer maps	Integration of Hydrogeological, Geophysical, Geological and Hydro-chemical data.
4.	Aquifer Management Plan	Preparation of aquifer management plan	Information on aquifer through training to administrators, NGO's, progressive farmers and stakeholders etc. and putting in public domain.

The aquifer mapping and management plan of Kakinada district is broadly carried out in following steps:

2.1 Data gap analysis, generation and Data Compilation: The identification of data gap was done after the detailed analysis, examination, synthesis and interpretation from available sources. The conversion of analog data in the form of digital data that could be processed readily on GIS platform. The data from erstwhile east Godavari district, basic data reports of exploratory wells/observation wells/ piezometers drilled by CGWB, details of wells drilled by State Departments, geophysical data of CGWB are compiled and integrated for aquifer mapping.

CGWB had drilled 09 no. of Exploratory wells, carried out 65 Vertical Electrical Soundings (VES) in the district so far. The ground water regime is being monitored form 54 GWM stations of both CGWB and GW & WA department (CGWB: 25 and GW & WA:29). The spatial distribution of data points is provided in Fig-2.1 and the no. of data points utilized for NAQUIM is provided in Table-2.2. The density of the data calculated as 1data point for 41 sq kms for deciphering the lateral and vertical disposition of aquifers, 1 data points per 56 sq kms for understanding the spatial and temporal variation in ground water regime including ground water quality. The data is utilized for NAQUIM in the district.

Table 2.2: Status of Data Integration

S. No.	Activity	No. of data Points	Density
1	Exploration	15	1 well/201 sq. kms
2	Geophysical	65	1 VES/46.6 sq. kms
	GW Regime Monitoring		
3	GW Quality Monitoring Stations	54	1 GWM/56 sq. kms
4	Ground water level Monitoring Stations	54	1 GWM/56 sq. kms

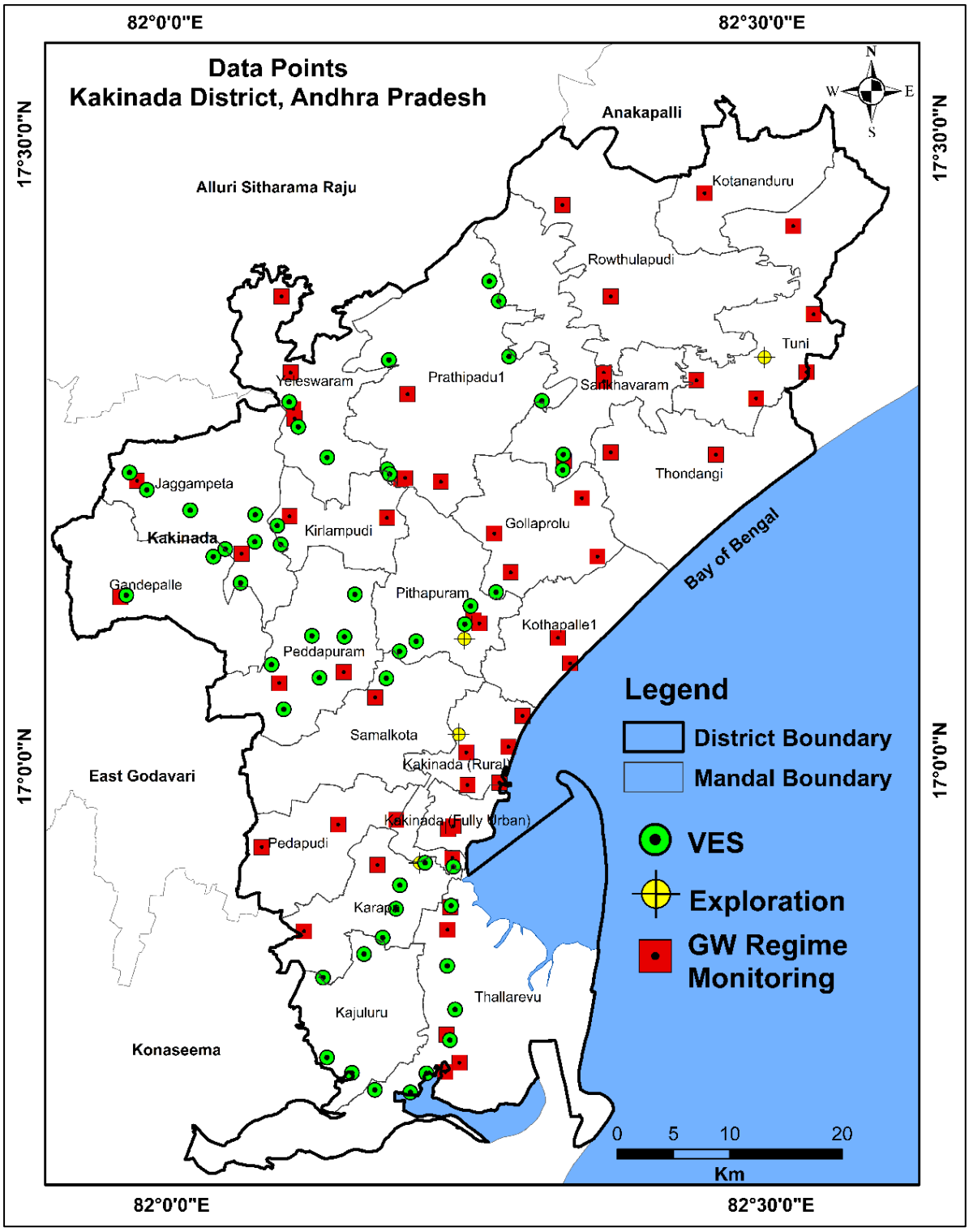


Fig. 2.1: Hydro geological data availability.

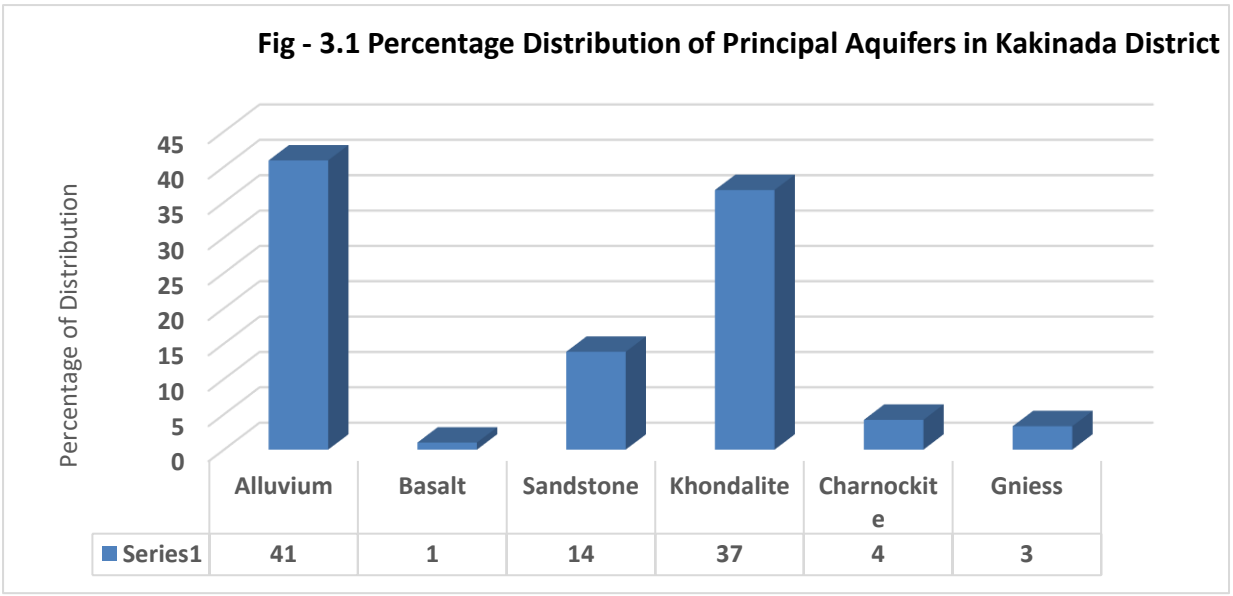
3. Geology, Hydrogeology and Aquifer Characterization

The district is underlain by Eastern Ghat Mobile Belt of Archaean age, Basalts of Mesozoic age, Sandstones of Teritiary age and Alluvium of Recent age. The Eastern Ghat Mobile Belt of Archaean age include Khondalites, Charnockites and Gneisses. The Mesozoic basalts, Teritiary sandstones and recent alluvium overlie the Archaeans. The lithological units of Khondalite Group include quartzite, talc- granulite and talc-silicate rock. The Charnockite Group include pyroxene granulite (basic Charnockite) and charnockite (acid/intermediate). Quaternary sediments, including brown, residual soil of fluvial origin occur along the river courses. Thick mantle of flood plain deposits comprising clay and silt in the district. The geological map and percentage distribution of geological formations in the district is shown in Fig-3.1 and 3.2 respectively. The distribution of lithological units is shown in Table- 3.1.

Table- 3.1: Distribution of Lithological units, Kakinada District, AP

S. No.	LITHOLOGY	Code	Area (Sq. kms)	Percentage (%)
1	Alluvium	AL	1271	41
2	Basalt	BS	31	1
3	Sandstone	ST	430	14
4	Khondalite	KH	1141	37
5	Charnockite	CK	131	4
6	Gneiss	GN	103	3
			3107	100

Fig - 3.1 Percentage Distribution of Principal Aquifers in Kakinada District



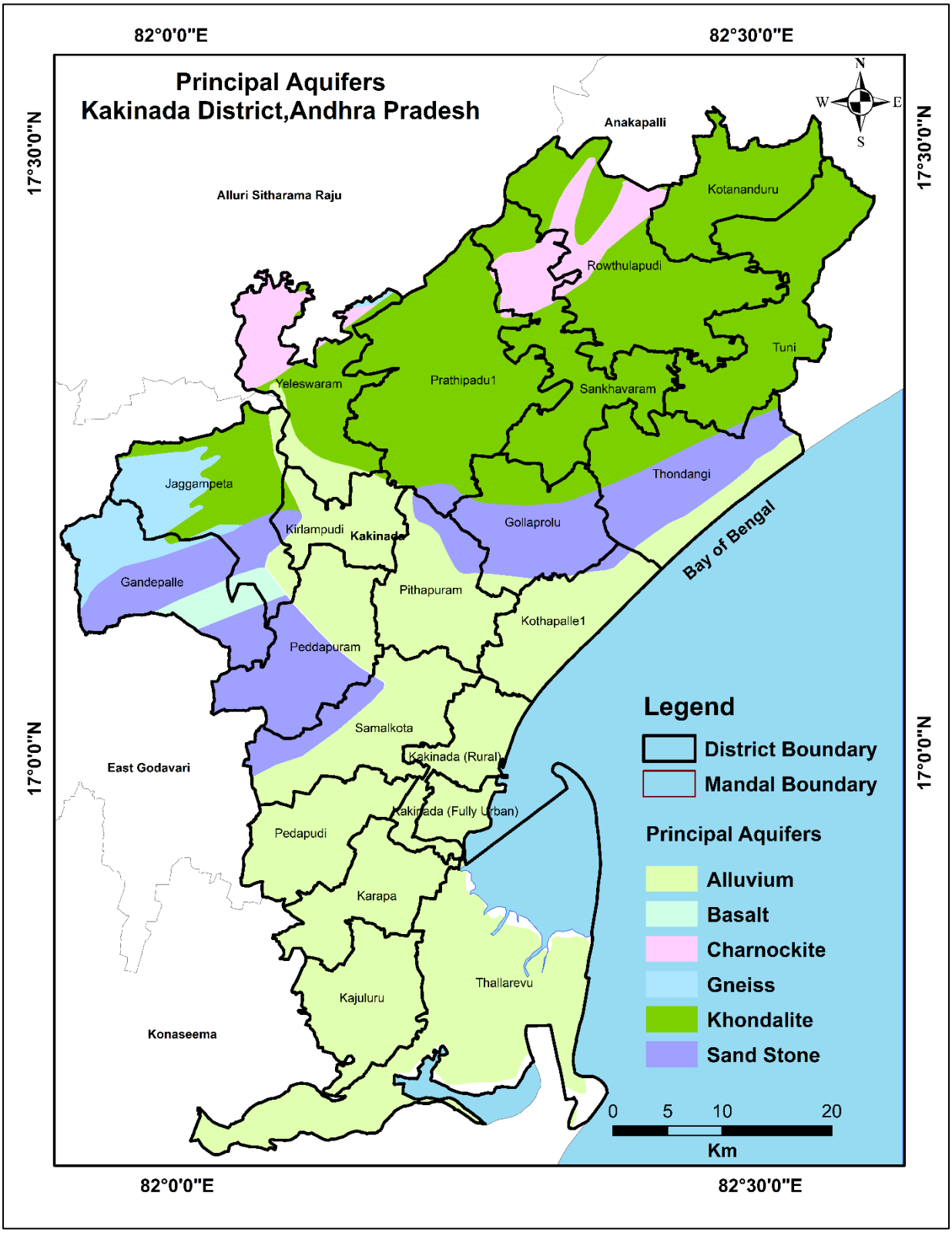


Fig.3.2: Geology of Kakinada district.

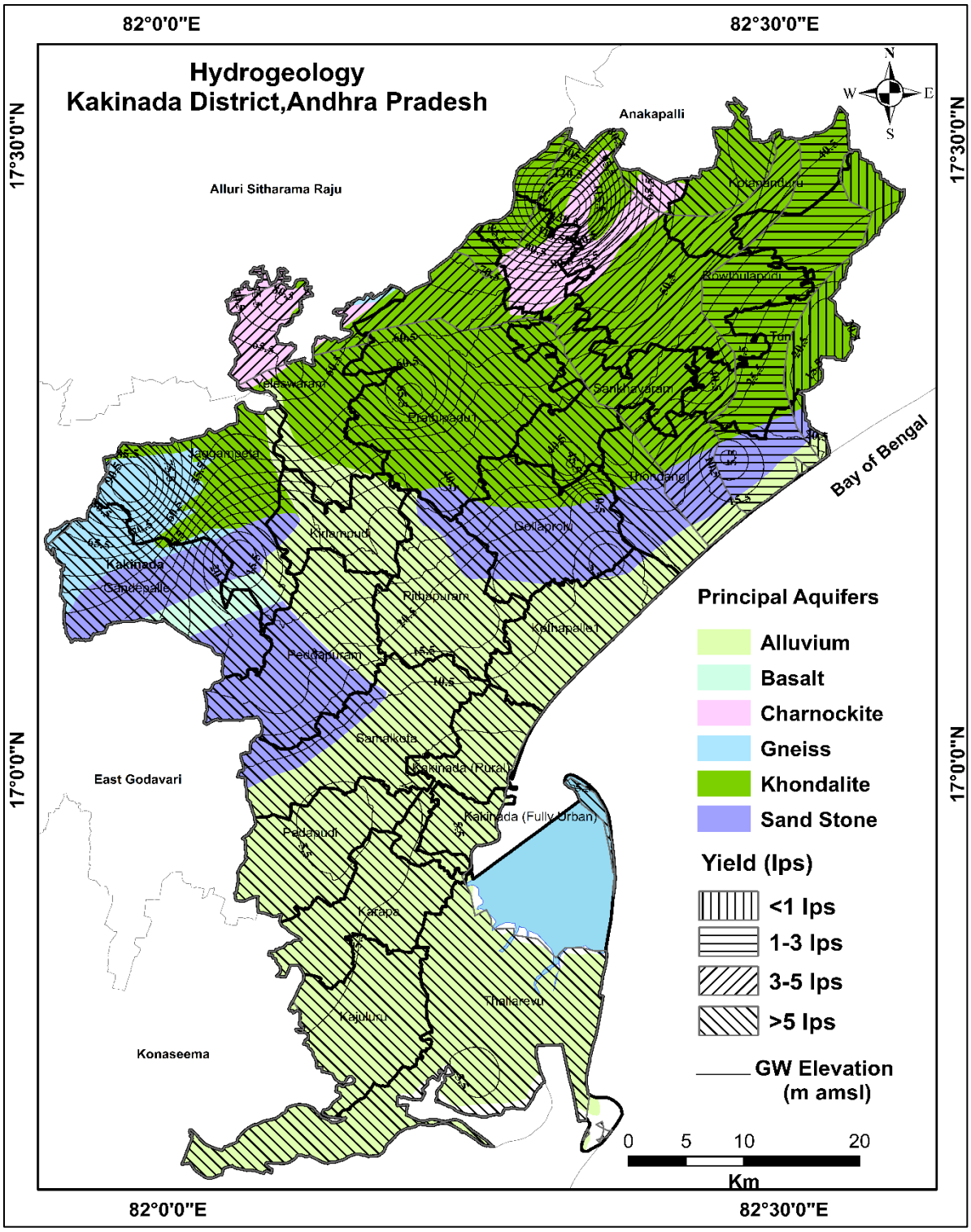


Fig-3.3 Hydrogeology Map of Kakinada district

Hydrogeology is concerned primarily with mode of occurrence, distribution, movement and chemistry of ground water occurring in the subsurface in relation to the geological environment. The occurrence and movement of water in the subsurface is broadly governed by geological frameworks i.e., nature of rock formations including their porosity (primary and secondary) and permeability. The principal aquifer in the area is Archean Khondalites, Charnockites etc overlain by Sandstones and Recent Alluvium. The occurrence and movement of ground water in these rocks is controlled by the degree of interconnection of secondary pores/voids developed by fracturing and weathering of hard and crystalline formation and presence of sand and clay layers in alluvium formation.

Data analysed from CGWB exploration and VES studies indicates that the weathering ranges from less than 3 m to 10 m with an average weathering thickness of 5 m. The fracture occurs in range of <30 m to >90 m with major occurrence at depth range between 30 to 60 m depth. The yield ranges from <1.0 to 5 lps.

3.1.1 Weathering Thickness: The area underlain by khondalites and Charnokites in the district is about 768 sq. kms. The weathering occurrence is confined to these formations. The Thickness of weathered zone varies from <3 m to 10 m with an average thickness range of 5 m. The spatial distribution of weathering thickness is shown in Fig.3.4. Thickness of weathering < 3 m occurs in ~6.5 % of the area, 3 to 6 m occurs in ~83 % of area, 6 to 9 m occurs in 10 % of area and >9 m occurs in 0.5% area.

Table 3.2- Distribution of Weathering Thickness

S. No.	Weathering Thickness (m)	Area (Sq kms)	Percentage
1	0 to 3 m	48.8	6.4
2	3 to 6 m	636.1	82.8
3	6 to 9 m	78.6	10.2
4	> 9 m	4.6	0.6
		768.2	**100**

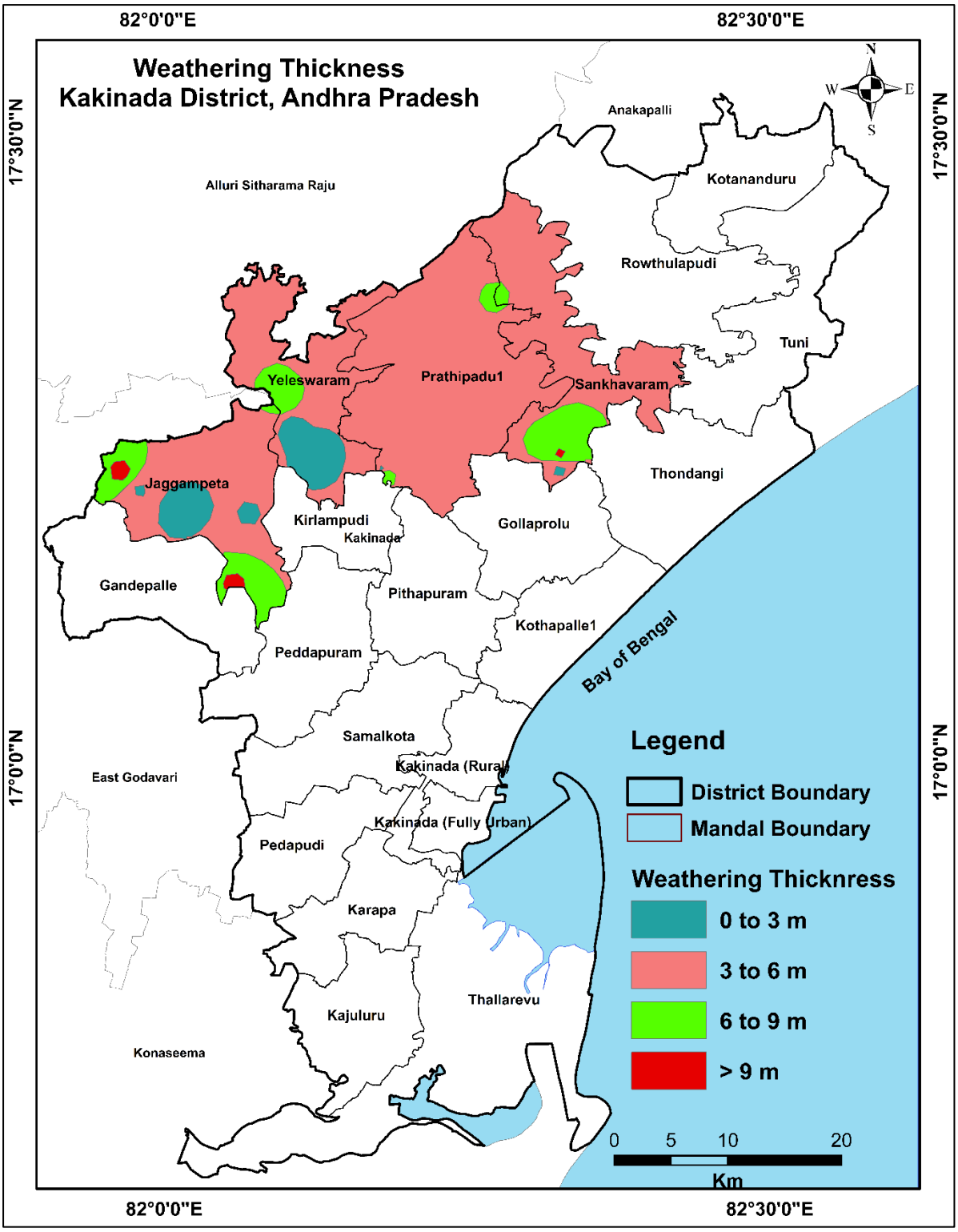


Fig-3.4 Depth to weathered zone of Kakinada district

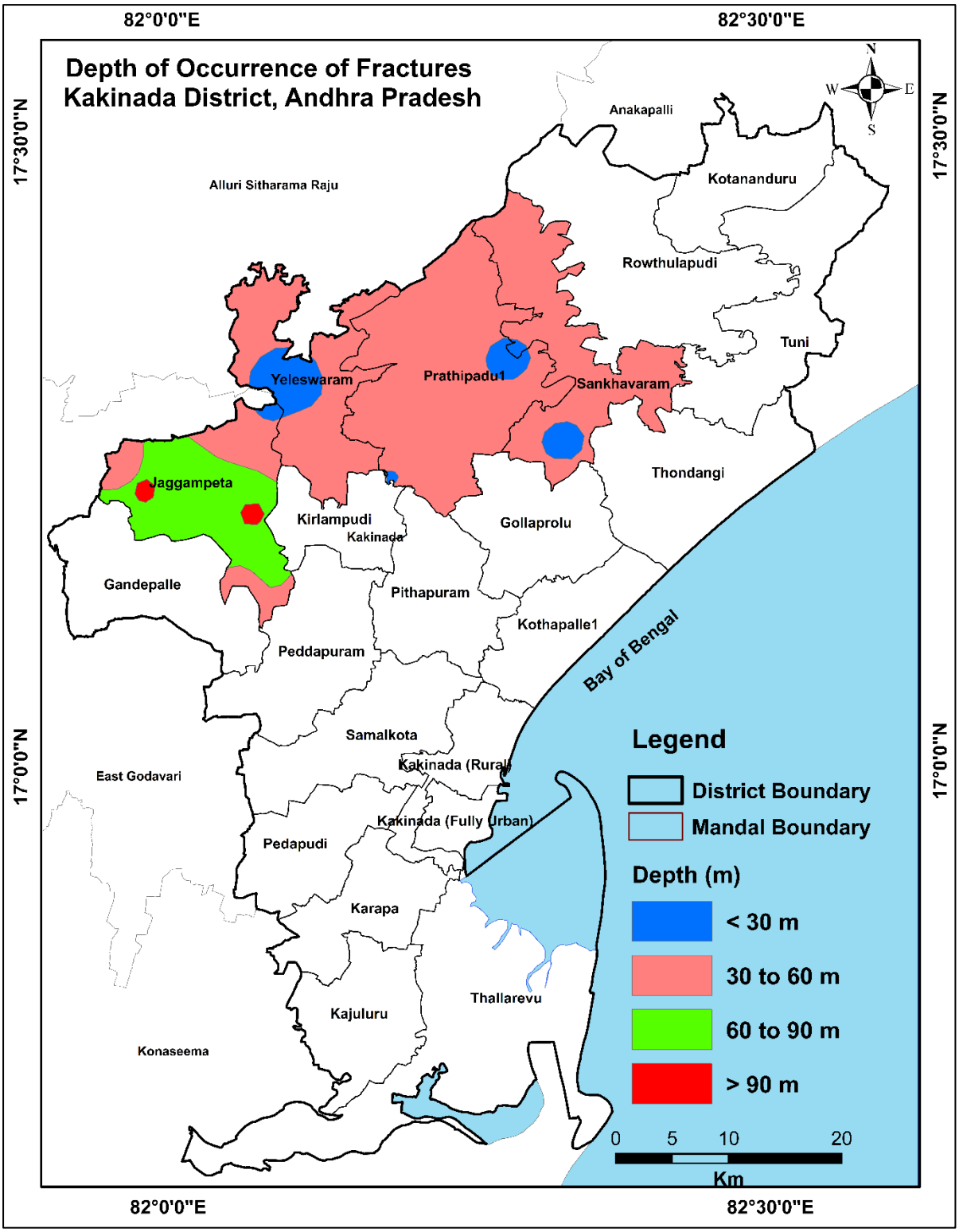


Fig-3.5 Depth of Fractured zone of Kakinada district

3.1.2. Fractured zone: The depth of fracturing varies from 10 to 100 m. From the data, it is inferred that fractures in the range of 30 to 60 m depth are more predominant (78 % of the area), 60 to 90 m occur in 14 % area; < 30 m occurs in 6% of the district. The Depth wise distribution of fractures is shown in Fig.3.5

Table 3.3- Depth of occurrence of Fractures

S No	Depth of Fracture Occurrence (m)	Area (Sq kms)	Percentage
1	< 30 m	48.7961	6.35
2	30 to 60 m	605.857	78.87
3	60 to 90 m	108.078	14.07
4	> 90 m	5.54629	0.72
		768.2	**100**

3.1.3. Ground Water Yield: The yield ranges from <1.0 to 5 lps. In majority of the area, the ground water yield in the range of 5 lps (72% area) followed by 3 to 5 lps and <1 lps. The map showing ground water yield of the district is shown in Fig.3.6.

Table 3.3- Yield Percentage

S No.	Yield Category	Area (Sq kms)	Percentage
1	<1 lps	66.8421	2.21
2	1-3 lps	258.208	8.55
3	3-5 lps	516.778	17.11
4	>5 lps	2177.88	72.12
		3019.7081	**100**

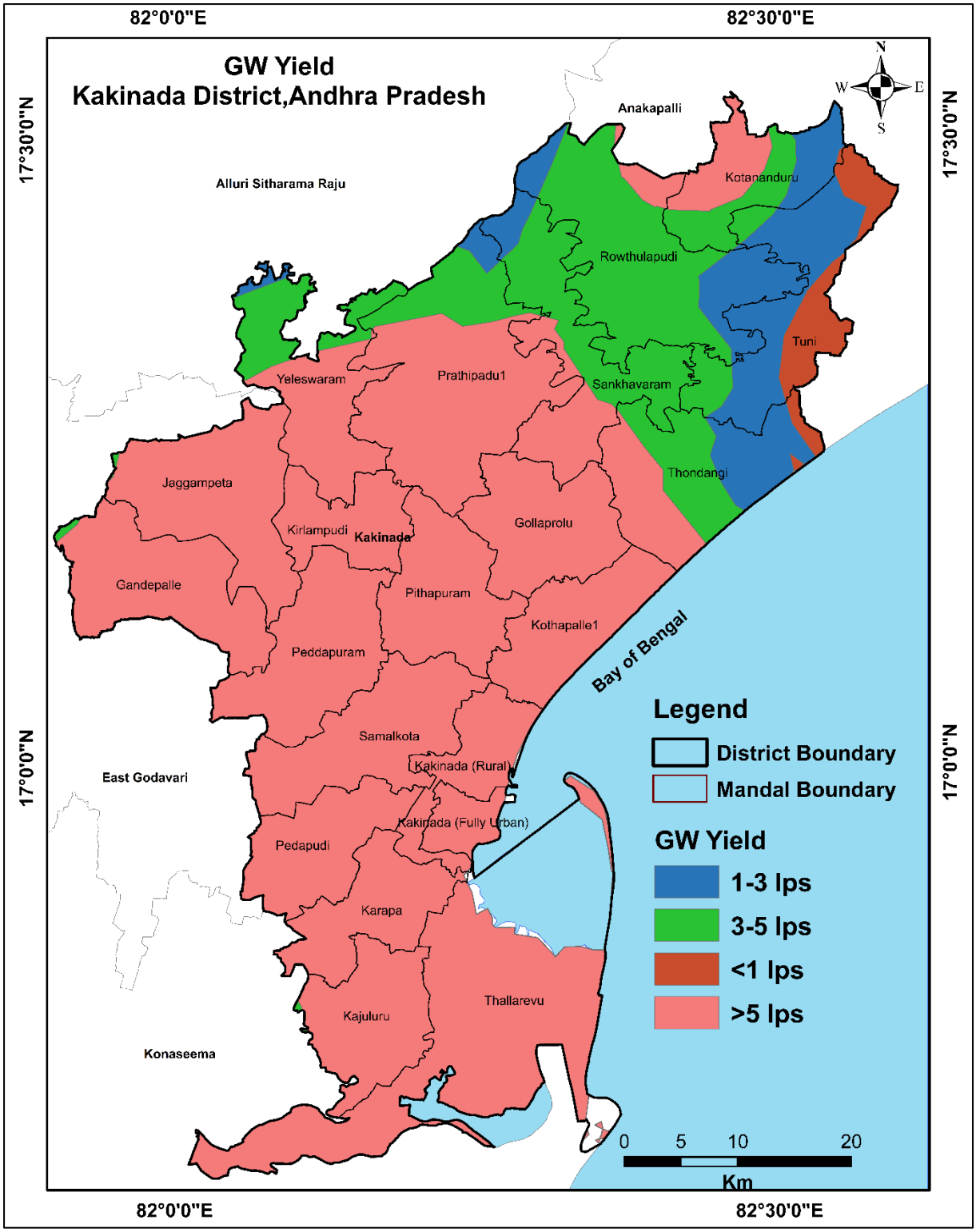
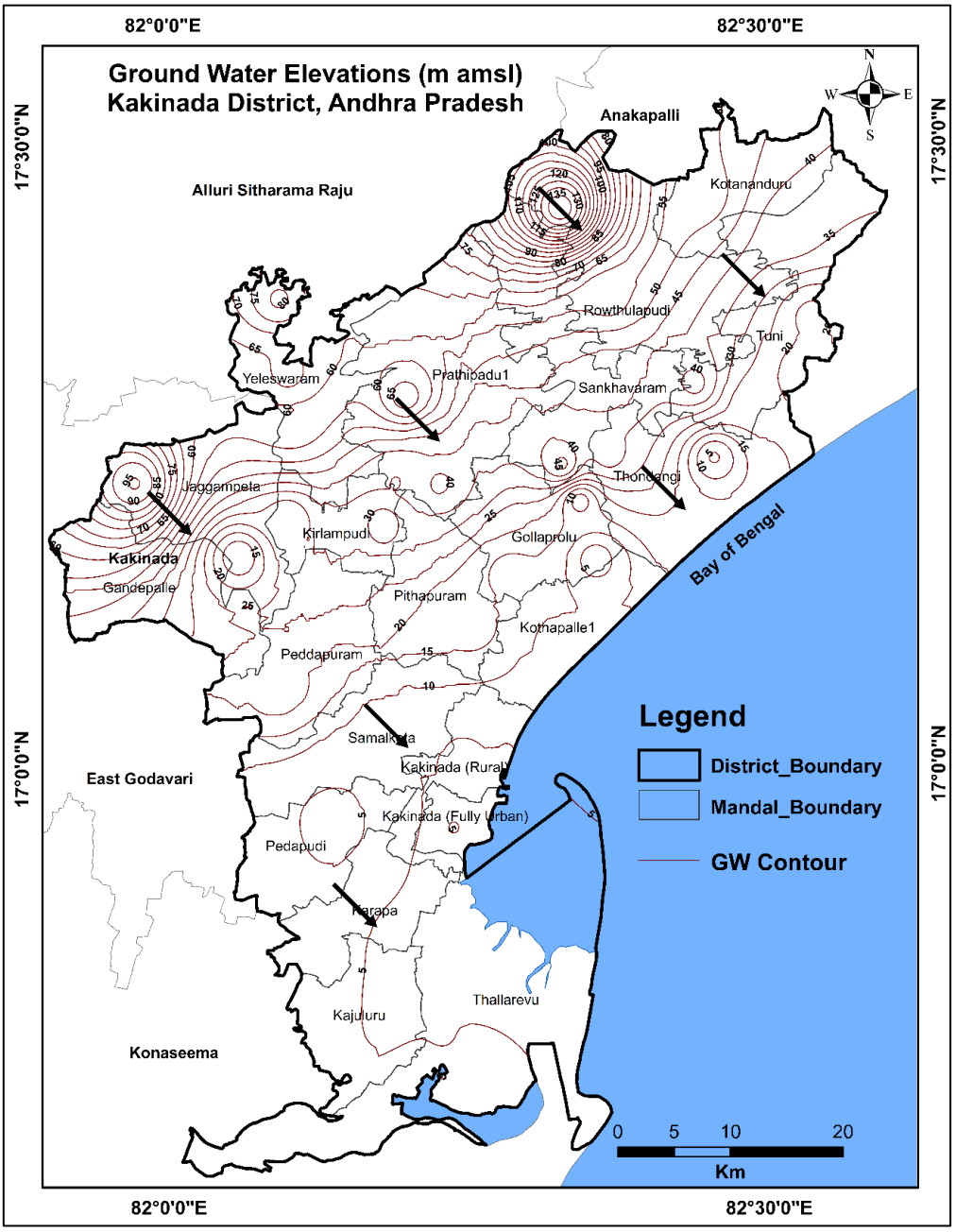


Fig-3.6: Ground Water yield potential map of Kakinada district.

3.2 Depth to Water Levels: Ground Water Levels are continuously being monitored by Central Ground water Board and Ground Water & Water Department in the district. The data of Ground water level monitoring from 55 monitoring stations (CGWB: 30 and SGWD: 25) of both pre and post-monsoon seasons (2012 to 2023) was utilized for understanding the ground water regime of the district.

3.2.1 Water Table Elevations: During pre and post-monsoon season (May and November), the water-table elevation ranges from <1 m amsl to 139 m amsl. **(Fig.3.7)**



3.7 Ground Water Elevation map of Kakinada district.

3.2.2 Long Term Depth to Water Levels (DTWL): The average DTWL of 10 years (2012 to 2023) for pre-monsoon and post-monsoon were analysed, the avg. DTWL varies from 1.2 m to 68.3 meter below ground level (m bgl) (average: 8.5 m bgl) and 0.5 to 61.9 m bgl (average: 5.8 m bgl) during pre-monsoon and post-monsoon seasons respectively.

3.2.2 (a) Pre-monsoon season: Majority of the water levels during this season are in the range of < 5 m covering 63 % of the area, followed by 5 to 10 m bgl (18 %) and 10 to 15 m (4%). DTWL more than 25 m is observed in 7.5 % of area in upland areas of Kakinada district. (**Fig.3.8**).

S No.	Class	Area (Km^2)	Percentage
1	< 5 m	1902	63
2	5 - 10 m	543	18
3	10 - 15 m	128	4
4	15 - 20 m	115	4
5	20 - 25 m	107	4
6	> 25 m	225	7
		3020	**100**

3.2.2 (b) post-monsoon season: Majority of the water levels during this season are in the range of <5 m (71%) of the area, followed by 5 to 10 m bgl (16 %) and > 25 m (3%) of area. (**Fig.3.9**).

S.No.	Class	Area ($Km^{2)}$	Percentage
1	< 5 m	2159	71
2	5 - 10 m	487.35	16
3	10 - 15 m	98	3
4	15 - 20 m	80.1	3
5	20 - 25 m	95	3
6	> 25 m	101	3

3.2.3 Depth to water Levels (2023): The DTWL of 2023 for pre-monsoon and post-monsoon were analysed. the avg. The DTWL varies from 0.4 m to 73.63 meter below ground level (m bgl) (average: 7.04 m bgl) and 0.72 to 85.50 m bgl (average: 7.21 m bgl) during pre-monsoon and post-monsoon seasons respectively.

3.2.3 (a) Pre-Monsoon Season: Majority of the water levels during this season are in the range of < 5 m covering 57 % of the area, followed by 5 to 10 m bgl (28 %) and 10 to 15 m (7%). DTWL more than 25 m is observed very sporadically in upland areas of Kakinada district.

S No.	Class	Area (Km^2)	Percentage
1	< 5 m	1716.00	56.80
2	5 - 10 m	832.95	27.57
3	10 - 15 m	198.97	6.59
4	15 - 20 m	109.20	3.61
5	20 - 25 m	78.78	2.61
6	> 25 m	85.00	2.81
		3020.90	**100**

3.2.3 (b) post-monsoon season: Majority of the water levels during this season are in the range of <5 m (73%) of the area, followed by 5 to 10 m bgl (11 %) and > 25 m (3%) of area. (**Fig.3.11**).

S.No.	Class	Area Km^2	Percentage
1	< 5 m	2213.2	73.28
2	5 - 10 m	331.774	10.98
3	10 - 15 m	129.063	4.27
4	15 - 20 m	127.217	4.21
5	20 - 25 m	118.528	3.92
6	> 25 m	100.501	3.33
		3020.283	**100**

3.2.4. Long term water level trends: Trend analysis for the last 10 years (2013-2023) is studied from 55 hydrograph stations of CGWB and SGWD for pre-monsoon and post-monsoon season respectively.

It is observed that during pre-monsoon season 23 wells shows falling trend ranging from 0.01 m to 7.20 m/year (Avg: 0.62 m/yr) and 32 wells shows rising trends ranging 0.01 to 1.41 m/yr (Avg: 0.29 m/yrs).

During post-monsoon season 27 wells shows falling trend ranging -0.004 to 1.128 m/yr (Avg:0.212 m/yr) and 28 wells shows rising trend ranging 0.001 to 3.530 m/yrs (Avg: 0.371 m/yrs).

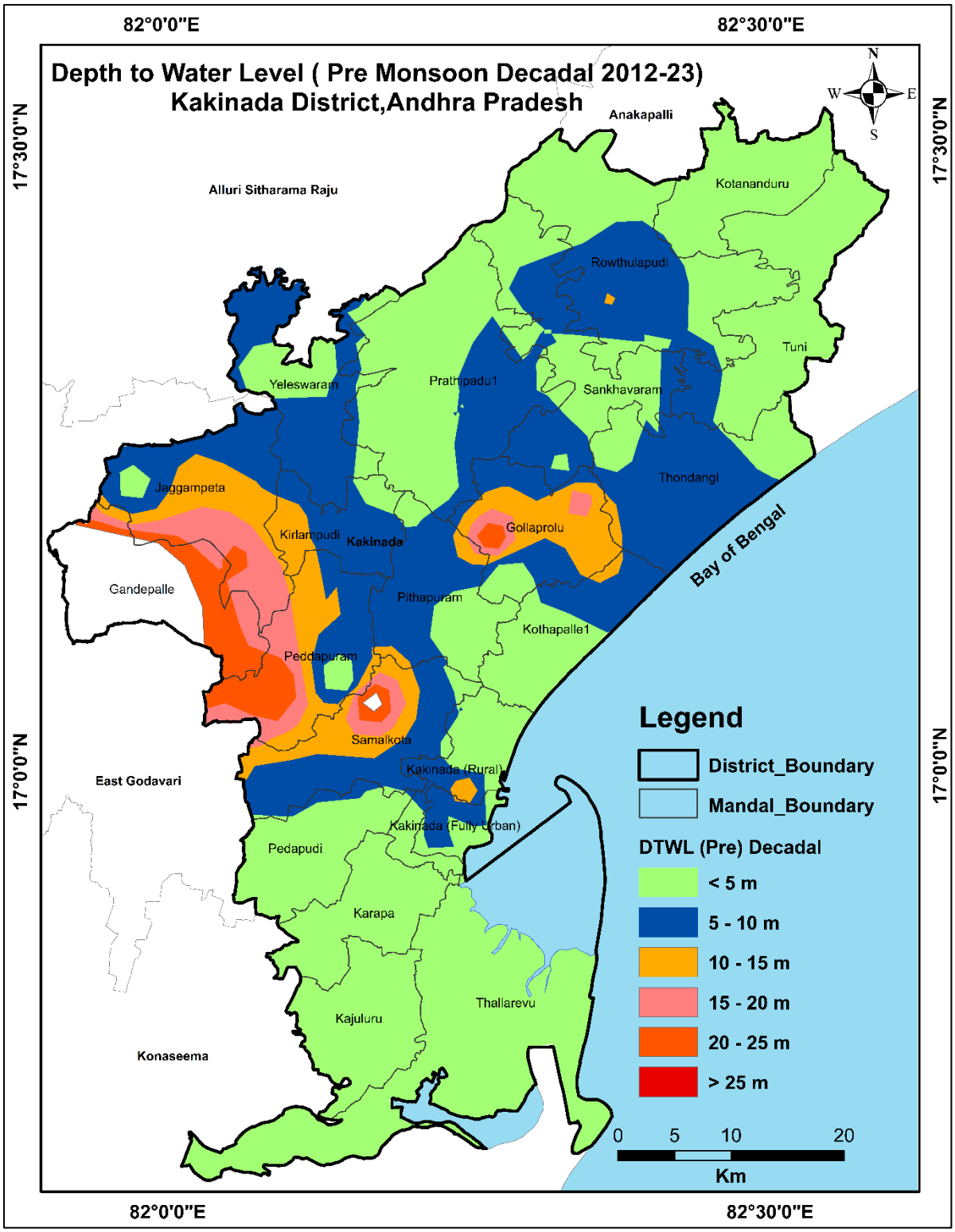


Fig.3.8: Depth to water levels Pre-monsoon (Decadal Average).

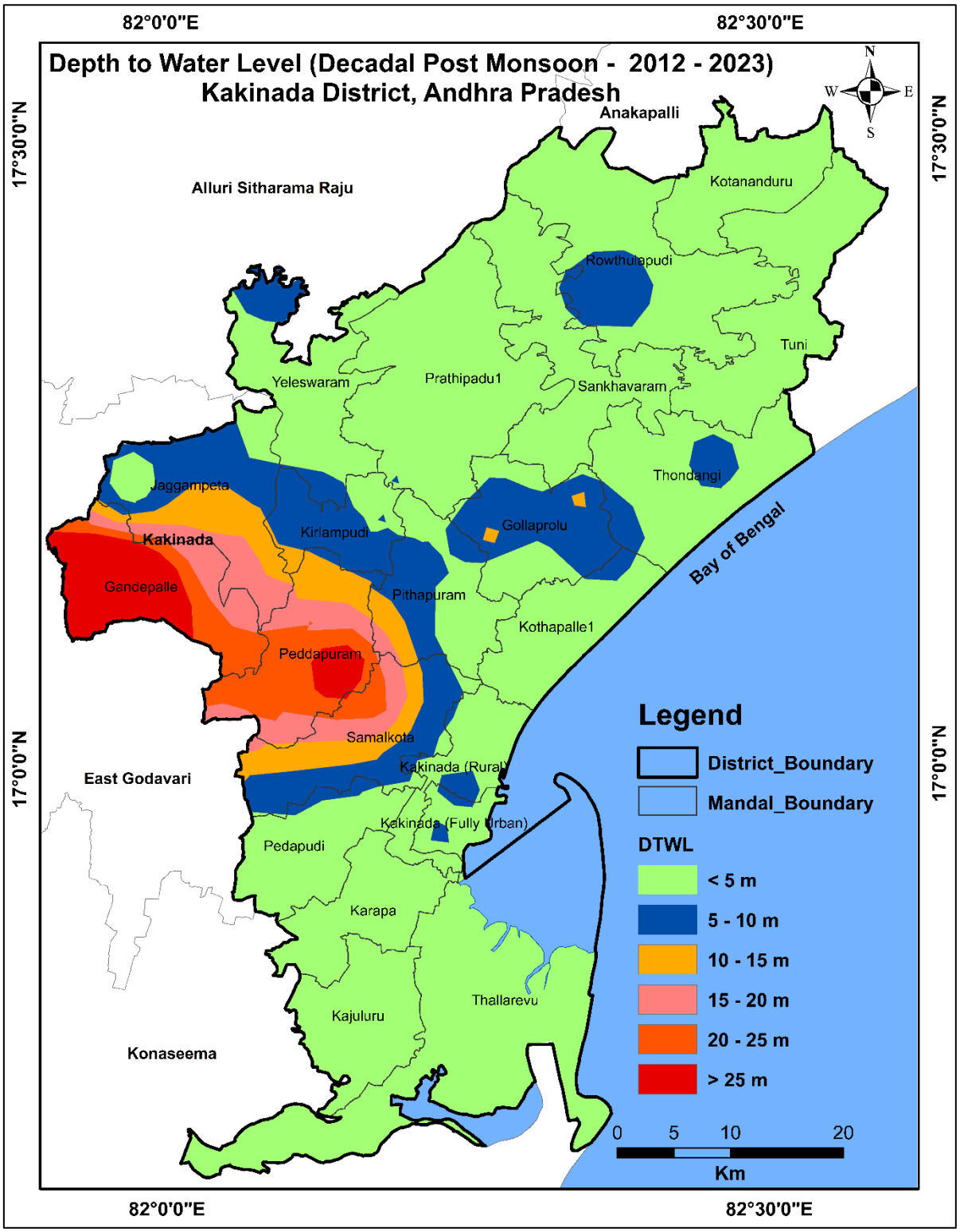


Fig.3.9: Depth to water levels Post-monsoon (Decadal Average).

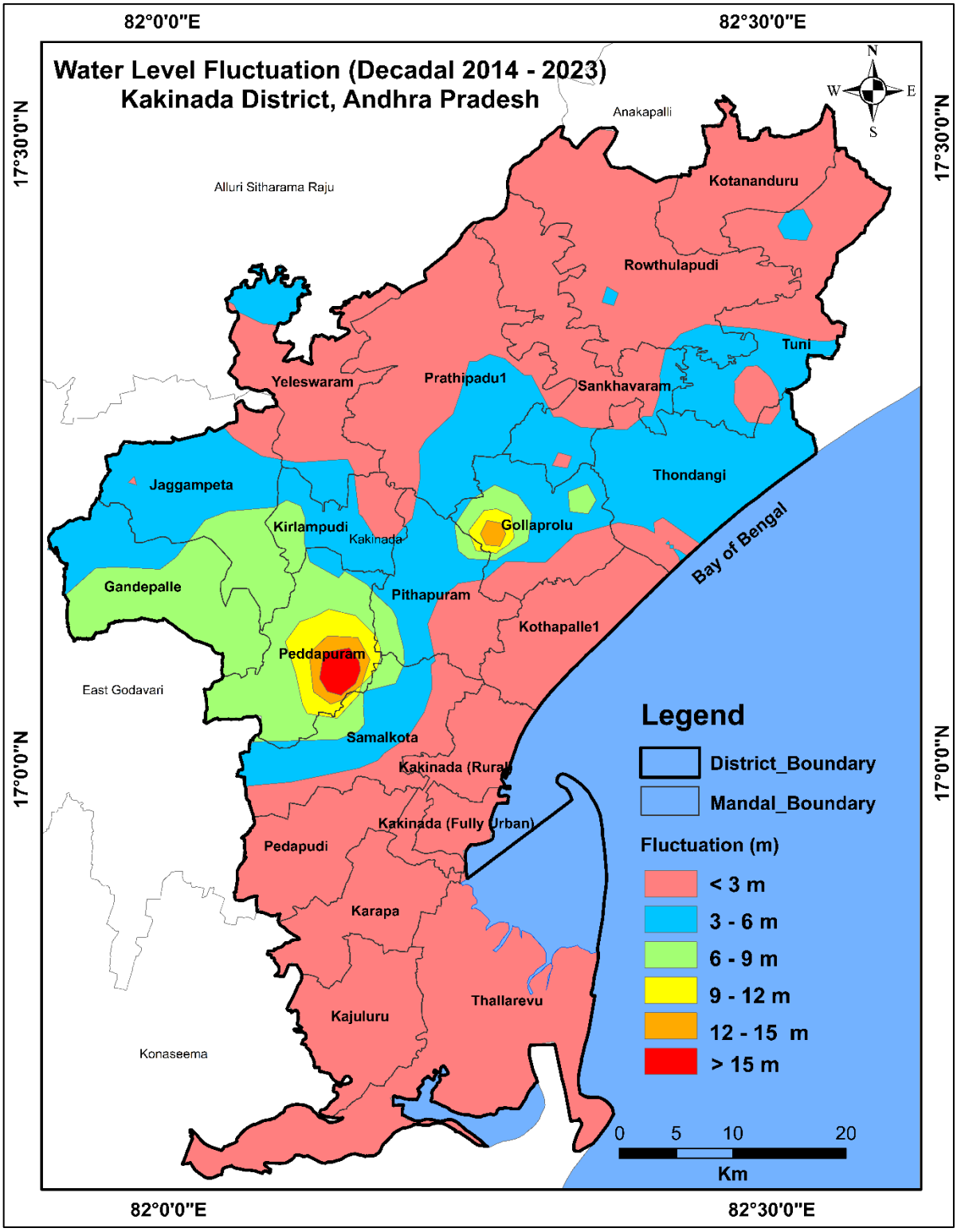


Fig.3.10: Water Level Fluctuations (m) (Nov with respect to May)

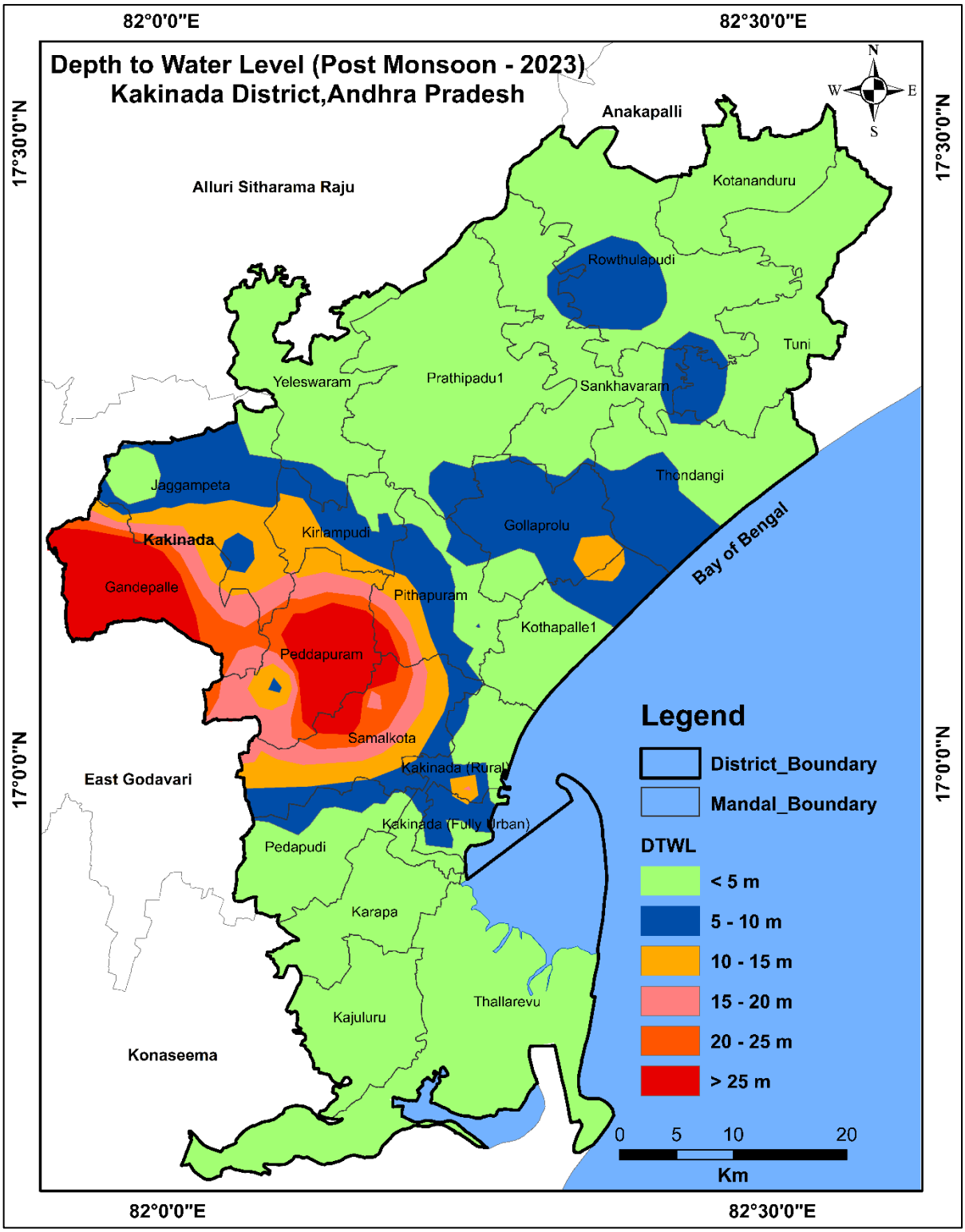


Fig.3.11: Depth to water levels Post-monsoon (Annual).

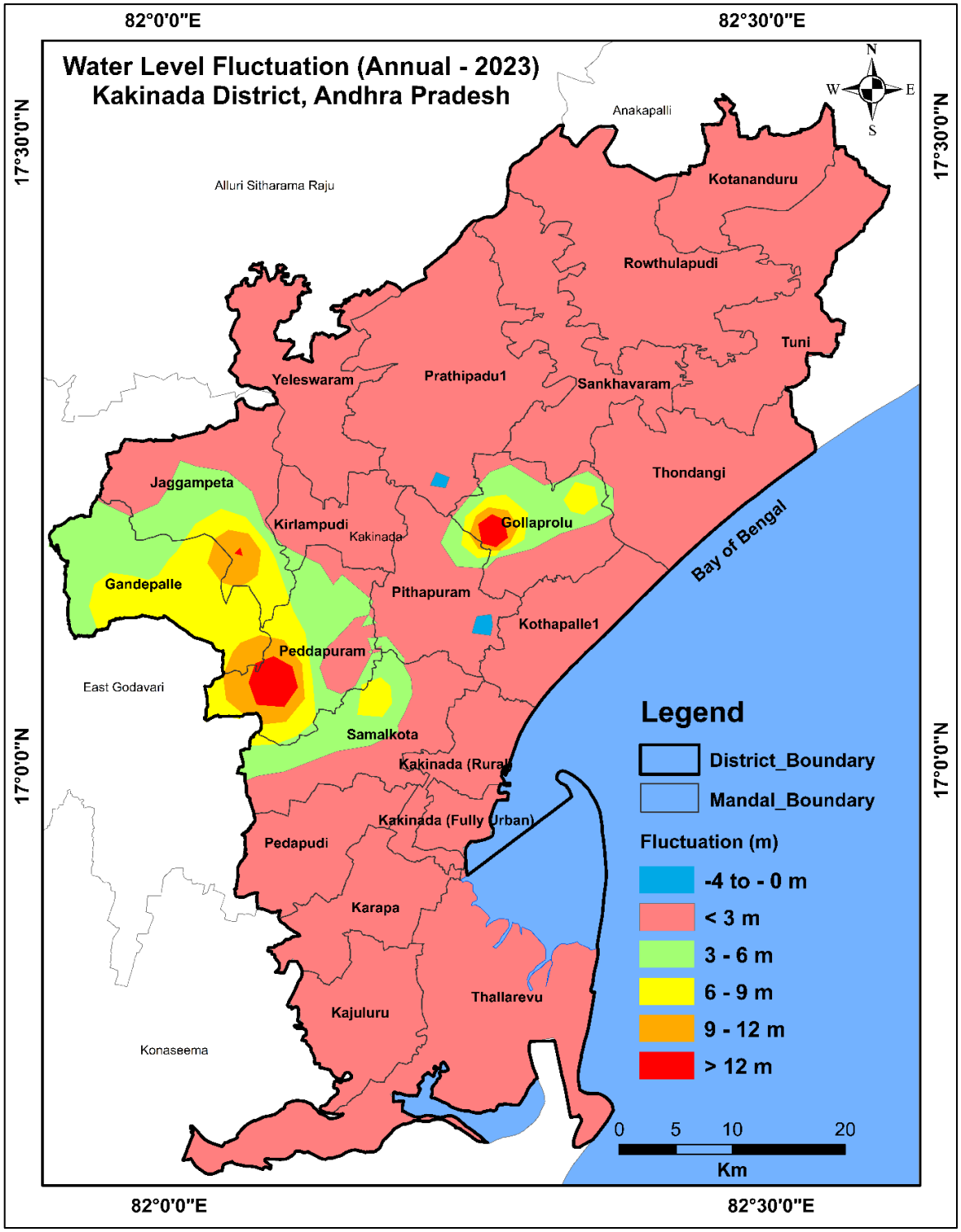


Fig.3.12: Water Level Fluctuations (m) (Nov with respect to May)

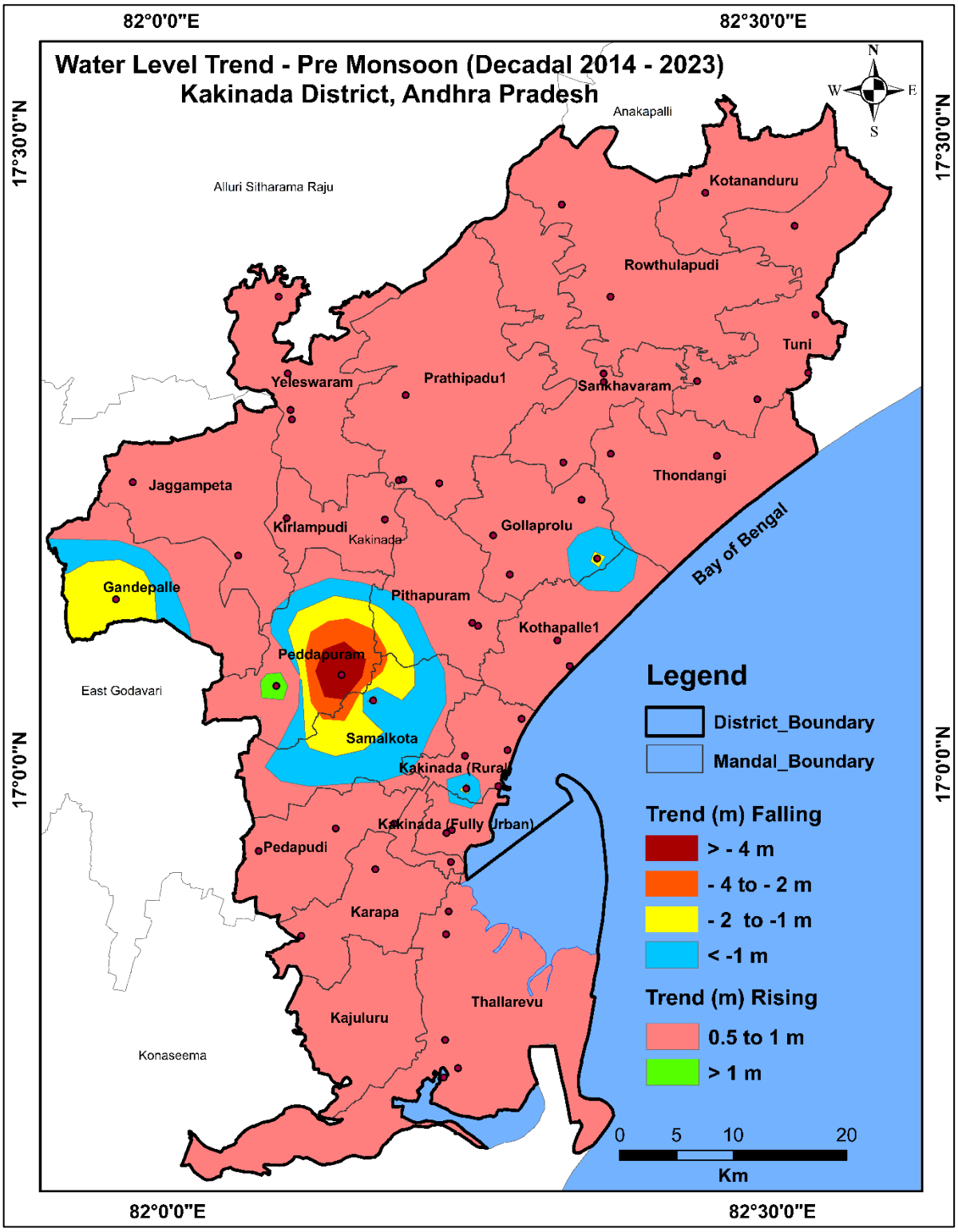


Fig.3.13: Water Level Trend- Pre-monsoon (Decadal Average).

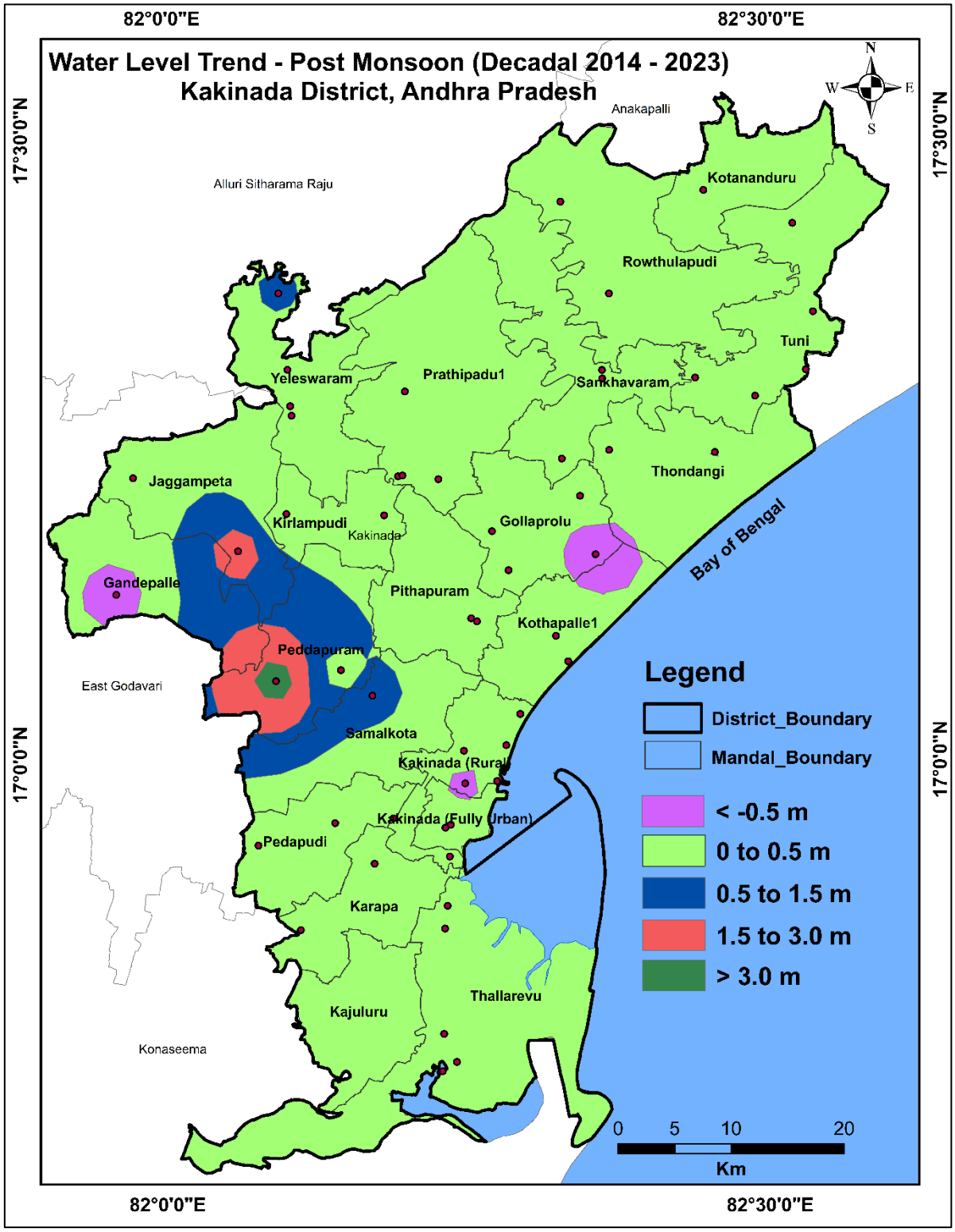


Fig.3.14: Water Level Trend- Post-monsoon (Decadal Average).

3.3. Hydro chemical Studies: For groundwater quality analysis 139 ground water monitoring stations were used for spatial and temporal variation of ground water quality.

Ground Water from the area is mildly alkaline to alkaline in nature with pH in the range of 6.8 to 8.99 (avg: 8.05). Electrical conductivity varies from 110 to 7111 (avg: 1726) µ Siemens/cm**.** In majority of area 2644 sq.km (80 %) EC is within 750 to 2250 µ Siemens/cm; in 1244.34 sq. kms (41%) area, it is in the range of 750 to 1500 and in 1173.64, it is in the range of 1500 to 2250 µ Siemens/cm (39%). In 137.5 sq. kms (4.5 %) area, it is <750 µ Siemens/cm and in 353 sq kms (11.7 %) area is 2250 to 3000 µ Siemens/cm and in 111.58 sq kms (3.7 % area), the EC is more than 3000 µ Siemens/cm. **(Fig.3.15 & Fig.3.16 & Fig 3.16 a).**

S.No.	EC (Pre)	Area	Area in %
1	<750	137.151	4.5
2	750 to 1500	1244.34	41.2
3	1500 to 2250	1173.64	38.9
4	2250 to 3000	353.298	11.7
5	> 3000	111.585	3.7

The Concentration of NO3 ranges from <1 to 240 mg/l with an average 66 mg/l. Nitrate concentration <45 mg/l is observed in 16 samples out of 28 samples and above permissible limit of >45 mg/l is observed 12 samples**.** The concentration of Fluoride (<1.5 mg/l) is within permissible limits in all 139 samples.

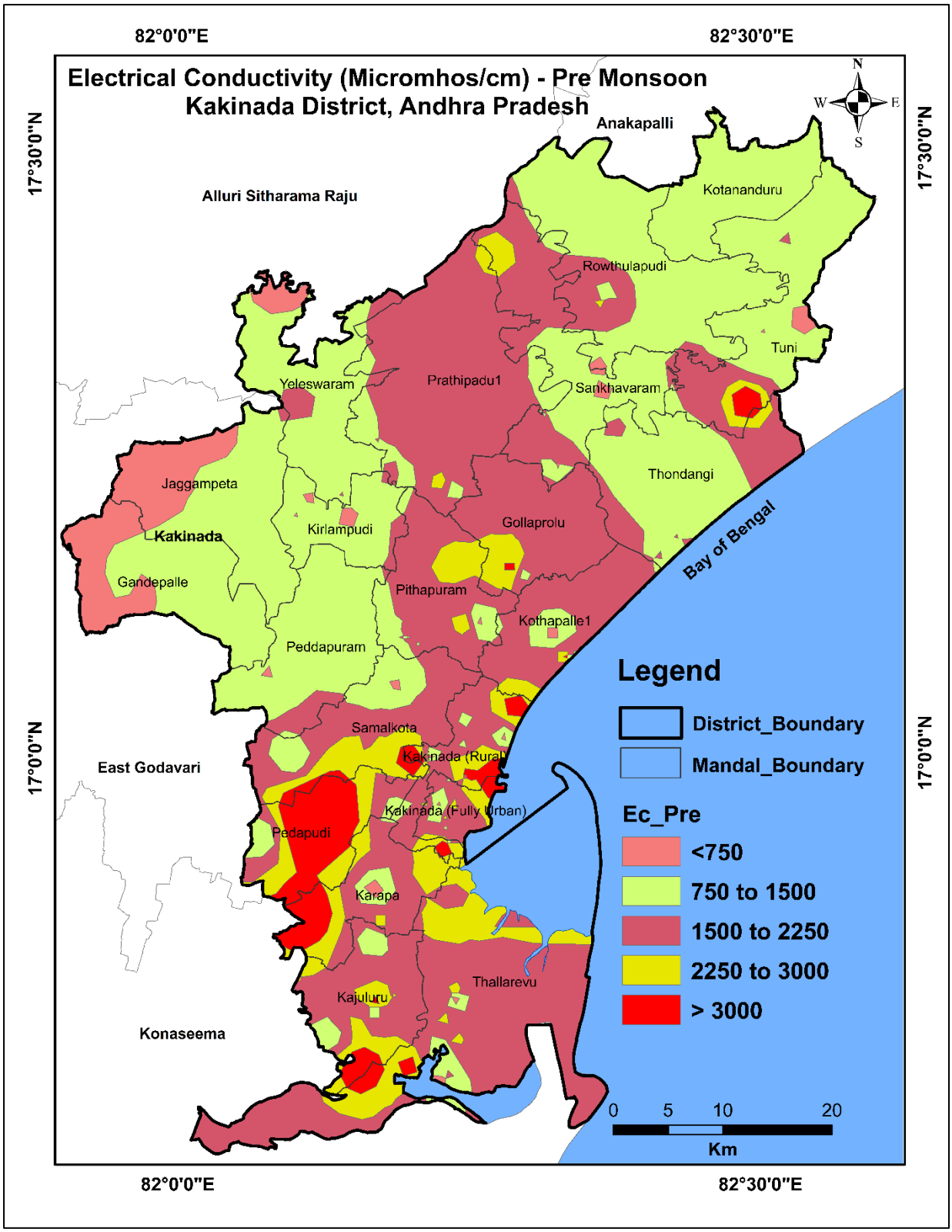


Fig.3.15. Distribution of Electrical Conductivity in Pre monsoon

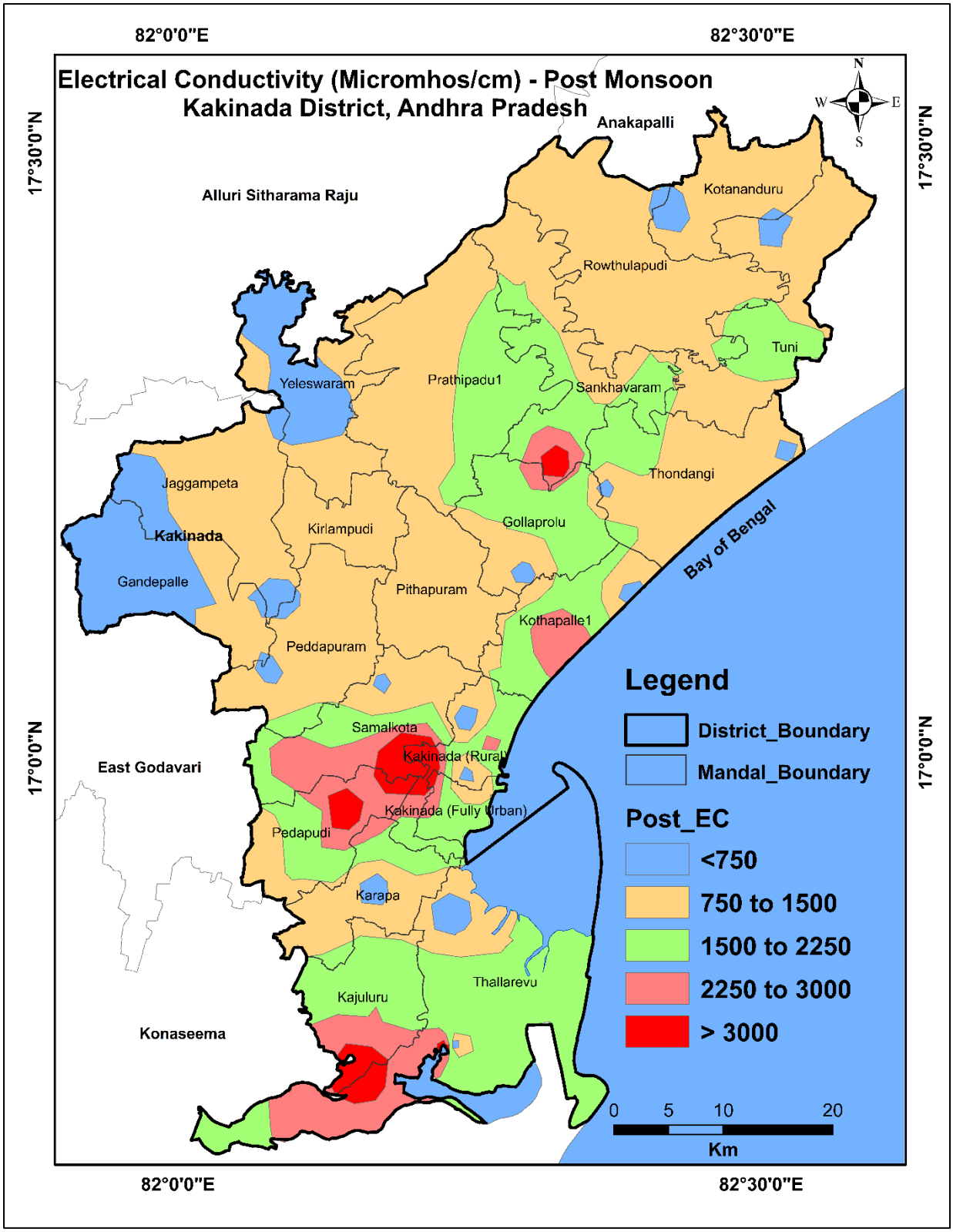


Fig.3.16. Distribution of Electrical Conductivity in Post monsoon

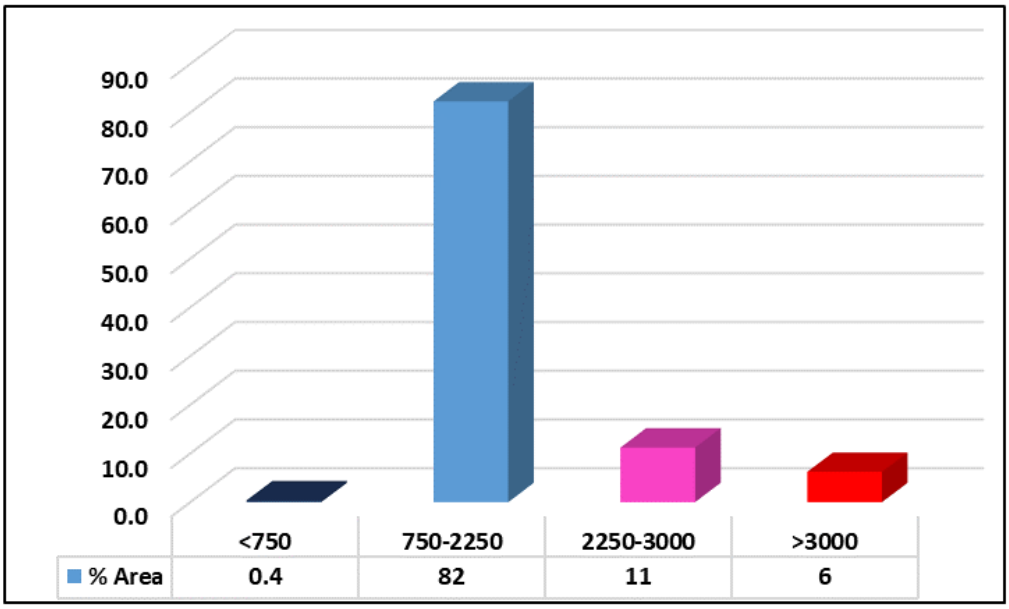


Fig.3.16a: Percentage of area (EC).

4. DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING

Conceptualization of 3-D hydrogeological model was done by interpreting and integrating representative 26 data points (15 exploration and 11 VES). The data is calibrated for elevations with Shuttle Radar Topography Mission (SRTM) data. The lithological information was generated by using the Rock Works-17 software and generated 3-D and hydro geological sections for Kakinada district **(Fig.4.1).** The 2 D hydro geological sections are shown **in (Fig.4.5 & Fig.4.6)**

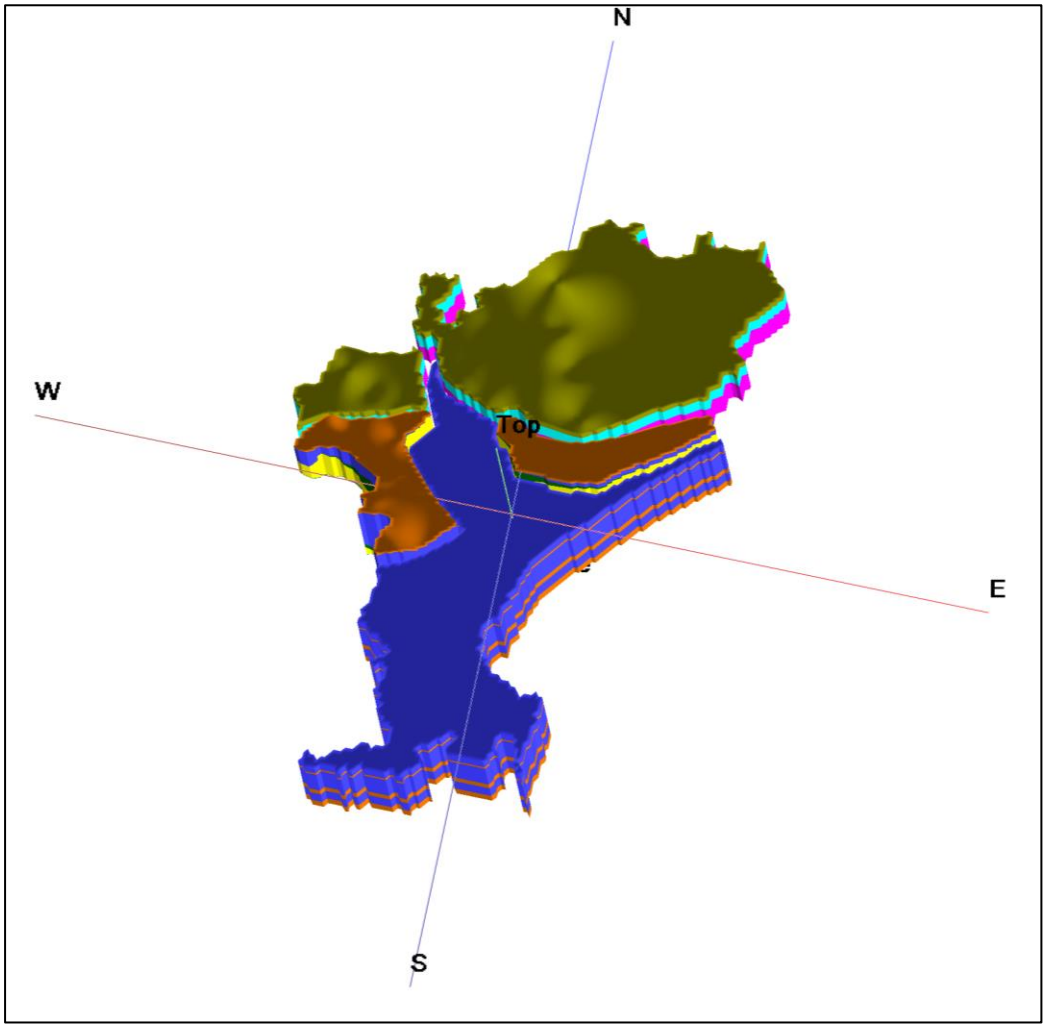


Fig.4.1: Aquifer disposition in 3D, Kakinada district, Andhra Pradesh.

4.1 Conceptualization of aquifer system in 3D:

Aquifers were characterized in terms of potential and quality based on integrated hydrogeological data and various thematic maps. The detailed analysis of the data reveals that the Sandstone, alluvium and Khondalite rocks are the principal aquifer system. Ground water occurs in unconfined, semi-confined and confined conditions in the study area.

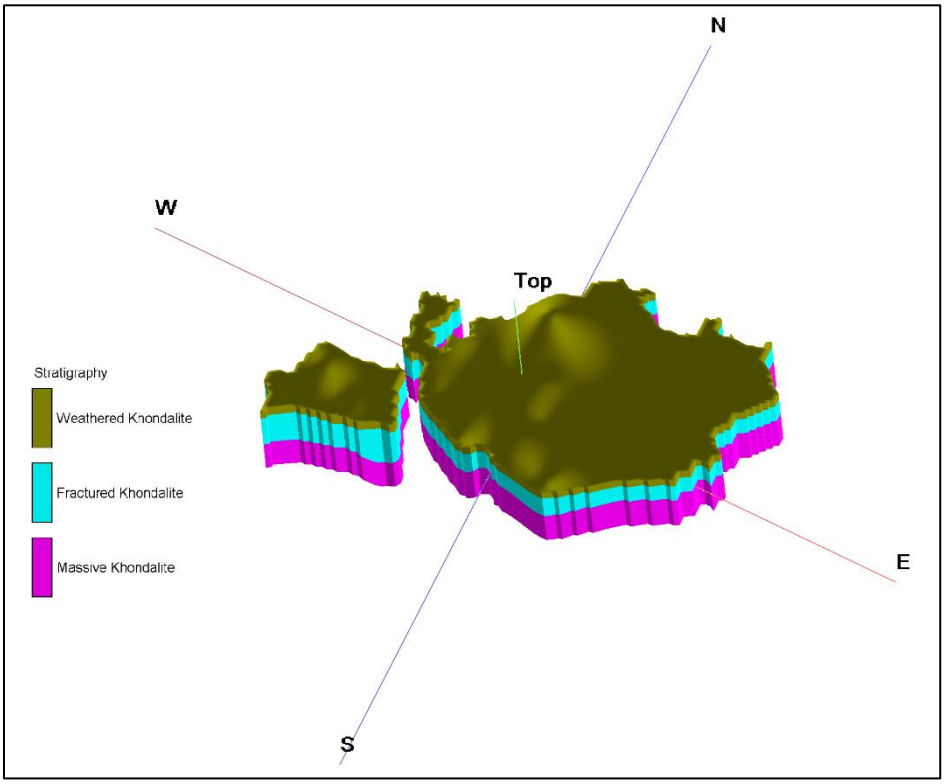


Fig.4.2: 3D Aquifer disposition in Hard Rock

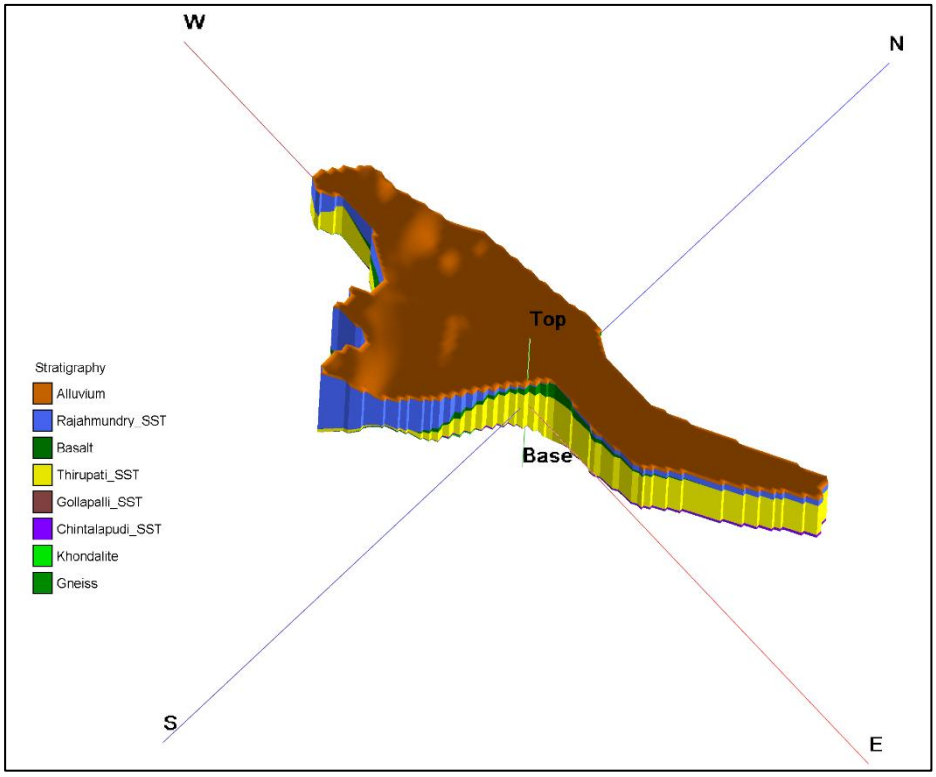


Fig.4.3: 3D Aquifer disposition in Sandstone

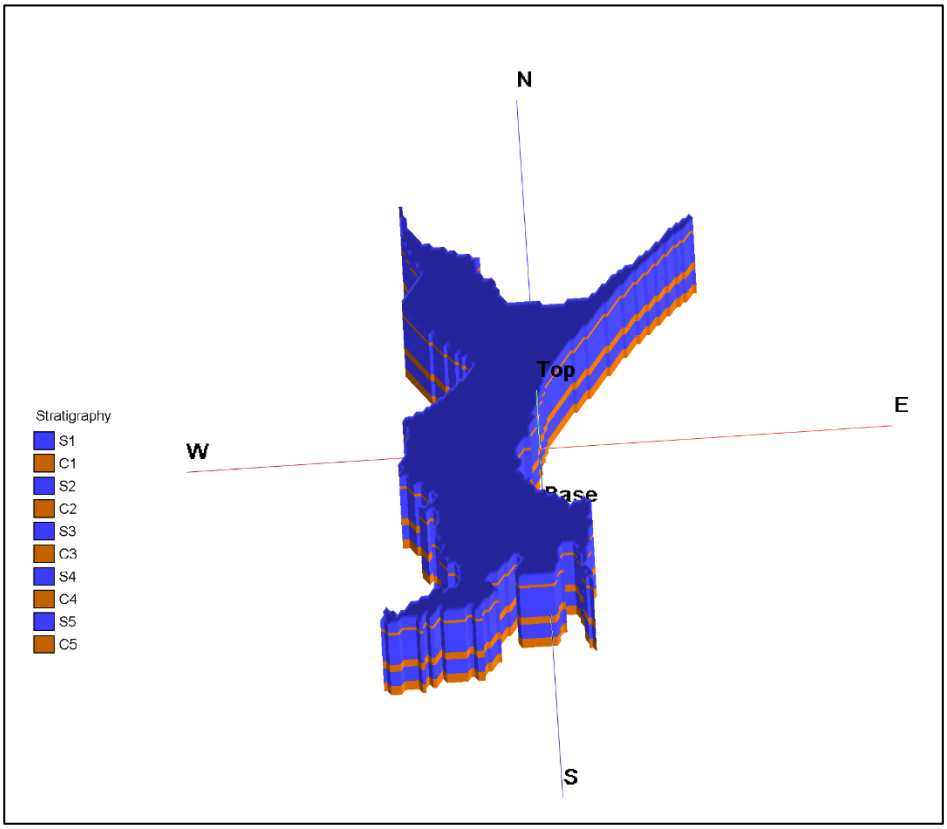


Fig.4.4: 3D Aquifer disposition in Alluvium

4.2 Hydrogeological Sections:

Hydro geological sections are prepared in W-E and SW-NE direction. (**Fig.4.5 & Fig 4.6**).

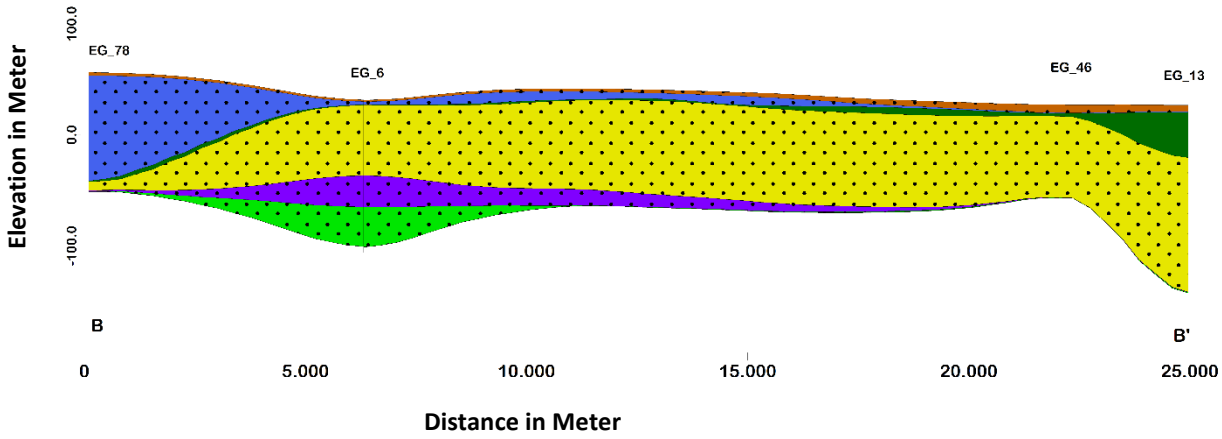


Fig.4.5: Hydrogeological Cross Section (W-E Direction).

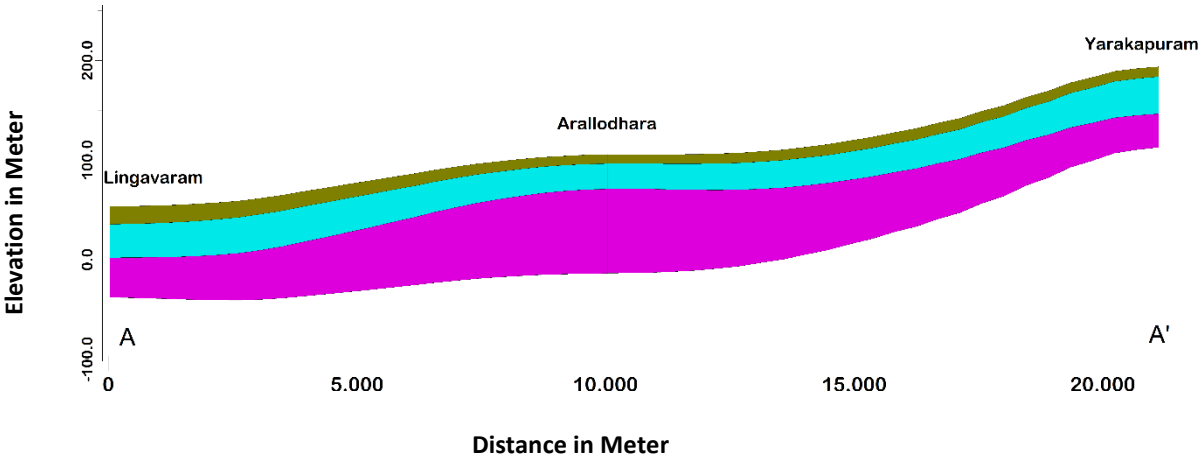


Fig 4.6 Hydro geological Cross Section NE to SW direction

5.0 GROUND WATER RESOURCES (2023)

The dynamic ground water resources are being estimated every year. The recent Ground Water estimation of 2023 of Kakinada district shows that, the net annual extractable groundwater resources in the district are 974.80 MCM, gross ground water draft for all uses 171 MCM, provision for domestic utilisation for the year 2025 is 22 MCM and Net Ground Water Availability for future use is 805 MCM. The stage of ground water extraction varies from 7 % in Kakinada (Rural) to 66% in Kakinada (Urban) with an overall SoE of 21%. Based on the stage of ground water development, all mandals in the district are categorized as Safe. The mandal wise dynamic ground water resources of the Kakinada district, Andhra Pradesh (2022) are given in **Table-5.1and Annexure**

Table-5.1 Ground Water Resources - 2023, Kakinada District

S. No.	Ground Water Resources - 2023, Kakinada District		
1	Total area of the district	Sq kms	3019.79
2	Recharge worthy area	Sq kms	2881.24
3	Recharge from Rainfall - Monsoon	MCM	163.36
4	Recharge from Other Sources - Monsoon	MCM	536.50
5	Recharge from Rainfall - Non-Monsoon	MCM	34.04
6	Recharge from Other Sources-Non-Monsoon	MCM	284.32
7	Total Annual Ground Water Recharge	MCM	1018.22
8	Total Natural Discharges	MCM	50.91
9	Annual Extractable Ground Water Resource	MCM	974.80
10	Irrigation Use	MCM	124.61
11	Industrial Use	MCM	25.78
12	Domestic Use	MCM	20.86
13	Total Extraction	MCM	171.24
14	Annual GW Allocation for Domestic Use as on 2025	MCM	21.91
15	Net Ground Water Availability for future use	MCM	805.10
16	Stage of Ground Water Extraction	(%)	21
17	Categorization (OE/C/SC/Safe)		Safe

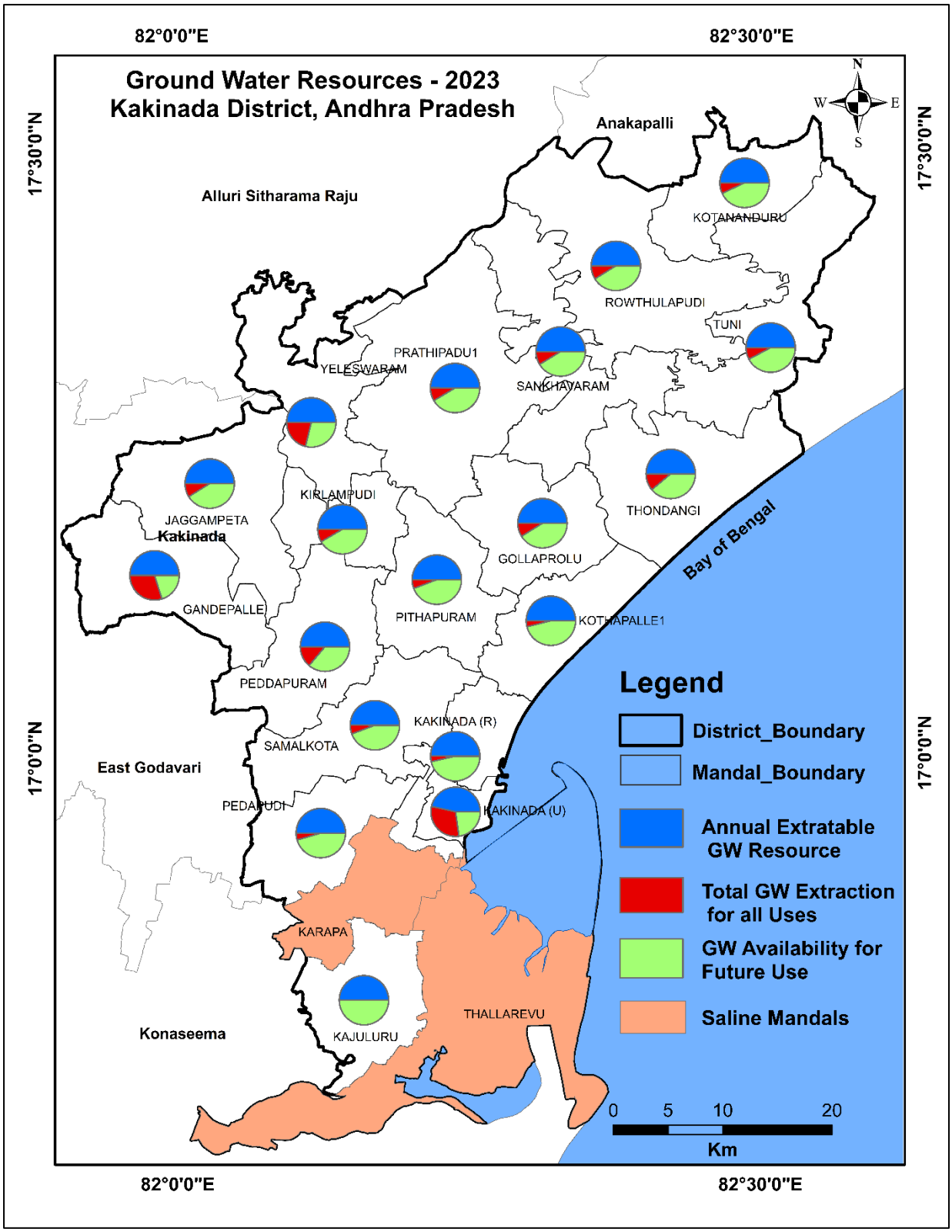


Fig.5.1: Categorization of Mandals (GWRA-2022), Kakinada district

6.0 Ground Water Development and Management

6.1 Ground Water Development:

The Ground Water Assessment – 2023 shows the annual extractable ground water resources is 975 MCM, whereas ground water extraction for all purposes is 171 MCM with stage of ground water extraction of 21%, indicating the scope for further ground water development in the district. Based on criterion of Depth to Water levels (<15 m), Rainfall (>750 mm) and stage of ground water extraction (<60%) and net annual availability of ground water for future use (805 MCM), a judicious enhancement of ground water extraction is recommended in the district by constructing 4433 bore wells in 215 villages in all 13 mandals (that can be taken up under YSR Jala Kala/convergence of schemes) which can bring an additional area of 7478 ha is under ground water irrigation in the district. The details of the proposed structures and area that can be irrigated is provided in Table-6.1 and the villages identified is provided in the map fig-3.23.

Table-6.1- The details of the proposed structures and area irrigated

S.No	District	Mandal	No of Villages	No. of Feasible Structures	Area Proposed to be irrigated (Ha)	Total cost (in Lakhs)
1	Kakinada	JAGGAMPETA	14	316	392.44	1596.94
2	Kakinada	KAKINADA (RURAL)	15	376	750.69	1768.54
3	Kakinada	KAKINADA (URBAN)	3	62	123.71	291.62
4	Kakinada	KIRLAMPUDI	10	179	357.48	1193.77
5	Kakinada	KOTANANDURU	13	269	268.36	1219.87
6	Kakinada	KOTHAPALLEE	16	617	1235.64	2904.32
7	Kakinada	PEDAPUDI	17	844	1691.61	3972.67
8	Kakinada	PITHAPURAM	28	892	1786.44	5948.07
9	Kakinada	PRATHIPADU	21	107	106.79	484.10
10	Kakinada	ROUTHULAPUDI	37	156	151.42	704.59
11	Kakinada	SANKHAVARAM	20	86	83.73	387.71
12	Kakinada	THONDANGI	9	394	395.03	1788.42
13	Kakinada	TUNI	12	135	135.12	612.43
			215	4433	7478.45	22873.04

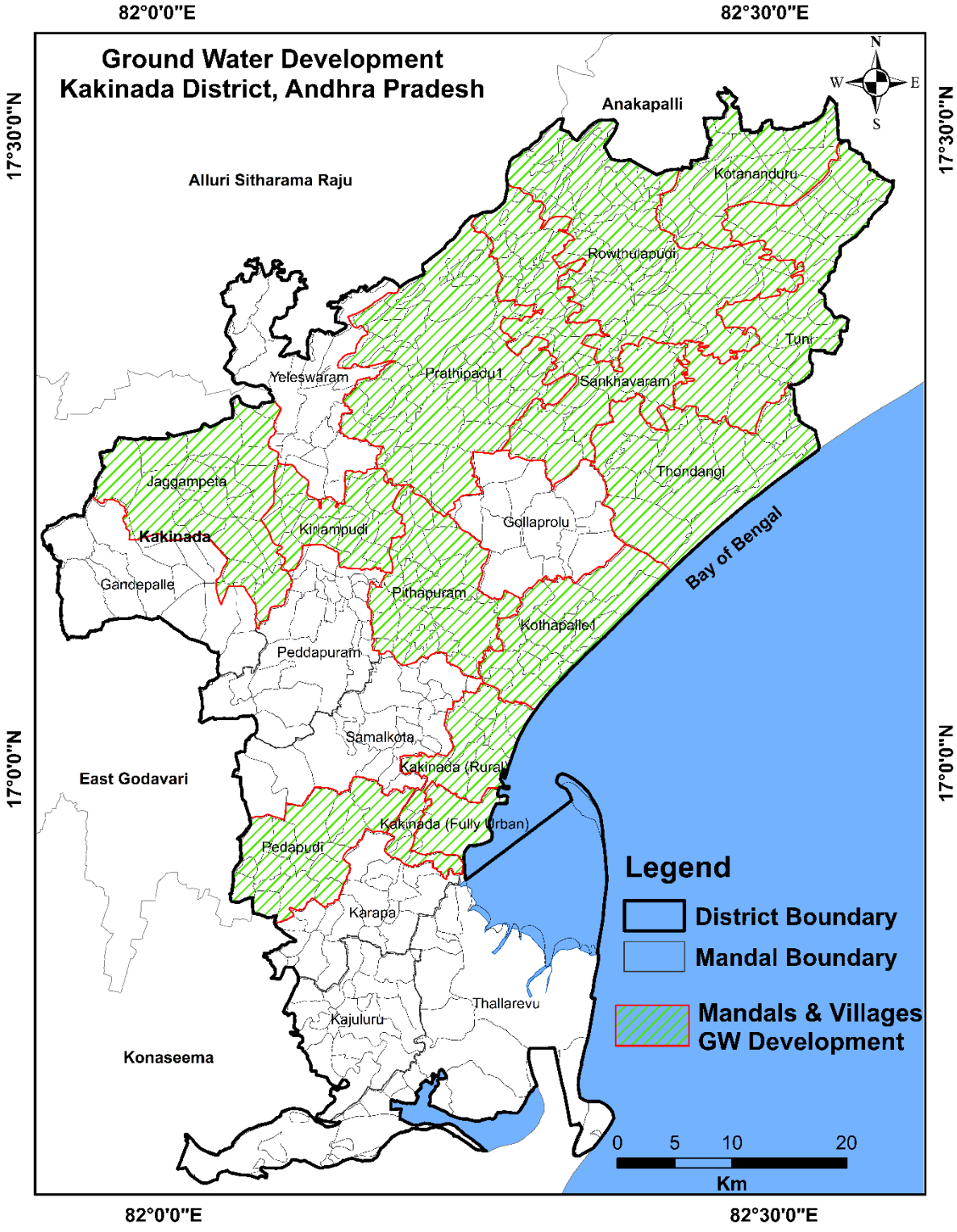


Fig:6.1- Map showing Villages/Mandals identified for Ground Water Development

6.2 Ground Water Management:

The supply side management include artificial recharge of available surplus runoff through construction of check dams and percolation tanks in rural areas and roof top rainwater harvesting in urban areas. More over repair renovation & restoration of existing tanks in rural and urban areas will also help in ground water recharge. The recharge potential of the aquifers in the district is 108 MCM. The District Water Management Agency (DWMA), Rural Development Department, Govt. of Andhra Pradesh had constructed 486 artificial recharge structures (31 Percolation Tanks, 455 Check Dams) and 42668 Water conservation structures (8715 Farm Ponds and 33953 other WCS) are constructed under IWMP and MGNREGS (Table 6.2- and Figs – 6.2 and 6.3).

Table- 6.2 Existing Artificial Recharge and Water Conservation Structures in Kakinada District

S.No.	MANDAL	No. of Farm Ponds	No. of CDs	No. of PTs	No. of Other Structures	Total Number of AR and WCS Structures
1	GANDEPALLE	1060	16	0	1010	2086
2	GOLLAPROLU	458	23	0	1901	2382
3	JAGGAMPETA	836	32	2	1171	2041
4	KAJULURU	5	0	0	2572	2577
5	KAKINADA (RU)	25	0	0	573	598
6	KAKINADA (U)	21	0	0	8	29
7	KARAPA	29	0	0	3454	3483
8	KIRLAMPUDI	45	0	0	2413	2458
9	KOTANANDURU	643	53	4	869	1569
10	KOTHAPALLEE	254	0	0	871	1125
11	PEDAPUDI	9	0	0	4231	4240
12	PEDDAPURAM	702	0	0	2003	2705
13	PITHAPURAM	129	1	0	2312	2442
14	PRATHIPADU	765	98	0	914	1777
15	ROUTHULAPUDI	1020	103	10	633	1766
16	SAMALKOTA	48	0	0	1525	1573
17	SANKHAVARAM	998	47	3	344	1392
18	THALLAREVU	44	0	0	4860	4904
19	THONDANGI	349	3	0	785	1137
20	TUNI	1024	68	11	519	1622
21	YELESWARAM	251	11	1	985	1248
	TOTAL	**8715**	**455**	**31**	**33953**	**43154**

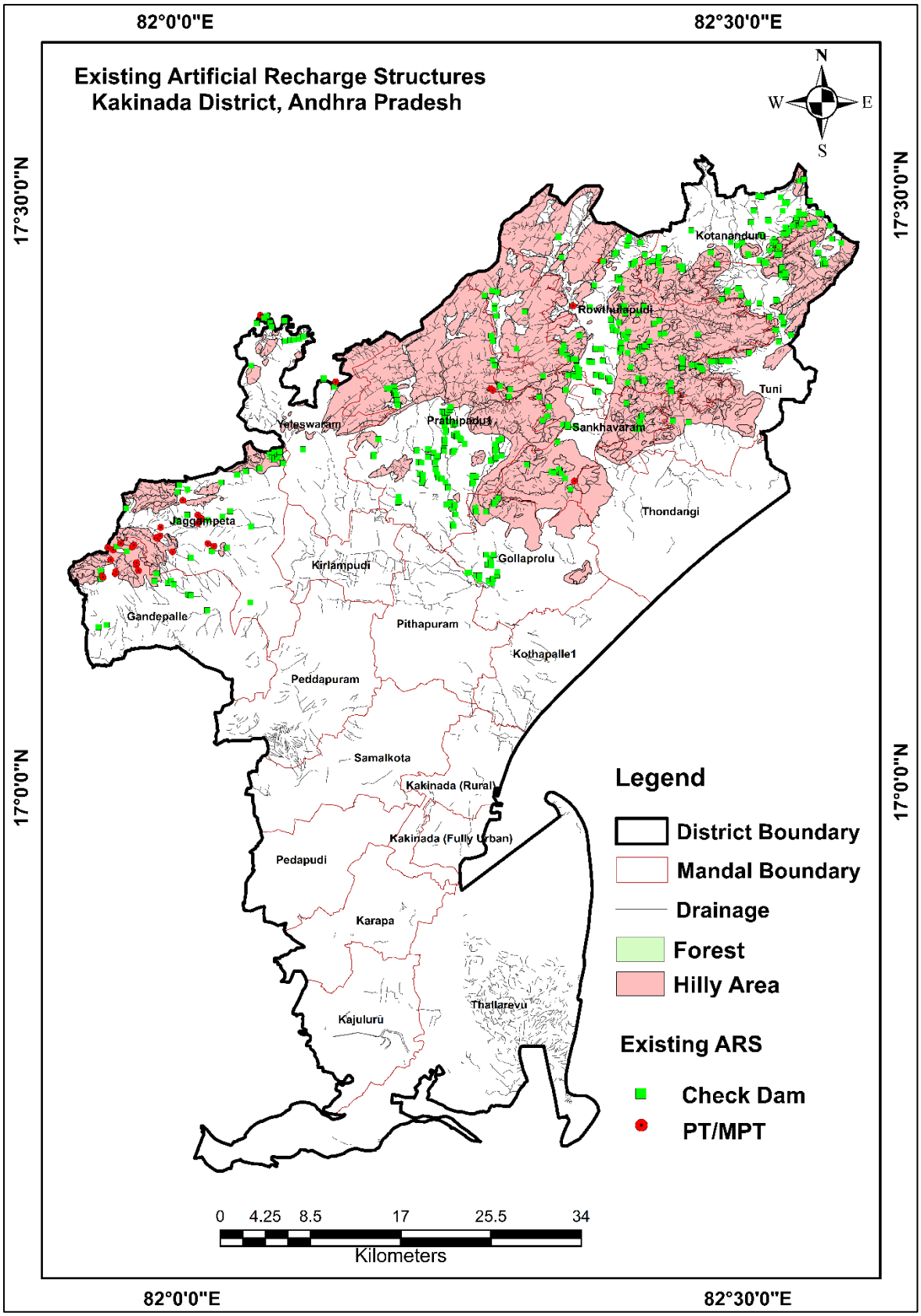


Fig-6.2 Existing Artificial Recharge Structures in Kakinada District

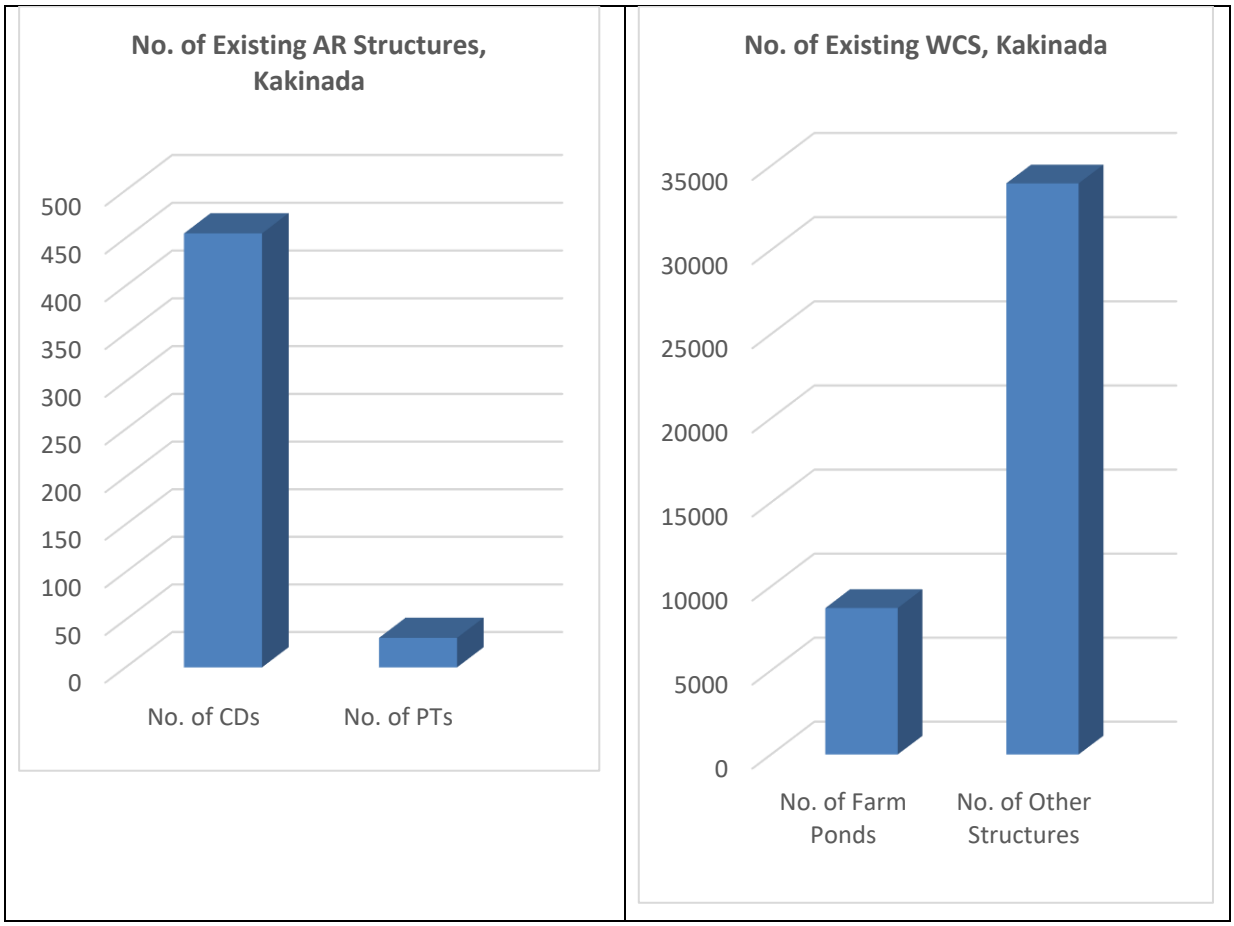


Fig-6.3: Graphical representation of existing ARS and WCS

In addition to the existing structures, it is recommended to construct 177 Percolation Tanks in the district (Table- 6.3). Further, it is recommended that the existing check dams and percolation tanks may be de-silted involving convergence of schemes and people's participation through the Mahatma Gandhi National Rural Employment Guarantee Scheme. This will also help in sustainable management of ground water resources. In addition, it is recommended for desiltaion of existing MI tanks and cascading of tanks. This can result in increase in Ayacut/Irrigation area, sustain the bore well yields and decrease the ground water irrigation. Roof top rainwater harvesting in Government buildings, proper waste water management, participatory groundwater management (PGWM), lining of sewerage to arrest leaching of nitrate and effective implementation of the existing 'Water, Land and Trees Act' of 2002 (WALTA-2002) are other recommended measures in the district.

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