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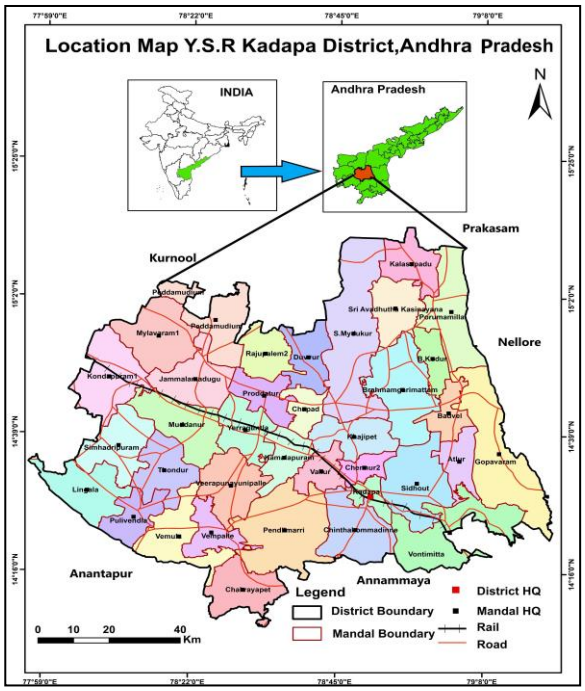
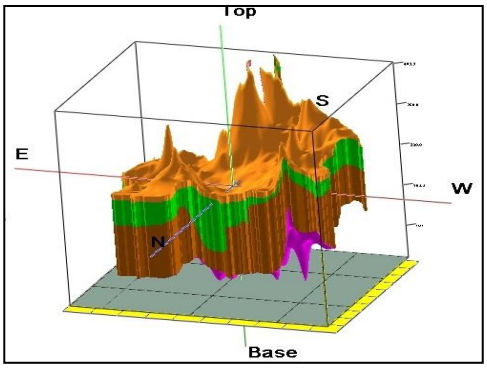
केंद्रीय भूमि जल बोर्ड

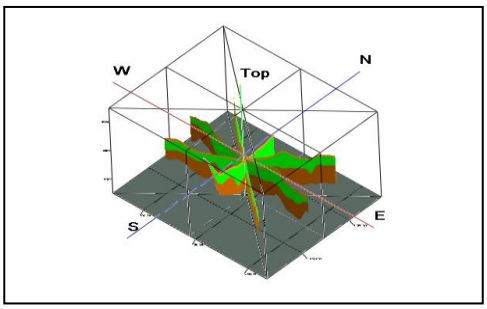
CENTRAL GROUND WATER BOARD

MINISTRY OF JAL SHAKTI
DEPARTMENT OF WATER RESOURCES, RD & GR
GOVERNMENT OF INDIA

REPORT ON
AQUIFER MAPPING FOR SUSTAINABLE MANAGEMENT OF GROUND WATER RESOURCES IN Y.S.R KADAPA DISTRICT, ANDHRA PRADESH







CENTRAL GROUND WATER BOARD
SOUTHERN REGION
HYDERABAD
February 2025

REPORT ON
AQUIFER MAPPING FOR SUSTAINABLE MANAGEMENT OF GROUND WATER RESOURCES IN HARD ROCK AREAS OF Y.S.R KADAPA DISTRICT, ANDHRA PRADESH

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AQUIFER MAPPING FOR SUSTAINABLE MANAGEMENT OF GROUND WATER RESOURCES IN Y.S.R KADAPA DISTRICT, ANDHRA PRADESH

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REPORT ON
AQUIFER MAPPING FOR SUSTAINABLE MANAGEMENT OF GROUND WATER RESOURCES IN Y.S.R KADAPA DISTRICT, ANDHRA PRADESH

AT A GLANCE

S.No.	Item		Particulars
1	District	:	Y.S.R Kadapa
2	Revenue Mandals (No.)	:	36
3	Villages	:	726 Nos
4	Geographical area	:	11,228 km^2
5	Mappable area	:	11,228 km^2
5	Population (2011 Census)	:	20.60 lakh
6	Density of population (2011 Census)	:	225 persons/km^2
7	Location	:	North latitude -14°09´40''-16°14´57'' East longitude - 78°07'02''-79°59'58''
8	Rainfall (Normal)	:	~500-906mm (avg: 682 mm) (SW: 56 % & NE: 36 %)
9	Geomorphology	:	Pediplain (41%), Structural hills (34%), Pediments (7%), Flood plains (8%).
10	Major Rivers	:	Pennar & its tributaries
11	Land Utilization (Ha) (2019-20)	:	Forest: ~36%, barren and uncultivable land 11.5%, land put to non-agricultural use is 12% of the area and Gross croppd area is ~22%.
12	Soils	:	Sandy loamy soils (40 %) and Clayey soils (51%)
13	Cropping Pattern (2019-20) (Gross cropped Area: 253458Ha)	:	Kharif: Food crops-43%, food grains-21, paddy-17%,cot-ton-7%, Non food crops-4% Rabi: Food crops-29%, food grains-28%, pulses-22%, oil seeds-4%, Non food crops-11%
14		:	**Major projects:** Kurnool-Kadapa canal (aycut: 92,001 acres), Tunghabhadra Project Low level

	Irrigation		canal (ayacut:1,51,134 acres), Mylavaram Reservoir Canal System (ayacut:75000 acres), Pulivendula Branch Canal (ayacut: 55,239 acres). Telugu Ganga Project (ayacut:1,86,832 acres) Chitravathi Balancing Reservoir right canal (ayacut: 60,000) GNSS (ayacut:1,55,000 acres) **Medium Projects**: Lower and Upper sagileru Project (ayacut: 19,303 acres),Buggavanka (ayacut: 9700 acres)
15	Prevailing Water Conservation/Recharge Practices	:	PT: 354 and CD: 2818 Micro irrigation: 10700 Ha.
16	Geology	:	Shale,Quartzite, Limestone, BGC and Granite.
17	Hydrogeological data points	:	349 hydrogeological data points (Exploration CGWB: 82), VES: 267 (CGWB)
19	Ground water yield (lps)	:	<0.1 to 13.77 lps (Avg:1.9 lps) <0.1 in Granites and <0.1 to 13.77 lps (avg: 2 lps) in Metasediments. Low yield (<1 lps):48 % of area, Moderate yield (1-3 lps):34% of area and high yield (>3 lps): 18% of area. Deepest Fracture : 185m at Thippireddipalle village (S.Mydukur mandal)
20	Water Levels Depth to water levels (m. bgl)	: :	88 wells Water table elevations during pre-monsoon season vary from 95.71-308.26 m. amsl and during post-monsoon season vary from 96.39-318.07 m. amsl. **Pre-monsoon**: 1.32 to 51.10 m bgl (average: 9.07 m bgl) and majority are in the range of 5- 10 m bgl (52 % area) followed by 10-20 mbgl (34% area, <5 mbgl (11%) and Deeper water levels (> 20 mbgl) occupy 3% of area. **Post-monsoon**: 0.89 to 31.02 m bgl (average: 8.00) and majority are in the range of 5-10 m bgl (48% area) followed by 10-20 mbgl (29% area) ,<5 mbgl (22% area) and Deeper water levels (>20m.bgl) occupy 1% of area.
21	Water Level Fluctuations (May vs. November)	:	-6.46 to 25.24 m with Average rise of 0.84 m.
22	Long term water level trends (2014-23)	:	**Pre-monsoon:** Falling trends: 04 wells (0.08 to 0.83 m/yr) Rising trends: 25 wells shows 0.02 to 4.64 m/yr.

			Post-monsoon: Falling trends: 14 wells (0.01 to 2.83 m/yr) Rising trends: 31 wells shows 0.02 to 10.52 m/yr.	
23	Hydrochemistry	:	Total 59 Pre Monsoon water samples.	
24	Electrical Conductivity (µ Siemens/cm)	:	**Pre-monsoon**: 240-5530 µ Siemens/cm (avg:1467) in 70 % of the area EC is within 1500 µ Siemens/cm.	
25	Fluoride mg/l	:	**Pre-monsoon**: 0.05-2.55 mg/L, 10% of samples are more than permissible limits.	
26	Nitrate mg/l	:	**Pre-monsoon**: 0.13-649 mg/L, 35 % of samples are more than permissible limits.	
25.2	Conceptualization		Weathered zone (~15 m), Fractured zone (13-185 m)	
26	Aquifer Characterization	:	Weathered zone (~15 m). 10-20m weathering occurs in 52% followed by < 10m in 25% of area and deep weathering occurs in 2 % of area.	Fractured zone(15-185 m.) Majority of fractures ~80% occurs within 100 m depth.
27	Aquifer wise Ground water yield	:	<0.1 lps in granite and <0.1 to 13.77 lps in metasediments. Avg: 2 lps in Metasediments.	
27.1	Transmissivity (m^2/day)	:	1- 270 m^2/day, in majority of wells it is < 30 m^2/day.	
27.2	Specific Yield	:	< 1 to 2 %	
27.3	Storativity	:	0.00001 to 0.0001	
28	Ground water Resources (MCM) (2023)	:		
28.1	Net Dynamic groundwater availability	:	1016.61 MCM	
28.2	Gross GW Draft	:	344.14 MCM	
28.3	Provision for Domestic &Industrial (2025)	:	46.54 MCM	
28.4	Average Stage of Ground water Extraction (%)		38%	
28.5	Net GW Availability for future use	:	688.69 MCM	
28.7	Categorization of mandals		• Mandal wise it varies from 10.76 % to 102% (OE:01, SC: 01 and Safe:34)	
29		:	• 1 mandal i.e Pulivendla categorized as over-exploited.	

	Major Ground Water Issues Identified		• Ground water Pollution • High fluoride concentration (>1.5 mg/L) occur in 10% of the samples. • High concentration of EC (> 3000 micro-seimens/cm) in 6 % of the area. • Deep water levels (> 20 m bgl) are observed during pre and post-monsoon season in 03 % and 01% of area. • Declining water levels: Out of 84 wells analyzed, 04 wells shown falling trend in pre-monsoon and 14 during post-monsoon season. • Low Sustainability: Low yield (<1 lps) occurs in ~48 % of area and reduction in yield over a period of time. • Change in land use from agricultural land to residential purposes.
30	Management Strategies	:	**Supply side measures** • To be taken up (Artificial Recharge Structure) :151 ARS (CD: 86, PT: 65) Water Conservation measures (WCM) Farm ponds • The size of form ponds can be 10 x 10 x 3 m. Total 4280 farm ponds are recommended (20 in each village in 214 villages) **Demand side measures** • Proposed micro Irrigation: ~10700 ha of additional land that can be brought under micro-irrigation • Other measures • Capacity building in power supply regulation (4 hours each in morning and evening) will increase the sustainability of wells • Laser levelling of irrigated land. • A participatory ground water management (PGWM) approach in sharing of ground water and monitoring resources. • The open stone quarries / abandoned quarries can be filled with soil and covered with vegetation; it will prevent further erosion and weathering of salts and minerals and also escalation of the salinity levels in aquifers. • Recommending to use of red mud pot to store potable household water in Fluoride contaminated areas to reduce the impact of fluorosis. • Recommend to cultivate high EC tolerant crops like cotton, safflower, sesame etc.

			• Change in cropping pattern from water intensive paddy to irrigated dry crops like pulses and oil seeds are recommended, particularly in water stress areas. • In urban and rural areas the sewerage line should be constructed to arrest leaching of nitrate.

ABBREVATIONS

2D	:	2 Dimensional
3D	:	3 Dimensional
ARS	:	Artificial Recharge Structures
Avg	:	Average
BDL	:	Below Detection Level
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	:	Hectare
Ha.m	:	Hectare meter
ID	:	Irrigated dry
IMD	:	India Meteorological Department
Km^2	:	square kilometre
LPS	:	Litres per second
M	:	Meter
M^3	:	Cubic meter
m bgl	:	Metres below ground level
MCM	:	Million cubic meter
Mg/l	:	Milligram per litre
MI	:	Micro irrigation
Min	:	Minimum
max	:	Maximum
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
Sy	:	Specific Yield
T	:	Transmissivity
WCM	:	Water conservation measures

EXECUTIVE SUMMARY

Y.S.R Kadapa district covering an area of 11,228 Km^2, receives an average annual normal rainfall of 682 mm of which SW monsoon contributes 56 % and north-east monsoon contributes 36 %. During the year 2022.

Administratively, the area is governed by 36 revenue mandals with 726 villages. The population of the district is ~ 20.60 lakhs (2011 census) with average density of 225 persons/km^2.

The area is underlain by Shales, Quartzites, limestones, BGC and Granites. Pediplain is the major geomorphic feature (41% of area), followed by structural hills (34%), pediments (7%), flood plain (8%), Structural valleys (4%), Piedmont zone, Denudational hills etc. Most of the area is drained by river Pennar and its tributaries. The gross cropped area during 2019-20 is 2,53,458 ha. Forest occupies 36% of the total geographical area, Barren and uncultivable land occupies 11.49% of area, land put to non agricultural uses occupies 12.25% of the area and current fallows occupies 10.30 % of the area. Main crops grown during Kharif (food crops-43%, food grains- 21%, cotton-7%, paddy-17%) and during Rabi (food crops-29%, food grains-28%, pulses-22% and oil seeds-4%).The soils are clayey soils (51%) and loamy soils (40%).

The major irrigation projects completed in Kadapa district are Kurnool-kadapa canal, Tunghabhadra Project Low level canal, Mylavaram Reservoir Canal System, Pulivendula Branch Canal, Telugu Ganga Project, Chitravathi Balancing Reservoir and Galeru Nagari Sujala Sravanthi Project. The total major irrigation projects completed in the district with 7,75,206 acres ayacut. The medium irrigation projects completed in the district are Lower and Upper sagileru Project and Buggavanka Project. The total medium irrigation projects completed in the district with 29,003 acres ayacut.

Ground water yield varies from <0.1 lps in Granite/Gneisses and <0.1 to 13.77 lps in metasediments. Majority of fractures occur within 100 m depth and deepest fracture is encountered at 185m.bgl at Thippireddipalle village (S.Mydukur mandal). Water levels are monitored through 86 Piezometers during pre and post-monsoon seasons of 2023. The average DTWL varies from 1.32 to 51.1 m bgl (average:9.07) and 0.89 to 31.02 m bgl (average: 8.00) during pre and post-monsoon season respectively. During pre-monsoon season 5-10 m.bgl water level range is more predominant (52% of area) followed by 10-20 m.bgl (34 % of area), <5 m.bgl (11%) and deeper water levels > 20 m.bgl occupy about 03 % of the area. During post-monsoon season <5-10 m.bgl water level is more predominant (48 % of area), followed by 10-20 m (29% of area) <5 m.bgl (22%) and deeper water levels >20 m.bgl occupy about 01

% of the area. Water level fluctuation (May Vs Nov) data indicate that 58% of the wells show rise in water level while 42% of wells show fall in water level. The water level fluctuations vary from -6.46 to 25.24 m with average rise of 0.84 m. The Long-term water level trend analysis for 10 years (2014 -2023) is analysed and it is observed that during pre-monsoon season 04 wells shows falling trend (0.08 m/yr to 0.83 m/yr) and 25 wells shows rising trend (0.02 to 4.64 m/yr). During post-monsoon season 14 wells show falling trend (0.01 m/yr to 2.83 m/yr) and 31 wells shows rising trends (0.02 to 10.52 m/yr).

Total 49 ground water samples (Pre-monsoon) were analysed for knowing the suitability of ground water for drinking purposes. In 70% of the areas EC is in the range of < 1500 µ Siemens/cm during pre-monsoon season of 2022. During pre-monsoon season, nitrate concentration in 35% of samples is beyond permissible limits of BIS (45 mg/l) and F concentration varies from 0.05 to 2.55 mg/l and found 90% of the samples within permissible limits of BIS (< 1.5 mg/l).

Based on 349 hydrogeological data points, aquifers from the area can be conceptualized in to 2 nos. namely 1) weathered zone (~15 m) and 2) fractured zone (15-185 m). Weathered zone has gone dry in most of the area due to over-exploitation during pre-monsoon season. Weathered zone in the range of <10 m occurs in 25 % of area, 10-20 m in 52 % of area, and deep weathering (> 20 m) in 02 % of area. Ground water yield of this zone varies from <0.1 to in granites and from 0.01 to 13.77 lps (avg: 2.0 lps) in metasediments. Transmissivity varies from 1 to 270 m^2/day, in majority of wells it is <30 m^2/day. Fracture zone varies from 15 to 185 (deepest fracture at Thippireddipalle village (S.Mydukur mandal). Analysis of occurence of fractures reveal that majority of fractures (~80 %) occur within 100 m depth and >100 m fractures occur in remaining areas.

Net dynamic replenishable ground water availability as on 2023 is 1016.61 MCM, gross ground water draft is 344.14 MCM, provision for drinking and industrial use for the year 2025 is 46.54 MCM and net available balance for future use is 688.69 MCM. The stage of ground water extraction is 38 %.

Major issues identified are over-exploitation (1 mandal), high fluoride concentration (>1.5 mg/L) occur in 10% of the samples during premonsoon season, high concentration of EC (> 3000 micro-seimens/cm) in 6% of the area during premonsoon season, deep water levels (> 20 m bgl) in 08% and 03% of the area during pre and post monsoon seasons and low yield in 48 % of the area. Other issues identified are water marketing, change in cropping pattern etc.

The management strategies mainly include both supply side and demand side. The supply side measure includes ongoing work under state Govt. sponsored NEERU- CHETTU

programme where silt has been removed from existing tanks. This will contribute ground water by recharge. Under supply side measures construction of artificial recharge structures in 11 mandals (Atlur, Chinthakommadine, Duvvur, Gopavaram, Lingala, Pendimarri, Porumammila, Sidhout, Vempalle, Vemula and Vontimitta) which include 86 CDs and 65 PTs. The expected volume to be recharged by these structures will be 3.92 MCM.

Under Water conservation measures, constructions of 4280 no.s of farm ponds are proposed in 214 villages. Demand side measure includes bringing ~10700 ha of additional land (@50 ha/villagein 214 villages) under micro-irrigation.

Other measure includes a participatory ground water management (PGWM) approach in sharing of ground water and monitoring resources on a constant basis along with effective implementation of the existing 'Water, Land and Trees Act' of 2002 (WALTA-2002). Subsidy/incentives on cost involved in sharing of ground water may be given to the concerned farmers. In urban and rural areas the sewerage line should be constructed to arrest leaching of nitrate. Recommending to use of red mud pot to store potable household water in Fluoride contaminated areas to reduce the impact to fluorisis in urban and rural areas the sewerage line should be constructed to arrest leaching of nitrate. Uranium causes radio toxicity as well as chemical toxicity. Therefore in U contaminated areas installation of permeable reactive barrier (Ferric iron, phosphate) in Govt sponsored RO plants is recommended. Restrict use of extensive chemical fertilizers as it will eventually degrade soil and leach to join ground water which already has high salinity. Recommend to cultivate high EC tolerant crops like cotton, sunflower,sesame etc. .

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 rocks 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 to meet climate change also. Thus the crux of National Aquifer Mapping (NAQUIM) is not merely mapping, but reaching the goal-that of ground water management through community participation.

Hard rocks (Granites/Gneisses) lack primary porosity, and groundwater occurrence is limited to secondary porosity developed by weathering and fracturing. Weathered zone is the potential recharge zone for deeper fractures and excessive withdrawal from this zone leads to drying up in places and reducing the sustainability of structures. Besides these quantitative aspects, groundwater quality also represents a major challenge which is threatened by both geogenic and anthropogenic pollution. In some places, the aquifers have high level of geogenic contaminants, such as fluoride, rendering them unsuitable for drinking purpose. High utilization of fertilizers for agricultural productions and improper development of sewage system in rural/urban areas lead to point source pollution viz., nitrate and chloride.

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.

Scope of study: The main scope of study is summarized 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) for 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.

1.1 Study Area:

Y.S.R Kadapa District is the extreme south eastern district of Andhra Pradesh situated within the geographical co-ordinate of 14°9'40" and 16°0'57" of Northern Latitude and 78° 07'02" and 79° 59'58" Eastern Longitude.The District is bounded on North by Kurnool, Prakasam Districts, South by Annamayya District West by Anantapur District and East by Nellore and Chittoor District (Fig.1.1). Total Geographical area of the District is 11,228 Km^2. with 3 Revenue Divisions, 36 mandals, 557 Gram Panchayats, 726 Revenue Villages and 2257 Habitations. As per the 2011 Census the population of the District is 20,60,654 of which the Rural Population is 12,51,364 and the Urban Population is 8,09,290. The density of population in the District is 225 per Sq.Km.

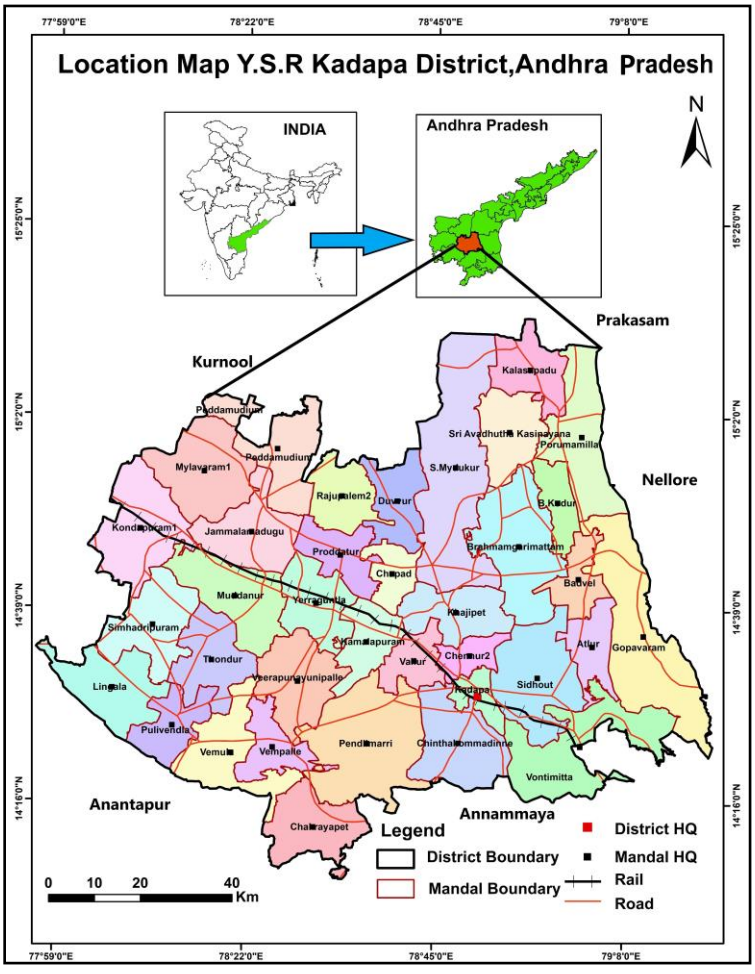


Fig.1.1: Location map of Y.S.R Kadapa district.

1.2 Climate and Rainfall:

The climate of the district is characterised by tropical wet and dry climate, characterized by year round high temperatures. Kadapa gets rainfall from both the South West monsoon as well as the North East Monsoon. June to October is usually the monsoon period. The normal mean daily minimum and maximum temperature of 34 °C and 40 °C during May and 25°C and 35°C during December. As per the IMD rainfall data, during the year 2022, normal annual rainfall varies between 500 mm (Vemula) to 906 mm (Porumamilla) with average of 682 mm (Fig. 1.2). SW monsoon contributes 56 % and 36 % is contributed by retreating monsoon (NE) season and rest by winter and summer rainfall. Rainfall increases from West to East.

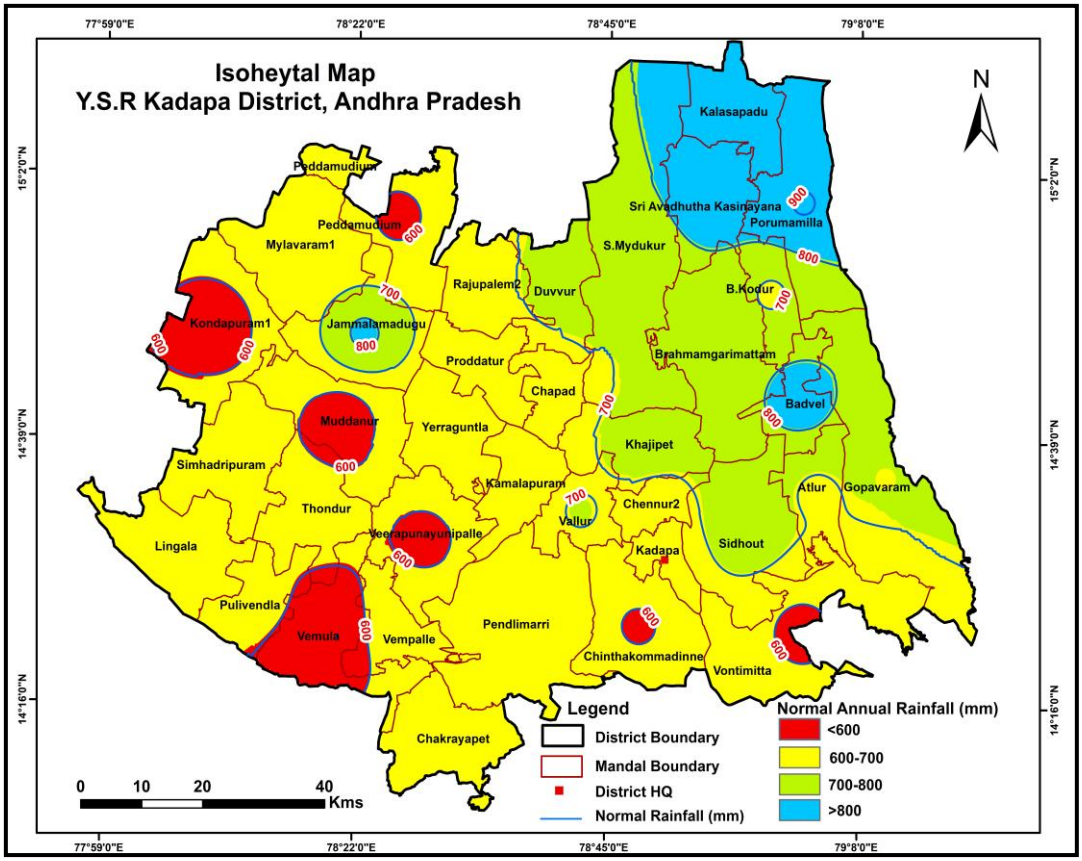


Fig.1.2: Isohyetal map of Y.S.R Kadapa district.

1.3 Geomorphological Set up:

The district exibits rolling topography with high and deep fronted hill ranges, valleys and plains. High hill ranges with intervening valleys are generally found in the eastern part of the district. Northern part of the district is occupied by thickly forested medium hill ranges. Southern part of the district is occupied by plateau. The major slope of the district is towards

east but in the southern part it slopes towards north, in the northern part towards south and in the western part towards southeast.

Pediplain is the major landform covering about 4603 km^2 (41 %) area. The other landforms observed are Structural hills (34%), Pediments 7%), flood plain (08%), Structural valleys (4%), Piedmont zone, Denudational hills etc. (Fig.1.3).

Table 1.1: Geomorphological features of Y.S.R Kadapa district.

S. No.	Geomorphology	Area (Sq kms)	Percentage (%)
1	Pediplain	4603	41
2	Structural Hills	3817	34
3	Flood Plain	898	8
4	Pediment	786	7
5	Structural valley	449	4
6	Piedmont zone	391	3.48
7	Denudational Hills	180	1.60
8	Others	104	0.92
TOTAL		**11228**	**100%**

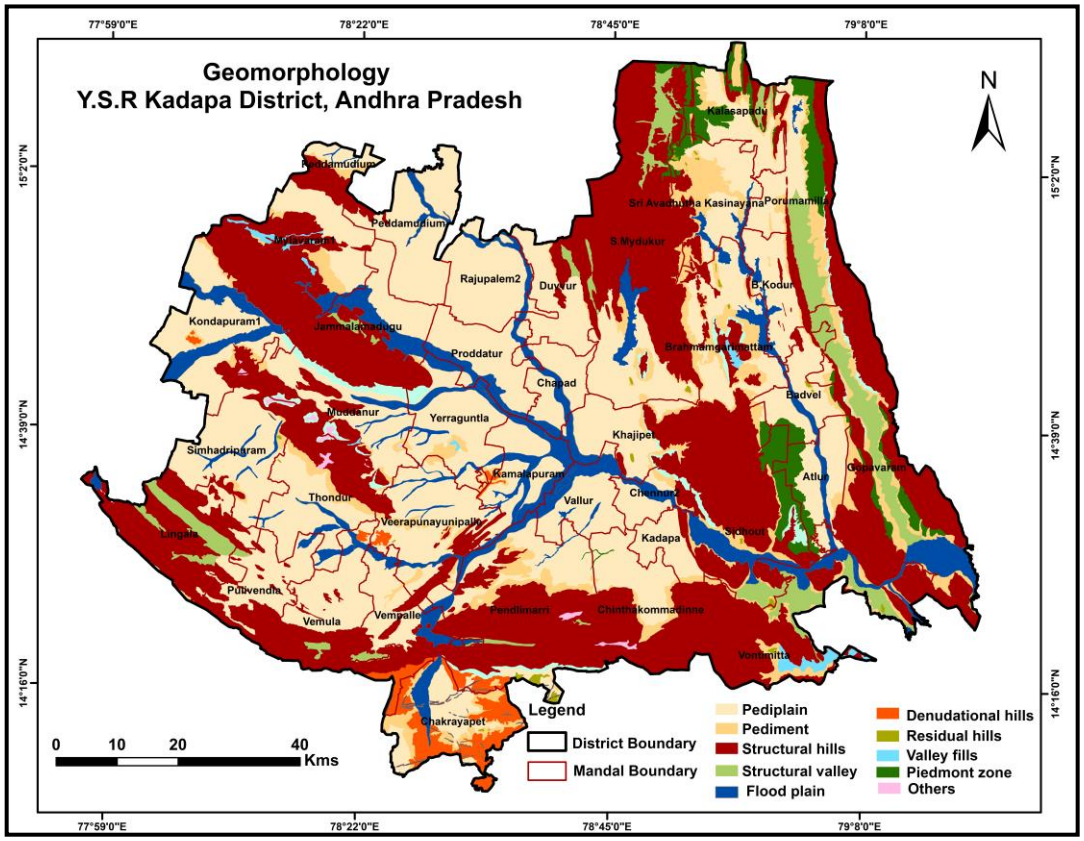


Fig.1.3: Geomorphology map of Y.S.R Kadapa district.

1.4 Drainage and Structures:

Y.S.R Kadapa District is drained by the Pennar Basin and its tributaries. This River rises in the Karnataka State and after passing through Anantapuram district enters this District at the North-Western corner near Tallaproddatur in Kondapuram Mandal. The chief Northern tributaries to Pennar are the Kunderu(Kundu), Sagileru and the southern tributaries – the Cheyyeru, Papagni and the Chitravathi. The drainage pattern is dendritic to sub- dendritic and parallel. The drainage is also regularly parallel to sub parallel demonstrating basic control. The Cuddapah basin is a major synformal structure with minor antiforms and synforms. Many lineaments trend NE-SW and are sub-parallel to the trends of geological formations, other lineaments run either in a ENE-WSW or E-W direction. Map depicting drainage, water bodies and watershed boundaries is presented in (Fig.1.4).

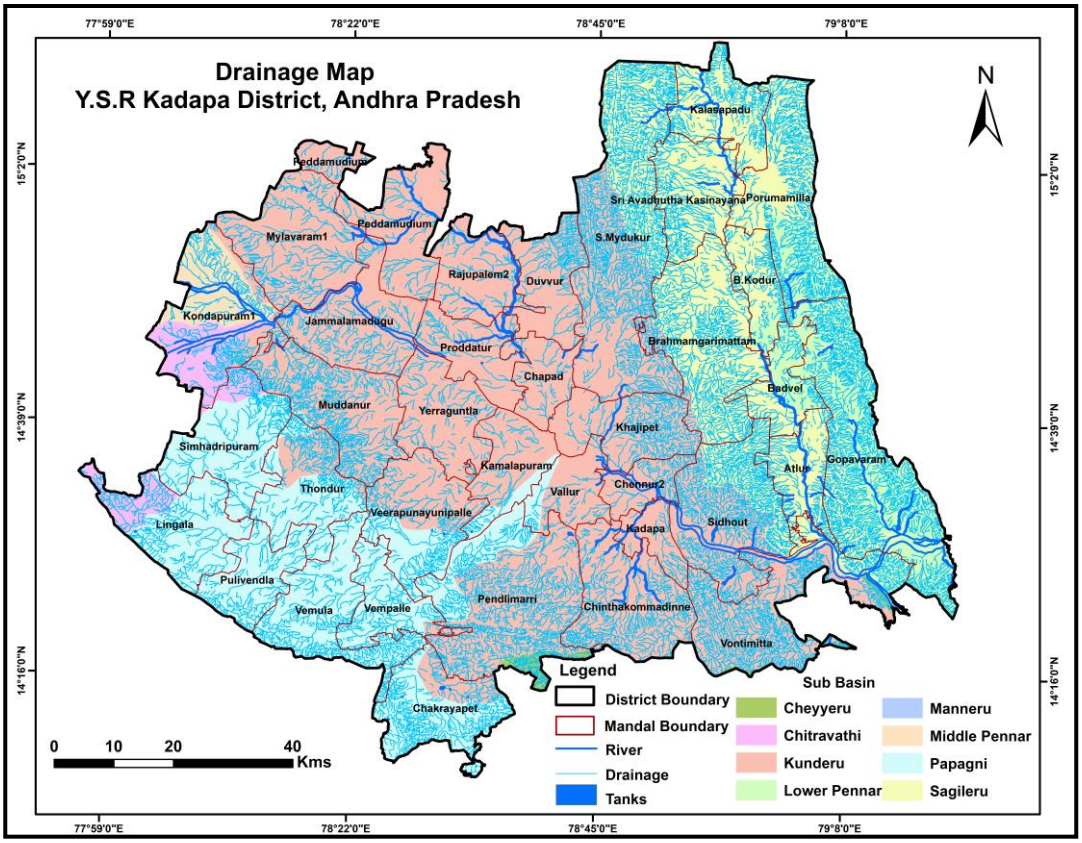


Fig.1.4: Drainage map of Y.S.R Kadapa district.

1.5 Land use and cropping pattern:

The total geographical area of Y.S.R Kadapa District is 11,22,760 hectares which constitutes an extent of forest is 4,03,690 hectares, Barren & Uncultivable land is 1,29,042 hectares, Land put to Non-agricultural uses is 1,37,621 hectares, Cultivable Waste is 29753 hectares, Current Fallows is 1,15,748 hectares, Other Fallow land is 53,801 hectares,Total Cropped Area is 2,53,458 hectares and Net Area Sown is 2,43,931 hectares and area sown more

than once is 9,527 hectares during the year 2019-20 (Fig 1.5). The gross area cropped during Khariff season is 1,84,410 ha and the major crops sown during khariff season are paddy, jowar, turmeric, pulses, cotton and oil seeds; while The gross area cropped during Rabi season is 454385 ha and the major crops sown during rabi season are paddy, jowar, bajra, pulses, cotton and oil seeds. Season wise cropping pattern is given in (Fig.1.6a and 1.6b).

Table 1.2: Details of Land use and Land cover in Y.S.R Kadapa district.

Land Utilization	Area (Ha)	% of Geographical Area
Forest	403690	35.95
Barren & uncultivable land	129042	11.49
Land put to non-agricultureal uses	137621	12.25
Cultivable waste	29753	2.65
Current fallows	115748	10.30
Other fallow lands	53801	4.79
Gross cropped area	253458	22.57
Total geographical area	**1122760**	**100**

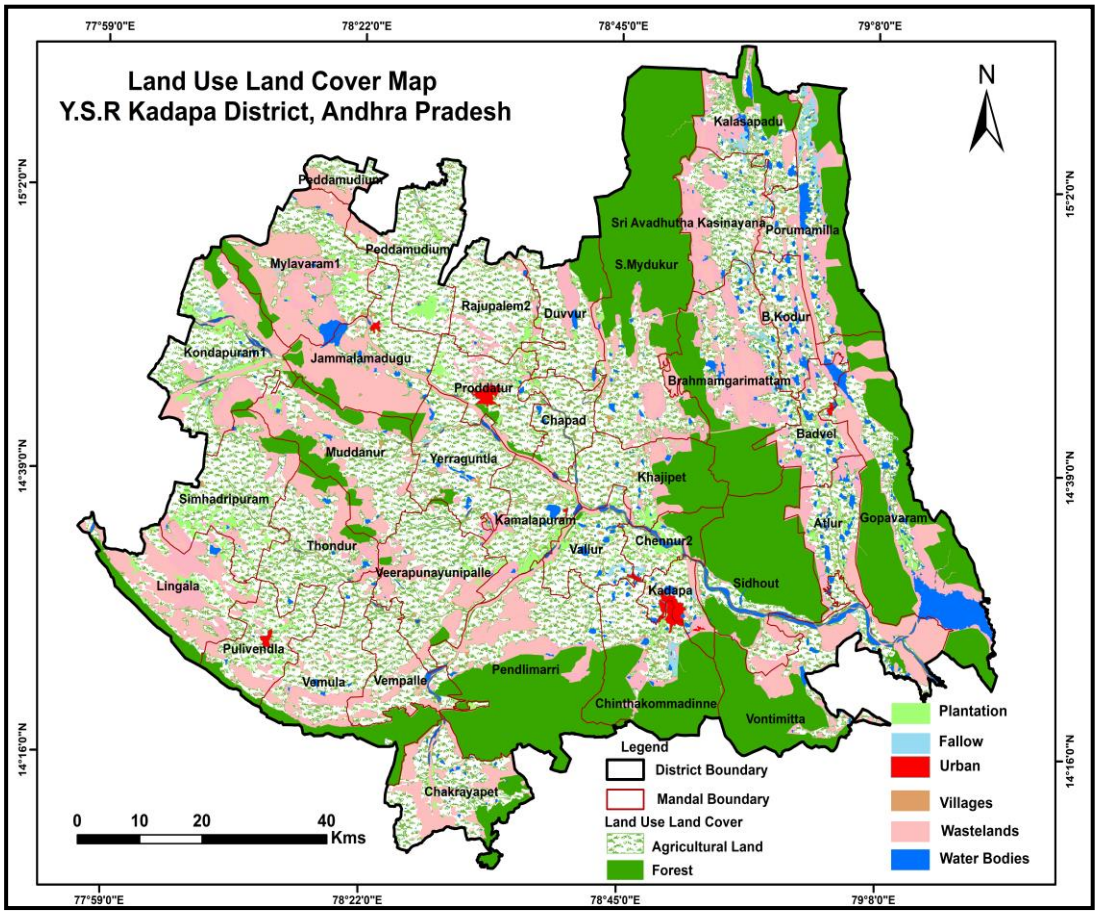
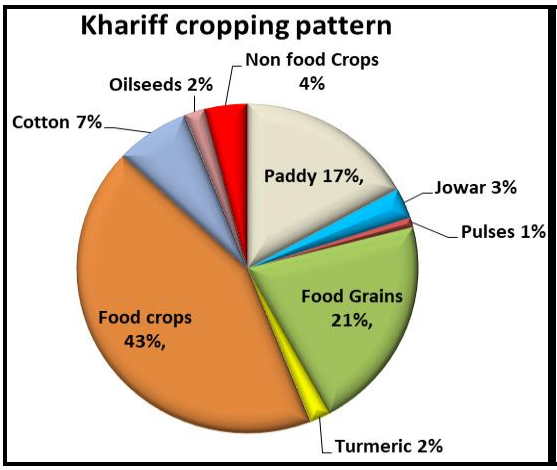


Fig.1.5: Land use and land cover of Y.S.R Kadapa district.

Table 1.3: Details of cropping pattern in Y.S.R Kadapa district.

Crops	Kharif (ha)	Rabi (ha)
Paddy	30560	6699
Jowar	4613	14566
Bajra	395	3400
Maize	218	2109
Pulses	2574	97808
Food Grains	39277	124975
Turmeric	2771	0
Food crops	79192	133815
Cotton	13410	1132
Oilseeds	3465	19032
Non food Crops	7935	50849



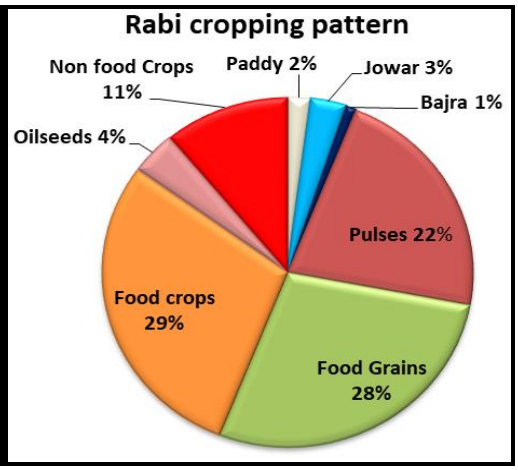


Fig.1.6a:Cropping pattern in Khariff **Fig.1.6b:Cropping pattern in Rabi**

1.6 Soils:

The area is mainly occupied by clayey soils (51%) (deep, well drained, gravelly clay with low avaialable water content (AWC) and loamy soils (40%) (red and sandy soils, which are shallow with low water holding capacity). Red loamy soils are predominant in eastern and southern parts of the district, Clayey soils are mostly seen in northern and small areas in southern part of the district and clayey to loamy mixed soils are mostly observed in central parts of the district (Fig.1.7).

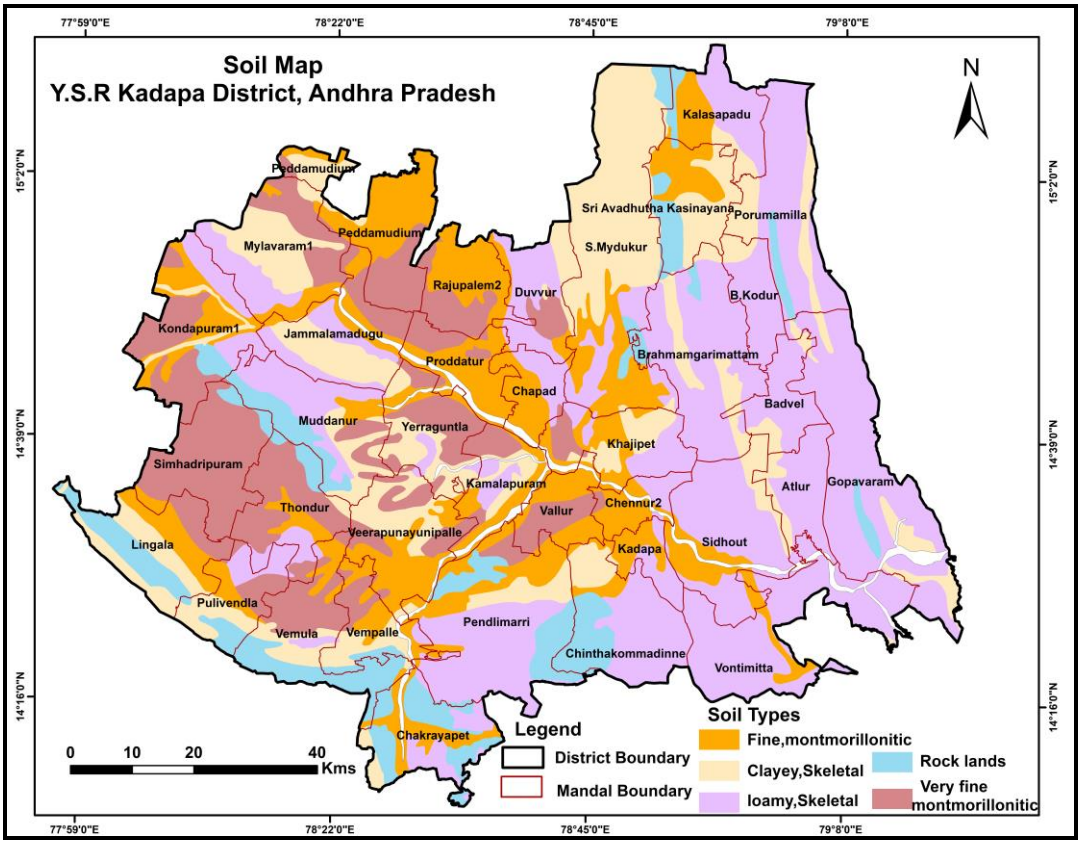


Fig.1.7: Soil map of Y.S.R Kadapa district.

1.7 Irrigation:

Pennar river is the major river flowing through the district, the other rivers traversing through the area, Chitravati, Cheyyair, Papaghni and Kundair are tributaries of pennar river. The development of irrigation is crucial for increasing the agricultural production. The irrigation projects are classified as major, medium and minor irrigation projects. Major and Medium Irrigation Projects of Y.S.R Kadapa District are given in (Fig.1.8).

Major Irrigation Project:

The major irrigation projects completed in Kadapa district are Kurnool-Kadapa canal with 92,001 acres ayacut, Tunghabhadra Project Low level canal (TBPLLC) with 1,51,134 acres ayacut, Mylavaram Reservoir Canal System (MRC) with 75000 acers ayacut Pulivendula Branch Canal (PBC) with 55,239 acres ayacut, Telugu Ganga Project (TGP) with 1,86,832 acres ayacut, Chitravathi Balancing Reservoir right canal with 60,000 acres ayacut and Galeru Nagari Sujala Sravanthi (GNSS) Project with 1,55,000 acres ayacut covered. The total major irrigation projects completed in the district with 7,75,206 acres ayacut.

Medium Irrigation Project:

The medium irrigation projects completed in the district are Lower and Upper sagileru Project with 19,303 acres ayacut, Buggavanka Project with 9,700 acre ayacut. The total medium irrigation projects completed in the district with 29,003 acres ayacut.

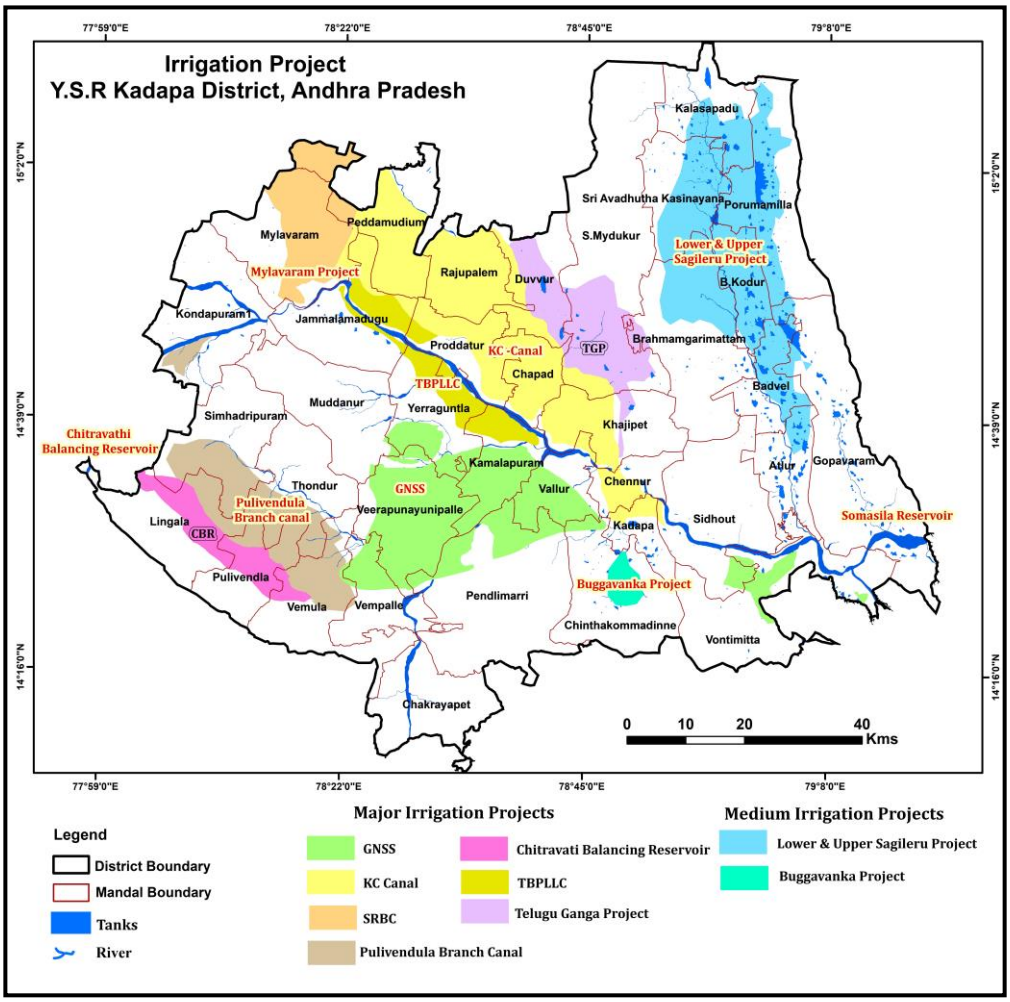


Fig. 1.8: Major and Medium Irrigation Projects of Y.S.R Kadapa district.

1.8 Geology:

The area is underlain by various rock types that belong to Late Archaean or Early Proterozoic era which are succeeded by rocks of Dharwarian Age and both are traversed by dolerite dykes. The older rocks are overlain by rocks of Cuddapah Super group and Kurnool Group belonging to Middle and Upper Proterozoic Age. The Archaean comprises the Peninsular Gneissic Complex, represented by granite, granodiorite, granite-gneiss and migmatite. The metasediment rocks of Cuddapah and Kurnool Group include mostly shales, quartzites and limestones (Fig1.9).

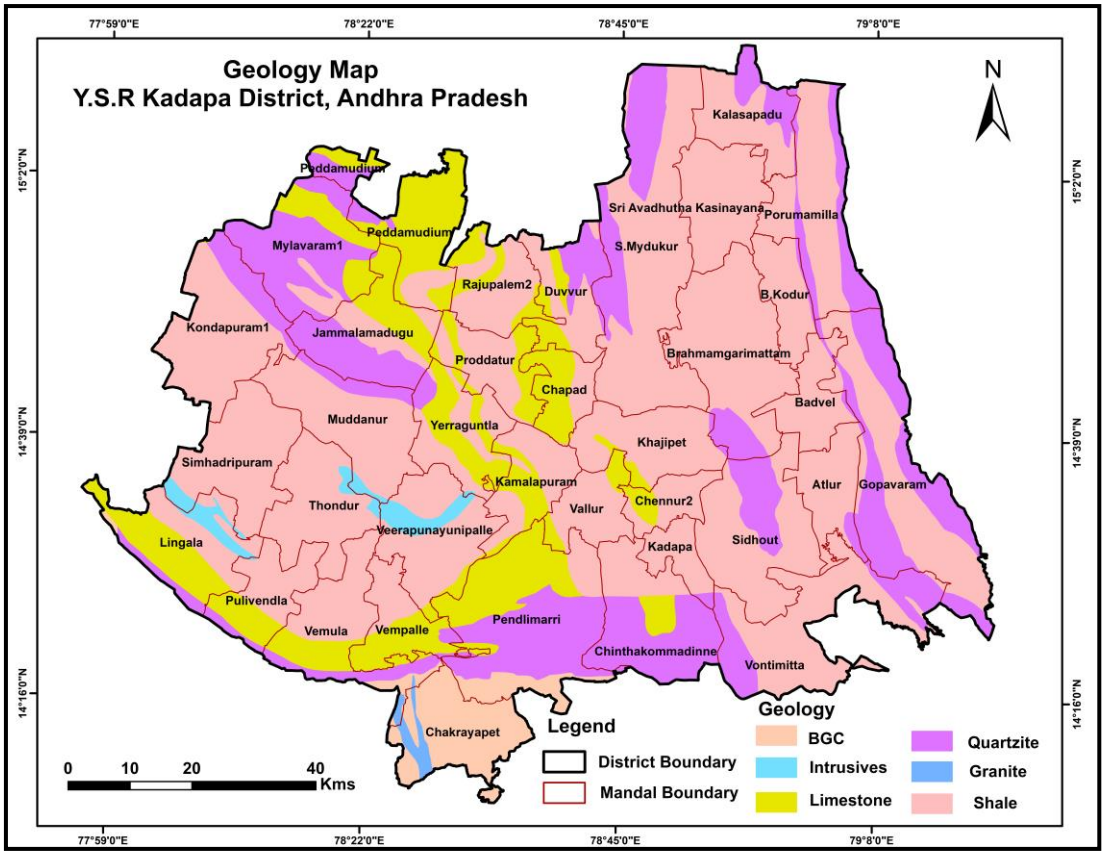


Fig.1.9: Geology map of Y.S.R Kadapa district.

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), borehole 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.

2.1 Hydrogeological Studies

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 granites, gneisses, Shales, Limestones and Quartzites and 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. Based on 349 hydrogeological data points (Fig.2.1) hydrogeological map is prepared.

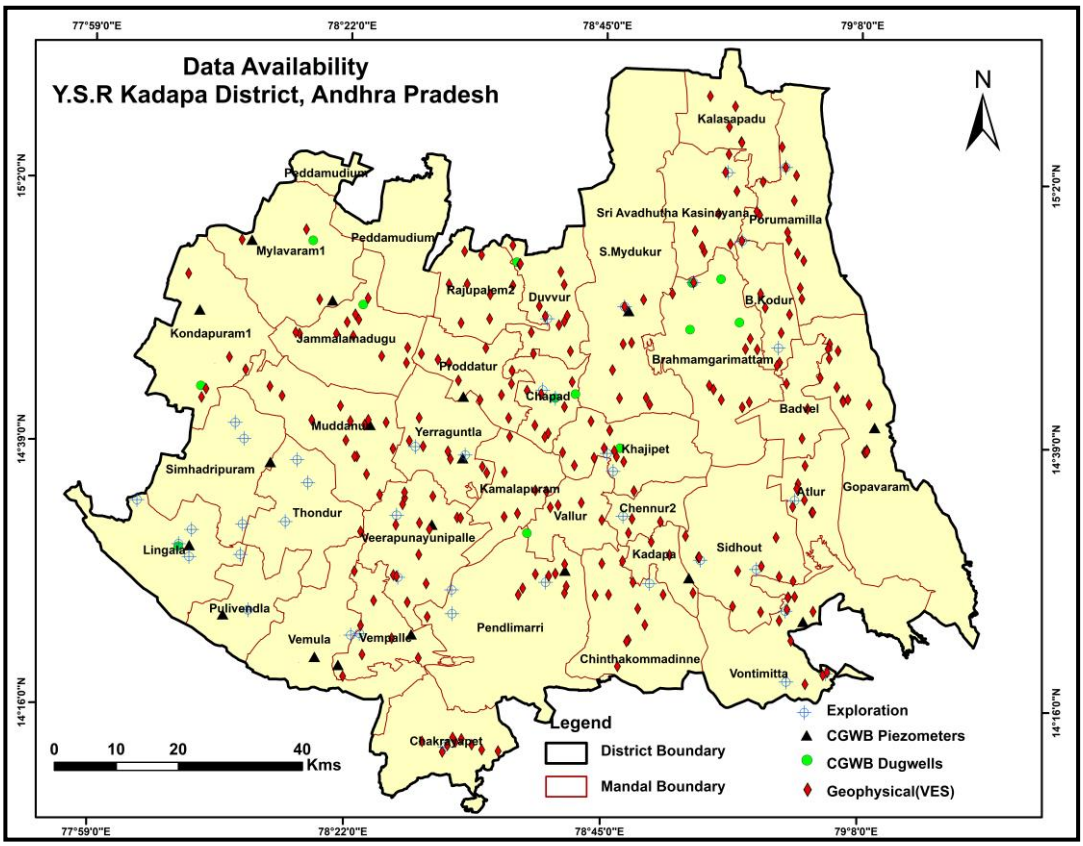


Fig. 2.1: Hydrogeological data availability map of Y.S.R Kadapa dist

2.1.1 Ground water occurrences and movement:

Ground water occurs under unconfined and semi-confined conditions and flows downward from the weathered zone (saprolite and sap rock) into the fracture zone. The main aquifers constitute the weathered zone at the top, followed by a discrete anisotropic fractured/fissured zone at the bottom, generally extending down to 200 m depth. The storage in granite rocks is primarily confined to the weathered zone and its overexploitation, mainly for irrigation purpose has resulted in desaturation of weathered zone at many places. The thickness of weathered zone generally extends upto 13m. in most of the granitic areas. Ground water in fractured zone is developed through construction of shallow/deep bore wells. Ground water in metasediments occurs under water table conditions in weathered portion of the formation and Ground water in fractured zone is developed through construction of deep bore wells down to a depth of 200 m.bgl.

At present, extraction is mainly through boreholes of 100-200 m depth, with yield between <0.2 and 13.7 litres/second (lps). ~ 80 % of fractures occur within 100 m depth and deepest fracture is encountered in Meta sediments (shales) at the depth of 185m (S.Mydukur mandal) and in Granite-gneiss at the depth of 97 m depth (Chakarayapet mandal). The hydrogeological map of the area is presented in(Fig.2.2).

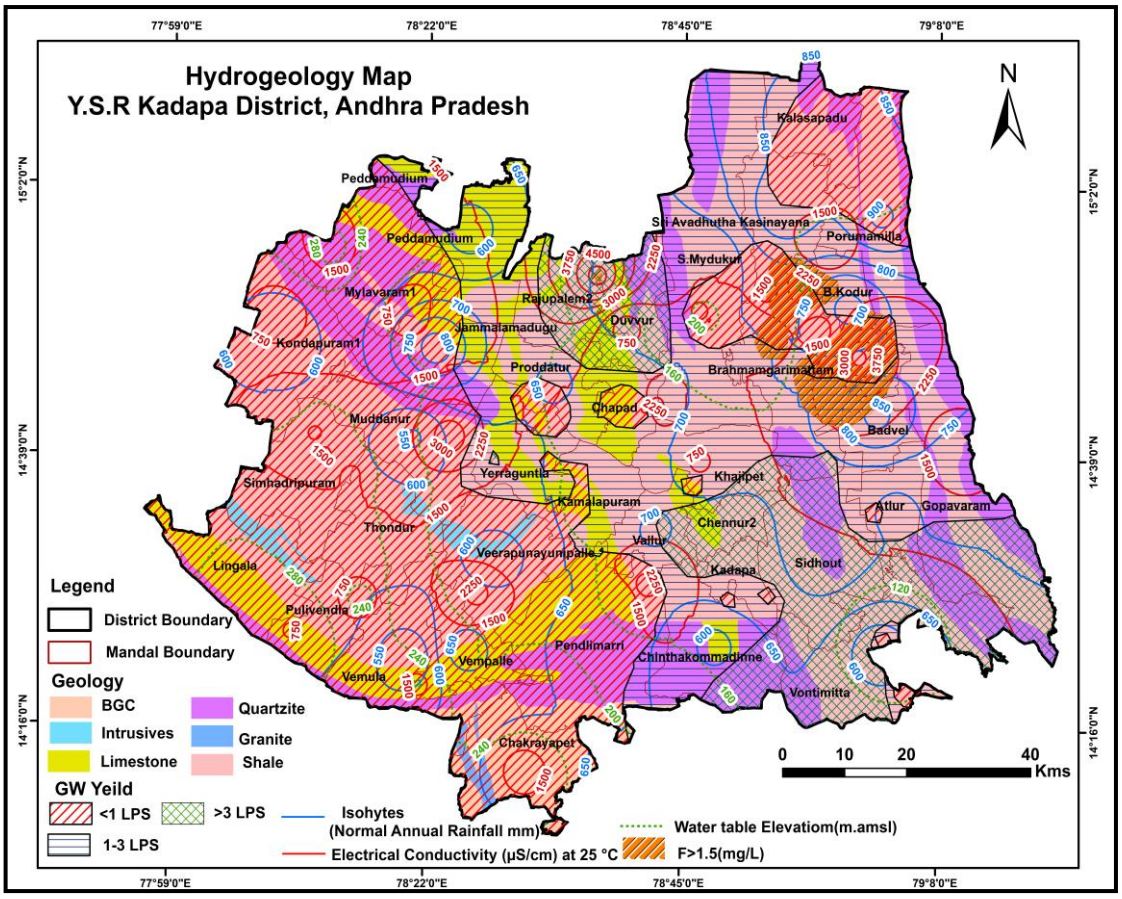


Fig.2.2: Hydrogeological map of Y.S.R Kadapa district.

2.1.2 Exploratory Drilling:

As on date, CGWB drilled 82 bore wells (exploratory, observation and piezometers), 79 wells were drilled in metasediment area and 03 wells were drilled in granitic area. Data analysed from CGWB wells indicates, 02 wells of shallow depth (30 m), 09 nos. (30-60 m), 24 nos. (60-100 m) 09 nos. (100-150 m) and 38 nos. (150-200 m) depth. Deepest fracture was encountered at 185 m.bgl at Thippireddypalli, S.Mydukur mandal.

Table:2.2: Details of Exploratory Wells Drilled in Y.S.R Kadapa District

No. of exploratory wells	82
Depth range (m bgl)	19-200
Depth of potential zone (m bgl)	60-100
General yield range (lps)	<0.1 to 13.77 lps (Avg:1.9 lps
Transmissivity (m^2/day)	1- 270 m^2/day
Storativity	0.00001 to 0.0001

2.2 Water Levels (2023):

Ground water regime monitoring is the basic component of groundwater management and it is carried out in parts of Y.S.R Kadapa district through National Hydrograph Network Stations (NHNS or NHS). NHS are observation wells, comprising of dug wells and purpose built bore wells – known as piezometers. Ground water levels from 88 wells (Dug wells: 13 and Piezometers: 75) were monitored during pre-monsoon and post-monsoon seasons respectively.

2.2.1 Water Table Elevations:

During pre-monsoon the water-table elevation ranges from 95.71 – 308.26 meter above mean sea level (m.amsl) and in Post-Monsoon 96.39-318.07. The ground water flow also has the same drainage flow direction (Fig.2.3).

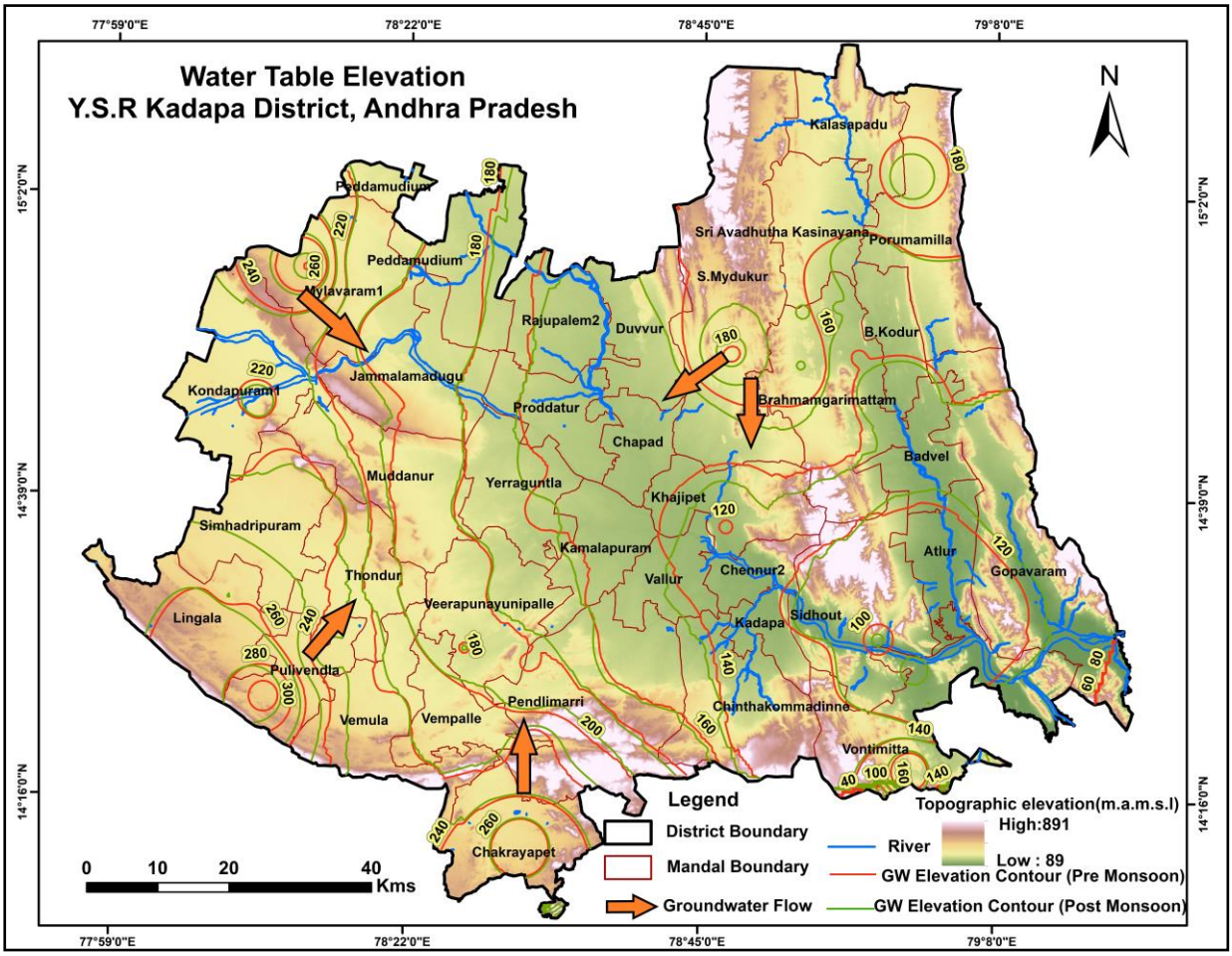


Fig.2.3: Water table elevations (m amsl) during pre and post-monsoon season-2023.

2.2.2 Depth to Water Levels (DTW):

The DTW varies from 1.32 to 51.1 meter below ground level (m bgl) (average: 9.07 m bgl) and 0.89 to 31.02 m bgl (average: 8.00) during pre and post-monsoon season of 2023 respectively.

Pre-monsoon season:

Majority of the water levels during this season are in the range of 05-10 m covering 52% of the area, followed by 10 – 20 m.bgl (34%), Shallow water levels < 5 m.bgl (11%) and deeper water levels > 20 m.bgl occupy about 03 % of the area falling in parts of Lingala, Mydukur, Sidhout, Vempalle, Porumamilla and Khajipet mandals (Fig.2.4).

Post-monsoon season:

Majority of the water levels during this season are within the range of 5-10 m.bgl covering 48% of the area, followed by 10-20m bgl (29 %), <5 m.bgl (22%) and deeper water levels >20 m.bgl occupy about 01 % of the area falling in parts of Sidhout, Lingala, Vempalle and Pendlimarri mandals (Fig.2.5).

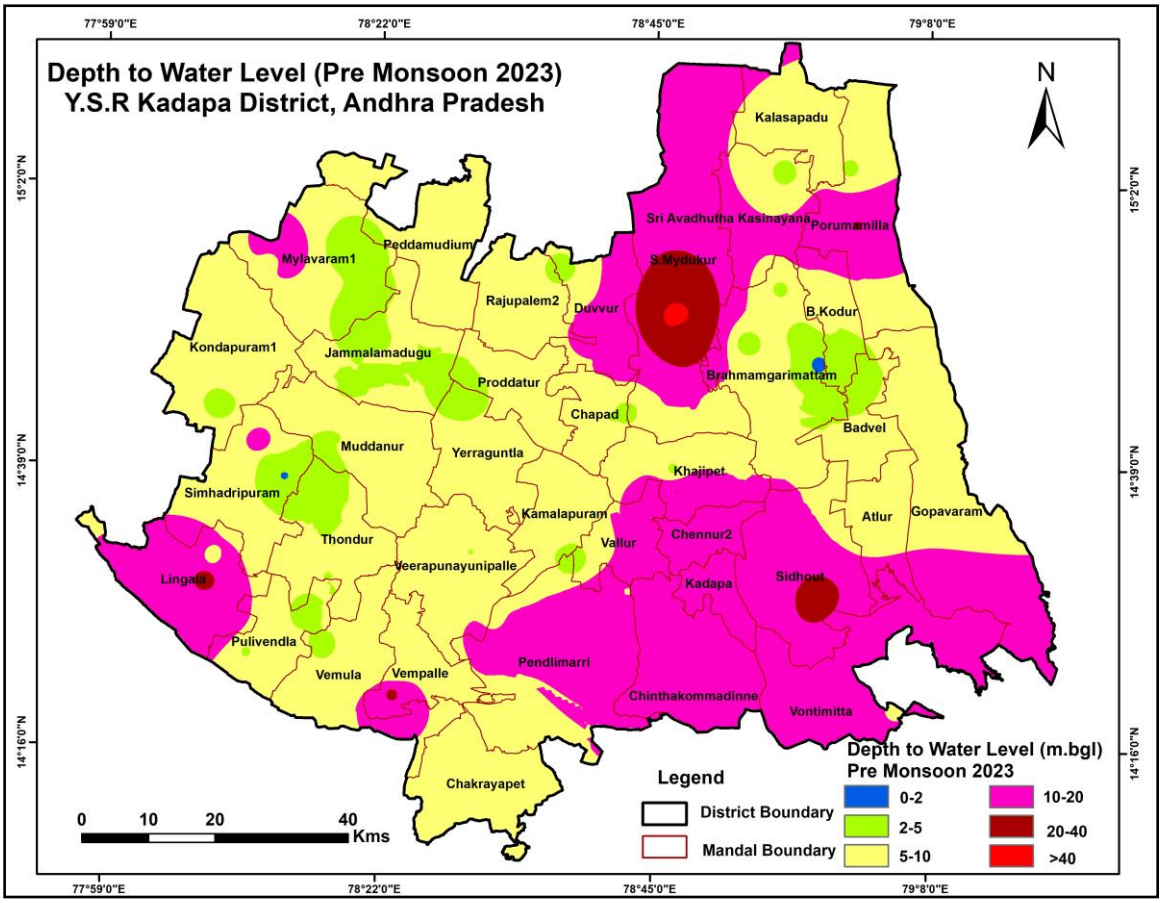


Fig.2.4: Depth to water levels Pre-monsoon (May-2023).

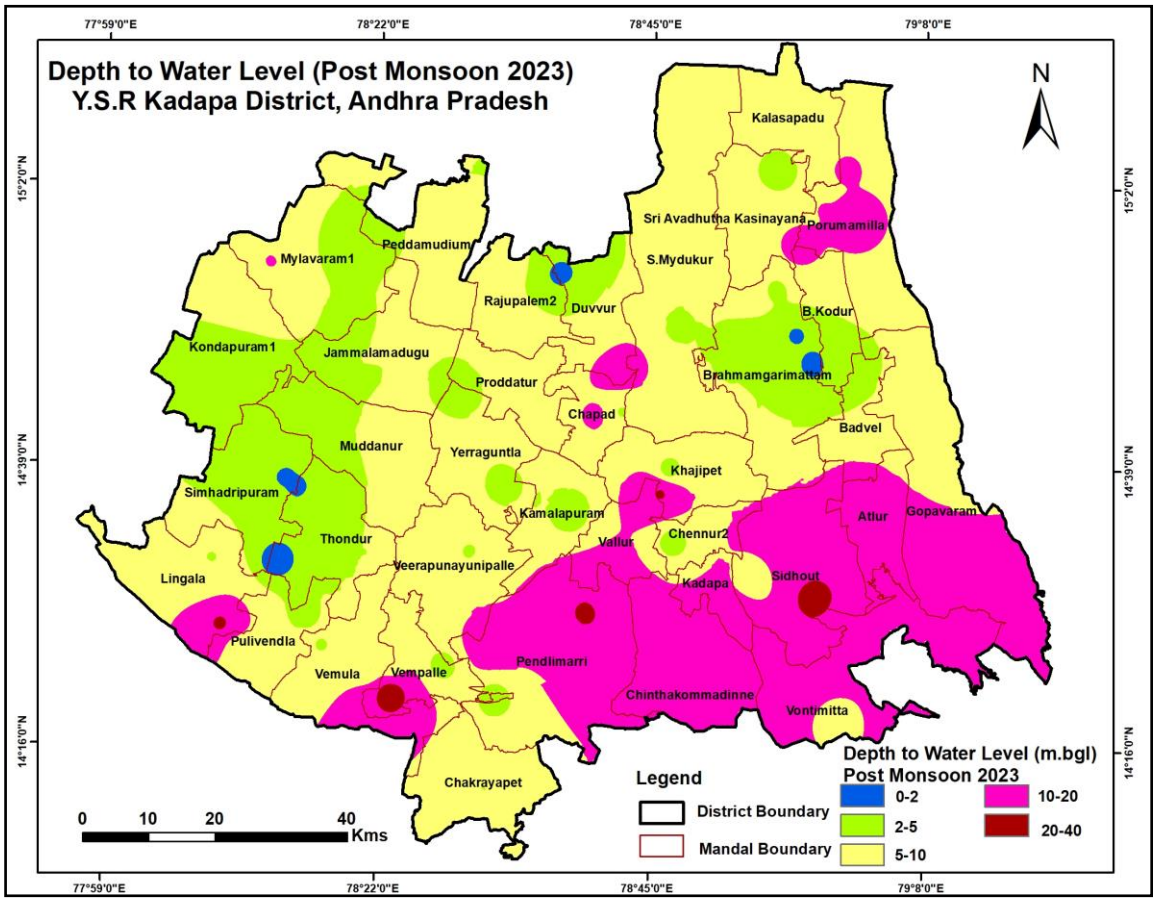
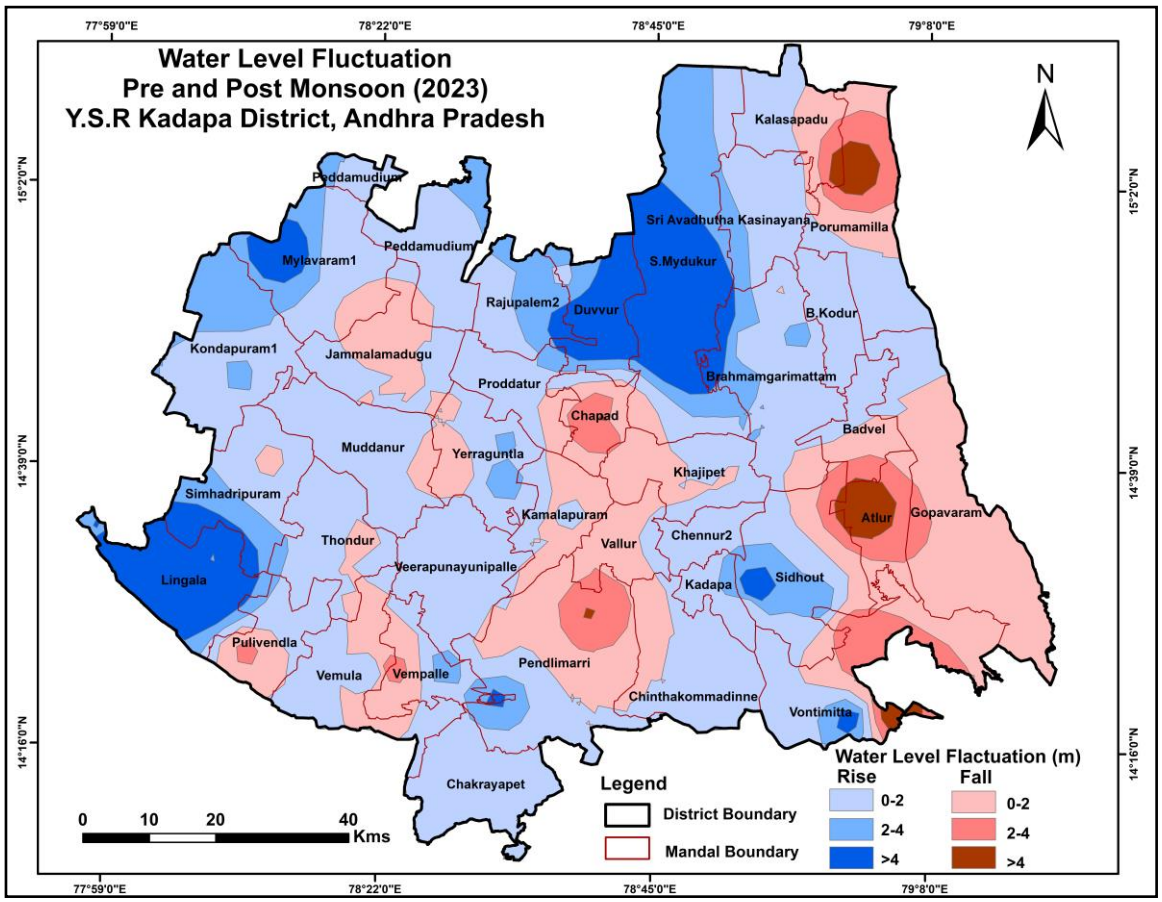


Fig.2.5: Depth to water levels Post-monsoon (Nov-2023).

2.2.3 Water Level Fluctuations (May Vs. November):

The water level fluctuations vary from -6.46 to 25.24 m with average rise of 0.84 m (Fig.2.6). 58% (35 wells) of the wells show rise in water level and 42% (25 wells) of the wells show fall in water level. Rise in water level between 0 to 2m is observed in 50% of the area, 2 to 4 m rise is observed in 11% of the area. Rise in water level >4 m is observed in 09% of area. fall in water level between 0 to 2m is observed in 24% of the area, 2 to 4 m fall is observed in 5% of the area. Fall in water level >4 m is observed in 1% of area.



.**Fig.2.6: Water Level Fluctuations (m) (Nov with respect to May-2023).**

2.2.4 Long term water level trends:

Trend analysis for the last 10 years (2014-2023) is studied from hydrograph stations of CGWB. It is observed that during pre-monsoon season, 04 wells show falling trend in the range of 0.08 m/yr to 0.83 m/yr and 25 wells show rising trend in the range of 0.02 m/yr to 4.64 m/yr. During post-monsoon season 14 wells show falling trend 0.01 to 2.83 m/yr and 31 wells show rising trends 0.02 to 10.52 m/yr (Fig.2.7 & 2.8) and graphical representation of water level trends given in (Fig. 2.9).

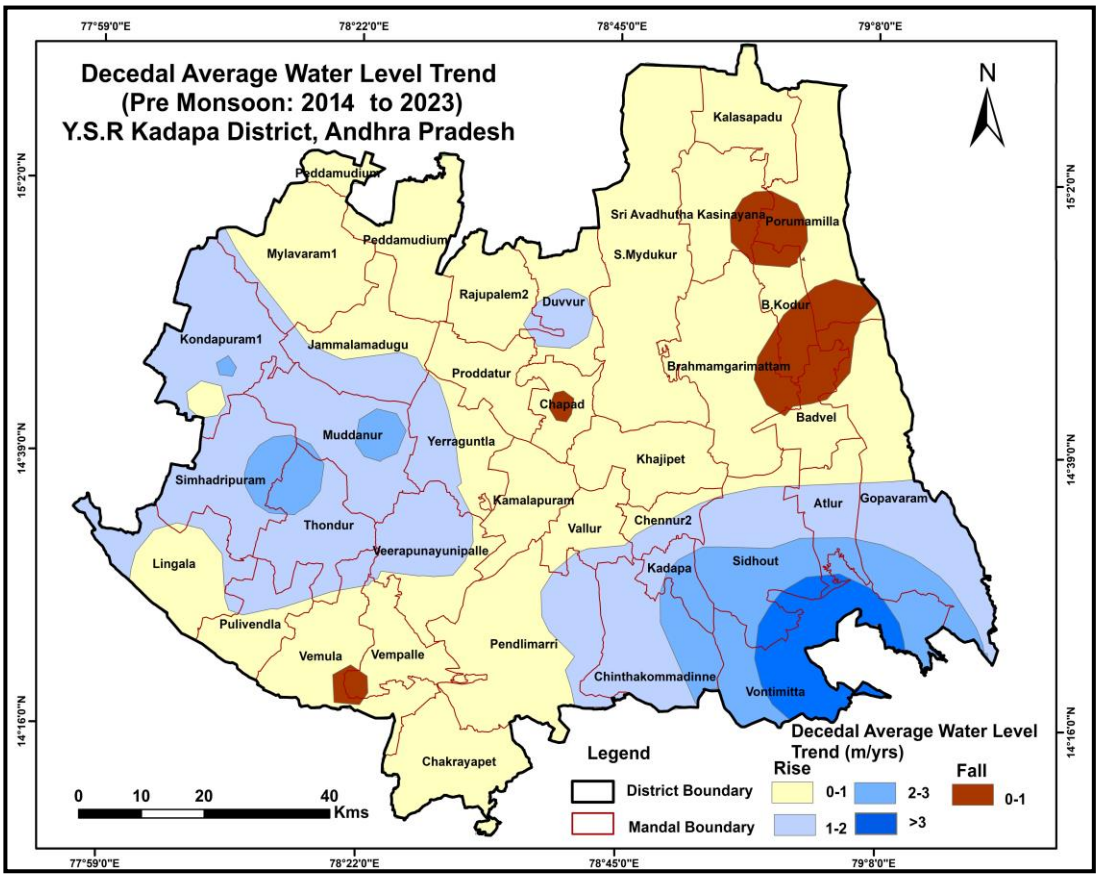


Fig.2.7 Long-term water level trends Pre Monsoon (2014-23)

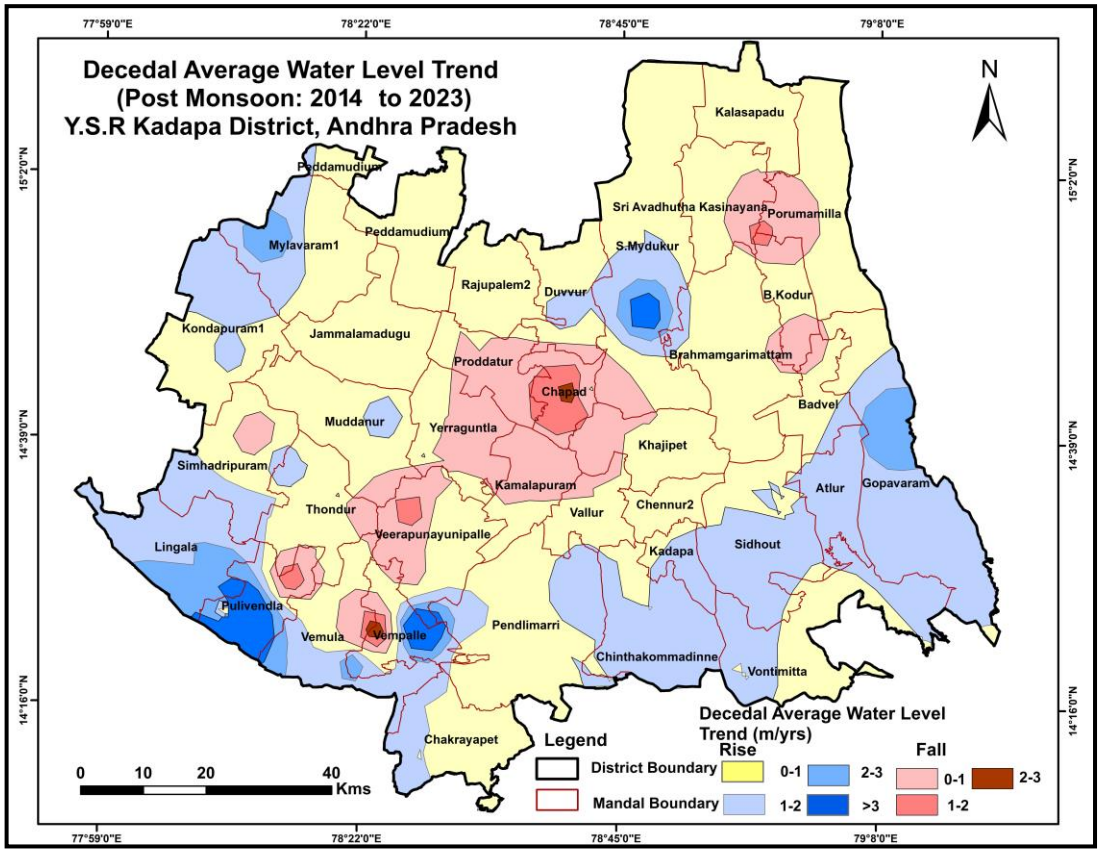


Fig. 2.8: Long-term water level trends Post Monsoon (2014-23)

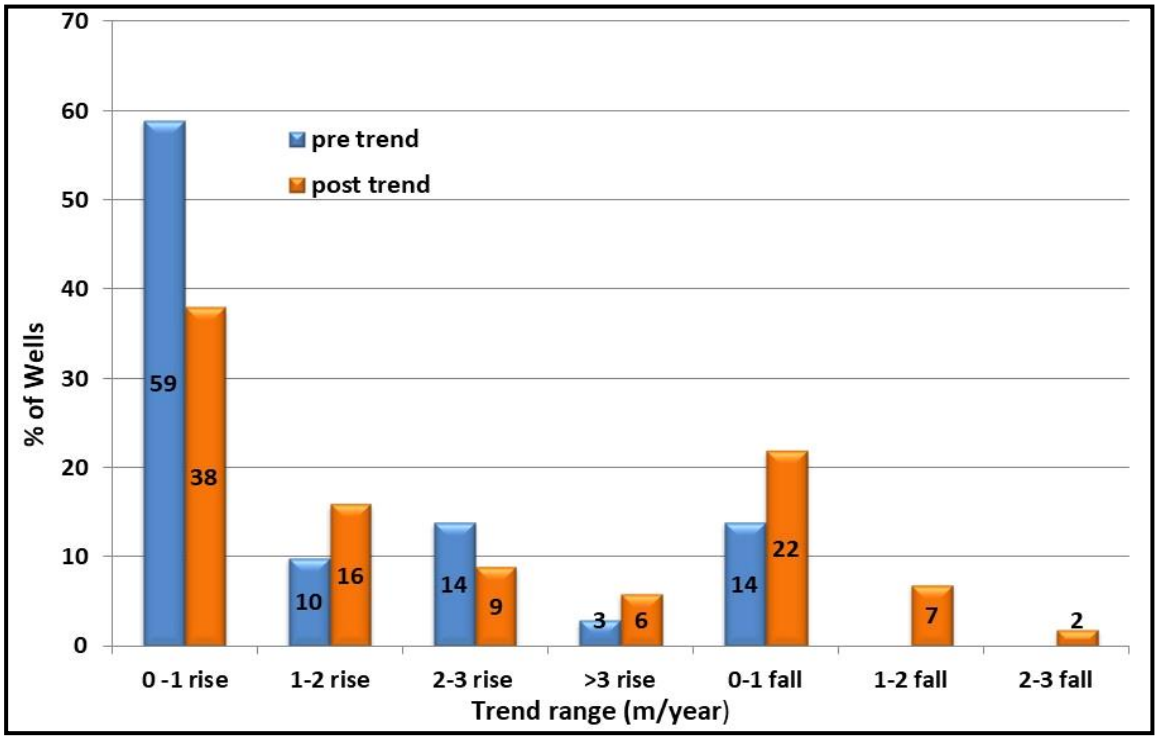


Fig. 2.9: Graphical representation of water level trends (2014-2023).

2.3 Hydro chemical Studies

To understand chemical nature of groundwater, total 49 water samples data is utilized from ground water monitoring wells of CGWB during the pre-monsoon season of 2022. Parameters namely pH, EC (in µS/cm at 25° C), TH, Ca, Mg, Na, K, CO_3, HCO_3, Cl, SO_4, NO_3 and F were analyzed.

2.3.1 Pre-monsoon (May-2022)

Groundwater from the area is mildly alkaline to alkaline in nature with pH in the range of 6.95-9.2(Avg: 7.78). Electrical conductivity varies from 240-5530 (avg: 1467) µ Siemens/cm**.** In 70 % of area EC is within 1500 µ Siemens/cm, in 24% area, it is 1500-3000 µ Siemens/cm and in 6 % area, it is > 3000 µ Siemens/cm (Fig.2.10). The Concentration of NO3 ranges from 0.13-649 mg/l with an average 59.76 mg/l. Nitrate concentration <45 mg/l is observed in 32(65 %) samples and above permissible limit of >45 mg/l is observed 17(35%) samples (Fig.2.11). The concentration of fluoride ranges from 0.05-2.55 mg/l with an average of 0.81 mg/l. In 44 samples (90%), fluoride concentration is observed less than the permissible limits (<1.5 mg/l) and in 05 (10 %) samples fluoride is more than the permissible range (>1.5 mg/l). High fluoride concentration is observed mostly in Brahmamgarimatam and Duvvur mandal of the district (Fig.2.12).

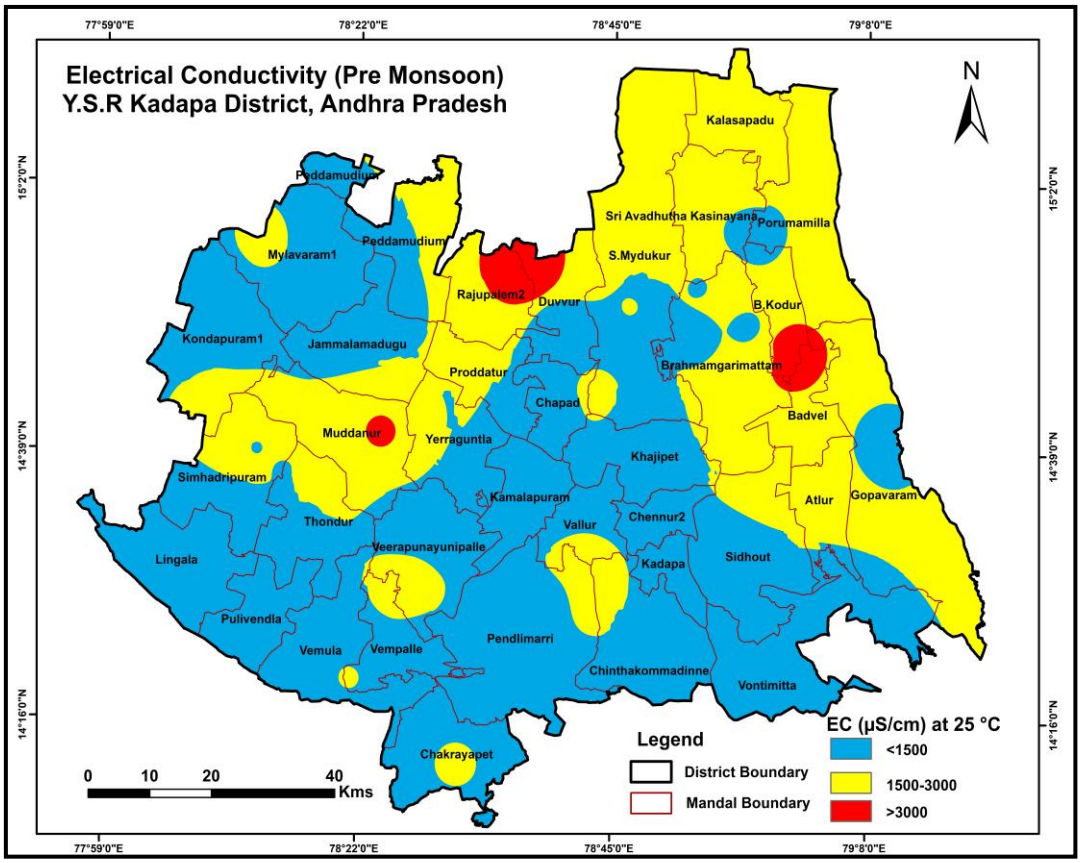


Fig.2.10: Concentration of Electrical conductivity (Pre-monsoon-2022).

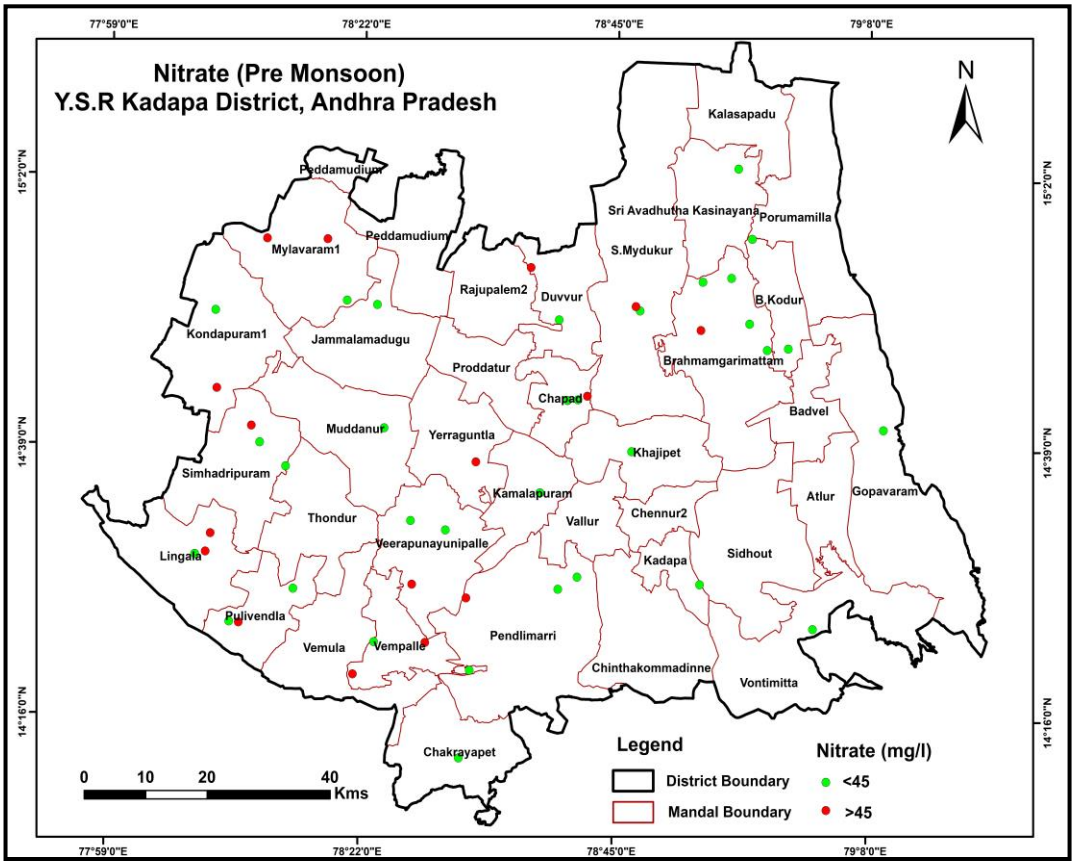


Fig.2.11: Distribution of Nitrate (Pre-monsoon-2022).

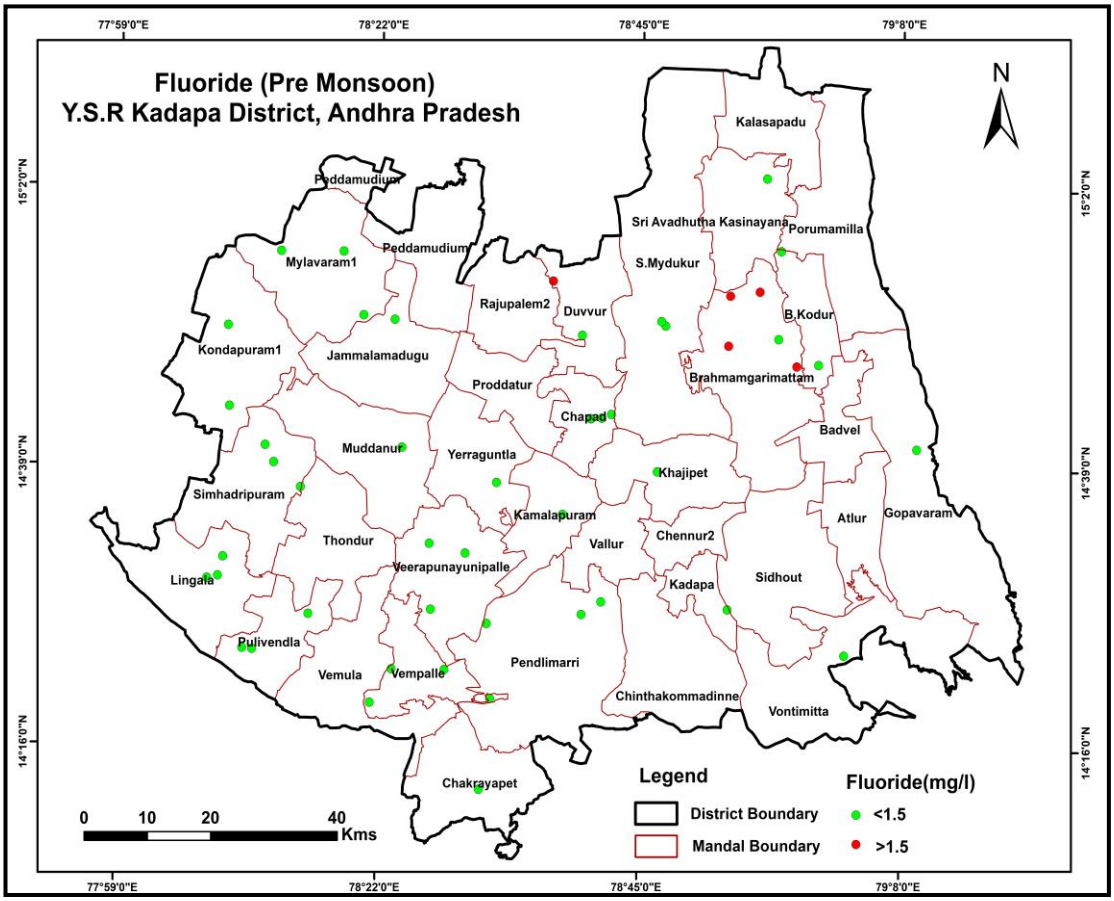


Fig.2.12: Distribution of Fluoride (Pre-monsoon-2022).

2.3.2 SUITABILITY OF GROUNDWATER FOR IRRIGATION PURPOSE

The chemical quality of irrigation water significantly impacts agricultural productivity. Accumulation of salts in the soil from irrigation can impede plant growth by disrupting osmotic processes. In addition to problems caused by excessive concentration of dissolved solids, certain constituents in irrigation water are especially undesirable and some may be damaging even when present in small concentrations. Irrigation indices viz. Sodium Adsorption Ratio (SAR) and Residual Sodium Carbonate (RSC) have been evaluated to assess the suitability of ground water for irrigation purposes.

Alkali Hazard

In the irrigation water, it is characterized by absolute and relative concentrations of cations. If thesodium concentrations are high, the alkali hazard is high and if the calcium & magnesium levelsare high, this hazard is low. The alkali soils are formed by the accumulation of exchangeable sodium and are characterized by poor silt and low permeability. The U.S. Salinity laboratory hasrecommended the use of sodium adsorption ratio (SAR) as it is closely related to adsorption of sodium by the soil.

SAR is derived by the following equation:

$$SAR = \frac{Na}{\sqrt{(Ca + Mg)/2}}$$

SAR Category	
S_1 – Low Sodium Water (SAR <10)	Such waters can be used on practically all kinds of soils without any risk or increase in exchangeable sodium.
S2 – Medium Sodium Water (SAR 10-18)	Such waters may produce an appreciable sodium hazard in fine textured soil having high cation exchange capacity under low leaching.
S_3 – High Sodium Water (SAR >18-26)	Such waters indicate harmful concentrations of exchangeable sodium in most of the soil and would require special management, good drainage, high leaching and addition of organic matter to the soil. If such waters are used on gypsiferrous soils the exchangeable sodium could not produce harmful effects.
S4 – Very High Sodium Water (SAR >26)	Such waters are unsatisfactory for irrigation purposes except at low or perhaps at medium salinity where the solution of calcium from the soil or addition of gypsum or other amendments makes the use of such waters feasible.

The computed SAR values ranges from 0.35 to 35.15. The maximum SAR value has been found at Kanagudur of Duvvur mandal. It is apparent from (Fig.2.13) that 90 % samples belong to excellent category (S1), 4 % water samples are associated with Medium sodium category (S2), 2 % water samples are associated with High sodium category (S3) and 4 % water samples are associated with Very high sodium category (S4). Percentage of groundwater samples according to SAR classifications is given in (Fig.2.13).

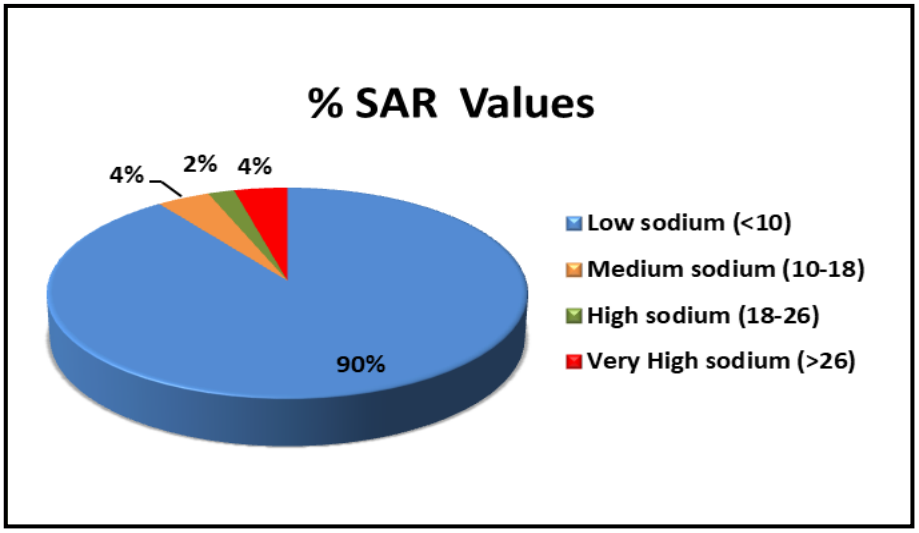


Fig. 2.13: **Percentage of groundwater samples according to SAR classifications**

Wilcox Diagram:

EC and SAR are very important in classifying irrigation water. The Wilcox diagram (Wilcox 1948) relating EC and SAR shows (Fig. 2.14). The Wilcox plot is also known as the U.S. Department of Agriculture diagram. The samples collected from the monitoring wells of Kadapa fall in to 9 classes(Fig. 2.14) as described below.
C_1S_1: Low salinity and low sodium waters are good for irrigation and can be used with most of the crops with no restriction on use on most of the soils.
C_2S_1: Medium salinity and low sodium water can be used for irrigation on almost all soils with little danger of Na problem/hazard, if a moderate amount of leaching occurs. Crops can be grown without any special consideration for salinity control.
C_3S_1: The high salinity and low sodium waters require good drainage. Crops with good salt tolerance should be selected.
C_3S_2: Thehigh salinity and medium sodium waters require good drainage and can be used on coarse textured or organic soils having good permeability.
C_3S_3: These high salinity and high sodium waters require special soil management, good drainage, high leaching and organic matter additions. Gypsum amendments make feasible the use of these waters.
C_4S_1: Very high salinity and low sodium waters are not suitable for irrigation unless the soil must be permeable and drainage must be adequate. Irrigation waters must be applied in excess to provide considerable leaching. Salt tolerant crops must be selected.
C_4S_2: Very high salinity and medium sodium waters are not suitable for irrigation on fine textured soils and low leaching conditions and can be used for irrigation on coarse textured or organic soils having good permeability.
C_4S_3: Very high salinity and high sodium waters produce harmful levels of exchangeable sodium in most soils and will require special soil management, good drainage, high leaching and organic matter additions. Gypsum amendment makes feasible the use of these waters.
C_4S_4: Very high salinity and very high sodium waters are generally unsuitable for irrigation purpose. These are sodium chloride type of waters and can cause sodium hazard. It can be used on coarse textured soils with very good drainage for very high salt tolerant crops. Gypsum amendments make feasible the use of these waters.

The (Fig. 2.15) shows US Salinity Laboratory diagram of deeper aquifer water samples of the district. It is observed that 61% of water samples are falling in C3-S1 class, 14% in C2-S1

class, 6% in C3-S2 class, 4 % in C4-S3, C4-S2, C4-S1 about 2% each of the samples falling in C1-S1, C3-S3, C4-S4 classes.

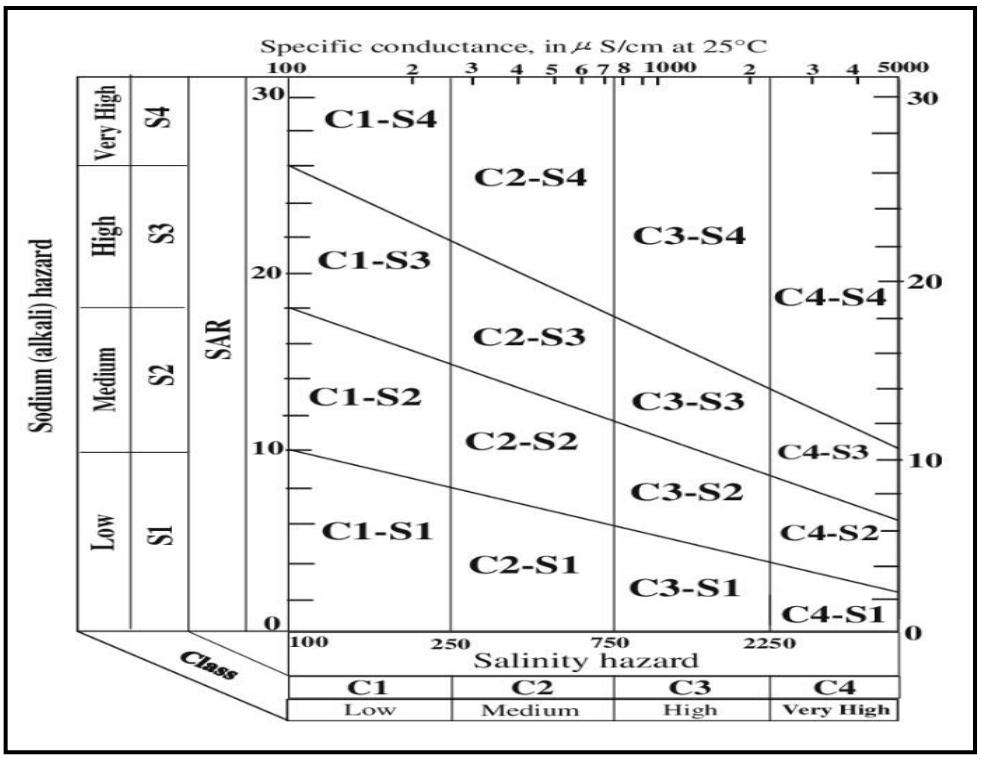


Fig.2.14 USSL Diagram for classification of irrigation waters

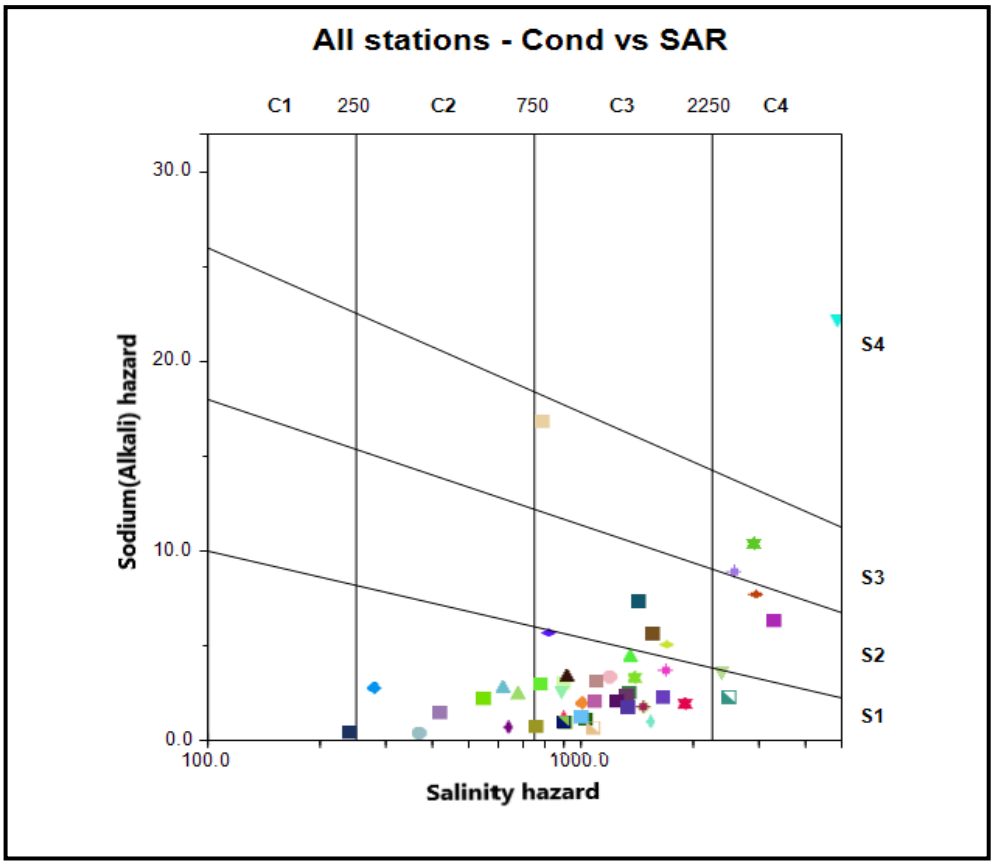


Fig: 2.15 USSL Diagram of Groundwater samples.

Piper diagram

Piper diagram (Piper 1944) describes the process responsible for the evolution of hydro geochemical parameter in groundwater. Based on the major Cation and major anion content in the water samples and plotting them in the trilinear diagram, hydro chemical facies could be identified. The types of facies are inter-linked with the geology of the area and distribution of facies with the hydro geological controls. Hydro chemical facies are delineated by plotting percentage reacting value of major ions on tri-linear diagrams know as Piper Diagram (Fig. 2.16).

For identification of different water faecies of groundwater, Piper diagram is widely used as it gives best graphical representation (Hill, 1940; Piper 1944) for finding out type of water. Groundwater can be grouped broadly into 5 types**.** The samples of Kadapa district mainly fall under one major geochemical facies (Fig. 2.17), that is Mg-HCO_3 type and some are Mixed type. Samples those who are Mg-HCO_3 type are positioned in extreme left of central shaped diamond indicates presence of weak acids exceed strong acids and alkaline earths exceeds alkalies. As we observe only one dominant geochemical facies of the samples analysed, it may be concluded that the water contains cations and anions mainly from geological formations such as shale, limestone and quartzites and these rocks have major contribution to control the geo hydrochemistry of ground water in Y.S.R Kadapa district.

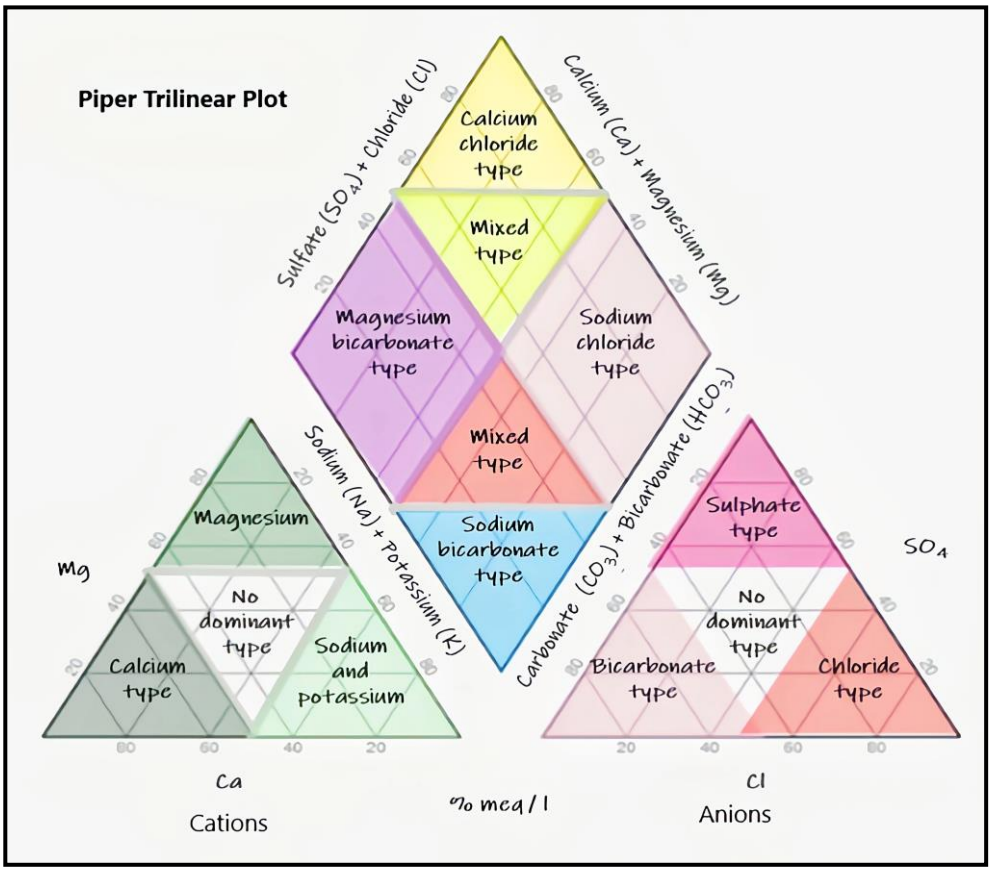


Fig.2.16 Piper Diagram

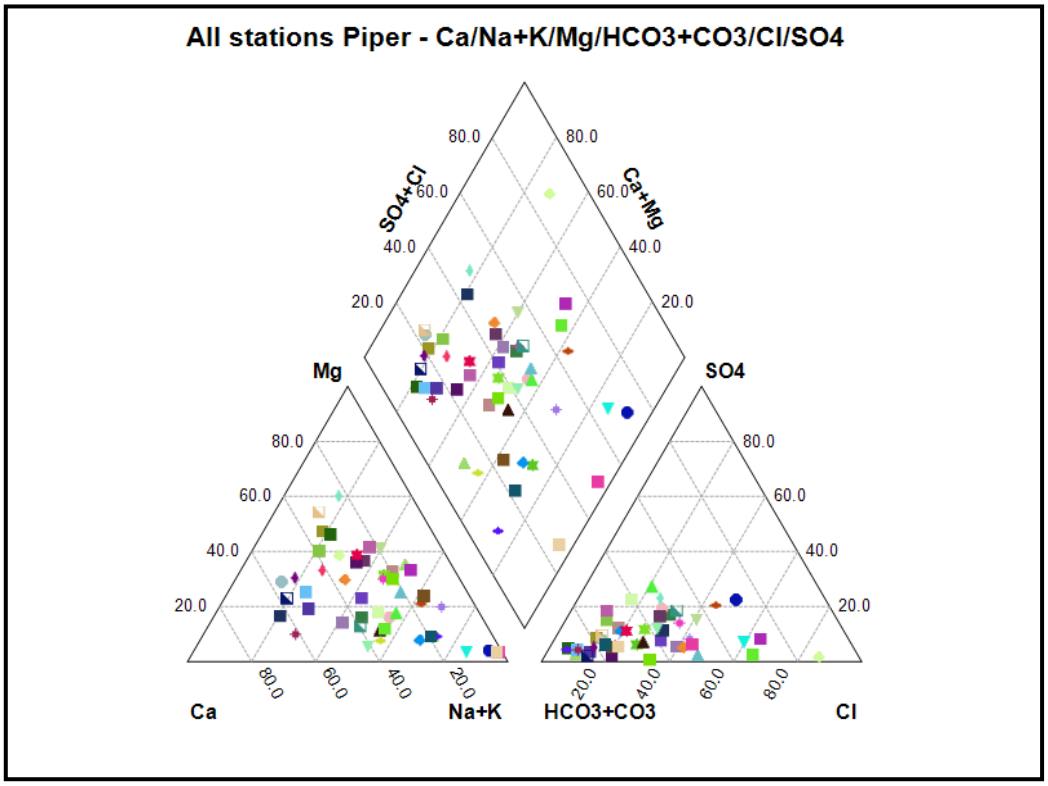


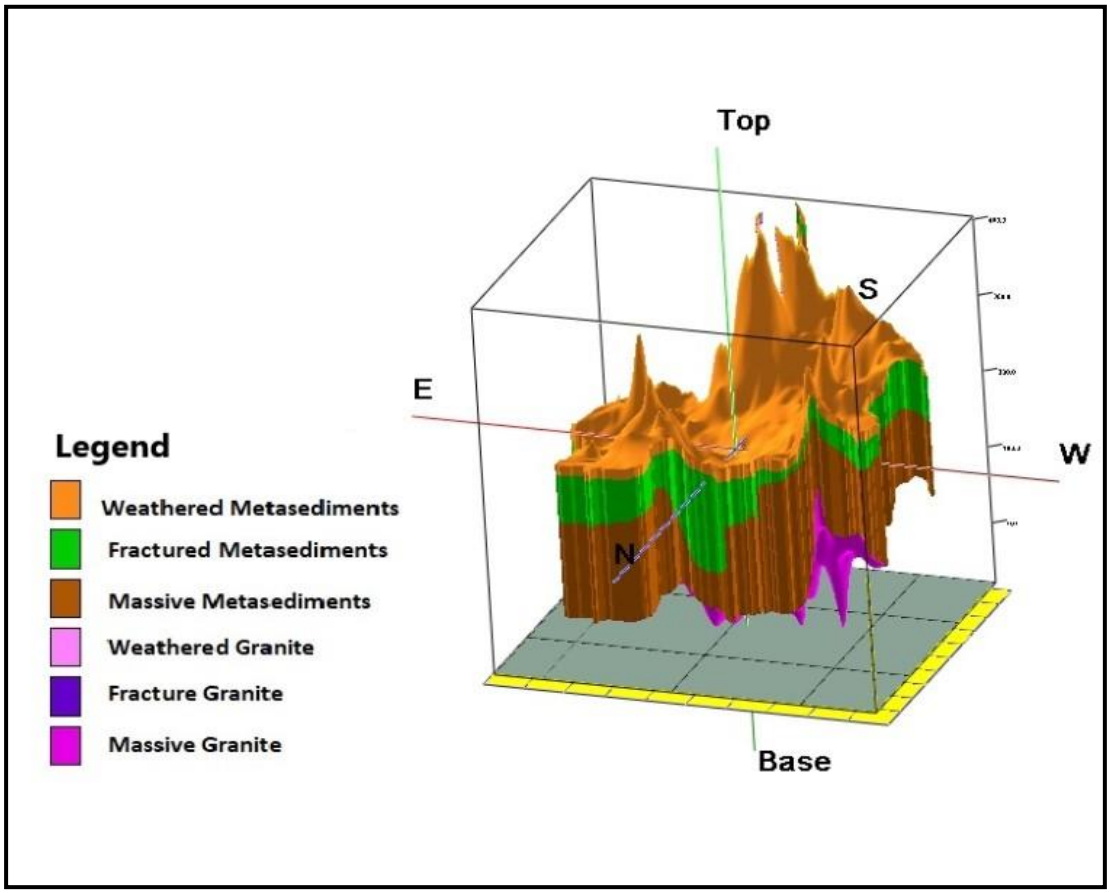
Fig.2.17 Piper plot of water samples collected from Y.S.R Kadapa district.

3. DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING

Conceptualization of 3-D hydrogeological model was carried out by interpreting and integrating representative data points (both hydrogeological and geophysical data) for preparation of 3D map, panel diagram and hydrogeological sections. The data is calibrated for elevations with Shuttle Radar Topography Mission (SRTM) data. The lithological information was generated by using the RockWorks-16 software and generated 3-D map and fence diagram for Y.S.R Kadapa district (Fig.3.1) and hydrogeological sections.

3.1 Conceptualization of aquifer system in 3D

Aquifers were characterized in terms of potential and quality based on integrated hydrogeological data and various thematic maps. Weathered zone is considered up to the maximum depth of weathering and first fracture encountered (below weathered depth) generally down to ~25 m depth and the fractured zone (fractured granite) is considered up to the depth of deepest fracture below weathered zone (~25-185 m).



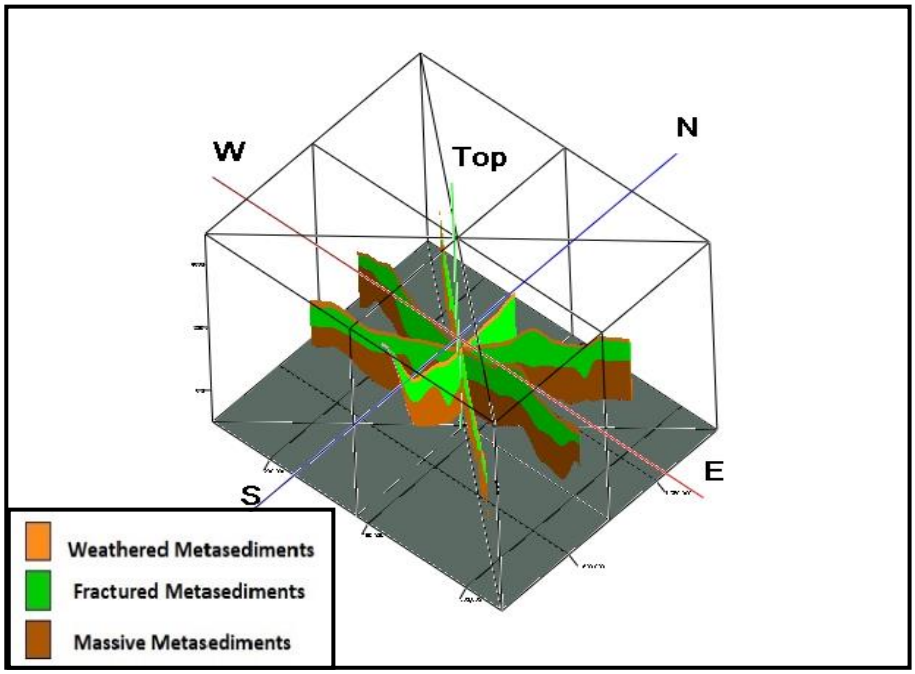


Fig.-3.1: 3D Model and fence diagram of the study area.

3.2 Hydrogeological Sections

Hydrogeological sections are prepared in N-S, SW-NE and NW-SE directions (Fig. 3.2).

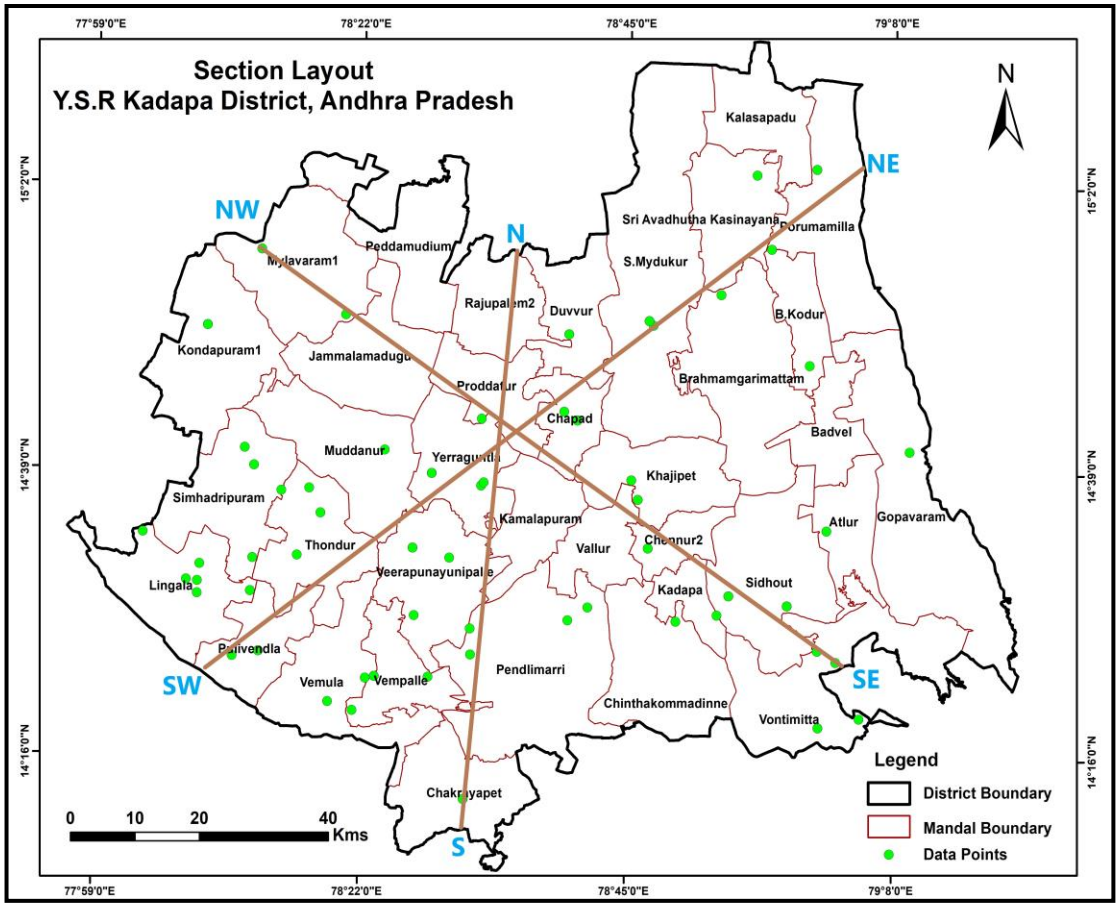


Fig.-3.2: Map showing Orientation of Hydrogeological cross sections.

3.2.1 North-South Section:

The section drawn along the N-S direction covering distance of ~86 kms (Fig.3.3a). It depicts thick weathered zone in central and Northern part and thin weatherd zones in the Southern part. Thick fractured zone in Northern part and thin fractured zone in the Southern part. The section is drawn by taking 5 data points from North to South namely Pullareddypeta, Laxmipet, Yerraguntla, Nadimadalam and Mahadevpally.

3.2.2 South-West and North-East Section:

The section drawn along the SW-NE direction covering distance of ~92 kms (Fig.3.3b). It depicts thick weathered zone in the South-Western part and thick fracture zones in the central part. The section is drawn by taking 7 data points from South-West to North-East namely Pulivendula, Ayyavaripalli, Yearraguntala, Chapudu, Adireddypalli and Sagileru.

3.2.3 North-West and South-East Section:

The section drawn horizontally along NW-SE direction covering distance of ~120 kms (Fig.3.3c). It depicts thick weathered zone in South Eastern part and thick fractured zone in the central part. The section is drawn by taking 6 data points from North-West to South-East namely Dhodium, Mylavaram, Khajipet, Upparapalli, Machupally and Gangaperuru.

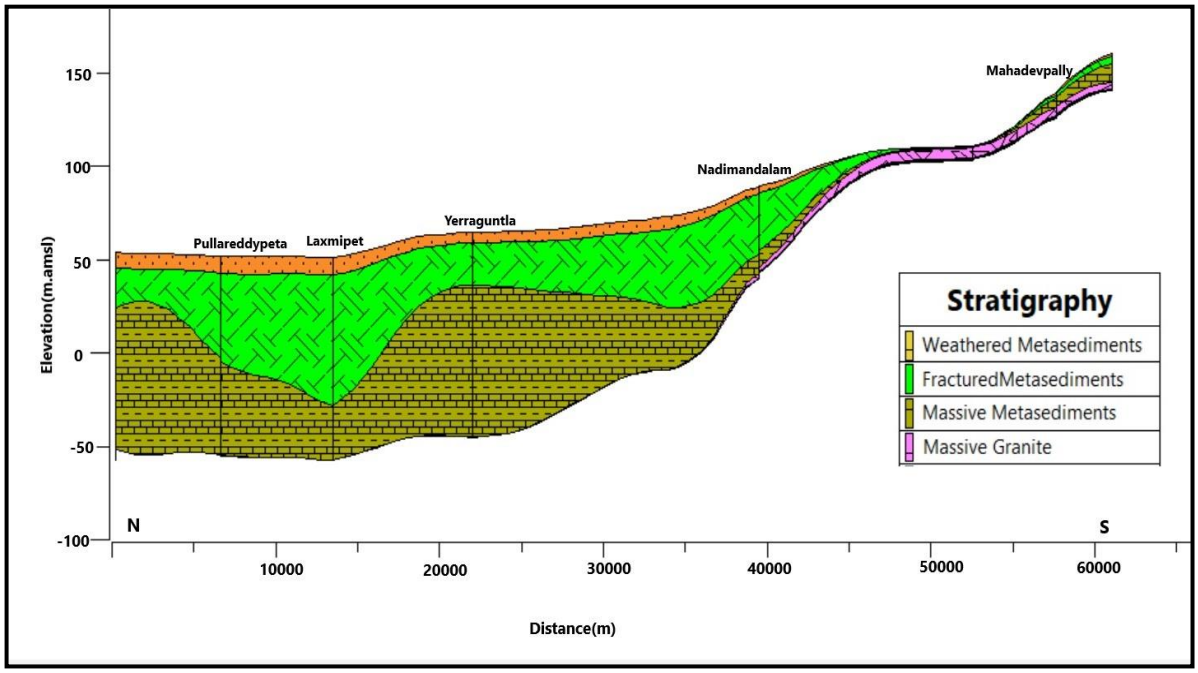


Fig.3.3a: Hydrogeological profile in N-S direction of Y.S.R Kadapa district.

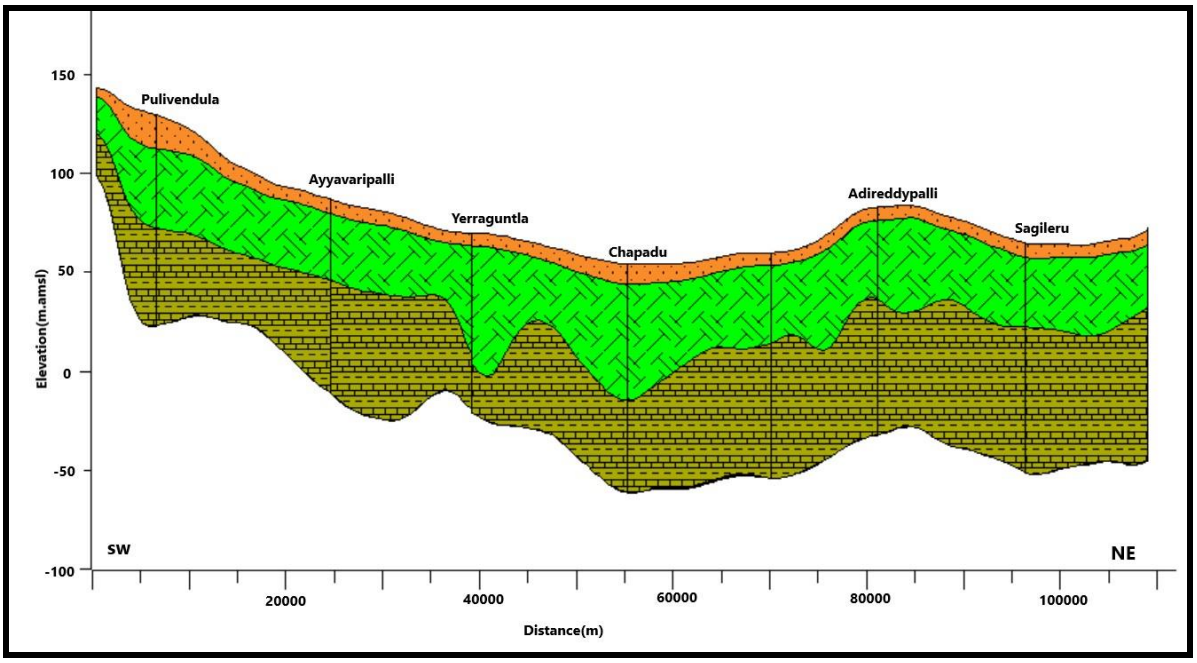


Fig.3.3b: Hydrogeological profile in SW-NE direction of Y.S.R Kadapa district.

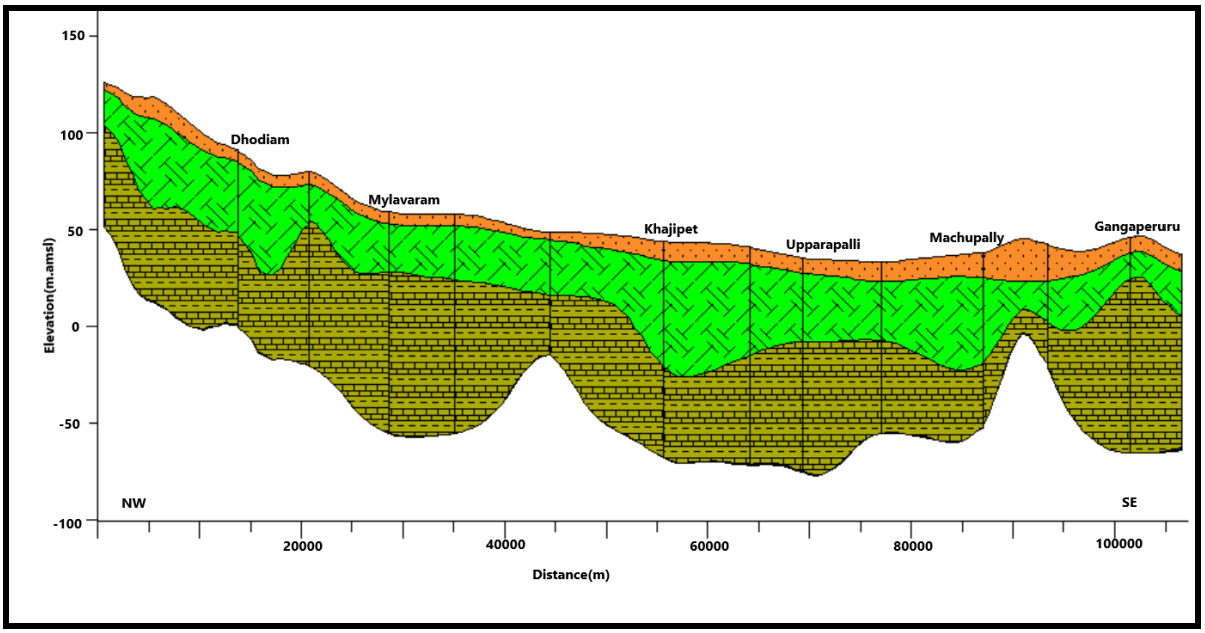


Fig.3.3c: Hydrogeological profile in NW-SE direction of Y.S.R Kadapa district.

4.0 AQUIFER CHARACTERIZATION

4.1 Weathered zone:

The Thickness of weathered zone varies from 2m to 69 m with an average thickness of ~15 m. The average thickness of weathering is 10 m in Limestones, 12 m in Granites and Granite gneisses, 20 m in Shales formation. The spatial and graphical presentation of weathering thickness is shown in (Fig.3.3 & Fig.3.4) respectively. Thickness of weathering < 10 m occurs in ~25 % of the area, 10 to 20 m occurs in ~52 % of area, 20-30 m occurs in 21 % of area. High thickness of weathering (>30 m) occurs in in 2% of the district in isolated parts of Sidhout, Vontimitta and Kadapa mandals.

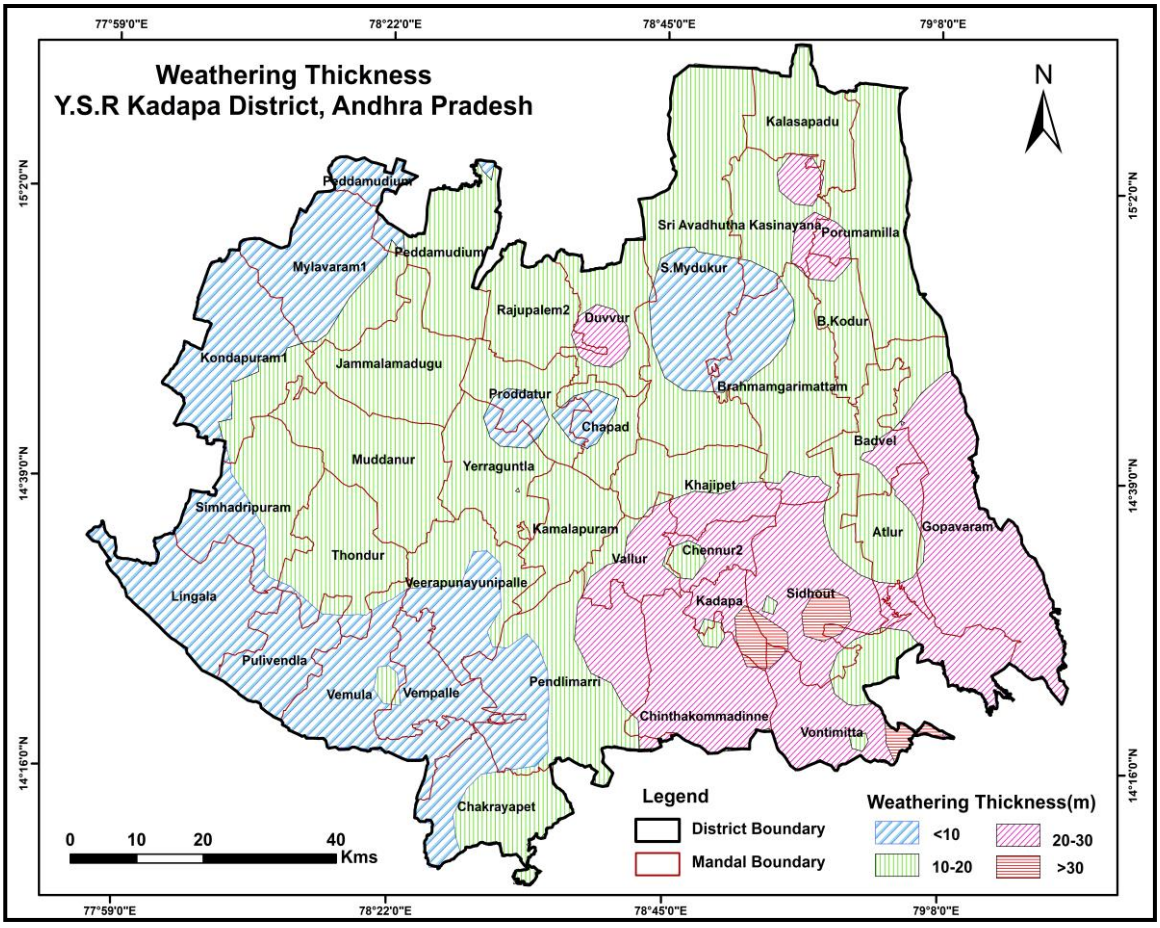


Fig.4.1: Thickness of Weathered zone of Y.S.R Kadapa district.

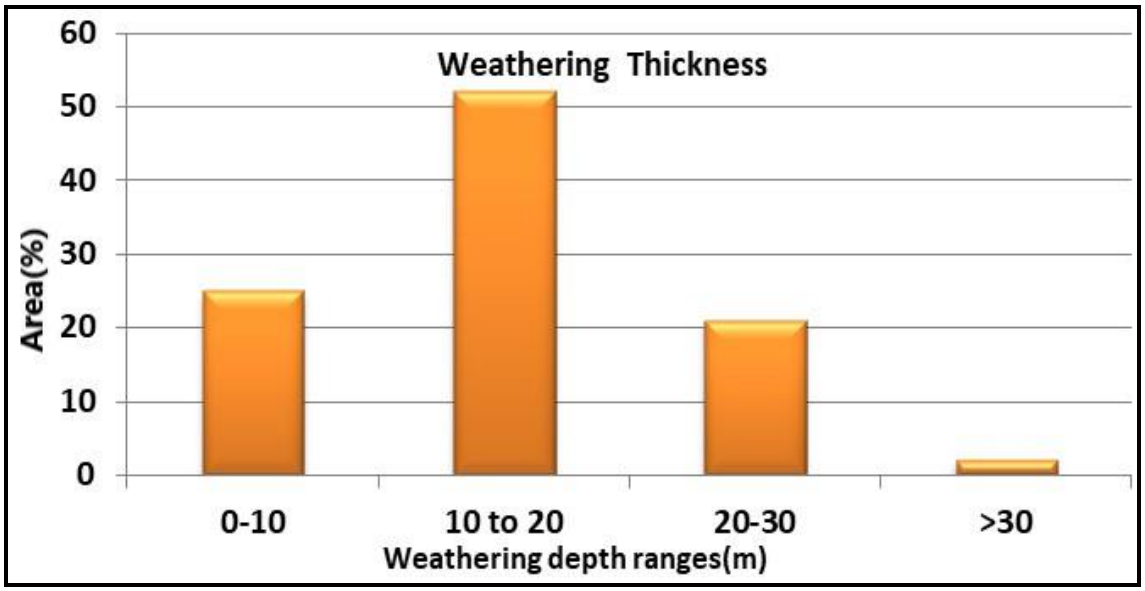


Fig.4.2: Depth wise weathered zone distribution of Y.S.R Kadapa district.

4.2 Fractured zone:

Based on Exploration data, it is inferred that fractures in the range of 60-100 m depth is more predominant (52 % of the area), <60 m in 42 % of the area and>100 m fractures occur in remaining areas. Deep fractures in the range of >150 m occur in Mydukur, Sidhout, Pulivendula, Kadapa, Atlur, Vontimitta, Lingala and Veerapunayunipalle mandals. The deepest fracture is encountered in Meta sediments (shales) at the depth of 185m in Thippireddipalle village (S.Mydukur mandal) and in Granite-gneiss at the depth of 97 m depth in Mahadevpally (Chakarayapet mandal). Analysis of occurence of fractures reveal that majority of fractures (~80 %) occur within 100 m depth (Fig.4.3) and graphical presentation of depth wise distribution of fractures given in (Fig.4.4).

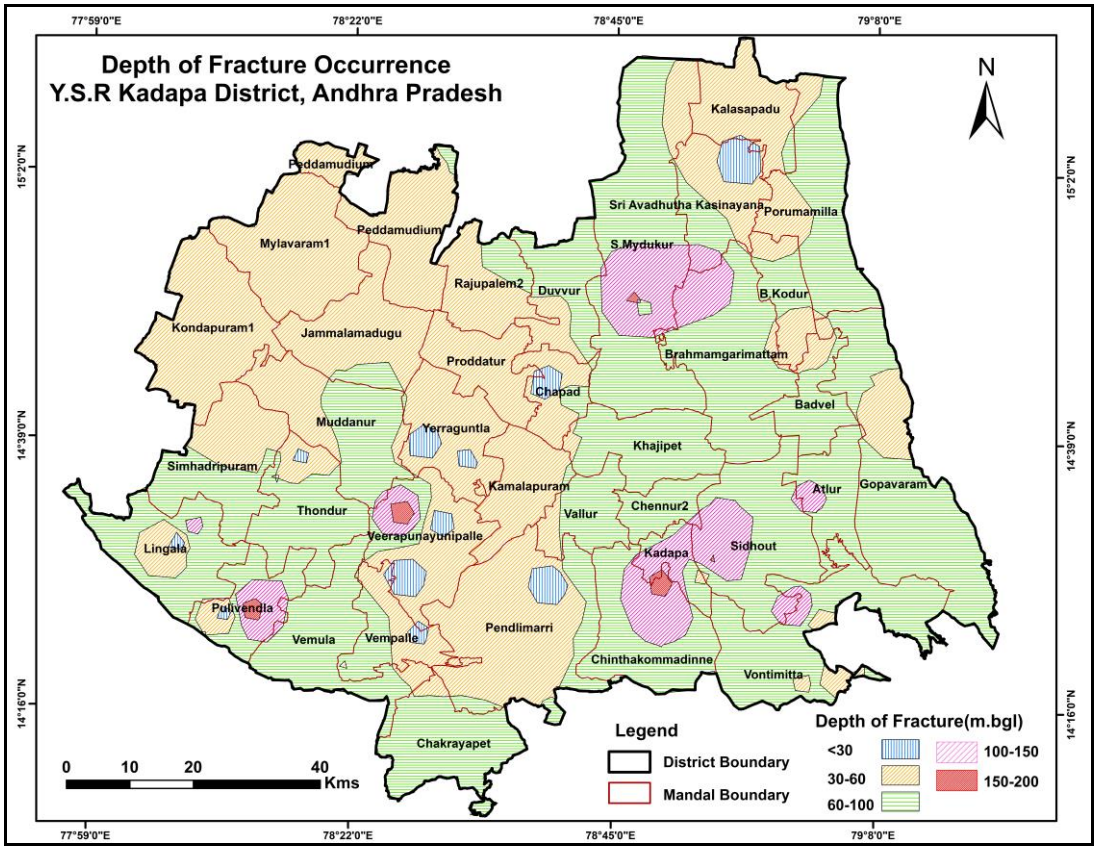


Fig.-4.3: Depth of Fractured zone of Y.S.R Kadapa district.

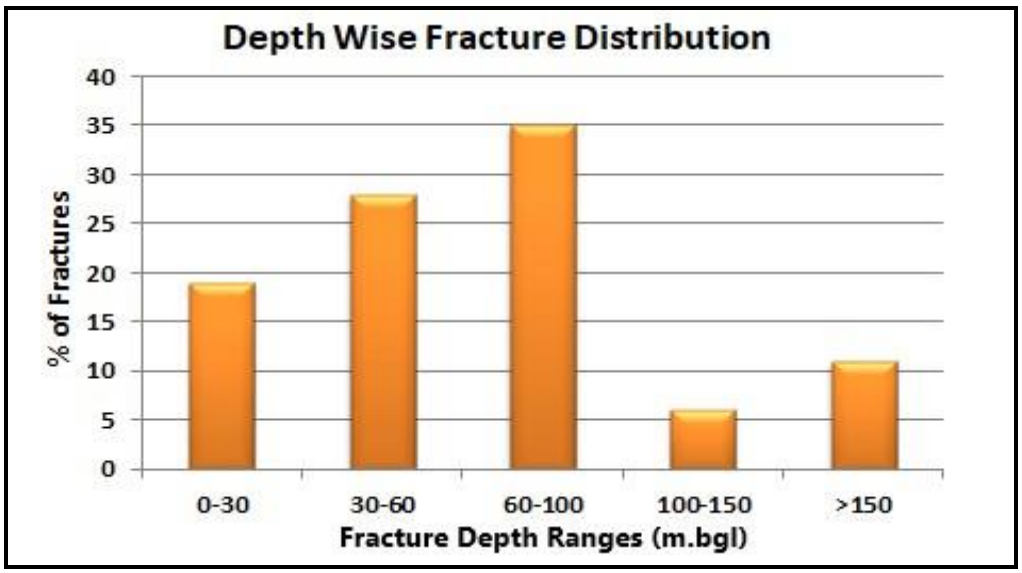


Fig.-4.4: Depth wise distribution of fractures of Y.S.R Kadapa district.

4.3 Ground Water Yield:

The yield ranges from 0.01 to 13.77 lps and highest discharge (13.77 lps) found in Vontimitta, Chennur and Duvur mandals. In majority of the area, the ground water yield in the range of <1 lps followed by 1-3 lps and 3 to 13 lps. The ground water yield of the district is shown in (Fig.4.5) and graphical presentation of Groundwater yield based discharge given in (Fig 4.6).

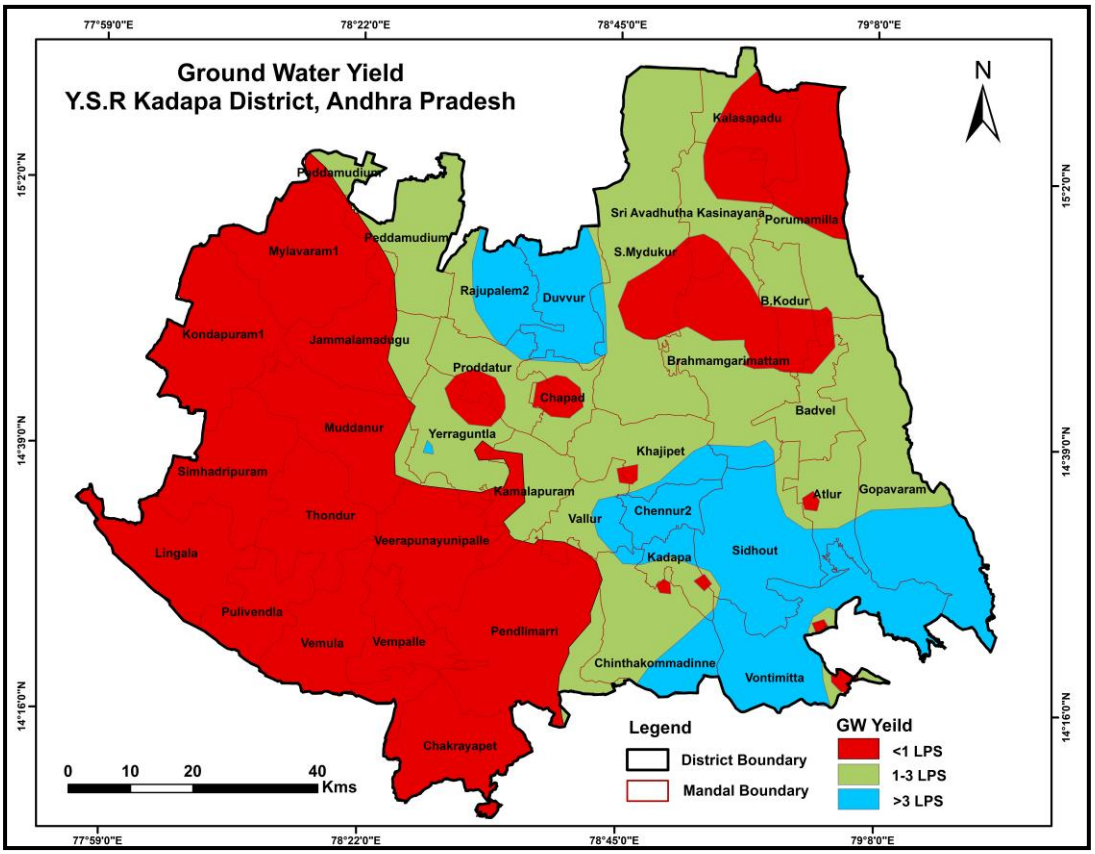


Fig-4.5: Ground water yield potential map of Y.S.R Kadapa district.

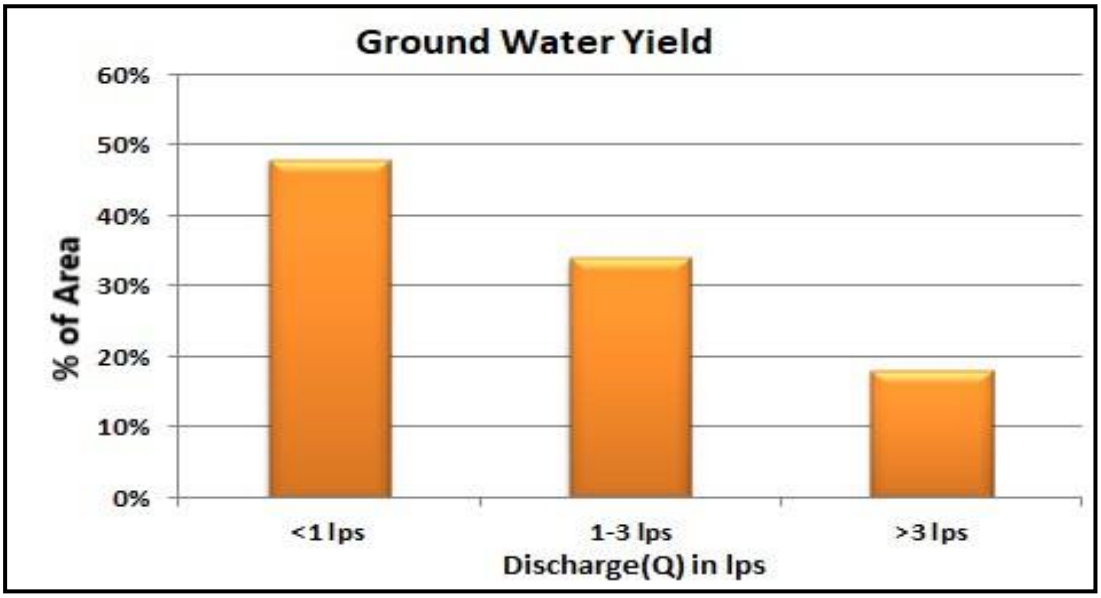


Fig.4.6: Groundwater Yield based on Discharge.

5. GROUND WATER RESOURCES (2023)

In hard rocks, for practical purpose it is very difficult to compute zone wise (aquifer wise) ground water resources, because the weathered zone (WZ) and fractured zone (FZ) are inter-connected with fractures/joints and fractured zone gets recharged through weathered zone. Therefore it is very difficult to demarcate the boundary between two aquifers; hence the resources are estimated considering entire area as a single aquifer system. Village wise dynamic and in-storage Ground Water resources are computed as per the guidelines laid down in GEC methodology.

While computing the in-storage resources, the general depth of deepest fractures in the area, pre-monsoon water levels and 2% of granular zone (depth below pre-monsoon water level and down to deepest fracture depth in the village) is considered. Computed dynamic and in-storage Ground Water Resources are given in Table-5.1.

As per 2023 GEC report, the net dynamic replenishable groundwater availability is 1016.61 MCM (Fig. 5.1), Gross Ground water draft for all uses 344 MCM (Fig.5.2), provision for drinking and industrial use for the year 2025 is 46.54 MCM and Net Ground Water Availability for future use is 688 MCM. The stage of ground water extraction varies from 10.76 in Peddamudium mandal to 102.23 in Pulivendla mandal with an overall stage of ground water extraction of 38%. 01 mandal (Pulivendla) falls in over-exploited category, 01 mandal (Vemula) in semi critical category and remaining 34 mandals fall in safe category. Based on 2023 resources, mandal categorization map is given in (Fig. 5.3).

Table-5.1: Computed Dynamic, In-storage ground water resources, Kadapa district

Parameters	Total (MCM)
Dynamic (Net GWR Availability)	**1016.61**
• Monsoon recharge from rainfall	545.42
• Monsoon recharge from other sources	231.20
• Non-monsoon recharge from rainfall	5.39
• Non-monsoon recharge from other sources	288.10
• Total Natural Discharge	53.5
Gross GW Draft	**344.14**
✓ Irrigation	297.60
✓ Domestic and Industrial use	46.54
Allocation of Ground Water Resource for Domestic Utilisation forprojected year 2025	42.64
Net GW availability for future use	688.69
Stage of GW Extraction (%)	**38.00**

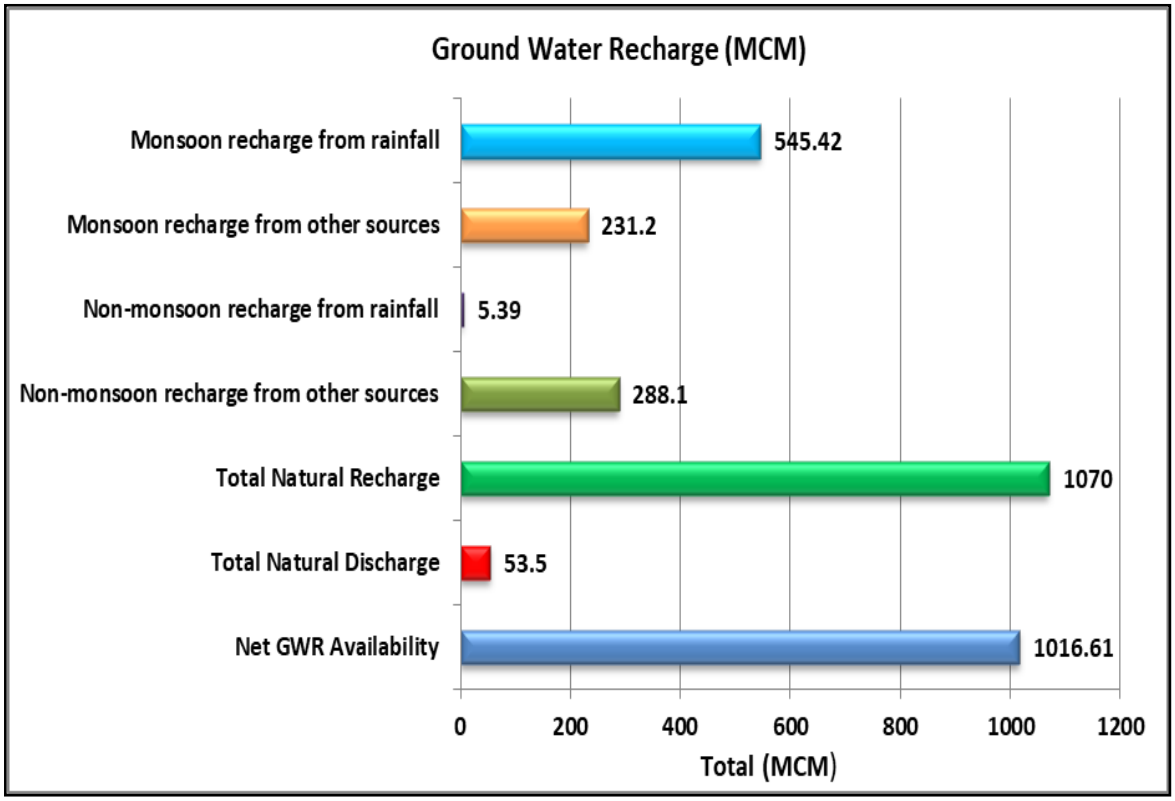


Fig 5.1: Ground Water Recharge

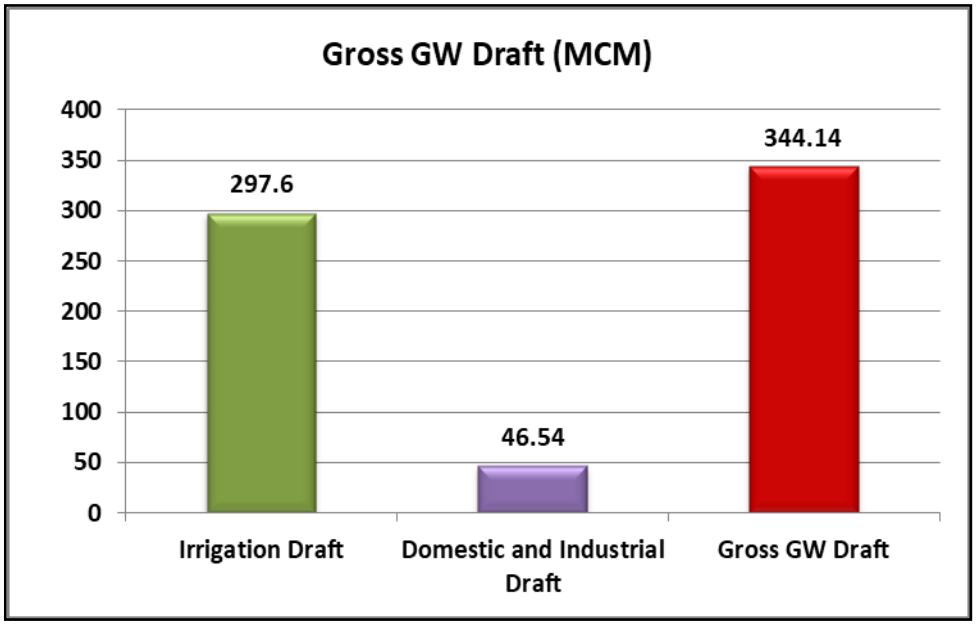


Fig 5.2: Ground Water Draft

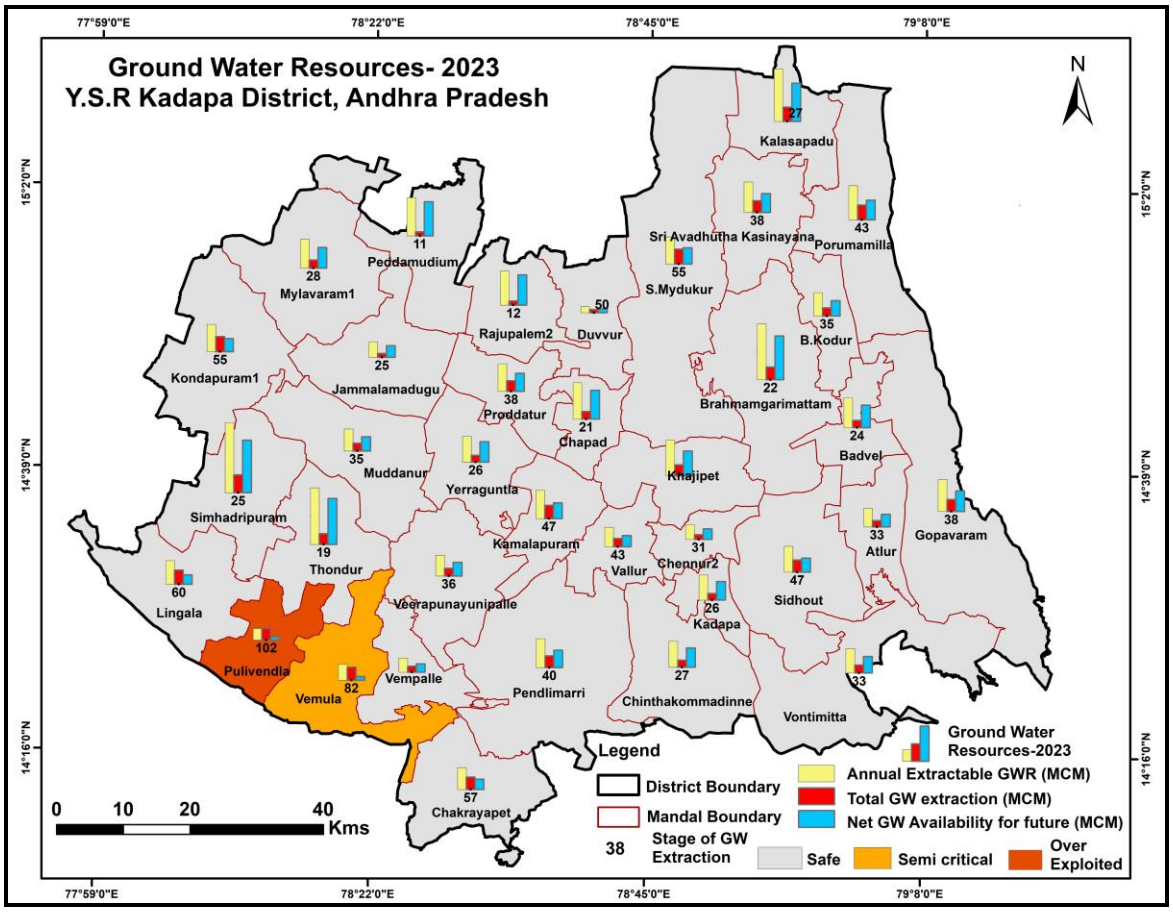


Fig.5.3: Categorization of mandals (GEC 2023).

6. GROUND WATER RELATED ISSUES and REASONS FOR ISSUES

6.1 Issues

Pollution (Geogenic and Anthropogenic)

1. Few mandals are fluorosis endemic where fluoride (geogenic) as high as 2.55 mg/L during pre-monsoon is found in groundwater. The high fluoride concentration (>1.5 mg/L) occur in 10% samples during pre-monsoon season of 2022 respectively. High fluoride concentration is observed mostly in Brahmamgarimatam and Duvvur mandals of the district

2. The high concentration of EC (> 3000 micro-seimens/cm) in 6% of the area is observed during pre-monsoon season of 2022 respectively in parts of B.Kodur, Muddanur and Duvvur mandals.

3. Higher concentration of Nitrate is observed in 35% of samples.

Over-exploitation

4. 1 mandal i.e Pulivendla is categorized as over-exploited and 1 mandal i.e Vemula is categorized as Semi critical as per 2023 GEC estimations.

Deep water levels

5. Deep water levels (> 20 m bgl) are observed during pre as well as post-monsoon season in 03 % and 1% of the area respectively, falling in parts of Lingala, Mydukur, Sidhout, Vempalle, Porumamilla and Khajipet mandals.

6. Out of the total wells analysed 04 wells during pre-monsoon 14 wells during post-monsoon showing falling trend in the last 10 years (@-0.08 to -0.83 m/yr and –0.01to 2.83 m/yr) respectively.

Sustainability

6. Low yield (<1 lps) occurs in ~48 % of area covering entire district. The yield from bore wells have reduced over a period of time and some bore wells which used to yield sufficient quantity of water have gone dry due to low rainfall.

5.2 Reasons for Issues

Geo-genic pollution (Fluoride)

7. Higher concentration of fluoride in ground water is attributed due to source rock, rock water interaction where acid-soluble fluoride bearing minerals (fluorite, fluoro-apatite) gets dissolved under alkaline conditions.

8. Higher residence time of ground water in deeper aquifer.

Anthropogenic pollution (Nitrate)

9. Higher concentration is due to unscientific sewage disposal of treated and untreated effluents in urban and rural areas. Use of NPK fertilizers and nitrogen fixation by leguminous crops.

Over-exploitation and Deep water levels

10. Over-extraction, low rainfall and limited artificial measures etc.

Sustainability

11. Absence of primary porosity, negligible development of secondary porosity, low rainfall, desaturation of weathered zone and urbanization.

7. MANAGEMENT STRATEGIES

High dependence on ground water coupled with absence of augmentation measures has led to a steady fall in water levels and de-saturation of weathered zone in some parts, raising questions on sustainability of existing ground water structures, food and drinking water security. The occurrence of fractures in fractured zone are very limited in extent, as the compression in the rock reduces the opening of fractures at depth and the majority (80%) of fractures occur within 100 m depth. Higher NO3- concentrations (> 45 mg/L) in weathered zone is due to sewage contamination and higher concentration of F- (>1.5 mg/L) in weathered zone and fractured zone is due to local geology (granite/gneiss rock), high weathering, longer residence time and alkaline nature of ground water.

7.1 Management plan

The uneven distribution of ground water availability and its utilization indicates that a single management strategy cannot be adopted and requires integrated hydro geological aspects along with socio-economic conditions to develop appropriate management strategy.

In the target areas of district 26223 MCM of unsaturated volume (below the depth of 5 m) is available during post-monsoon season, having 524.47 MCM of recharge potential (2%). This can be utilized for implementing management strategy. The study suggests notable measures for sustainable ground water management, which involves a combination of various measures given below.

1. Supply side measures
2. Demand side measures
3. Regulatory measures
4. Institutional measures

7.1.1 Supply side measures:

The supply-side management of ground water resources can be done through the artificial recharge by computing surplus run off available within river sub-basins and also by repairing, renovation and restoration of existing tanks.

7.1.2 Artificial Recharge Structures

The areas feasible for construction of recharge structures has been demarcated based on the analysis of post-monsoon depth to water level data and existing data on artificial recharge structures constructed under various schemes of MGNREGS and by Rural Development department, Govt. of Andhra Pradesh. The availability of unsaturated volume of aqui

fer was computed by multiplying the area feasible for recharge and unsaturated depth below 5 mbgl. The recharge potential of aquifer is calculated by multiplying the unsaturated volume with specific yield of the aquifers (0.02 for hard rock).

The source water availability is estimated from the rainfall and run-off correlations. The runoff was calculated by taking into account of normal monsoon rainfall of the mandal and corresponding runoff yield from Strangers table for average catchment type. Out of the total run-off available in the mandal, only 20% is considered for recommending artificial recharge structures in intermittent areas.

The storage required for existing artificial recharge structures by State Govt. departments under MGNREGS schemes is deducted to find the available surplus run-off for recommending the additional feasible artificial recharge structures. 50% of the available surplus run-off is considered for the recommendation of artificial recharge structures, as the remaining 50 % is recommended for implementing water conservation measures in recharge areas through MGNREGS.

As the stage of ground water development in the district is 38 % and all 34 mandals are falling in safe category as per the GEC 2023 estimation, the artificial recharge structures are not proposed for entire district. Total 11 mandals have deeper water levels in post monsoon season (Atlur, Chinthakommadine, Duvvur, Gopavaram, Lingala, Pendimarri, Porumammila, Sidhout, Vempalle, Vemula and Vontimitta). Areas where water level is shallow are not considered for recharge, because it may lead to water logging condition which in turn would affect the yield of agricultural crops. Also area covered under forests, hilly terrain where slope exceeds 20 degrees, human settlements are not taken into consideration as recharge structures are not feasible in these areas. Hence, mandals with deeper water levels are considered for constructing ARS.

Table.6.1. Proposed ARS in Y.S.R Kadapa district.

Total geographical area of district (sq.km)	11228
Area feasible for recharge (sq.km) 11 Mandals	2780.77
Unsaturated Volume (MCM)	32247.73
Recharge Potential (MCM)	644.95
Surplus run-off available for recharge (MCM)	**21.16**
PROPOSED ARTIFICIAL RECHARGE STRUCTURES	
Percolation Tanks (@ Av. Gross Capacity=0.007 MCM*2 fillings = 0.0140 MCM)	65
Check Dams (@ Av. Gross Capacity=0.007 MCM* 5 fillings = 0.035 MCM)	86
Total volume of water expected to be recharged (in MCM)	**3.92**

The total unsaturated volume (below the depth of 5 m) available for artificial recharge is 32247.73 MCM, having 644.95 MCM of recharge potential (2%). The available surplus run-off can be utilized for artificial recharge through construction of percolation tanks and check dams at suitable sites. The number of percolation tanks, and check dams are decided based on the number of suitable streams available in the district. Thus, after taking into consideration all the factors, only 21.16 MCM of surplus water is available for recharge, which is given in table. This surplus water can be utilized for constructing 86 check dams and 65 percolation tanks at suitable sites. The amount of recharge from these artificial recharge structures was calculated by considering 0.0140 MCM per percolation tanks and 0.035 MCM per check dam. The existing and proposed artificial recharge structures are given in (Fig. 7.1) and (Fig. 7.2.) *(The locations recommended for checkdams and percolation tanks on map are tentative with subject to field verification)*

- After effective utilization of this yield, there will be 3.92 MCM of ground water recharge with new structures.
- All existing artificial recharge structures are to be desilted and maintained properly.
- Roof top rainwater harvesting structures should be made mandatory to all Government buildings.

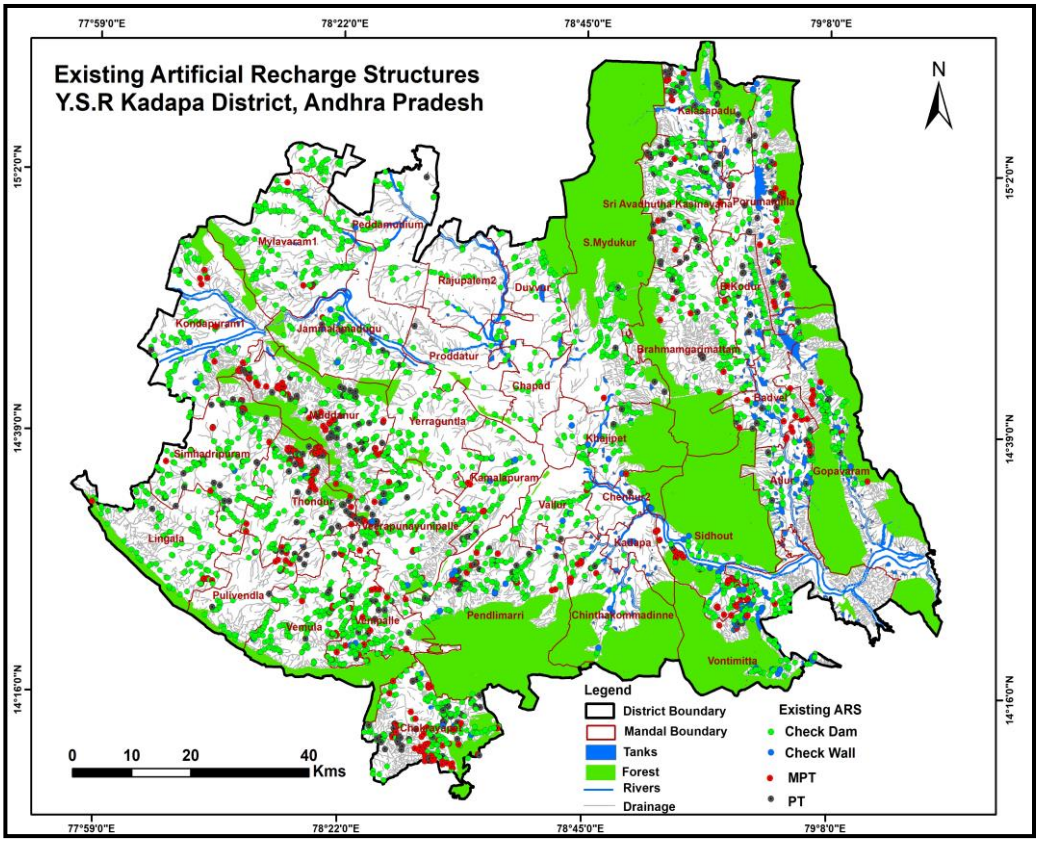


Fig.7.1: Locations of Existing Artificial Recharge Sructures.

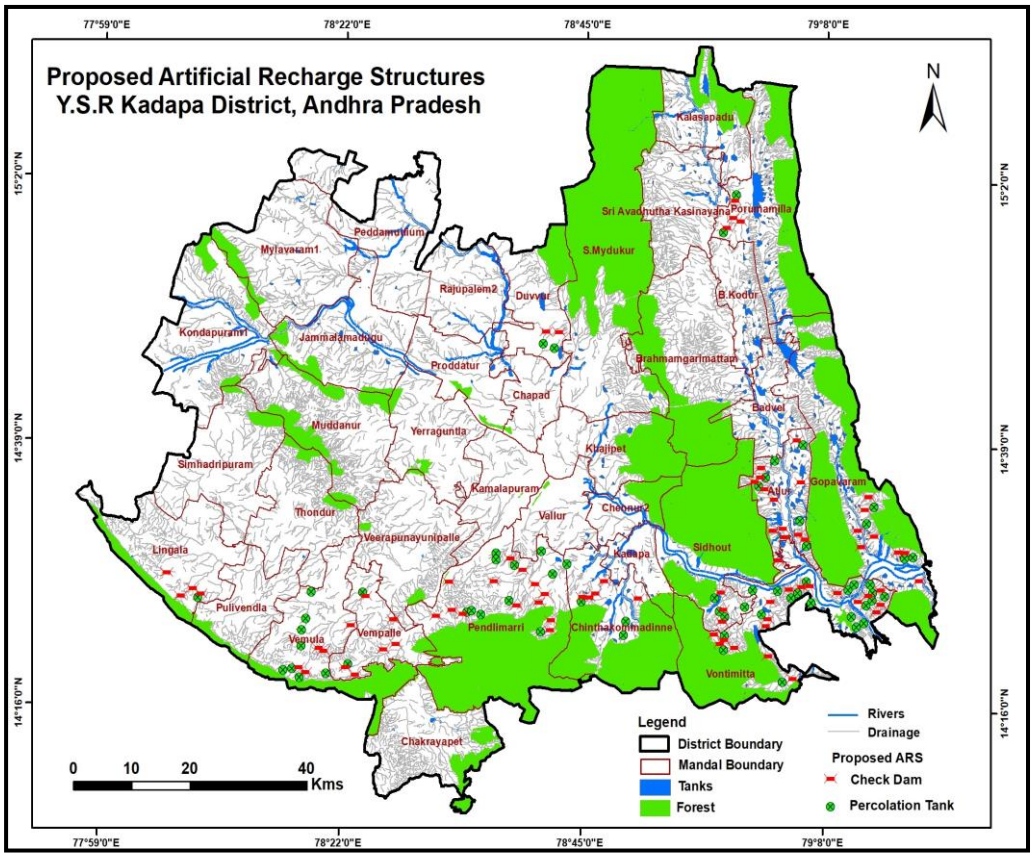


Fig.7.2: Locations of proposed Artificial Recharge Sructure

7.1.3 Other supply side measures:

- Existing ARS like percolation tanks and check dams categorized under major repair by the state Govt. need to be repaired.
- Existing ARS like percolation tanks and check dams and dried dug wells can be desilted involving people's participation through the Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS) (NREGA 2005). This will also help in sustainable management of ground water resources.

7.1.4 Demand side measures: In order to manage the available resources more effectively the following measures are recommended.

7.1.5 Proposed Work

- Micro-irrigation: The sprinkler and drip irrigation system with suitable cropping pattern wherever feasible may be practiced as a measure for ground water conservation, protection and management. About 10,700 ha. of land can be brought under micro-irrigation (@50 ha/village in 214 villages, considering 1 unit/ha @0.6 lakh/ha). With adoption of micro irrigation practices, the total water requirement for irrigation can be reduced upto 60% to 70%.
- Change in cropping pattern from water intensive paddy to irrigated dry crops like pulses and oil seeds are recommended, particularly in water stress areas. If necessary some regulatory rules may be framed and implemented.
- To avoid the interference of cone of depression between the productive wells, intermittent pumping of bore wells is recommended through regulatory mechanism. Power supply should be regulated by giving power in 4 hour spells two times a day in the morning and evening by the concerned department so that pumping of the bore well is carried out in phased manner to allow recuperations of the aquifer and increase sustainability of the bore wells.
- As a mandatory measure, every ground water user should recharge rainwater through artificial recharge structures in proportionate to the extraction.

7.1.6 Other measures

- A participatory ground water management (PGWM) approach in sharing of ground water and monitoring resources on a constant basis along with effective implementation of the existing 'Water, Land and Trees Act' of 2002 (WALTA-2002) are the other measures suggested. Subsidy/incentives on cost involved in sharing of ground water may be given to the concerned farmers.

- The open stone quarries / abandoned quarries can be filled with soil and covered with vegetation; it will prevent further erosion and weathering of salts and minerals and also escalation of the salinity levels in aquifers.
- Recommending to use of red mud pot to store potable household water in Fluoride contaminated areas to reduce the impact of fluorosis
- In urban and rural areas the sewerage line should be constructed to arrest leaching of Nitrate.
- Restrict use of extensive chemical fertilizers as it will eventually degrade soil and leach to join ground water which already has high salinity.
- Recommend to cultivate high EC tolerant crops like cotton, sunflower, sesame etc.

Acknowledgment

- I would like to express my sincere thanks to Dr. Sunil Kumar Ambast (Chairman CGWB), G.Krishnamurthy (Regional Director CGWB), Rani V.R. (Scientist-D) for encouragement, guidance and support. I am grateful to all officers and officials of CGWB Hyderabad, Andhra Pradesh Water Department, Ground Water and Water Audit Department, Rural Development Department, Rural Water Supply Department, Directorate of Economics and Statistics, Minor Irrigation, Govt of Andhra Pradesh for providing the data for the preparation of report.

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Annexure 1

Proposed supply side interventions for Artifical recgarge structures

Proposed villages for constructing check dams		
Mandal	**Village**	**No. Of structures**
Atlur	Nallayapalle	1
Atlur	Kamalakuru	1
Atlur	Yerraballe	1
Atlur	Madapur	1
Atlur	Thamballagondi	1
Atlur	Gujjalavaripalle	1
Atlur	Shrotriya Venkatapuram	1
Atlur	Kumbhagiri	1
Atlur	Kamasamudram	1
Atlur	Kondur	1
Atlur	Pidathalaveerayapalle	1
Atlur	Jannavaram	1
Atlur	Varikunta-1	1
Chinthakommadinne	Apparajupalle	1
Chinthakommadinne	Buggaletipalle	1
Chinthakommadinne	Boggalapalle	1
Chinthakommadinne	Kolumulapalle-1	1
Chinthakommadinne	Rudrayagaripalle	1
Duvvur	Madirepalle	1
Duvvur	Pedda Jonnavaram	1
Gopavaram	Kalvapalle-1	1

Gopavaram	Ramapuram-4	1
Gopavaram	Madakalavaripalle	1
Gopavaram	Gopavaram-3	1
Gopavaram	North Ramapuram	1
Gopavaram	South Ramapuram	1
Gopavaram	Brahmanapalle-8	1
Gopavaram	Boddecherla	1
Kadapa	Chinnachowk	1
Kadapa	Ramarajupalle-1	1
Kadapa	Akkayapalle	1
Kadapa	Nagarajupet	1
Kadapa	Chemmumiahpet	1
Lingala	Kommanuthala	1
Lingala	Lopatnuthala	1
Lingala	Lingala-3	1
Lingala	Peddakudala	1
Pendlimarri	Binduraopalle	1
Pendlimarri	Machanur-1	1
Pendlimarri	Eguva Palle	1
Pendlimarri	Kothapeta-5	1
Pendlimarri	Chabali	1
Pendlimarri	Rampathadu	1
Pendlimarri	Moillakalava	1
Pendlimarri	Konayapalle	1
Pendlimarri	Tummalur	1
Pendlimarri	Sangatipalle	1
Pendlimarri	Ganganapalle-1	1
Pendlimarri	Thippireddipalle-1	1

Pendlimarri	Konduru-2	1
Porumamilla	Lachampalle	1
Porumamilla	Musalreddipalle	1
Porumamilla	Siddanakitchayapalle	1
Porumamilla	Korrapatupalle	1
Sidhout	Kadapayapalle	1
Sidhout	Jyothi	1
Sidhout	Tokkolu	1
Vempalle	Tangedupalle	1
Vempalle	Ramireddipalle	1
Vempalle	Muthukuru	1
Vempalle	Naguru	1
Vempalle	Alavalapadu-2	1
Vempalle	Pamulur	1
Vemula	Pendluru	1
Vemula	Chintalajutur	1
Vemula	Gollalagudur	1
Vemula	Pernapadu	1
Vemula	Peddajutur	1
Vontimitta	Ponnapalle	1
Vontimitta	Kudumalur	1
Vontimitta	Darjipalle	1
Vontimitta	Gollapalle-7	1
Vontimitta	Pennaperuru	1
Vontimitta	Kotapadu-5	1
Vontimitta	Darjipalle	1
Vontimitta	Gangaperuru	1
Vontimitta	Brahmanapalle-11	1

Vontimitta	Madhavaram-3	1
Vontimitta	Gundlamada	1
Vontimitta	Rachagudipalle	1
Vontimitta	Vontimitta-1	1
Vontimitta	Narayanarajupeta	1
Vontimitta	Jowkulapalle	1
Vontimitta	Kuruguntapalle	1
Vontimitta	Mangampeta	1
Vontimitta	Chintarajupalle	1

Proposed villages for constructing percolation tanks		
Mandal	**Village**	**No. Of structures**
Atlur	Kumbhagiri	1
Atlur	Kamasamudram	1
Atlur	Kondur	1
Atlur	Vemalur	1
Atlur	Jannavaram	1
Atlur	Varikunta-1	1
Chinthakommadinne	Chinamachupalle	1
Chinthakommadinne	Rachinnayapalle	1
Chinthakommadinne	Rudrabharathipeta	1
Chinthakommadinne	Thadigotla	1
Duvvur	Dasaripalle	1
Duvvur	Idamadaka	1
Gopavaram	Kalvapalle-1	1
Gopavaram	Ramapuram-4	1
Gopavaram	Madakalavaripalle	1
Gopavaram	Gopavaram-3	1

Kadapa	Akkayapalle	1
Kadapa	Nagarajupet	1
Lingala	Bonala	1
Pendlimarri	Kothapeta-5	1
Pendlimarri	Chabali	1
Pendlimarri	Rampathadu	1
Pendlimarri	Moillakalava	1
Pendlimarri	Konayapalle	1
Pendlimarri	Tummalur	1
Pendlimarri	Pendlimarri-2	1
Pendlimarri	Chennamraju Palle	1
Pendlimarri	Pagadalapalle-1	1
Pendlimarri	Vellatur	1
Porumamilla	Korrapatupalle	1
Porumamilla	Kavalakuntla	1
Sidhout	Ponnavolu	1
Sidhout	Kadapayapalle	1
Sidhout	Jyothi	1
Sidhout	Tokkolu	1
Vempalle	Ramireddipalle	1
Vempalle	Muthukuru	1
Vemula	Pendluru	1
Vemula	Chintalajutur	1
Vemula	Gollalagudur	1
Vemula	Pernapadu	1
Vemula	Peddajutur	1
Vemula	Chagaleru	1
Vemula	Vemula-2	1

Vemula	Gondipalle-1	1
Vontimitta	Ponnapalle	1
Vontimitta	Kudumalur	1
Vontimitta	Darjipalle	1
Vontimitta	Gollapalle-7	1
Vontimitta	Pennaperuru	1
Vontimitta	Kotapadu-5	1
Vontimitta	Pennaperuru	1
Vontimitta	Gangaperuru	1
Vontimitta	Brahmanapalle-11	1
Vontimitta	Madhavaram-3	1
Vontimitta	Gundlamada	1
Vontimitta	Rachagudipalle	1
Vontimitta	Vontimitta-1	1
Vontimitta	Narayanarajupeta	1
Vontimitta	Jowkulapalle	1
Vontimitta	Kuruguntapalle	1
Vontimitta	Mangampeta	1
Vontimitta	Chintarajupalle	1
Vontimitta	Konarajupalle	1
Vontimitta	Pennaperuru	1