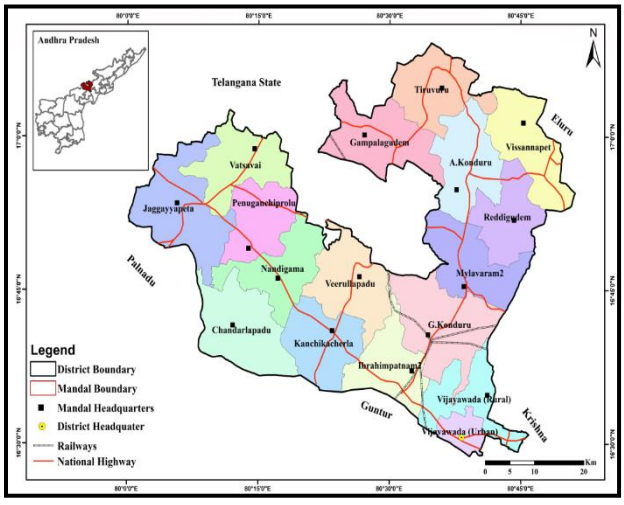
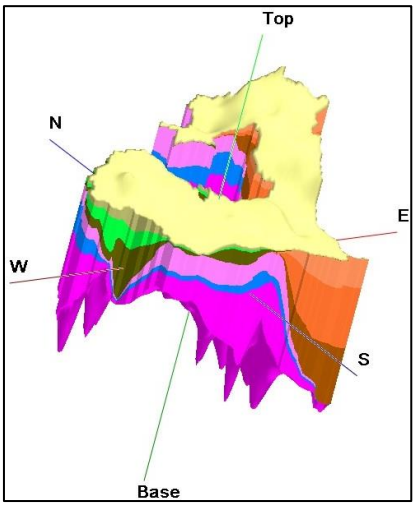
केंद्रीय भूजल बोर्ड
जल संसाधन, नदी विकास और गंगा संरक्षण विभाग,
जल शक्ति मंत्रालय
भारत सरकार

Central Ground Water Board Department of Water Resources, River Development and Ganga Rejuvenation,Ministry of Jal Shakti, Government of India

REPORT ON
AQUIFER MAPPING FOR SUSTAINABLE MANAGEMENT OF GROUND WATER RESOURCES IN NTR DISTRICT,ANDHRA PRADESH
(AAP-2023-24)





CENTRAL GROUND WATER BOARD
SOUTHERN REGION, HYDERABAD,
FEBRUARY 2025

REPORT ON

AQUIFER MAPPING FOR SUSTAINABLE MANAGEMENT OF GROUND WATER RESOURCES IN NTR DISTRICT,ANDHRA PRADESH

(AAP-2023-24)

Contributors' page

Principal Author & Compilation of existing data, Preparation of GIS map and Management Plan	Ms. Monika, Scientist-C (Hydrogeologist) CGWB, SR, Hyderabad, Telangana State.
Supervision & Guidance	Shri Ravi Kumar Gumma Scientist-D & OIC, CGWB, APSUO, Visakhapatnam, AP.
	Shri G. Krishnamurthy Regional Director, CGWB, SR, Hyderabad, Telangana State.

NTR DISTRICT AT GLANCE

Sl.No	Items		Statistics
1	**GENERAL INFORMATION**		
	i) Geographical area (Sq. Km)		3315
	ii) Administrative Divisions (As on 3/2023)Revenue Divisions Number of Mandals Number of Villages		03 17 321
	iii) Populations (As per Census 2011)		22.18 lakhs
	iv) Average Annual Rainfall (mm)		971
2.	**GEOMORPHOLOGY**		
	Major Physiographic Units: Pediplain, Deltaic Plain & Flood Plain		
	Major Drainages: Krishna and Muniyeru		
3.	**LAND USE (Area in Hectares) (HAND BOOK OF STATISTICS-2020 NTR DISTRICT)**		
	1	Forests	38519
	2	Barren & uncultivable land	14441
	3	Land put to non-agricultural uses	52492
	4	Cultivable waste	5270
	5	Permanent pastures and other grazing lands	5607
	6	Land under miscellaneous tree crops & groves not included in net areasown	3115
	7	Current fallows	16515
	8	Other fallow lands	16703
	9	Net Area Sown	178956
	10	Total Cropped Area	208977
	11	Area Sown More than Once	30021
4.	**MAJOR SOIL TYPES:** 1. Black soil which constitute 57.6% of the villages 2. Sandy Clay-loams with 22.3% and 3. Red loamy with 19.4% of the villages		
5.	**AREA UNDER PRICIPAL CROPS** (Area in Hectares) (2019-20) Paddy-79524, Jowar-115, Maize-8250, Total food grains-95195, Total foodcrops-144239 & Total Oil Seads-1158.		
6.	**IRRIGATION BY DIFFERENT SOURCES (Area in Hectares/ no of structures)**		
	Dug wells		4282/5449
	Tube wells/Bore wells		40504/19789
	Tanks/Ponds/Water conservation structures		20734
	Canals		29908
	Lift Irrigation		11502
	Net Irrigated area (Area in Hectares.) (2019-20)		70992
	Gross Irrigated area (Area in Hectares.) (2019-20)		108463

7.	**NUMBERS OF GROUND WATER MONITORING WELLS.**	
	a) CGWB b) SGWD	33 71
8.	**PREDOMINANT GEOLOGICAL FORMATIONS:** The study area is underlain by various geological formation from Archaean to Teritary age, with some isolated pockets of Recent to Sub-recent alluvium. Archean to proterozoic Banded Gneiss, occupies 41% of the area. The Archean Charnockite (19% of the area) and Khondalite (30% of the area) overlies the Archean Granitic Gneiss(41% of the area). The Precambrian metasedimentary formation covers of Kurnool and Cuddapah system covers 4% of the area and remaining 6% is alluvium sediments along the river channels	
9.	**HYDROGEOLOGY:** Major Water Bearing Formation: The principal aquifer in the area is charnockites and gneisses 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 andweathering.	

Depth to water Level during 23-24

Period	Phreatic Aquifer (DTW)		Semi-confined /Confined Aquifer (PZ head)	
	Min	Max	Min	Max
Pre-Monsoon	0.95 (Ibrahimpatnam)	26.60 (Mallela)	NA	NA
Post Monsoon	0.75 (Anigandlapadu)	18.54 (Shermohammedpet)	NA	NA

Long Term (10 Years) Water Level Trend (2013 to 2023)

Trend	Pre-Monsoon	Post- Monsoon
Rise (m/Yr)	0.0318 (A Konduru-New) to 0.2893 (Penuganchiprolu)	0.05228 (Kakarla) to 1.47187 (Vissannapet-New)
Fall (m/Yr)	-0007 (Makkapeta) to -0.3786 (Kottareddigudem)	-0.00606 (Chintalapadu) to –3.3054 (Muktyala- Pz 2)

10.	**GROUND WATER EXPLORATION BY CGWB (As on 31-03-2024)**	
	No. of exploratory wells	32
	No. of piezometer/water table wells	14
	Depth range (m bgl)	30-200
	Depth of potential zone (m bgl)	35-200
	General yield range (lps)	25-85
	Transmissivity (m^2/day)	0.4 to 12
	Storativity	$4.84 * 10^{-6}$ to $1.06 * 10^{-4}$
	GROUND WATER QUALITY	
	Presence of chemical constituents more than permissible limit	High Fluoride & Nitrate at isolated pockets
	Type of water	Potable in general

11.	**DYNAMIC GROUND WATER RESOURCES (As on 2022)**	
	Net Ground Water Availability	859.94
	Monsoon recharge from rainfall	199.61
	Monsoon recharge from other sources	388.18
	Non-monsoon recharge from rainfall	12.15
	Non-monsoon recharge from other sources	305.26

	Total Natural Discharge	45.26
	Gross GW Draft	187.51
	Irrigation	158.14
	Domestic and Industrial use	29.37
	Allocation of Ground Water Resource for Domestic Utilization for projected year 2025	18.2
	Net GW availability for future use	673.67
	Stage of GW development (%)	23.10

13	**GROUND WATER CONTROL AND REGULATION (2022)**	
	Number of Over Exploited Blocks	Nil
	Number of Critical Blocks	Nil
	Number of Semi Critical Blocks	Nil
	Number of Safe Blocks	38
	Number of Saline Blocks	Nil
	No. Of Blocks Notified by CGWA	Nil

14 DATA INTEGRATION

Data	Aquifer	Total Data Points	Source	
			CGWB	SGWD
Panel Diagram (3-D)	1 no	50	Expl:50	
Hydrogeological CrossSections	03 no	50	Expl: 50	
Fence/panel Diagrams	1 no	50	Expl: 50	
Depth of weathering	1 no	50	Expl: 50	
Depth of fracturing	1 no	50	Expl: 50	
Depth to Water Level Maps(2022)	Combine	104	NHS:33	NHS:71
Decadal Water Level Maps(2013-22)	Combine	86	NHS:21	NHS:65
Water quality pre-2022	Combine	21	NHS: 21	

15 AQUIFER CHARACTERIZATION AND DISPOSITION

Era	Archean Crystallines	
Prominent Lithology	Granite Gneiss/Charnockite (Basement)/Khondalite	
Aquifer types	Aquifer-1 (Weathered Zone)	Aquifer-2 (Fracture Zone)
Thickness range	1 - 35 m	up to 200m
Depth range of fractures	-	80% fracture encountered within 100m
Range of yield potential	<3	<1 to >10 lps
Transmissivity (m2/day)	More than 1 to 200 sqm/day	
Storativity	$4.84 *10^{-6}$ to $1.06*10^{-4}$	
Quality (Suitability of Irrigation)	Yes	Yes

16	MAJOR GROUND WATER PROBLEMS AND ISSUES
	i) Deeper Water Levels in North western part of the study area ii) Limited Yield Potential in Hard Rock. iii) Higher concentration of Nitrate is observed in 42% of samples. iv) EC is >2000 µ Siemens/cm covering an area around 1326 sq.kms (40%). v) Higher concentration of Fluoride (>1.5 mg/l) is observed in 4 samples at localized pockets. vi) Demand Supply Management
17	**MANAGEMENT STRATEGIES**
	❖ In addition, roof top rainwater harvesting structures should be made mandatory to all Government buildings (new and existing). ❖ Existing ARS like percolation tanks and check dams can be de-silted involving people's participation. ❖ The sprinkler and drip irrigation system with suitable cropping pattern is recommended where the yield of bore well is <2.0 lps identified in 288.8 sq.km 9%) of the district Particularly in North western parts of the district as a measure for groundwater conservation, protection and management. ❖ De siltation and cascading of existing MI tanks and filling up MI tanks with surface water schemes. This can result in increased ayacut, sustainability of bore wells and decrease the ground water irrigation. ❖ Participatory groundwater management (PGWM) approach are recommended. ❖ In urban and rural area, 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	:	Indian 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
MSP	:	Minimum Support price
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

The NTR District lies between 16˚ 30' and 17˚ 50' N of the Northern Latitude and 80˚ 0' and 80˚ 45' of the Eastern Longitude. It spreads over an area of 3315 Sq Kms. The district is bounded by Telangana State in the North, Palnadu and Guntur district in the west, Krishna district in the south and Eluru in the east.

Administratively, the district is governed by 03 Revenue Divisions viz., Vijayawada, Tiruvuru and Nandigama, 17 revenue mandals including 1 Vijaywada Urban Mandal and 311 Gram Panchayats. There are 5 municipalities Jaggayahpet, Vijayawada Municipal Corporation, Nandigama, Tiruvuru and Ibrahimpatnam.

Geomorphologically the district can be broadly divided into 3 distinct units, viz., Pediplains, Fluvial & Pediment. The Pediplains covers 61% of the area which can be classified as an extensive, multi-concave, rock cut erosion surface formed by the coalescence of two or more adjacent pediments and occasional desert domes. Based on the thickness of weathering, they are further classified as shallow, moderate and deep pediplains. The Fluvial Landforms covers almost 18.8% of the area followed by Structural Landforms, Pediment, Deltaic Plain, Denudational Hills, Plateau covering an area of 7.0%, 6.9%, 4.1%, 2.0%, 0.3% respectively.

Agriculture is the main stay of the people in the district. The total cropped area of the district is 208977 hectares during the year 2020 which forms 63% of the total area of the district. The principal crops being grown are Paddy, Cotton, Dry fruits, Non-food crops, pulses & maize. The total gross cropped area during the year 2019- 20 is 208977 ha and net sown area is 178956 ha. The gross area cropped during Kharif seasonis 17,3202 ha the gross area cropped during Rabi season is 42400.

The area irrigated by ground water is 44,786 ha (41%) whereas 63,677 ha of area are mainly irrigated by surface water sources (59%).

Three major Irrigation Projects and medium Irrigation Projects and 443 Minor Irrigation tanks. Nagarjuna Sagar Project with ayacut area of 230497 hectares, Polavaram Project with ayacut of 9012 hectares, Krishna Delta System project with ayacut of 4782 Ha are the Major Irrigation Projects with a total ayacut of 244291 hectares and other medium projects have an ayacut of 6814.5 Ha. There are 443 Minor Irrigation sources in the district with a total registered ayacut is 26958 Ha but actual area irrigated is 17633 Ha**.**

The study area is underlain by various geological formation from Archaean to Teritary age, with some isolated pockets of Recent to Sub-recent alluvium. Archean to proterozoic Banded Gneiss, occupies 41% of the area (Table:1.3). The Archean Charnockite (19% of the area) and Khondalite (30% of the area) overlies the Archean Granitic Gneiss (41% of the area). The Precambrian metasedimentary formation covers of Kurnool and Cuddapah system covers 4% of the area and remaining 6% is alluvium sediments along the river channels

As on 31/12/2022, CGWB drilled 32 bore wells (exploratory, observation and piezometers) in the district. A total of 47 exploratory borewell data of CGWB (32) and SGWD (15) were used for the hydrogeological studies. 5 wells are located in Semi consolidated formation and 36 wells in consolidated rock areas.

The Water levels are being monitored through 104 wells (CGWB:33, SGWD: 71 PZ) number of monitoring wells. In Majority of the areas, water level during pre-monsoon season is in the range of 2-10 m in 84% of the area, followed by shallow water level <2 m bgl in 1% of the area and deeper water levels

>10 m bgl in 15% of the area. During post-monsoon season water level is in the range of 2-5 m in 59% of the area, followed by 5-10 water level m bgl in 36% of the area and deeper water levels >10 m bgl in 3% of the area.

Out of 101 wells, 73 wells records water level rise. The water level rise varies from <1 to 4.66 m in all the wells (Fig.3.3). Rise in water level between 0 to 2 m is observed in 73% of the area, 2-4 m rise is observed in 7.8% of the area. Rise in water level > 4 m is observed in 3.4% of area.

Water level fall is recorded 28 wells (Fig 3.3). Fall in water level between 0 to 2 m is observed in 14.3% of the area, 2 to 4 m is observed in 1.1% of area and fall of more than 4 m is observed in 0.4% of the area. During Pre-Monsoon, water-table elevation ranges from 18.97-123.80 meter above mean sea level and in post-monsoon season 21.23-130.08 meter above meansea level (m amsl). The ground water flow also has the same drainage flow direction.

To understand chemical nature of groundwater, total 21 data points is utilized from groundwater monitoring wells, exploratory wells and well inventory. During pre-monsoon season of 2021 21 samples were analyzed. Electrical conductivity varies from 390-5370 (avg:2019) µ Siemens/cm. In 62 % of area, EC is within 2000 µ Siemens/cm, in 34 % area, it is between2000-3000µ Siemens and in 4% of area it is beyond permissible limit Average concentration of TDS is 1165 mg/L and NO3 ranges from 0.4-307.7 mg/L. Nitrate concentration in 43% of samples is beyond permissible limits of 45 mg/L. Fluoride concentration varies from 0.18-2.76 with 19% of samples is beyond the permissible limits of BIS and rest is within the permissible limit. B

The aquifers of **NTR** district can be conceptualized in to Aquifer-**1,** the shallow aquifer is considered up to the maximum depth of weathering and first fracture encountered (below weathereddepth) generally down to ~30 m depth. They are unconfined aquifers. Ground water yield varies from <3 lps (avg: 1.0 lps) in weathered granite and metasedimentary aquifers. The aquifer-II is the deeper aquifer which tapped the fractured zone. Ground water in the second aquifer occurs under semi-confined to confined condition in the fractures up to the maximum depth of 180 m bgl (deepest fracture encountered). The depth of fracturing varies from 25 m to 180 m with yield of <1 to more than 10 lps. The specific capacity of the consolidated formation ranges between 5 and 700 lpm/mdd and transmissivity of consolidated formation varies from <1 to more than 100 sq.m/day. The storativity varies from 4.84 $*10^{-6}$ to $1.06*10^{-4}$

The annual extractable ground water resource (GWRA-2022) is 859.94 MCM, the gross ground water draft for all uses is 187.51 MCM, provision for drinking and industrial use for the year2025 is 18.2 MCM and net available balance for future irrigation use is 673.67 MCM. The stage of ground water development varies from 54.10 % to 7.33 % and all assessment (mandals) units have been categorized as Safe.

The district has no such major issue in terms of ground water, there are few localized issues i.e.,deep Water Levels & declining trends, it can be assessed that In the North and North West parts of the study area is backward area of NTR districtcomprises Jaggyapet, Vissanapet, Veerullapadu , Tiruvuru and A. Konduru Mandals and the average decadal water level is more than 10m in 11% of the area in pre-monsoon and more than 15% of the area in post-monsoon. The Over all stage of ground water development in the study area

is 23%, except Chandralapadu mandal which have SOD> 50%, where vulnerability of groundwater resource in future is identified.

Low yield (<2 lps) occurs in 288.8 Sq.km (~9%) is found in many places as the study area is mainly comprises hard rocks such as Charnockites, Khondalites and granite gneiss as per ground water exploration data. The mainaquifers being hard rock the yield depends on the thickness of aquifers. EC is >2000 µ Siemens/cm covering around 1326 sq.kms (40%) in parts of encountered in Gampalagudem, Vissannapet , Tiruvuru and Veerullapadu Mandals. Higher concentration of Nitrate is observed in 42% of samples. This 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. Higher concentration of Fluoride (>1.5 mg/l) is observed in 4 samples out of 21 samples in localized pockets of Jagganathapuram village of Veerullapadu mandal

The management strategies mainly include both supply side and demand side measures. Considering the stage of Ground water development (SOD), it is recommended that instead of planning for new artificial recharge structure for the entire study area, it is more viable to propose structures only in areas having SOD >50% to control further increase in stage of groundwater development, where vulnerability of groundwater resource in future is identified and also to consider the desilting and maintenance of existing CD's and PT's. involving people's participation. Roof top and open space rain water harvesting for artificial Recharge in Vijayawada Mandal. The sprinkler and drip irrigation system with suitable cropping pattern is recommended where the yield of bore well is <2.0 lps identified in 288.8 sq.km (9%) of the district Particularly in North western parts of the district as a measure for groundwater conservation, protection and management. De siltation and cascadingof existing MI tanks and filling up MI tanks with surface water schemes. This can result in increasedayacut, sustainability of bore wells and decrease the ground water irrigation. Participatory groundwater management (PGWM) approach is recommended. In urban and rural area, the sewerage line should be constructed to arrest leaching of nitrate.

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 extraction** " 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 increase in population , 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 for implementation, 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.

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 summarized below.

- Compilation of existing data (exploration, geophysical, groundwater level and groundwater quality with geo-referencing information and identification of principal aquifer units.
- 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.
- Quantification of groundwater availability and assessing its quality.
- To delineate aquifer in 3-D along with their characterization on 1:50, 000 scale.
- Capacity building in all aspects of ground water extraction and management through information, education and communication (IEC) activities, information dissemination,

education, awareness and training.

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

1.3 Area details: NTR District is a newly proposed district which is carved out from erstwhile district of Krishna, the district NTR is named as a mark of respect and recognition of the of the stellar contribution of Sri Nandamuri Taraka Rama Rao Garu, who officiated for 3 times as a Chief Minister of Erstwhile Andhra Pradesh. NTR District with its district headquarters at Vijayawada, lies between 16˚ 30' and 17˚ 50' Northern Latitude and 80˚ 0' and 80˚ 45' Eastern Longitude (**Fig.1.1**). It spreads over an area of 3315 Sq Kms and accounts for 2% of total area of the State. The district is bounded by Suryapet District of Telangana State in the North, Palnadu and Guntur district in the west, Krishna and Eluru in the east.

Administratively, the district is governed by 3 Revenue Divisions viz., Vijayawada, Tiruvuru and Nandigama, 17 revenue mandals including Vijaywada Urban mandal and 311 Gram Panchayats. There are 5 municipalities Jaggayahpet, Vijayawada MunicipalCorporation, Nandigama, Tiruvuru and Ibrahimpatnam.

The total population of the district as per 2011 population census is 22.18 lakhs. Out of this,the rural and urban populations are 9.09 lakhs and 13.09 lakhs respectively forming 41% and 59 % of total population. The density of population is 670 per Sq.km. The population of females per 1000 males is 991. The decennial growth rate is registered at 11.05% whereas the density of population per Sq. Km has been increased from 604 to 670 in the period 2001-2011.

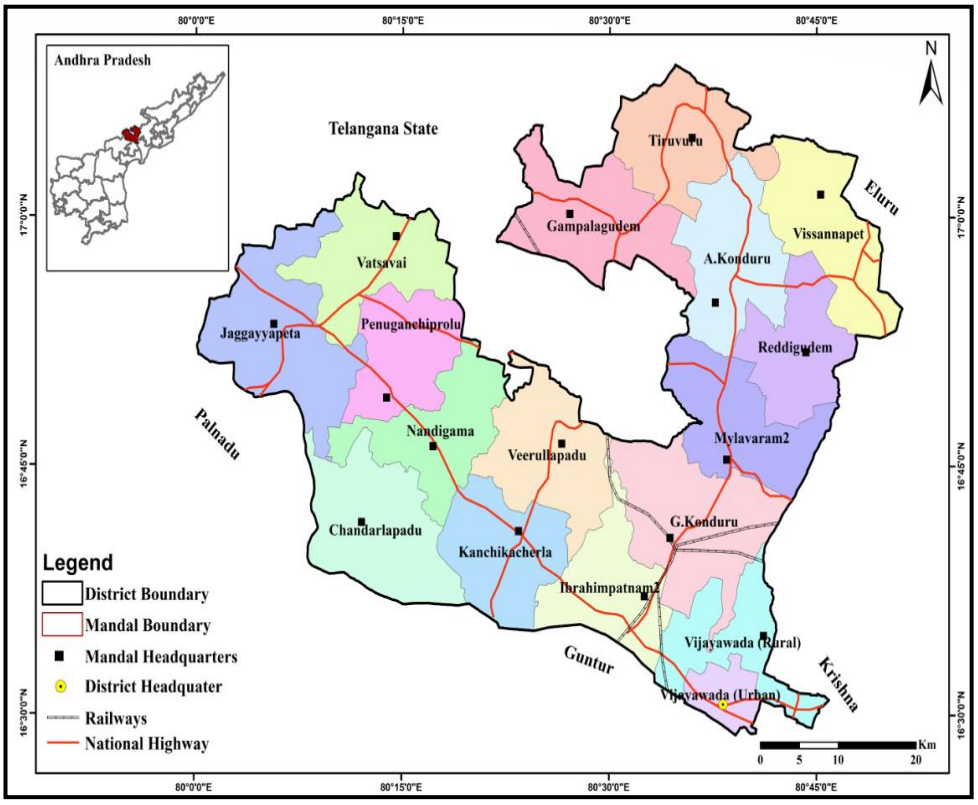


Fig.1.1: Location Map of NTR district.

1.4 Climate and Rainfall: The climate of the study area can be described as tropical climate conditions with extreme hot summer and cold winter prevail in this district. April to June is the hottest months with high temperature in May. The monsoon usually breaks in the middle of June and brings good rains up to middle of October. The normal rainfall of this district is 970.83 mm, 2/3 rds. of which is received through the South West monsoon. The average rainfall recorded during the 2022 it is 761.00 mm Generally, April, May and June are the hottest months with highest maximum temperature recorded was 37.5^{0}C in May whereas the temperature is low in the months of December and January the minimum temperature was recorded i.e., 20.3^{0}C in January during 2021-22. The Isohyetal map of NTR district is shown is Fig-1.2.

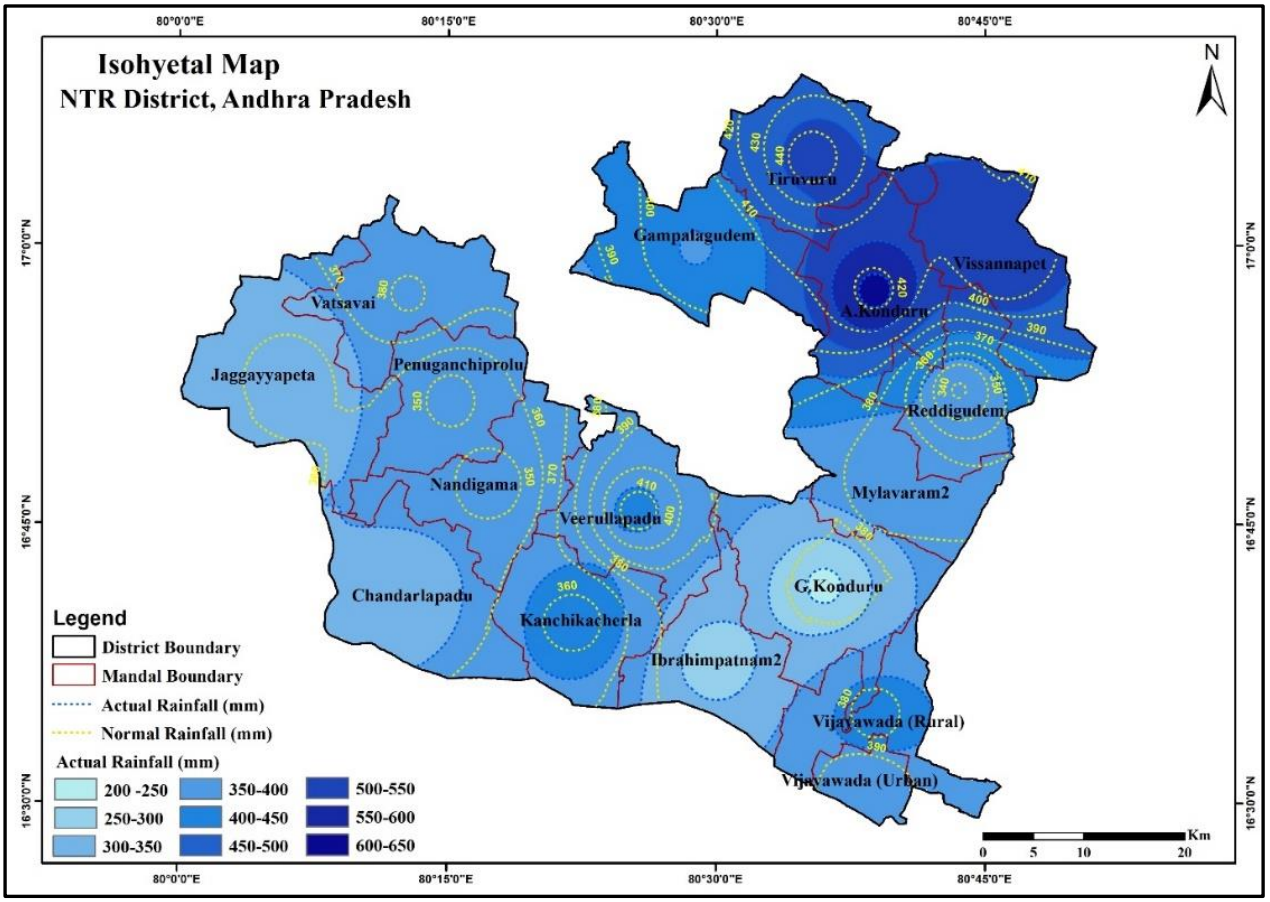


Fig.1.2: Isohyetal map of NTR district.

1.5 Geomorphological Set up: Geomorphologically, the district can be broadly divided into 3 distinct units, viz., Pediplains, Fluvial & Pediment. The Pediplains covers 61% of the area which can be classified as an extensive, multi-concave, rock cut erosion surface formed by the coalescence of two or more adjacent pediments and occasional desert domes. Based on the thickness of weathering, they are further classified as shallow, moderate and deep pediplains. The Fluvial Landforms covers almost 18.8% of the area followed by Structural Landforms, Pediment, Deltaic Plain, Denudational Hills, Plateau covering an area of 7.0%, 6.9%, 4.1%, 2.0%, 0.3% respectively. (Table-1.1) & (Fig.1.3).

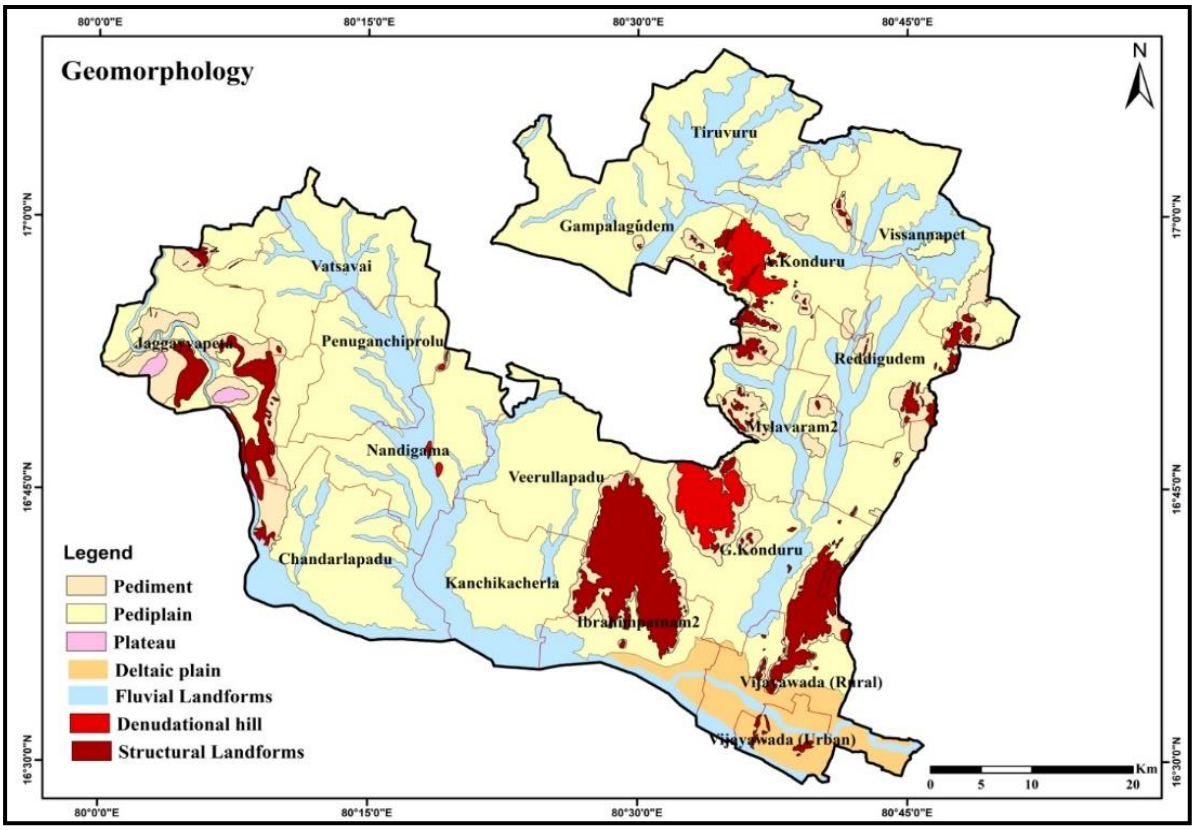


Fig.1.3: Geomorphology map of NTR district.

Table-1.1: Geomorphological features of NTR District

S.No.	Description	Area (Sq.kms)	%
1	Pedi plain	2023	61.0%
2	Fluvial Landforms	622	18.8%
3	Structural Landforms	231	7.0%
4	Pediment	228	6.9%
5	Deltaic Plain	135	4.1%
6	Denudational Hills	66	2.0%
7	Plateau	10	0.3%
	Total	3315	100%

1.6 Drainage and Structures: The famous river Krishna is flowing in this District (Fig.1.4). It is perennial in nature and flows along the western boundary of the district. Part of upland mandals as well as the delta mandals is now having the facility of utilizing the Krishna river water for irrigation purpose. Among the other streams and tributaries Muniyeru, Budameru and Tammileru are significant. Muniyeru is the chief tributary of the river Krishna and it flows from north to south across erstwhile Jaggaiahpeta and Nandigama taluks. Agriculturally, the importance of the above sources is more as they not only feed minor irrigation tanks but also provide for lift irrigation sources and ground water potential. The general drainage pattern is dendritic to sub-dendritic. The drainage density is high in consolidated formations, low in semi-consolidated formations, whereas in alluvial areas the density is meagre.

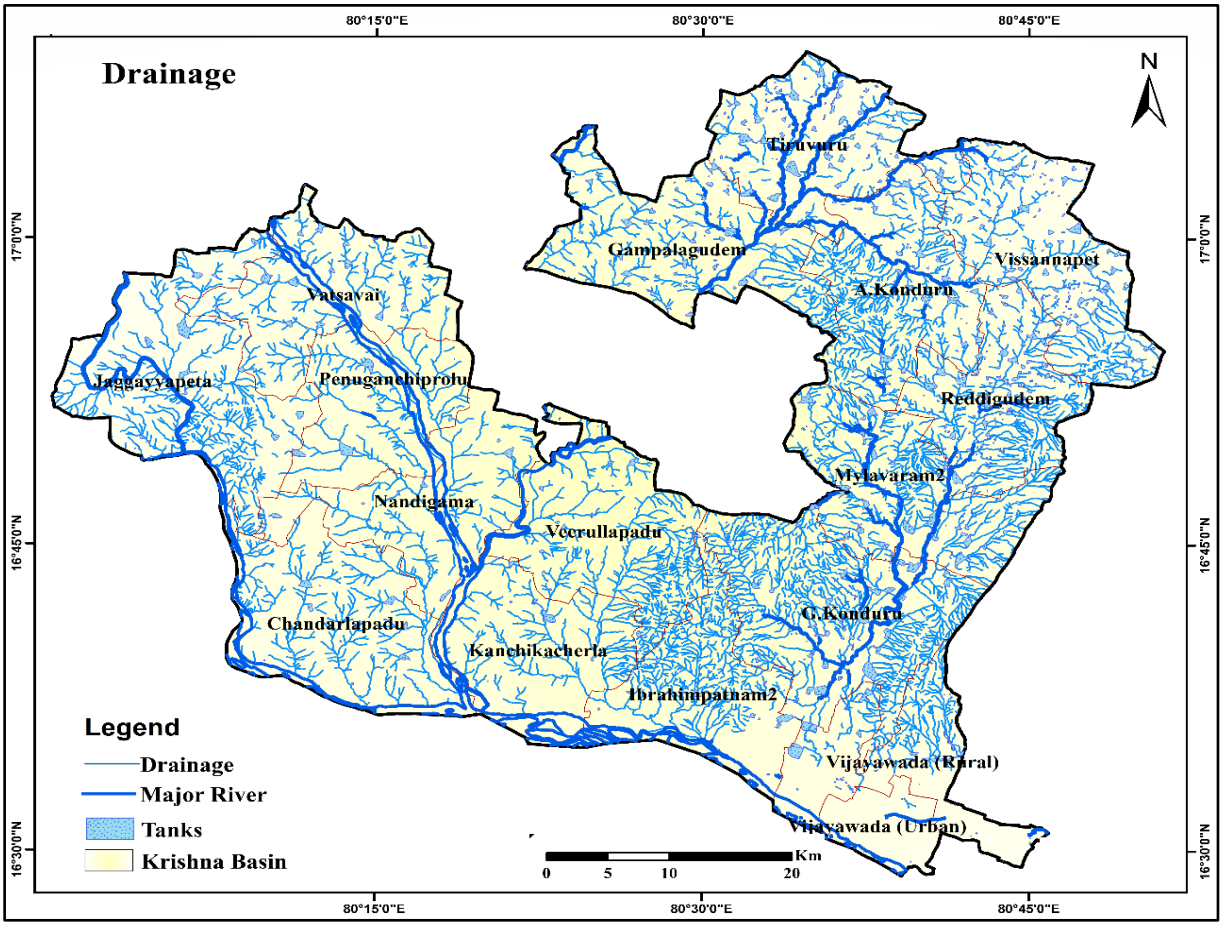


Fig.1.4: Drainage map of NTR district.

1.7 Land use pattern (2020): The total geographical area of the district is 331500 hectares. Out of this, 12% of the area is covered by forests. The rest is distributed among Barren and Uncultivable land and Land Put to Non-Agricultural Uses which constitute 4.35%and 15.83% of the geographical area respectively. The Net area sown forms 54% of the total geographical area while the cultivable waste, fallow lands, permanent pastures and miscellaneous tree crops constitute 15.24%. (Table No-1.2) & (Fig.1.5) & (Fig.1.6)

Table -1.2: Land Use Particulars, NTR District

S.NO	CATEGORY	AREA (Hectares)
1	Total Geographic al Area	331500
2	Forest Area	38519
3	Barren & Uncultiva ble Land	14441
4	Land put to Non. Agricultur al uses	52492
5	Cultivable waste	5270
6	Permanen t Pastures & other	5607
7	Misc. Tree crops & groves not	3115
8	Other Fallows	16515
9	Current Fallows	16703
10	Net Area Sown	178956
11	Total Cropped Area	208977
12	Area Sown More than Once	30021

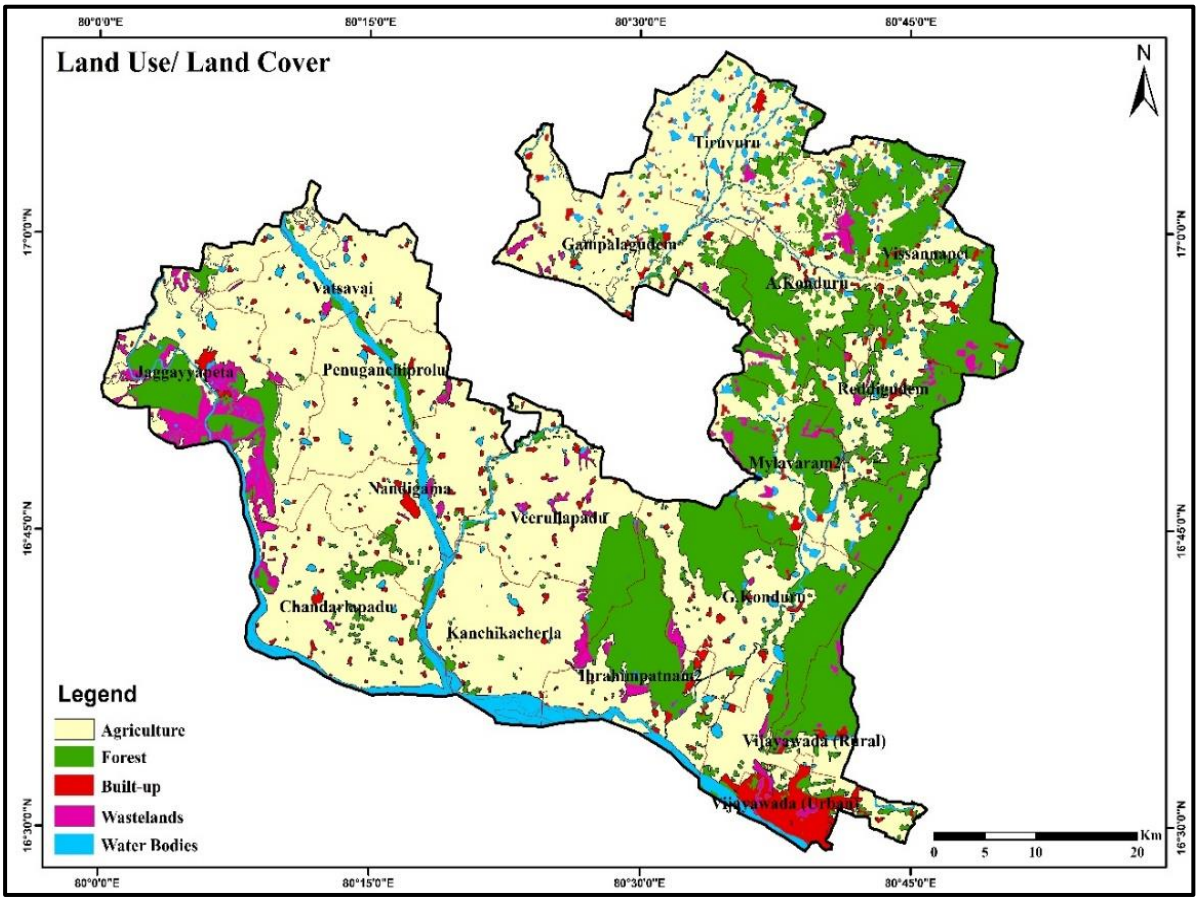


Fig.1.5: Land use and land cover map of NTR district.

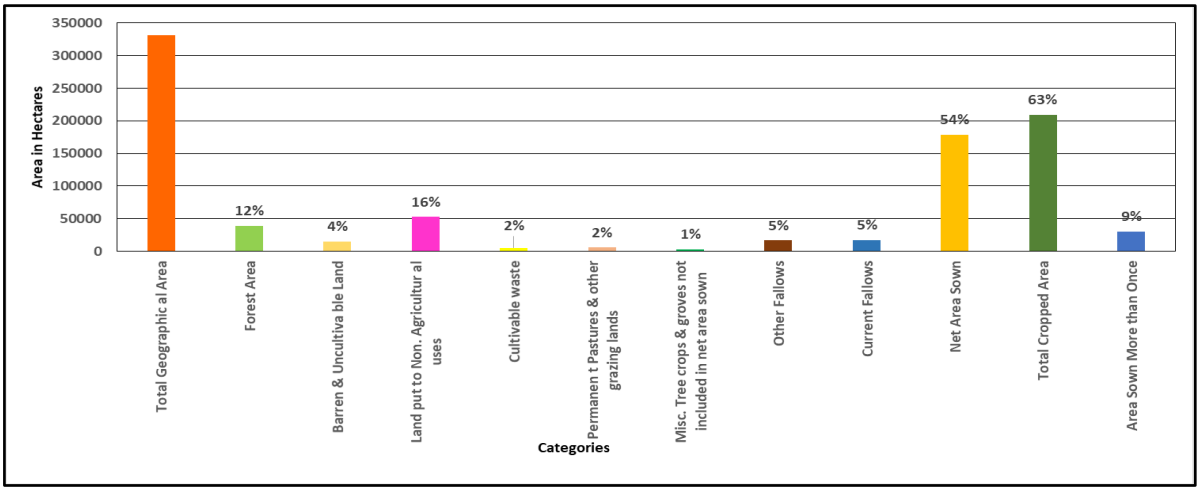
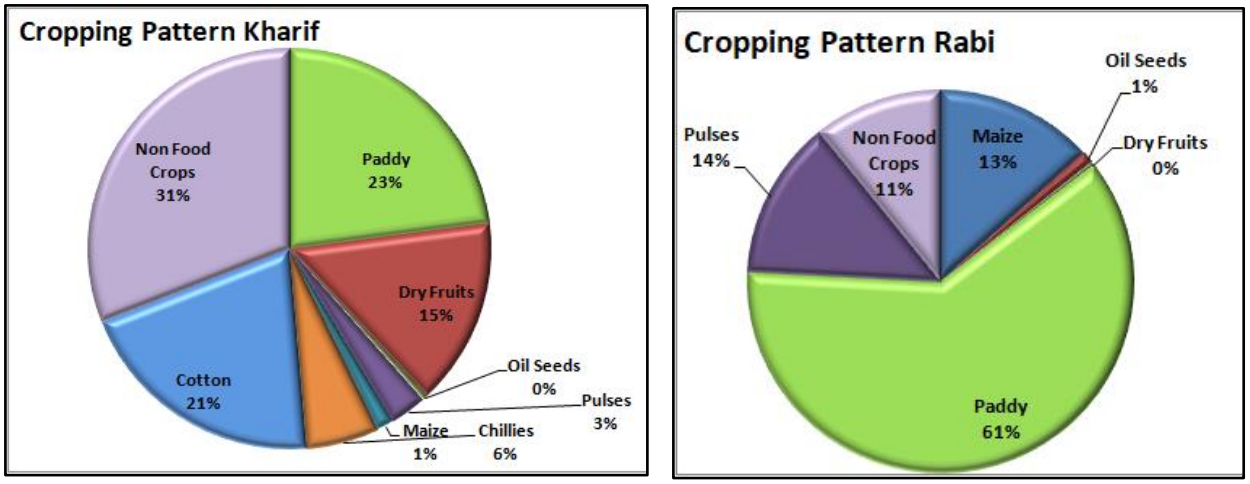


Fig.1.6: Bar chart showing landuse and landcover classification.

1.8 Agriculture: Agriculture is the main stay of the people in the district. The total cropped area of the district is 208977 hectares during the year 2020 which forms 63% of the total area of the district. The principal crops being grown are Paddy, Cotton, Dry fruits, Non-food crops, pulses & maize. The total gross cropped area during the year 2019- 20 is 208977 ha and net sown area is 178956 ha. The gross area cropped during Kharif seasonis 17,3202 ha and the major crops grown during kharif season are Non food crops (31%), Paddy (23%), Cotton (21%),dry fruits (15%), pulses (3%), chillies (6%) and 1% remaining other crops. The gross area cropped during Rabi season is 42400 ha and the major crops grown during the period are Paddy (61%), pulses (14%), Total oil seeds (1%), Maize (13%), non food crops (11%) and 1%remaining other crops. Season wise cropping pattern is given in Fig.1.7a and Fig.1.7b. Land use and land cover map of the district is depicted in Fig. 1.6.

Fig 1.7a & 1.7b Crop wise irrigation Status in the NTR District

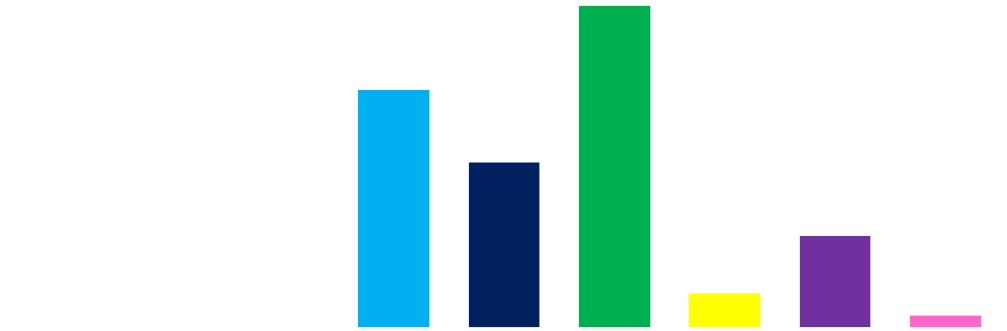


In the district, there are 1,55,052 marginal farmers (Below 1.00 Hectares of land), 42,034 small farmers (1.0-2.0 Hectares of land), 17,968 semi-medium farmers (2.0-4.0 Hectares of land), 4711 medium farmers (4.0-10.0 Hectares of land) and 325 large farmers (10 & above Hectares of land).

1.9 Irrigation: During the agricultural year 2019-20, the net irrigated area in the district is 17633 lakh hectares out of net cropped area of 26958 hectares. The net area irrigated in the district by canals, tanks, tube wells & filter points and other wells. The area irrigated under canals is 29908 hectares, tanks is 20734 hectares, bore wells is 40504 hectares and dugwells and other sources is 5815 hectares. An extent of 11502 hectares is irrigated under lift irrigation sources. The gross area irrigated is 108463 hectares which is inclusive of 37471 hectares under area irrigated more than once. The area irrigated by ground water is 44,786 ha (41%) whereas 63,677 ha of area are mainly irrigated by surface water sources (59%). There are ~5449 dug wells and there are 19,789 bore wells in the district. The salient features of irrigation are givenin Table-1.3 & Fig 1.8.

Table-1.3: Salient Features of Irrigation Kharif and Rabi season

Source of	Irrigation	Kharif	%	Rabi	%	Total	Gros area
Ground Water	Bore wells	23834	33%	16670	45%	40504	44,786 (41%)
	Dug wells	2475	3%	1807	5%	4282	
Surface Water	Canals	19717	28%	10191	27%	29908	63,677 (59%)
	Tanks	16642	23%	4092	11%	20734	
	Lift Irrigation	7596	11%	3906	11%	11502	
Others	Others	1046	1%	487	1%	1533	



	Gross	Canals	Tanks	Tube	Dug	Lift	Other
% Area	100%	28%	19%	37%	4%	11%	1%
Area (Hectare)	108463	29908	20734	40504	4282	11502	1533

Fig 1.8 Bar chart showing source of irrigation

The gross area irrigated is 108463 hectares. In which, 50% of the irrigation is through surface irrigation and 41% of the area is irrigated through ground water irrigation

1.10 Irrigation Projects: Three major irrigation projects and medium irrigation projects and 443 minor irrigation tanks are present in the district. Nagarjuna Sagar Project with ayacut area:of 230497 hectares, Polavaram Project with ayacut of 9012 hectares, Krishna Delta System project with ayacut of 4782 hectare are the major irrigation projects with a total ayacut of 244291 hectares and other medium projects have an ayacut of 6814.5 Ha. There are 443 Minor Irrigation sources in the district with a total registered ayacut is 26958 Ha but actual area irrigated is 17633 Ha**.(Fig 1.9)**

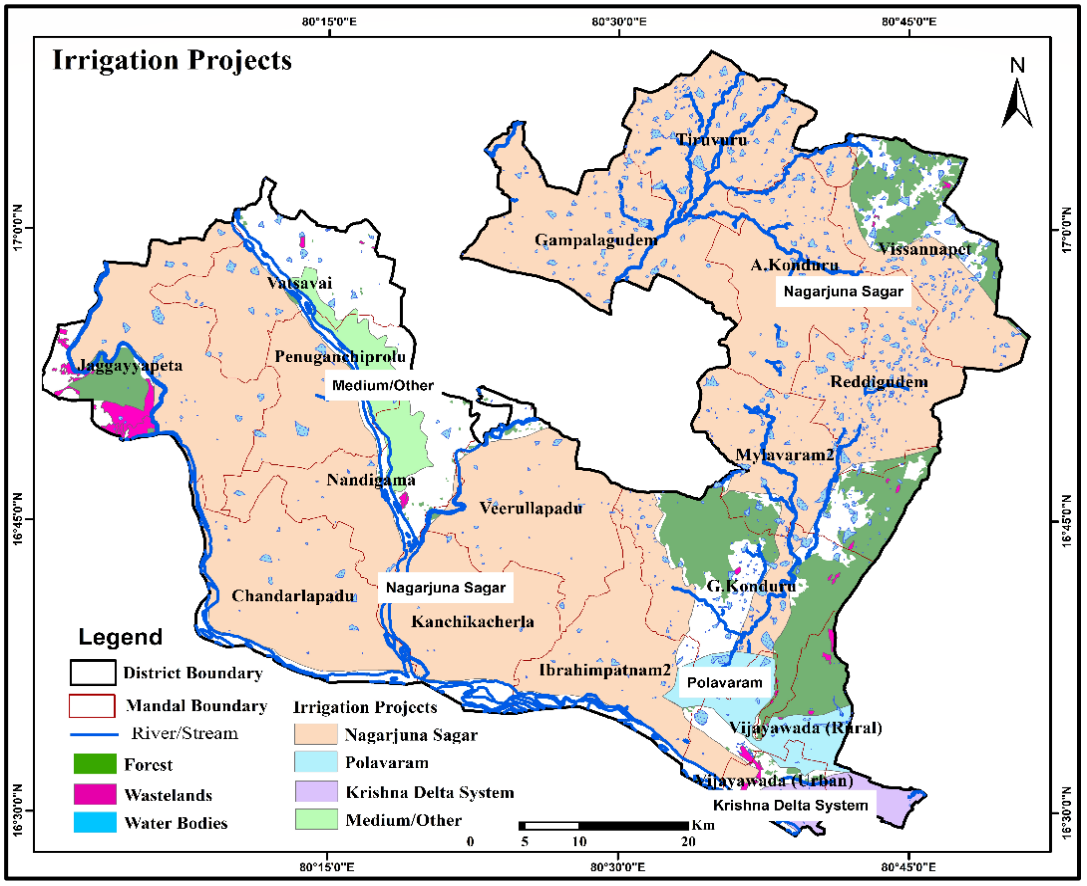


Fig 1.9 Irrigation Projects

1.11 Prevailing water conservation/Recharge practices: In the district there are ~8 percolation tanks, 578 Check dams/Check Walls and 10,230 farm ponds. Till 2019-20, ~ 4000 ha area is brought under micro-irrigation practices (Drip and Sprinklers).**(Fig 1.10).** The canal system and irrigation system is given in Fig 1.11

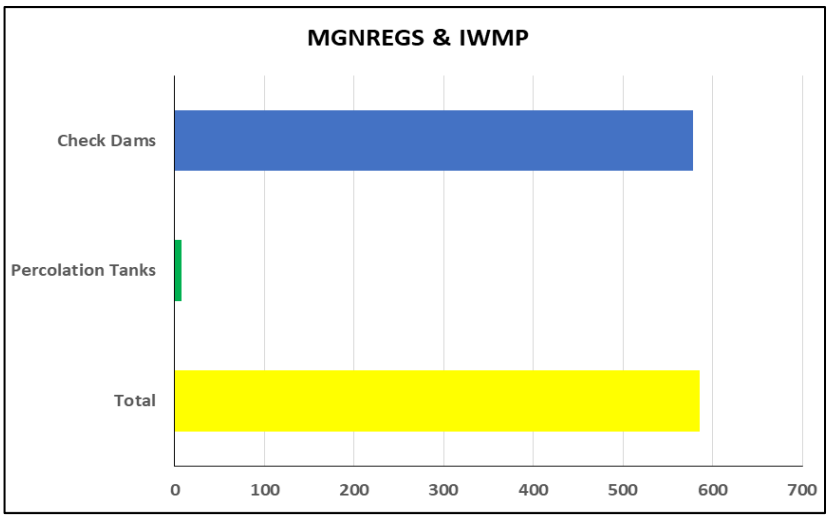


Fig 1.10 water conservation structures

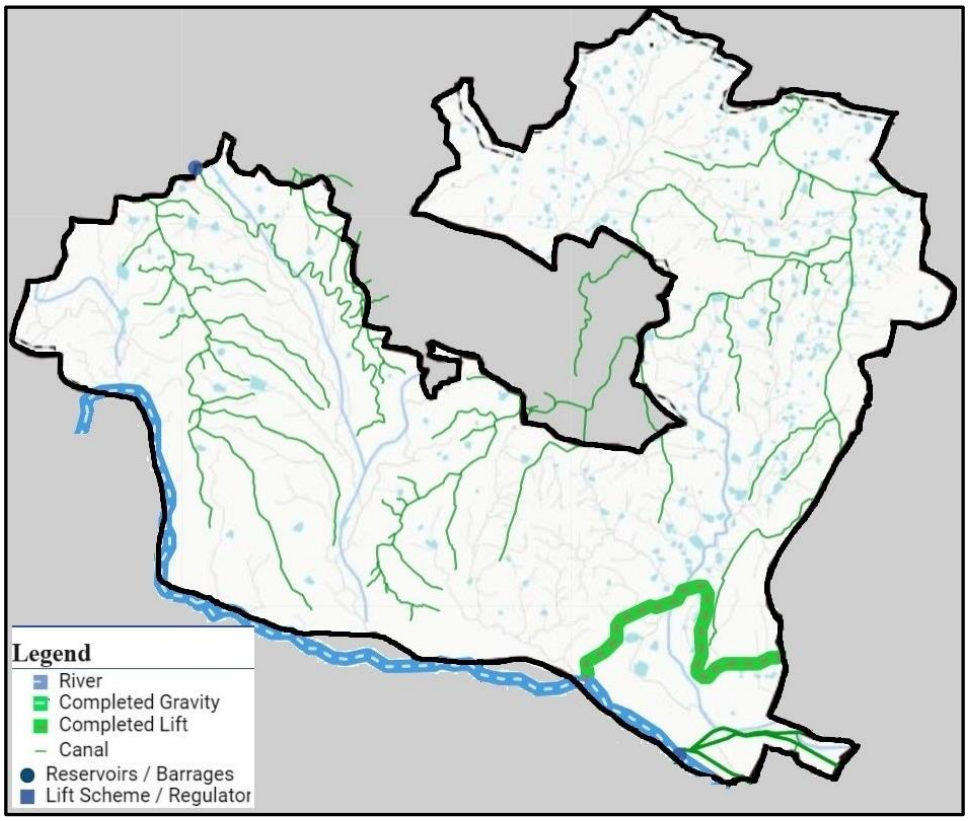


Fig 1.11 Canal System and Irrigation system in NTR district

1.12 Soils: Four types of soils viz., a) Clayey-skeletal, mixed, .b) Fine, Loamy, Kaolinitic and mixed type. c) Loamy-skeletal,mixed; and d) Rock lands and loamy-skelets. The district is majorly covered with Fine, Loamy, Kaolinitic and mixed type (**Fig.1.12**).

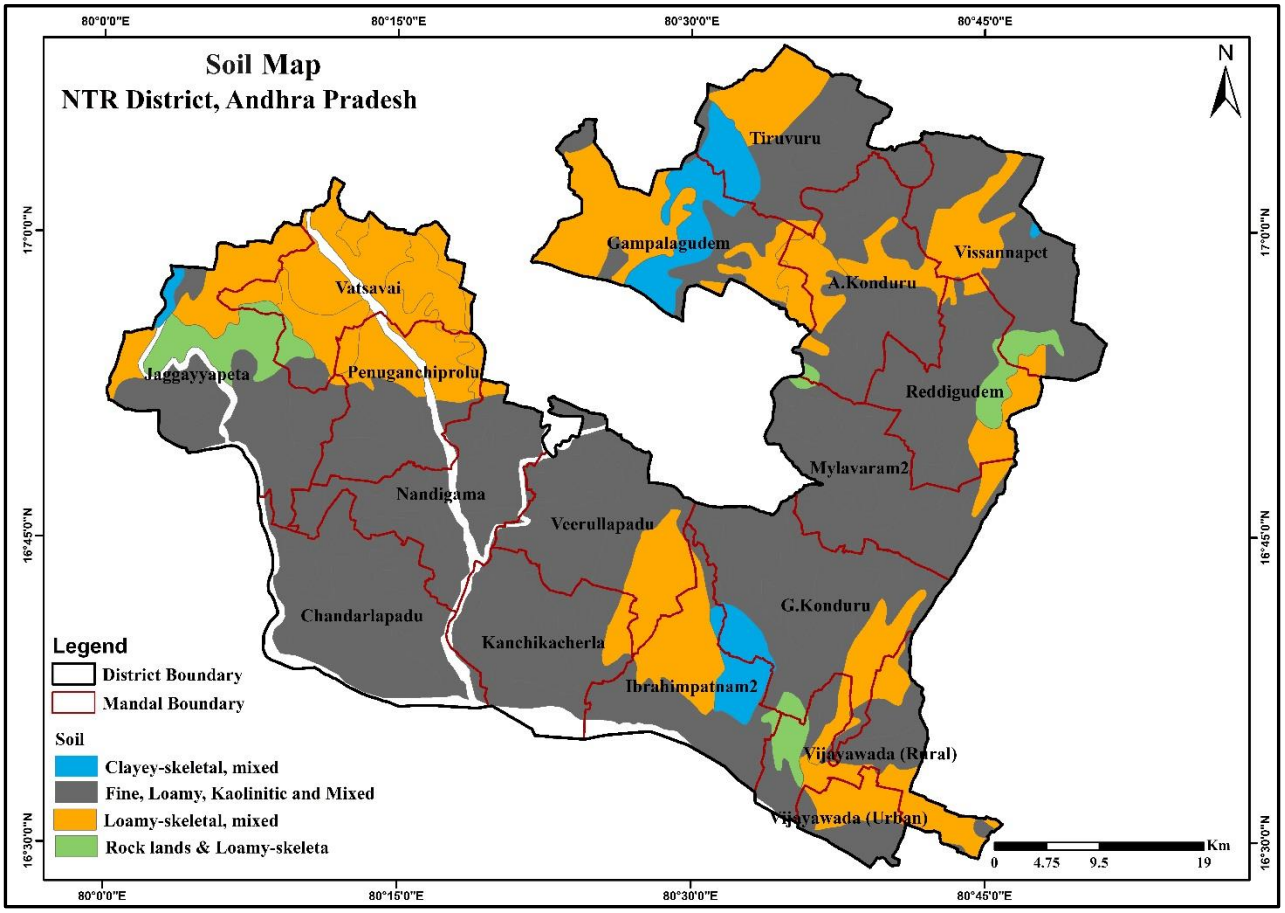


Fig.1.12: Soil map of NTR district

1.13 Geology: The study area is underlain by various geological formation from Archaean to Teritary age, with some isolated pockets of Recent to Sub-recent Alluvium. Archean to proterozoic Banded Gneiss, occupies 41% of the area (Table:1.3). The Archean Charnockite (19% of the area) and Khondalite (30% of the area) overlies the Archean Granitic Gneiss (41% of the area). The Precambrian metasedimentary formation covers of Kurnool and Cuddapah system covers 4% of the area and remaining 6% is alluvium sediments along the river channels (Fig1.10).

Table 1.4

Era	Period	Formation	Location
Quaternary	Sub-Recent to Recent	Alluvium	Along the river banks
Tertiary	Upper Gondawana	Sandstone	Tiruvuru
Pre-Cambrian	Kurnool System	NTR district (Parts)Narji Limestone & shales, Banaganapalli Quartzites	Jaggayyapeta
	Cuddapah System	Cumbum Quartzites & Phyllites	

……Unconformity……..……			
Archean	Dharwar	Veins of Pegmatite, dolerite dykes, Granite Gneisses, Charnockites khondalltes	Nandigama, Vijayawada, Vissannapet, Tiruvur mandals and Kondalli hills

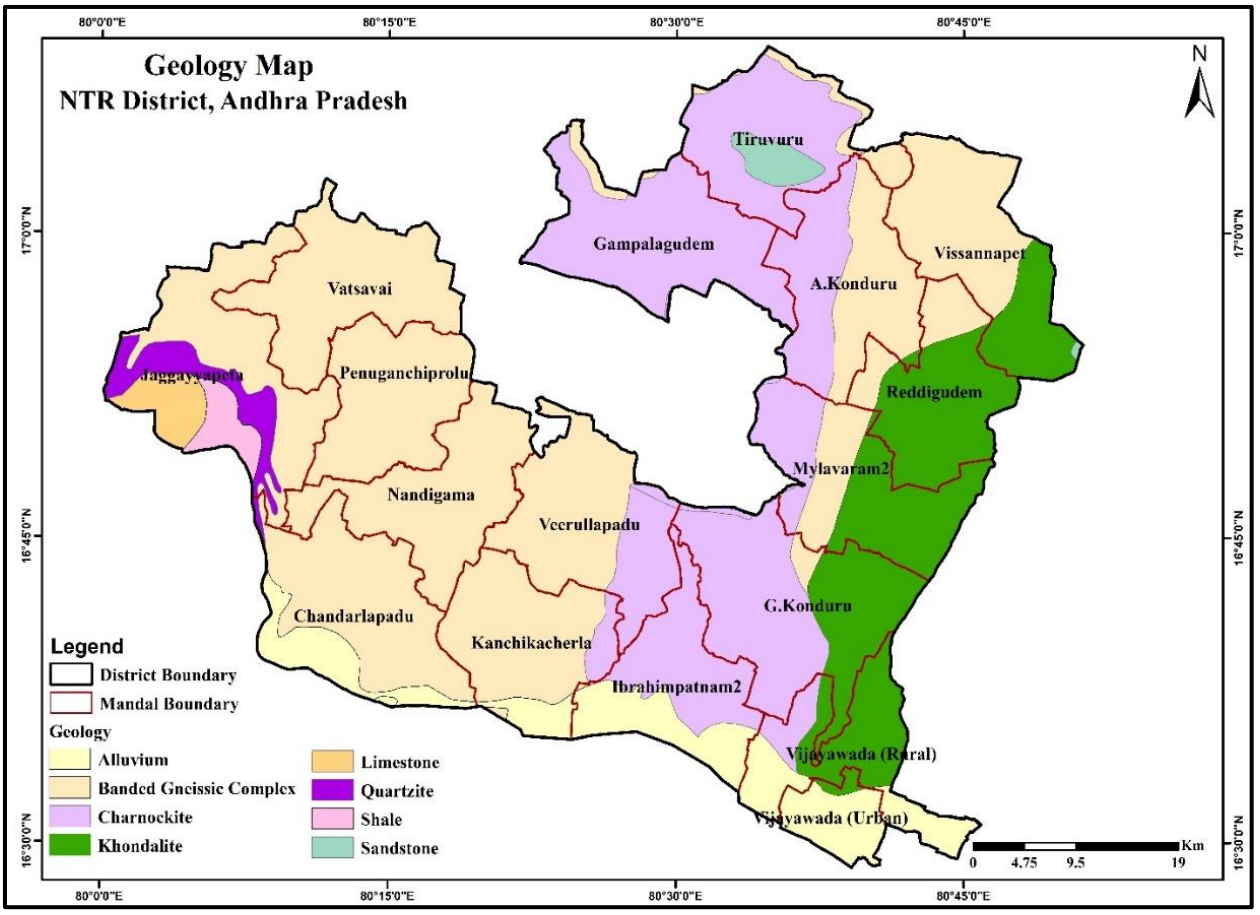


Fig.1.12: Geology Map of NTR district.

Aquifer/Formation	Area (Sq.kms)
Alluvium	249
Banded Gneissic	1572
Charnockite	874
Khondalite	469
Limestone	38
Quartizte	56
Shale	30
Sandstone	27

1.14 Mineral Sources

Table 1.5: Mandal wise distribution of mineral resources

Minerals	Mandals
Chromate	Kondapally hills and adjoining areas
Diamond	Paritala, Ustepalls, Kodavatikallu, Ramannapet, Uryavaram, Kothapet, Nemalipuram, Mugaluru, Putrela etc.
Iron Ore	Jaggayyapet area
Lime Stone	Jaggayyapet area
Mica	Tiruvuru area

In view of the present demand for chromate for Visakhapatnam Steel Plant, it may be worthwhile to carry out detailed exploration to assess the grade and reserves. As regards diamonds, detailed exploration of diamond ferrous gravels of Paritala and other areas is taken up by Geological Survey of India to assess the potentiality of the deposits. Most of the iron ore from Jaggayapeta area has already been mined andexported and the mining industry was closed down.

2. Data Collection and Generation

The historically available data of geology, geophysics, hydrogeology, and hydrochemistry generated under various studies by the CGWB through Systematic Hydrogeological studies, Reappraisal Hydrogeological studies, Groundwater Management studies, Exploratory drilling, and special studies have been utilized for data gap analysis, alongwith the data collected from various State and Central government departments. **(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 exploratory wells, delineation of principal aquifers (vertical and lateral) and compilation of 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 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 and nitrate.
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-chemicaldata.
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 Exploratory Drilling: Information on aquifer geometry, groundwater potential of various formations, fracture systems, their characterization is primarily inferred from the exploratory drilling data. CGWB has a total of 32 ranging from 40m to 200m; 17 wells of shallow depth and 15 of deeper depths wells in the study area. A total of 47 exploratory borewell data of CGWB (32) and SGWD (15) were used for the hydrogeological studies. There are 5 wells located in Semi consolidated formation and 36 wells in consolidated rock areas.

2.2 Water Level: Ground water regime monitoring is the basic component of groundwater management and it is carried out in parts of NTR district through National Hydrograph Network Stations (NHNS or NHS). NHSs are observation wells, comprising of dug wells and purpose built bore wells – known as piezometers. There are 104 wells (CGWB:33, SGWD: 71 PZ)part of the NHS. CGWB wells are being monitored four times (January, May, August and November) in a year whereas; the monitoring wells of State Ground Water Department (SGWD) are being monitored every month. These 104 groundwater monitoring wells were used in order to understand the annual as well as decadal spatial-temporal behavior of the groundwater regime.

2.3 Hydro chemical Studies: Water quality data of Exploratory wells, NHS monitoring wells and Key Wells are utilized for understanding the spatial variation of quality in the district. A total of 33 NHS Pre monsoon Ground water monitoring well data of Central Ground Water Board is utilized to understand the chemical characteristics of groundwater. Parameters namely pH, EC (in µS/cm at 25 ° C), TH, Ca, Mg, Na, K, CO3, HCO3, Cl, SO4, NO3 and F were analyzed.

2.4 Geophysical Studies: Geophysical data on VES and profiling are used to extract information on the weathered thickness, fracture depth, thickness of fracture in the district. For the interpretation of the aquifer geometry geophysical data in conjunction with the available groundwater exploration data is utilised. The VES data from Tiruvuru, A Konduru, Vissanapeta, and Mylavaram areas were analysed for NAQUIM. The measurements were taken at the central part of the profile leaving 200m on either side of the profile. The VES positions were all along the seismic profile at most of the shot points to a maximum electrode separation of 400m (AB).

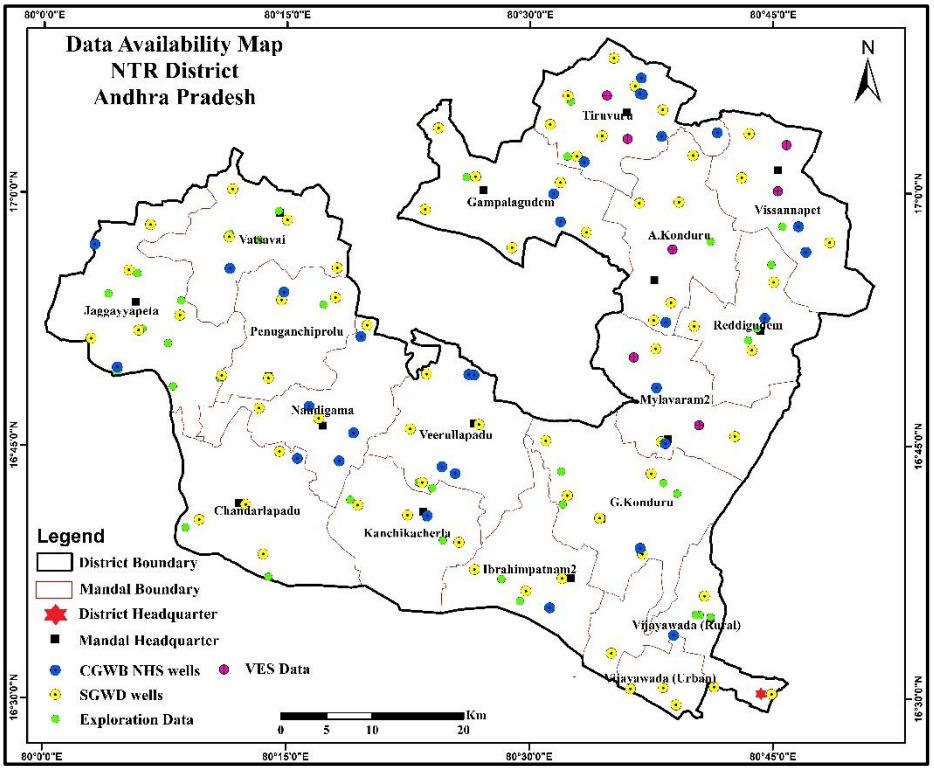


Fig. 2.1: Map Showing Hydrogeological data availability in NTR District.

3. Data Interpretation, Integration and Aquifer Mapping

In order to establish the three-dimensional disposition of aquifer system in the area, the existing data of litho logical logs of exploratory wells studies carried out by CGWB were used to prepare a hydrogeological cross section, fence diagram and 3D Model. The data has been analyzed using Rockworks 17 software and is presented below in the hydrogeological cross sections A-A' to C- C' (Fig.3.2(a) to Fig.3.2(c)) and Solid Model of the district showing the depiction of Aquifer Groups up to 200m. Map showing section lines are presented in Fig. 3.1. In Hard rock area weathered Aquifer depth of occurrence is from 0 to 36 m and fractured aquifer depth of occurrence is from 35 to 200m. Hydrogeological cross sections are placed at Figs 3.2 a to 3.2 c. Fence Diagram and 3D Solid Model of NTR district is depicted in Fig. 3.3 and 3.4 respectively.

3.1 Conceptualization of Aquifer system in 2D

Conceptualization of 3-D hydrogeological model was carried out by interpreting and integrating representative 46 data points (both hydrogeological and geophysical down to 200 m) for preparation of 3-D map, panel diagram and hydrogeological sections. (**Fig.3.3 and 3.4)** along with hydrogeological sections.

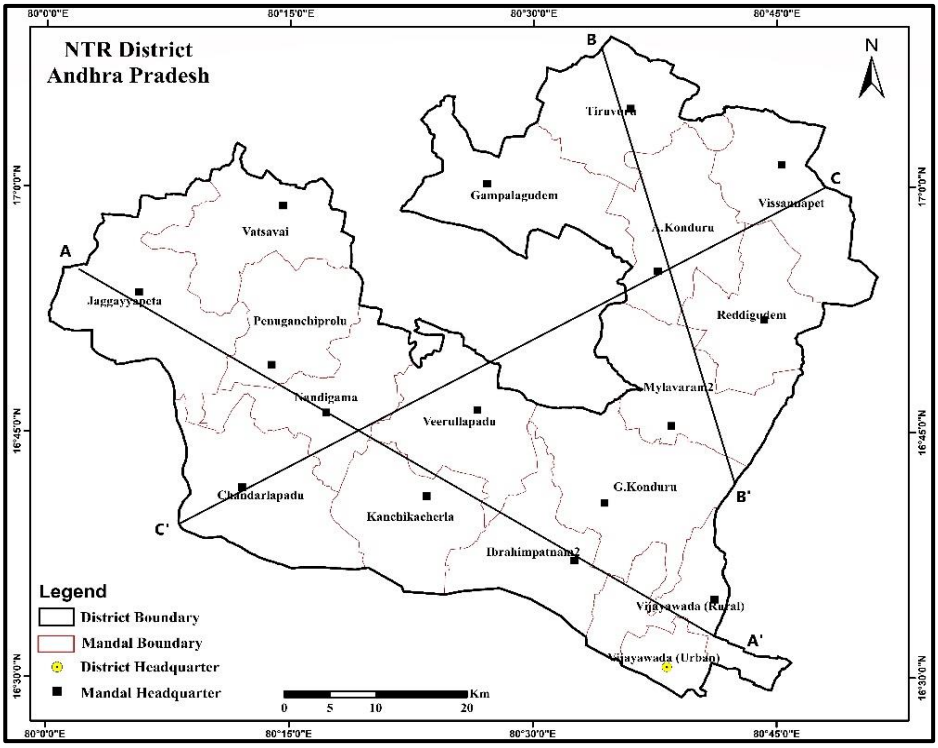
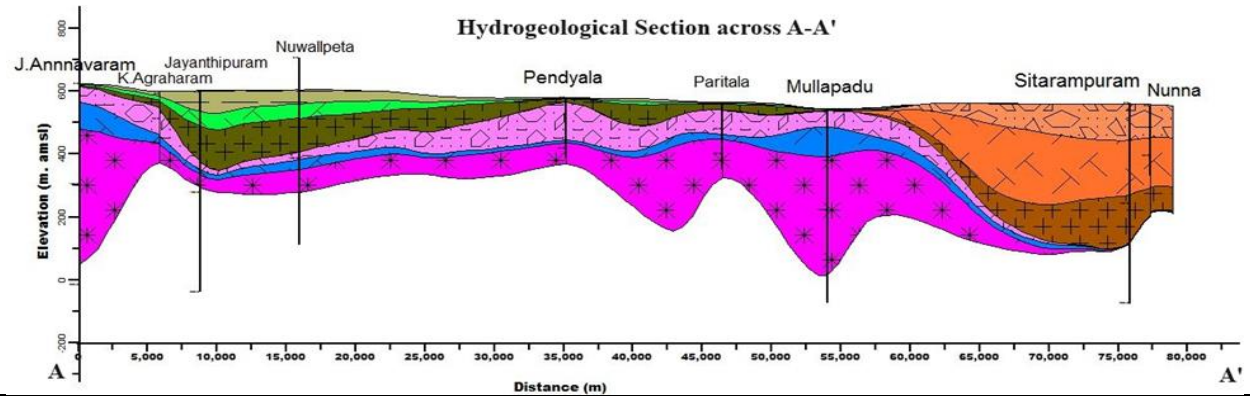


Fig :3.1 Map Showing Cross Sections

3.2 Aquifer Disposition



Section A-A' The Section is drawn roughly NW-SE direction and start from J. Annavaram to Nunna passing through Nawabpeta, Pendyala & Mullapadu. A thin stretch of metasedimentary formation extends upto 10 km into the Jaggayapeta Mandal from NW boundary and the metasedimentary rocks tappers out as moved in east direction. The thickness of fractured granitic zone increases in the central part of the study area (Fig 3.2 a) .

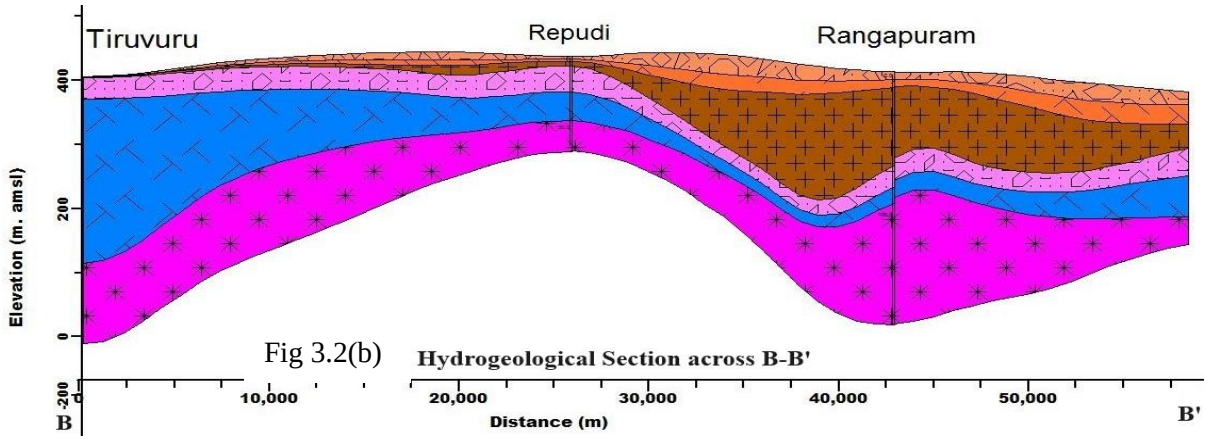


Fig 3.2(b)

Section B-B' The section is drawn roughly N-SE direction and start from Tiruvuru to Rangapuram passing through Repudi. Geological formation encountered more or less same as in the section of Khondalites underlain by Gneiss/Charnockites. Fig3.2 (b)

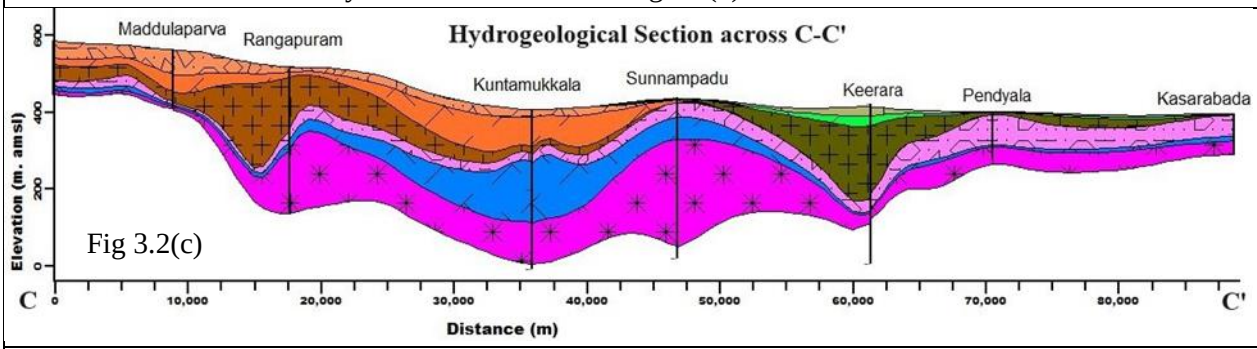


Fig 3.2(c)

Section C-C' The section is drawn from NE-SW direction and depicts thick Khondalite zone overlying the Charnockite/Granite gneiss base in the north east direction and reduces in the central part. As we move towards the south west direction Charnockite/Granite gneiss are overlain by metasediments (Fig 3.2 c).

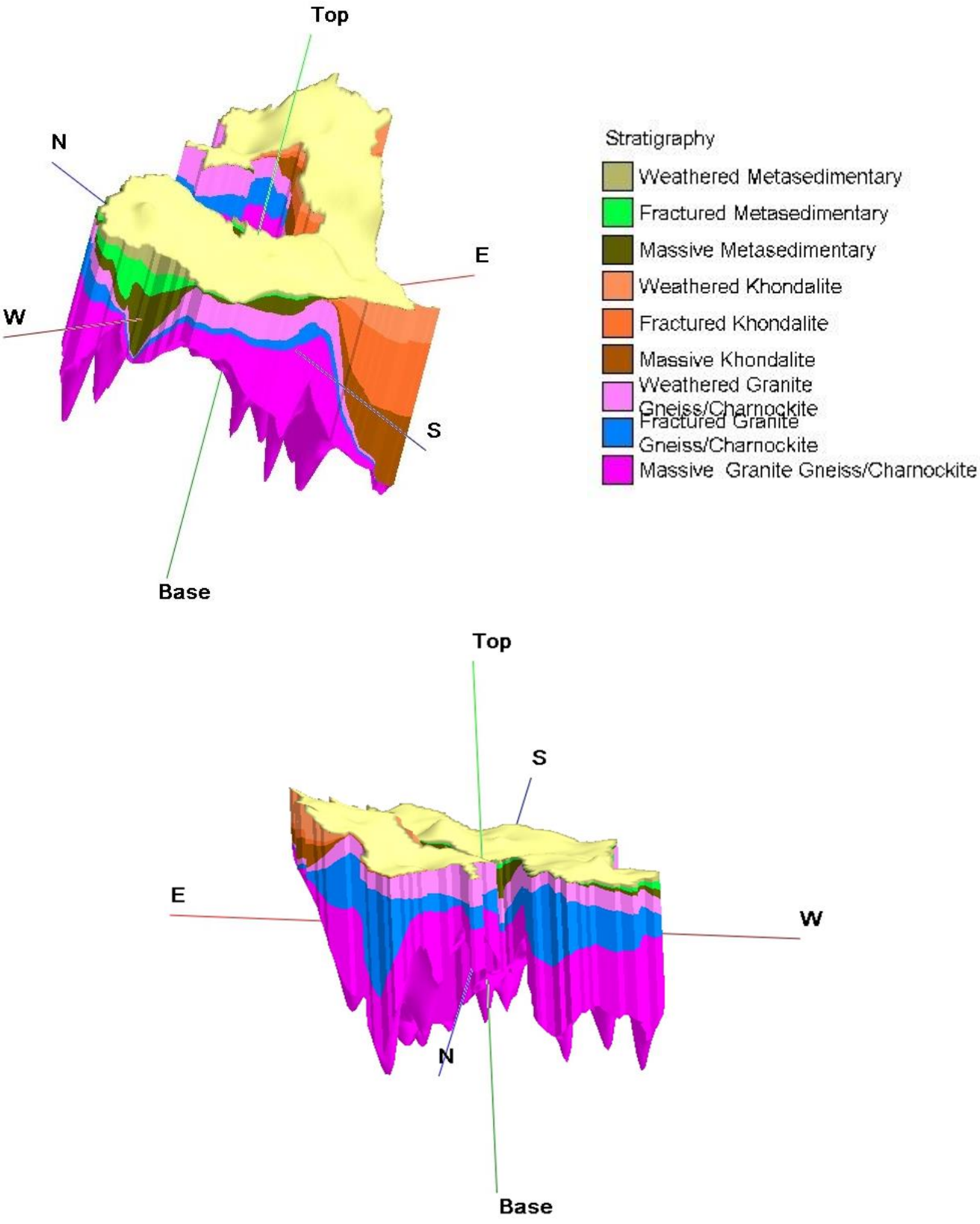


Fig.-3.3 & 3.4: 3-D Model for study area

Finally, the study of these sections revels the identification and delineating the aquifers vertically and laterally. On the basis of occurrence and movement of ground water, rock units of the NTR district is classified mainly into two categories. The main aquifers constitute the weathered zone at the top, followed by a discrete anisotropic fractured zone at the bottom. 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 aquifer units identified includes- Shallow Aquifer and Deeper Aquifer.

3.3 Weathered zone: in the district, the weathered thickness ranges from 10-30 mbgl. The weathered thickness ranging from 10 to 20 mbgl is noticed in 14% of the district followed by 20 to 30 m and < 10m thickness bgl. The deeper weathered thickness >30 m bgl observed in G. Konduru mandal. The weathered thickness map is given in Fig 3.5.

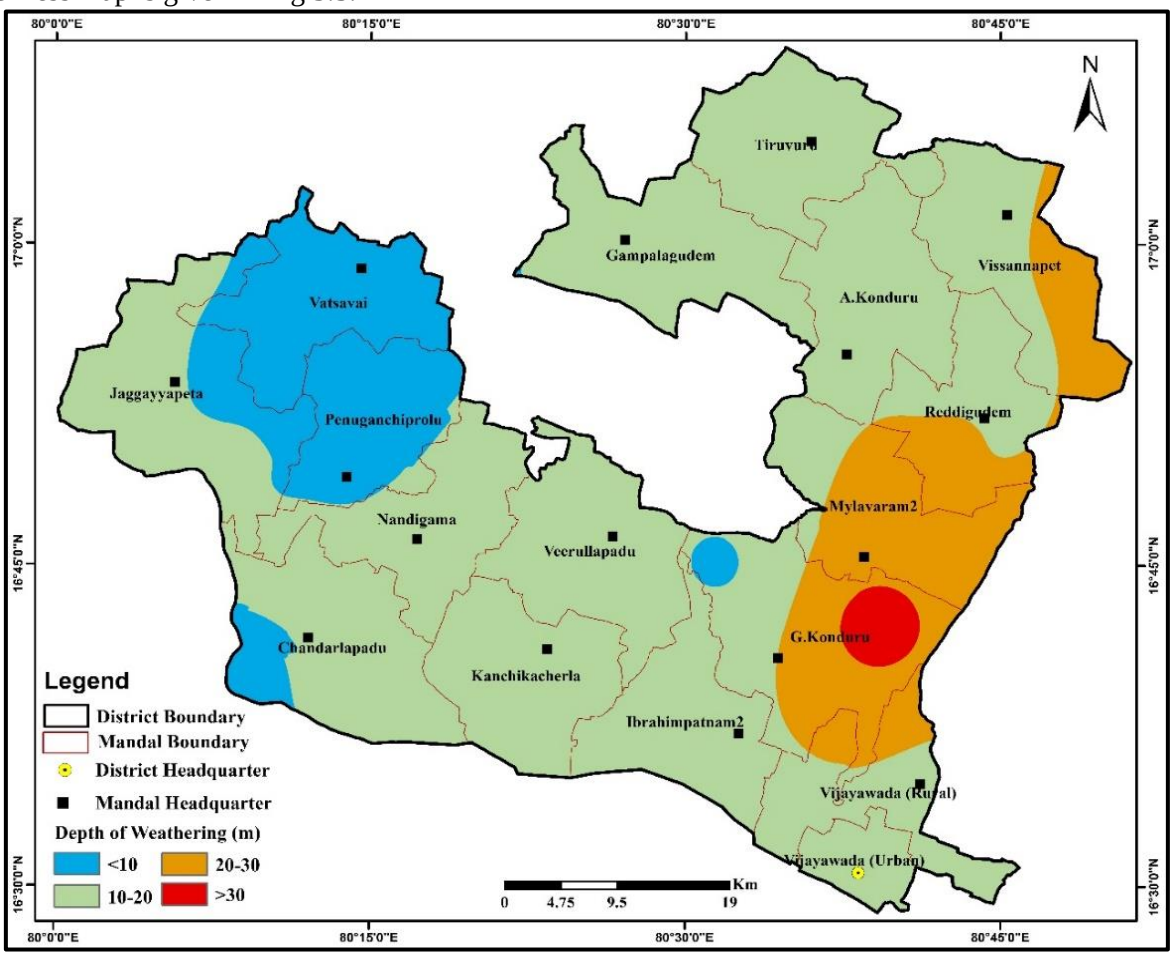


Fig 3.5 Weathering Thickness

3.4 Aquifer Characterization of Shallow Aquifer: (Aquifer-1): It consists of weathered residuum where ground water occurs under water table condition and is mainly developed by construction of dug wells or shallow bore wells as hand pump. The shallow aquifer is considered up to the maximum depth of weathering and first fracture encountered (below weathered depth) generally down to ~30 m depth. They are unconfined aquifers. Ground water yield varies from <0.1 to 2 lps (avg: 1.0 lps in weathered granite/gneiss aquifer, 0.4 to 6.9 lps (avg: 3.6 lps) in weathered Khondalites and 1 to 12 lps (avg: 4 lps) in metasedimentary aquifers. The transmissivity varies from <1 to 70m^2/day in weathered archean crystalline aquifers and varies upto <100 m^2/day in metasedimentary aquifers.

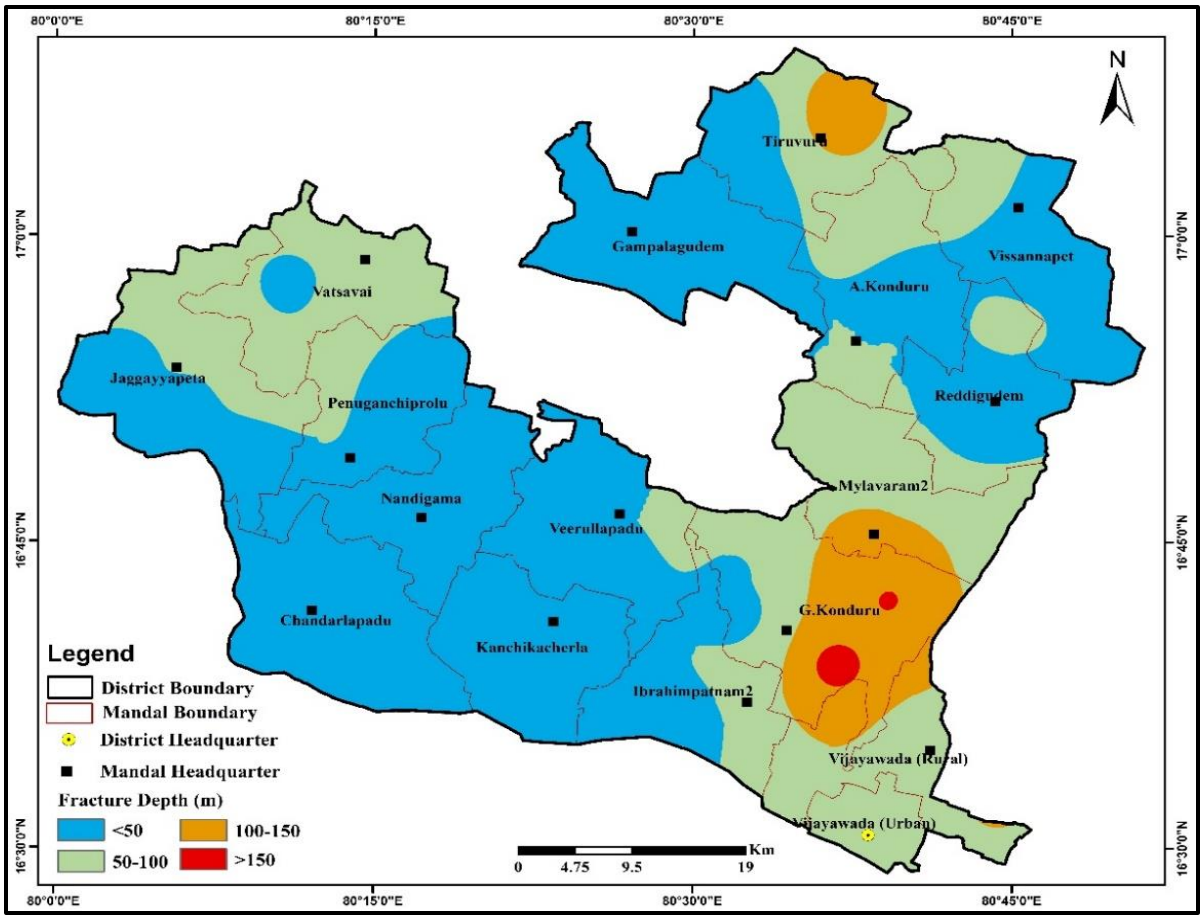


Fig 3.6 Depth of occurrence of Fractures

3.5 Fracture Zone: Based on CGWB & SGWD data, it is inferred that fractures in the range of 30 to 50 m depth are more predominant (57% of the area), 50-100 and 100 to 150 fractures occur in 34% and 7% of area respectively and deep fractures in the range of 120-150 m. Analysis of occurrence of fractures reveal that majority of fractures (~80 %) occur within 100 m depth (Fig. 3.6)

3.6 Aquifer Characterization of Deeper Aquifer (Aquifer II): The aquifer-II is the deeper aquifer which tapped the fractured zone. Ground water in the second aquifer occurs under semi-confined to confined condition in the fractures upto the maximum depth of 180 m bgl (Deepest fracture encountered). The depth of fracturing varies from 25 m to 180 m with yield of <1 to more than 10 lps. The specific capacity of the consolidated formation ranges between 5 and 700 lpm/mdd and transmissivity of consolidated formation varies from <1 to more than 100 sq.m/day. The storativity varies from 4.84 *10^{-6} to 1.06*10^{-4}.

3.7 Ground water Yield: Ground water yield from weathered and fractured units of aquifer varies from < 1 to >10 lps. Based on exploratory data of CGWB, yield map is prepared and shownin **Fig.3.7**. In most of the area wells yields are in the range of 2-3 lps in ~80 % of the area and < 2lps in ~9 % of the area observed, followed by yield >3 lps is observed in 11% of the area. Wells located in the command area have higheryield (2-3 lps) and sustain for more hours of pumping as compared to non-command area where yields are relatively low with sustainability for 2-3 hrs.(Fig 3.7)

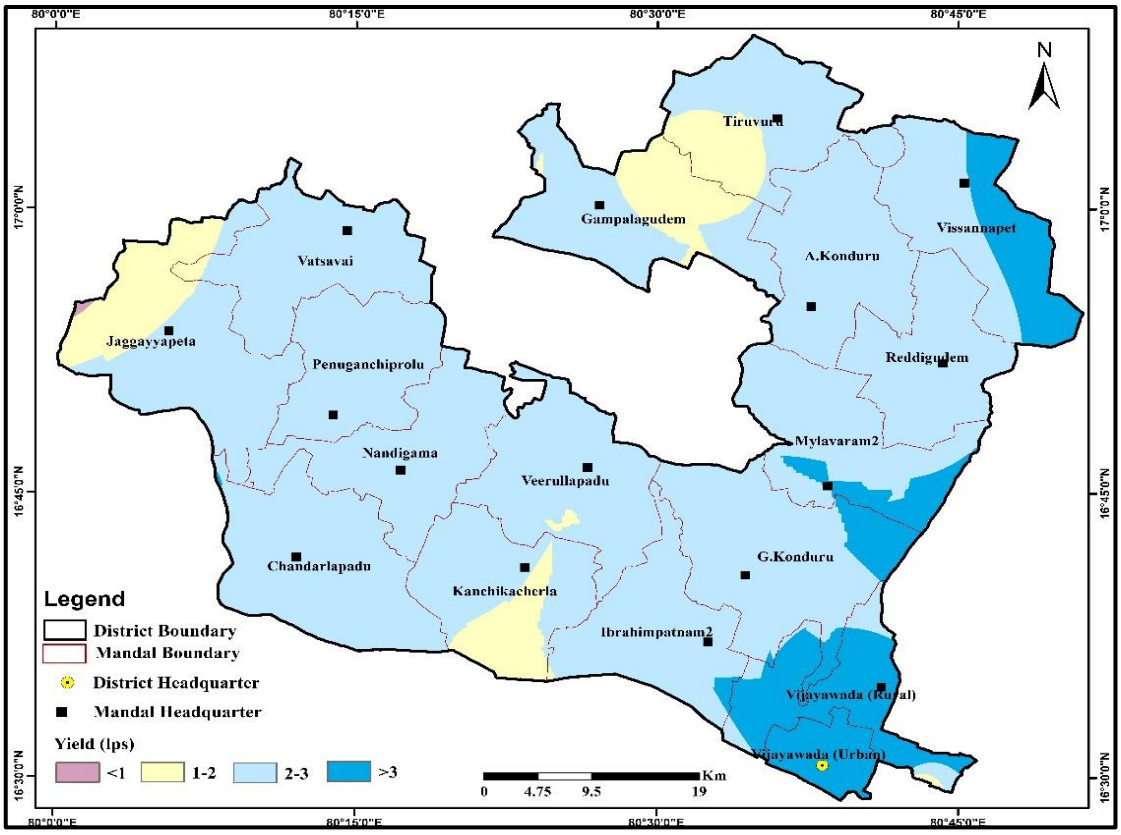


Fig.3.7 Ground water Yield

	Aquifer-I	**Aquifer-II**
Depth (mbgl)	**0-30 m**	**Upto 200m**
Weathering depth	**~ 30 m**	
Yield (lps)	**<0.1 to 2 W. Granite** **0.4 to 6.9 W. Khondalite** **1 to 12 W. Metasedimentary**	**<1 to >10 lps** **Sp. Capacity: 5 to 700 lpm/m**
T		
S		

3.8 Hydrogeological Aspects of Aquifer System in the various mandals of study area

Out of the total study area of 3,315 sq.km approximately 92 % of the area is underlain by the Arechean group of rocks consisting khondalites, granites, gneisses and charnockites and remaining 8% is covered with alluvium and sanstone etc., exposed in Jaggayyapet, Tiruvur, Nandigama, Vijayawada. These rocks are devoid of primary porosity due to compaction and consolidation. These formations tend to become ground water repositories with the development of secondary porosity and permeability with weathering and fracturing. Groundwater in these rocks occurs under water table conditions restricted to weathered, fractured and jointed horizons.

The thickness of the weathered mantle of the crystalline rocks varies widely from 0 to 10m near the hill slopes and out crops, to as much as 40 m in valleys and topographic lows. This weathered formation has been extensively developed by open dug wells and shallow bore wells. Water from these rocks is extracted by dug wells of depth ranging from 6 to 20 m bgl. Domestic wells are mostly circular with about 1m diameter or rectangular with dimensions of 4m X 6m to 10m X l5m. In the areas underlain by shales and limestones in Jaggayyapet the open wells are used for domestic and irrigation purposes and the depth to water level in these wells varies from 3 to 15mbgl. Available data indicates that these wells sustain 2 to 3 hours of continuous pumpage in a day.

In parts of Tiruvur mandal especially in Vissannapet area, weathering of khondalites has been observed down to the depth of l5 m bgl. The dug wells tapping this aquifer have depths ranging from 5 to 14 m and the depth to water level varies from 1.5 to 7.5 m bgl. The yield of the wells, computed from the reported recuperation, vary from 50 to 250m^3/day. In contrast to khondalites, granites are less susceptible to weathering and as such the thickness of the weathered zone is very much limited, usually 6 to 12m thick. Dug wells tapping this zone vary in depth from 5 to l l m bgl. The yields of these wells range from 20 to 100 m^3/day.

In Jaggayyapet mandal, ground water occurs in granite gneisses intruded by dykes of dolerite and quartz reefs, shales, limestones etc., In the granite gneisses the open wells drilled in weathered and jointed granitic rocks, whose depth range is between 2 and 12 m bgl. The depth to water level in these rocks varies from 1.2 to 9.0 m bgl. Analysis of pumping test data has indicated that the average rate of inflow of water into the wells vary from 275 to 534 lph/sq.m. In the quartzites of Cuddapah group, ground water occurs ln joints, fissures and fractures. The dug wells in these formations range in depth upto 15 m bgl and depth to water from 1.5 to 7 m bgl. In the limestones ground water is reported to occur in solution channels, joints, fractures and other types of large openings. The wells located in the limestones range in depth from 3 to 14 m bgl and depth to water level from 1.5 to 13 m bgl. Wells located in shales range in depth from 5 to 10 m bg1. Very limited yields are obtained from wells located in shales.

In Tiruvur area, ground water occurs in the weathered crystalline rocks and in the pegmatites associated with them. Dug wells and dug-cum-bore wells are the ground water abstraction structures in the area. In west of Munneru River, in the gneissic granites, the ground water conditions are comparatively better than those in the east. In this area, the yield of the wells is controlled by the degree of weathering, thickness of the weathered zone and presence of fractures, joints etc. The dug wells in this granitic area range in depth from 4 to l2m bgl and depth to water vary from 2 to 10 m bgl. Groundwater in this formation occurs mostly under water table conditions and rarely under semi-confined to confined conditions. In some of the dug wells, in

order to improve the yield, further bore of 100 mm diameter has been drilled from the bottom of the wells to further depths of 5 to l5 m. Water is lined from these dug-cum-bore wells by centrlfugal pumps and is used for irrigation. These wells sustain 4 to 6 hours continuous pumping at an average discharge of l0m^3/hr.

Table 3.1. Salient features of Aquifer system in NTR

Era	Archean Crystallines	
Prominent Lithology	Granite Gneiss/Charnockite (Basement)/Khondalite	
Aquifer types	Aquifer-1(Weathered Zone)	Aquifer-2(Fracture Zone)
Thickness range	1 - 35 m	up to 200m
Depth range of fractures	-	80% fracture encountered within 100m
Range of yield potential	<3	<1 to >10 lps
Transmissivity (m2/day)	More than 1 to 200 sqm/day	
Storativity	4.84 *10^{-6} to 1.06*10^{-4}	
Quality (Suitability of	Yes	Yes

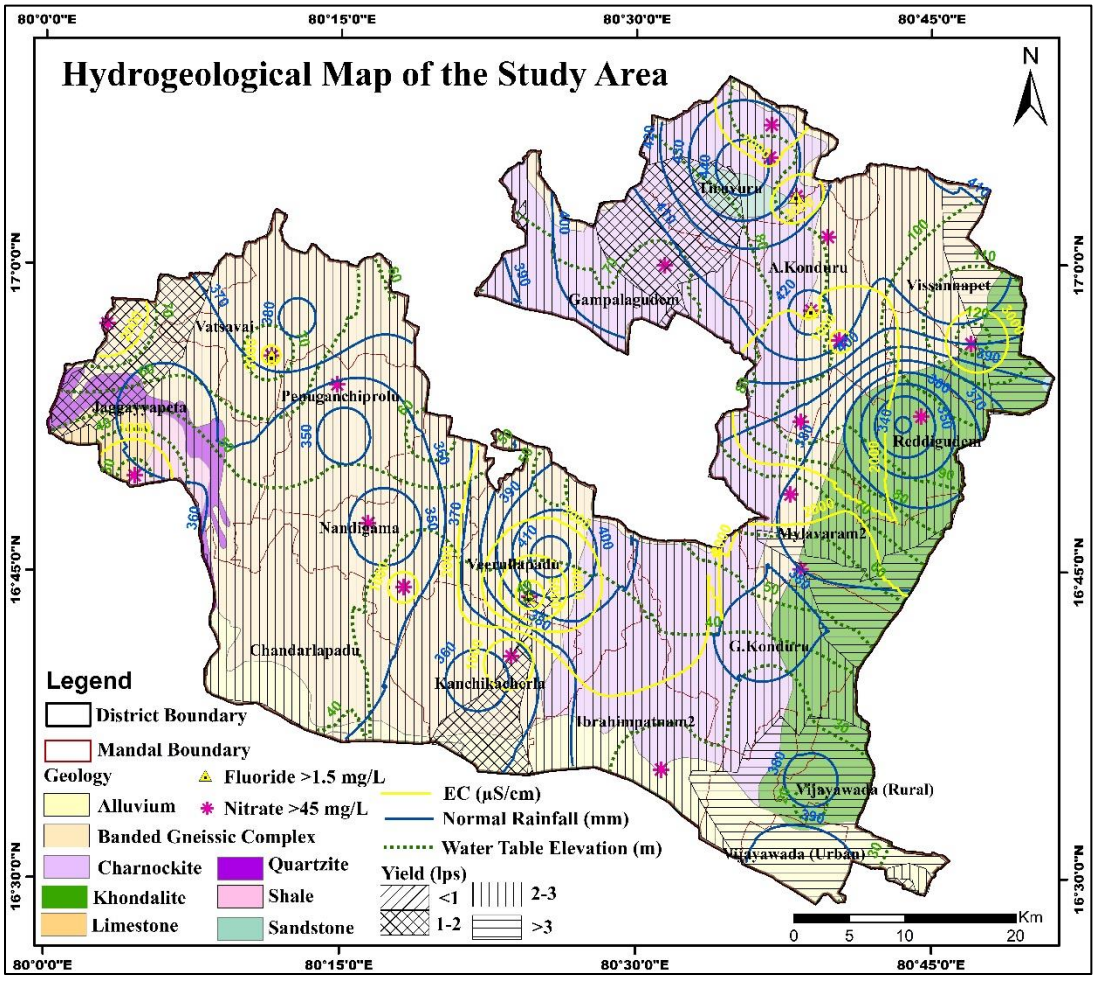


Fig 3.8 Hydrogeological Map of NTR District

3.9 Groundwater Regime Monitoring

Ground water regime monitoring is the basic component of groundwater management and it is carried out in parts of NTR district through National Hydrograph Network Stations (NHNS or NHS). NHSs are observation wells, comprising of dug wells and purpose built bore wells – known as piezometers. There are 105 wells (CGWB:33, SGWD: 72 PZ) falling in the district covered under NHS. The following maps have been generated to understand the behavior of ground water regime.

3.9.1 Depth to Ground Water Levels (Pre-monsoon 2023)

The depth to water level of pre-monsoon 2023 (Fig 3.9) in the district that the majority of the water levels are in the range of 50to 10m bgl followed by 2 to 5 mbgl which is observed in majority of the mandals. The depth to water level of 10 to 20 mbgl, 20 to 40 m bgl and >40 mbgl is noticed in Jaggayyapeta, Vissannapet and Vijaywada Rural and Urban mandals.

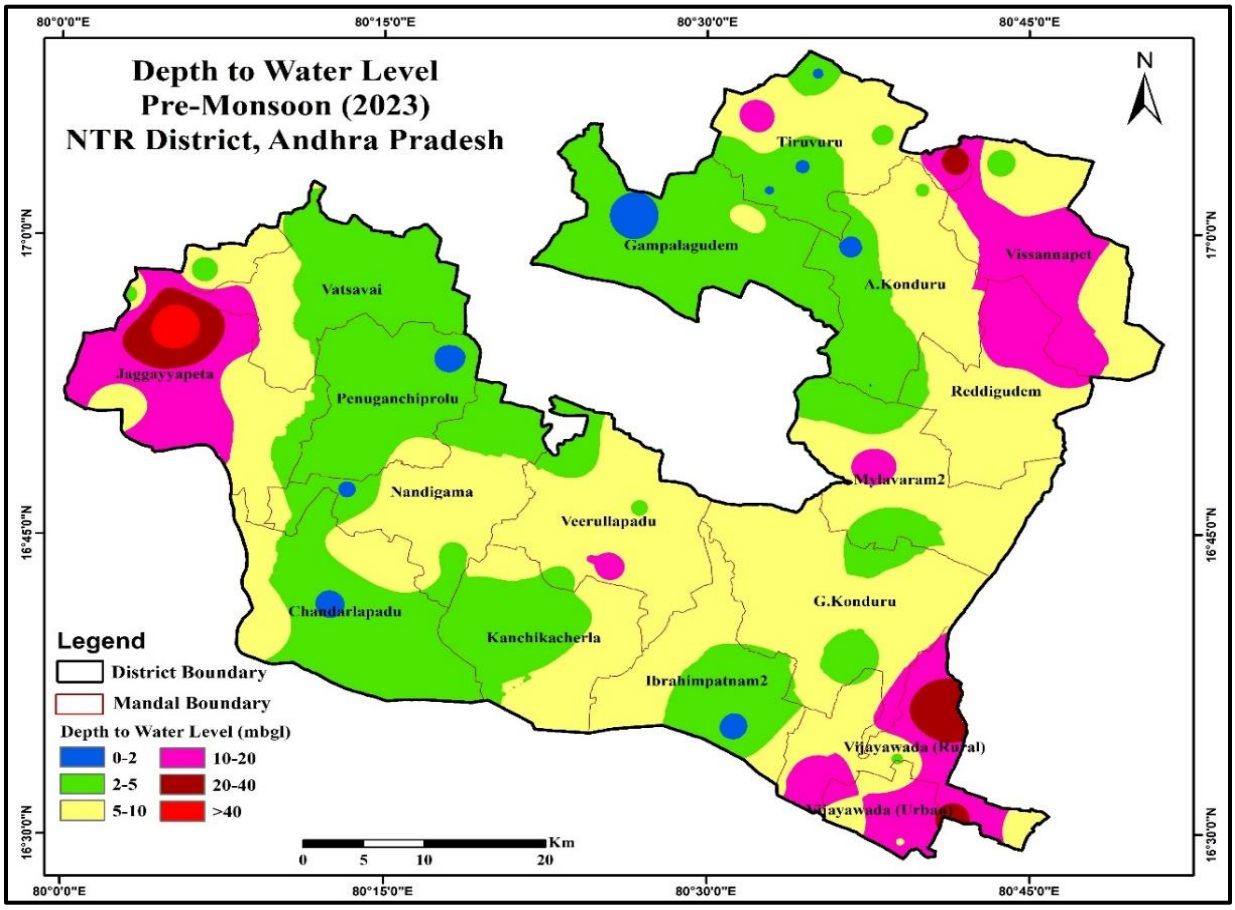


Fig 3.9 Depth to Ground Water Levels (Pre monsoon 2023)

3.9.2 Depth to Ground Water Levels (Post monsoon 2023)

In Majority of the areas, water level during this season is in the range of 2 to 5 m in 59% of the area, followed by 5 to 10 water level m bgl in 36% of the area. Deeper water levels >10 m bgl is observed in 3% of the area. (Fig 3.10)

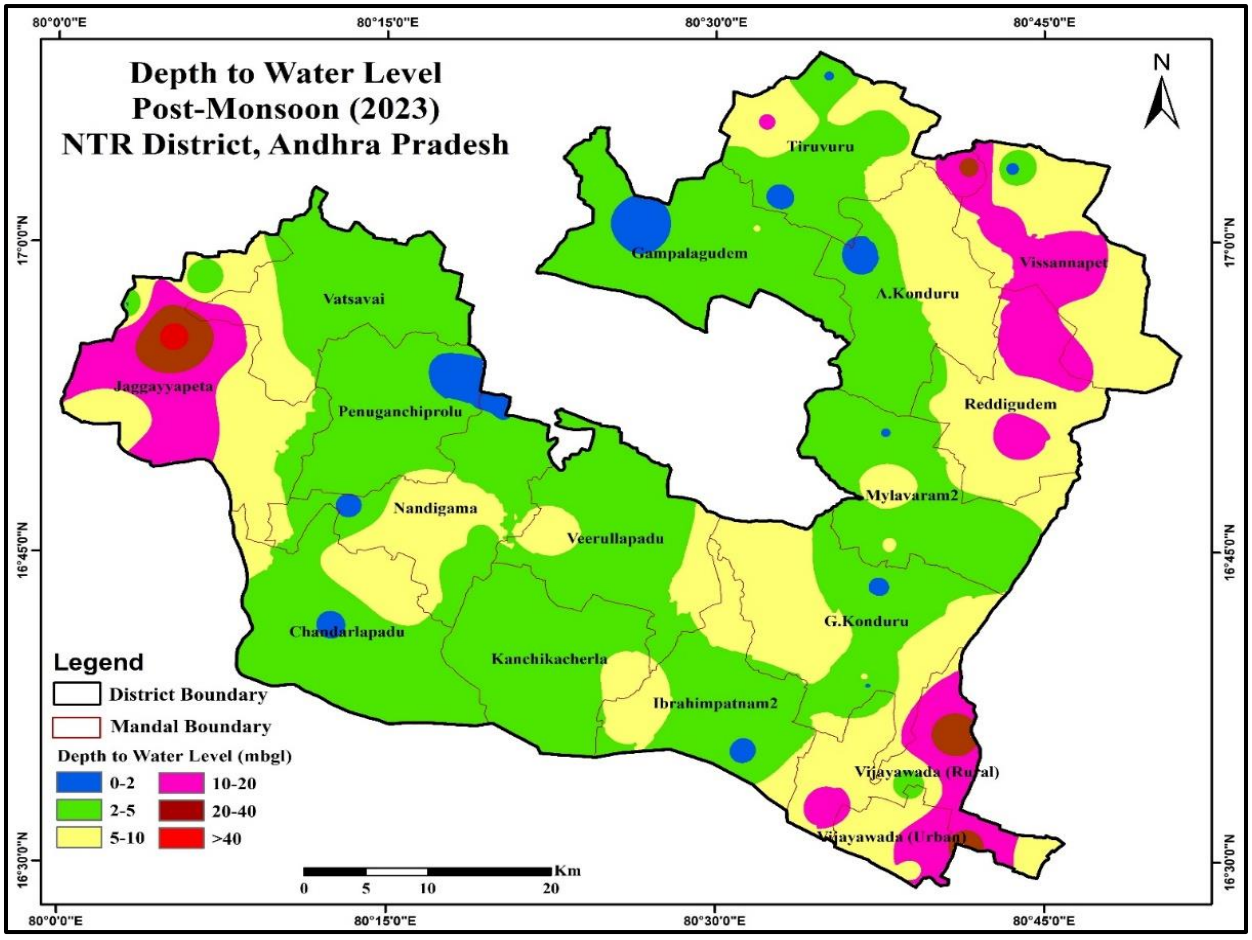


Fig 3.10 Depth to Ground Water Levels (Post monsoon 2023)

3.9.3 Water Level Fluctuations (May vs. November 2023)

Out of 101 wells, 73 wells records water level rise. The water level rise varies from <1 to 4.66 m in all the wells (Fig. 3.11). Rise in water level between 0 to 2 m is observed in 73% of the area, 2 to 4 m rise is observed in 7.8% of the area. Rise in water level > 4 m is observed in 3.4% of area.

Whereas the water level fall is recorded 28 wells (Fig 3.11). Fall in water level between 0 to 2 m is observed in 14.3% of the area, 2 to 4 m is observed in 1.1% of area and fall of more than 4 m is observed in 0.4% of the area.

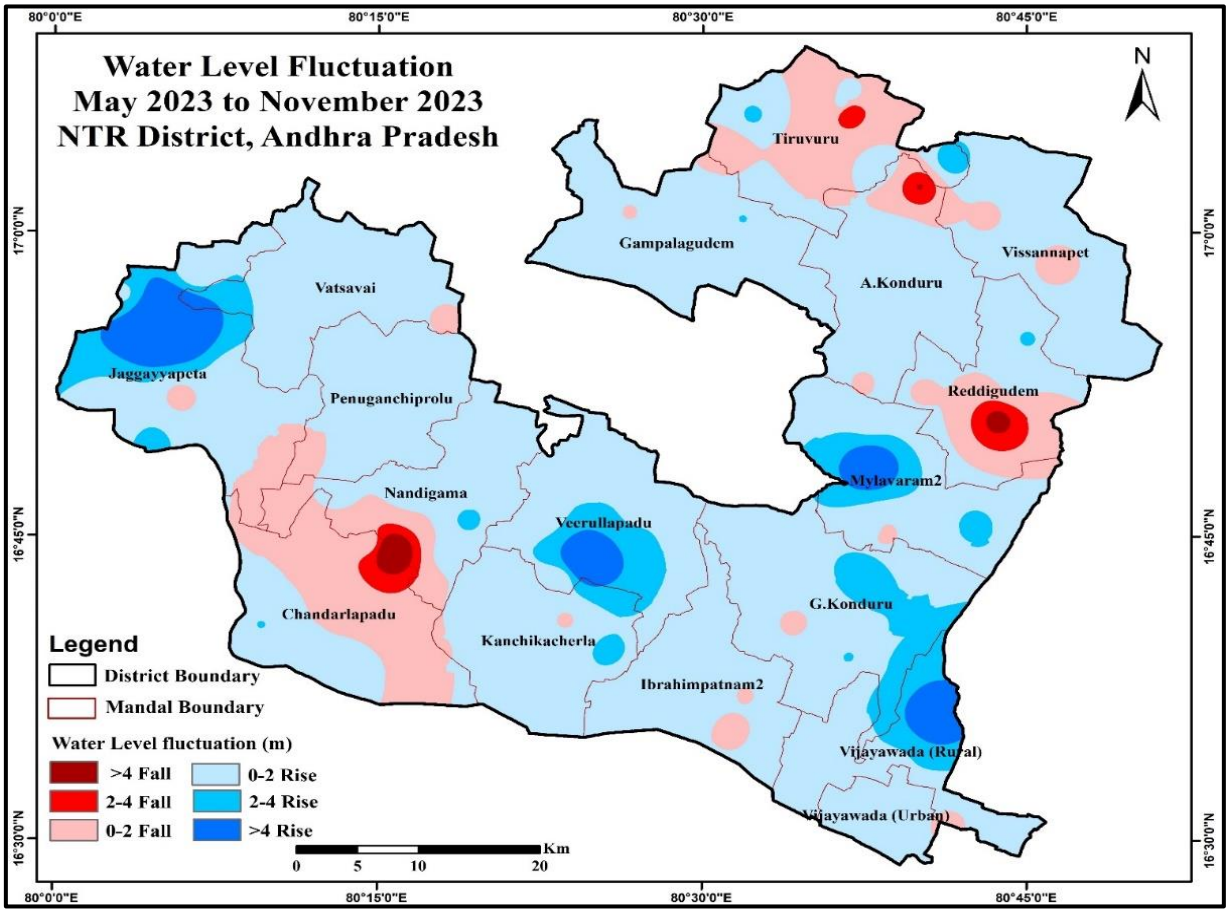


Fig 3.11 Water Level Fluctuations (May vs. November 2023)

3.9.4 Decadal Average Depth to water level map (Pre monsoon 2023)

In majority of the areas, decadal water level during Pre monsoon 2014-2022, in the range of 5 to 10 m in 32% of the area, followed by deeper water levels in range of 10 to 20 m, 10 to 20 m and >20m in 20 %, 21% and 3% of the area respectively and shallow water level ranges < 2 m in 1% and 2 to 5 m in 23% of the area. (Fig 3.13)

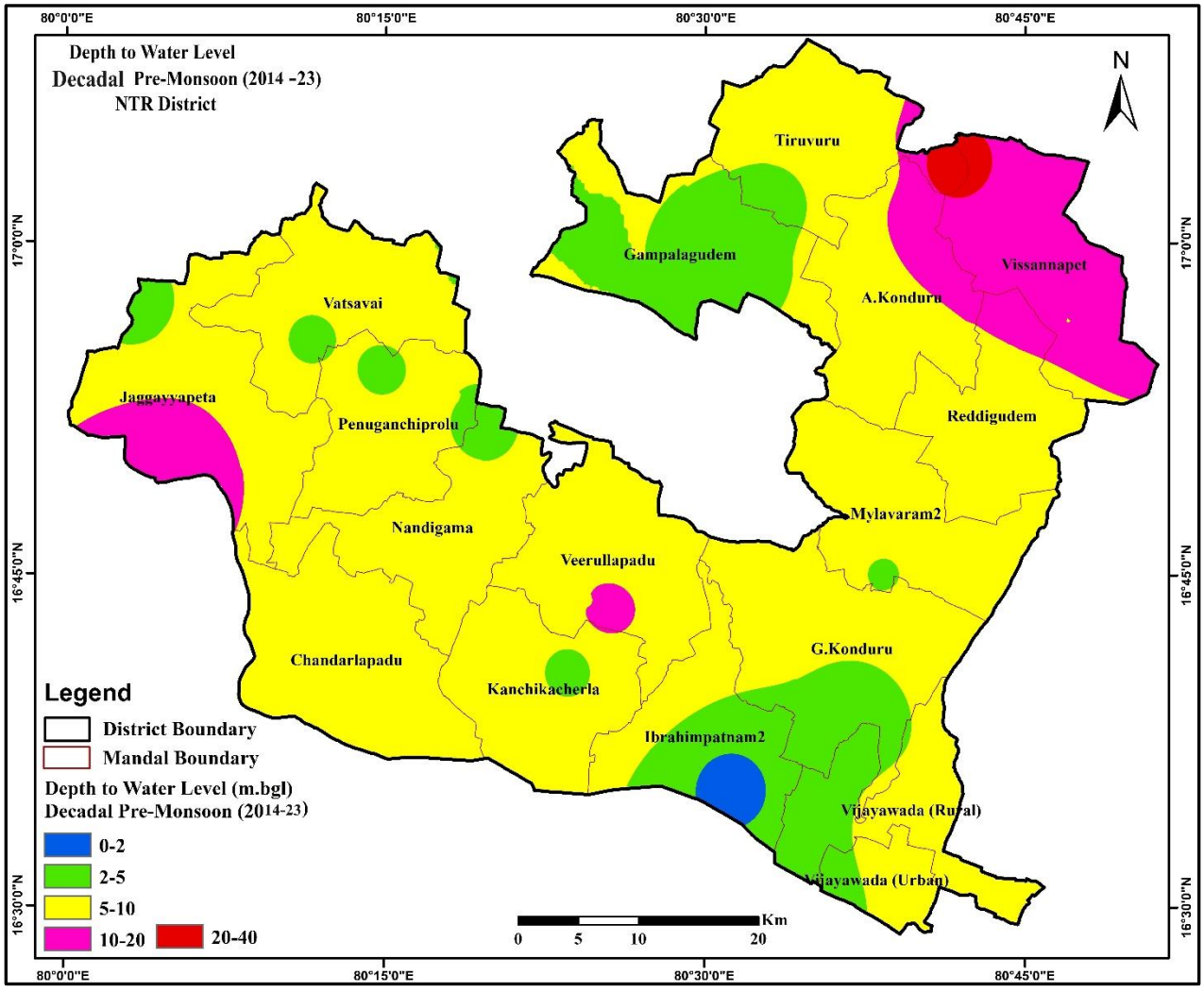


Fig 3.12 Decadal Average Depth to water level map (Pre monsoon 2014-2022)

3.9.5 Decadal Average Depth to water level map (Post monsoon 2023)

In majority of the areas, decadal water level during Post monsoon 2023, in the range of 2 to 5 m in 83% of the area and followed by deeper water levels in range of 5 to 10 m and >10 m in 14% and 1 % of the area respectively and the shallow water level ranges < 2 m in 2% of the area. (Fig 3.14)

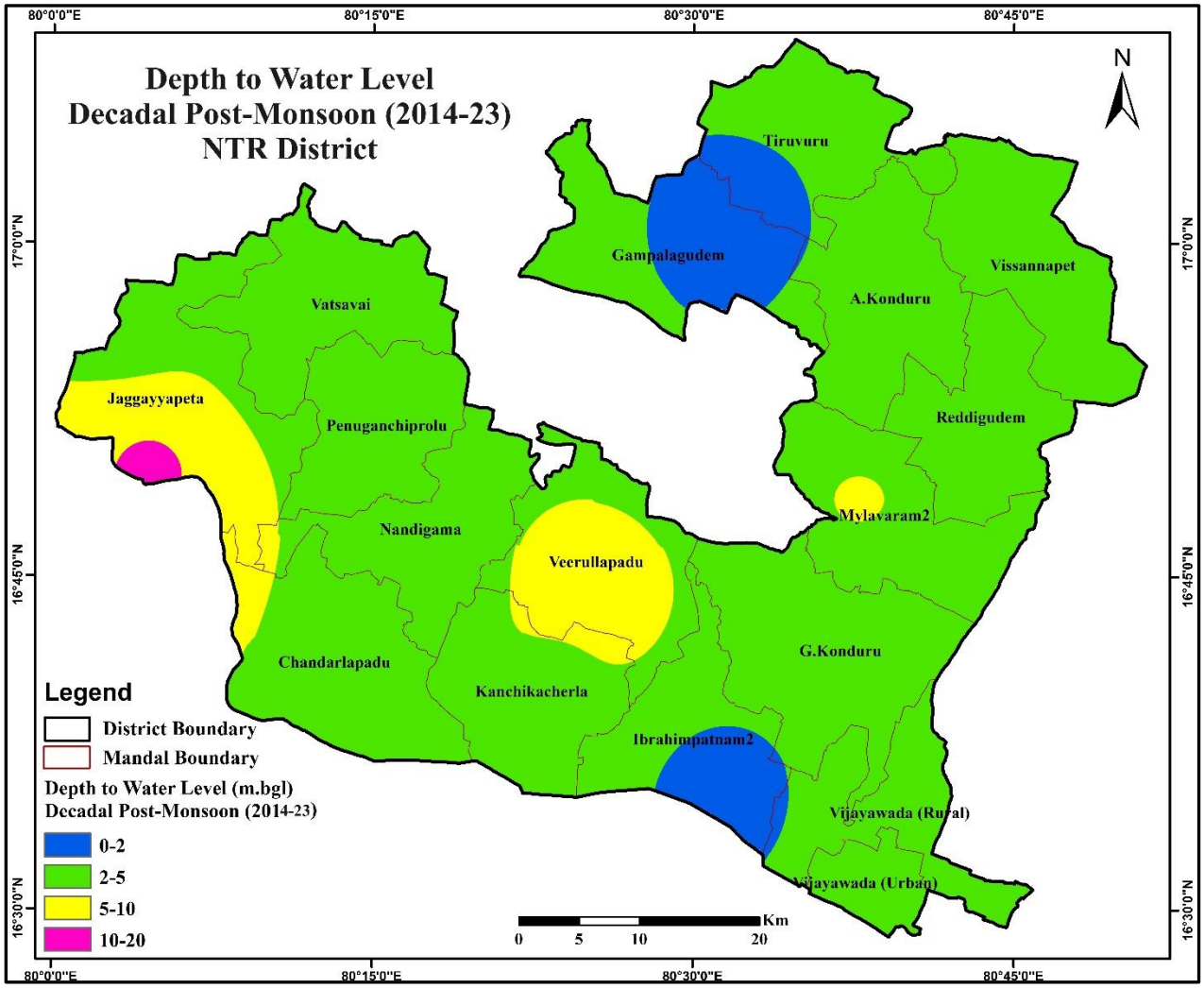


Fig 3.13 Decadal Average Depth to water level map (Post monsoon 2014-2023)

3.9.6 Decadal Water Level Fluctuations (May vs. November 2013-2023)

Out of 28 wells, 22 wells records water level rise. The water level rise varies from <1 to 8 m in all the wells (Fig 3.15). Rise in water level between 0 to 2 m is observed in 76% of the area, 2 to 4 m rise is observed in 20% of the area and >4m is observed in 2% of the area. Water level fall is recorded in 6 wells which ranges from 0 to 2 m which is distributed as patches towards central and north-eastern part of the district.

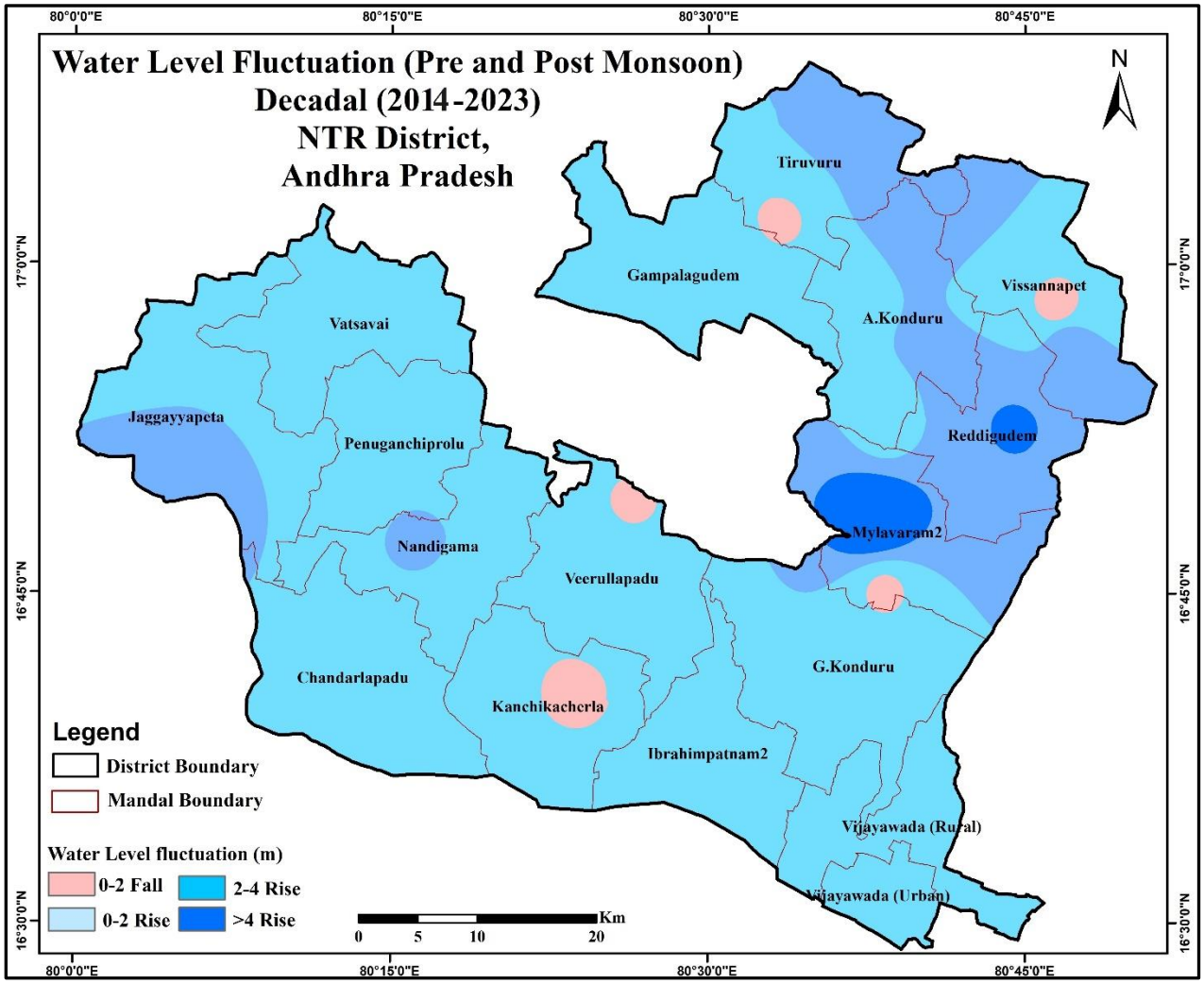


Fig 3.14 Decadal Water Level Fluctuations (May vs. November 2014-2023)

3.9.7 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,12 wells shows falling trend in the range of 0.01 m/yr to 0.34 m/yr in north-eastern parts of the district and 11 wells shows rising trend 0.001 m/yr to 0.28 m/yr. During post-monsoon season 12 wells show falling trend 0.003 to 0.74 m/yr and 15 wells shows rising trends 0.002-1.38 m/yr (Fig. 3.16).

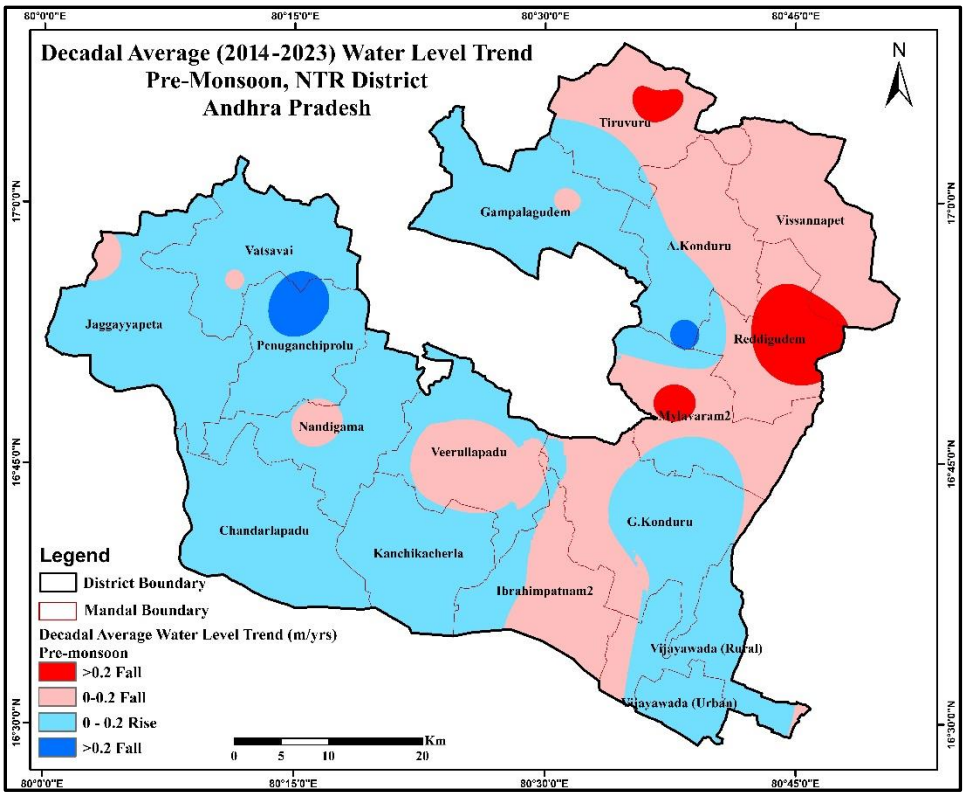


Fig 3.15 Pre-monsoon long term water level trends (10 yrs)

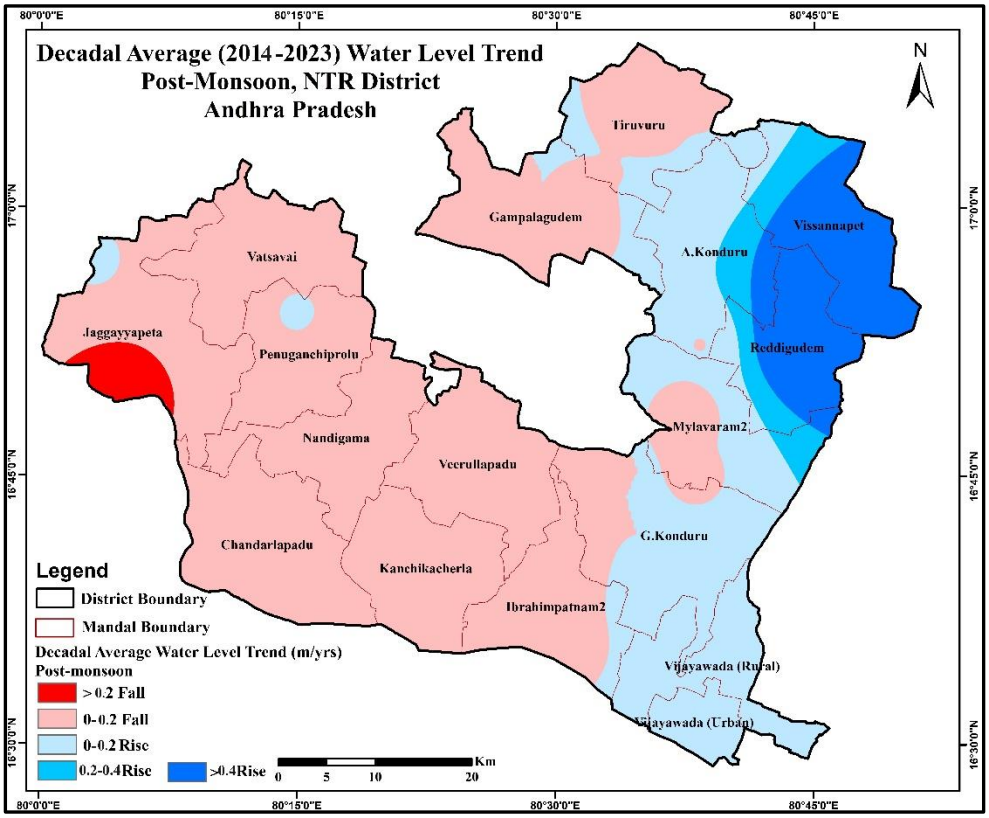


Fig 3.16 Post monsoon long term water level trend (10 yrs)

3.9.8 Water Table Elevation: During pre-monsoon, water-table elevation ranges from 18.97-123.80 meter above mean sea level and in post-monsoon season it is 21.23-130.08 meter above mean sea level (m amsl). The ground water flow direction also has the same as drainage flow direction towards north to south and east to west. (Fig.3.17).

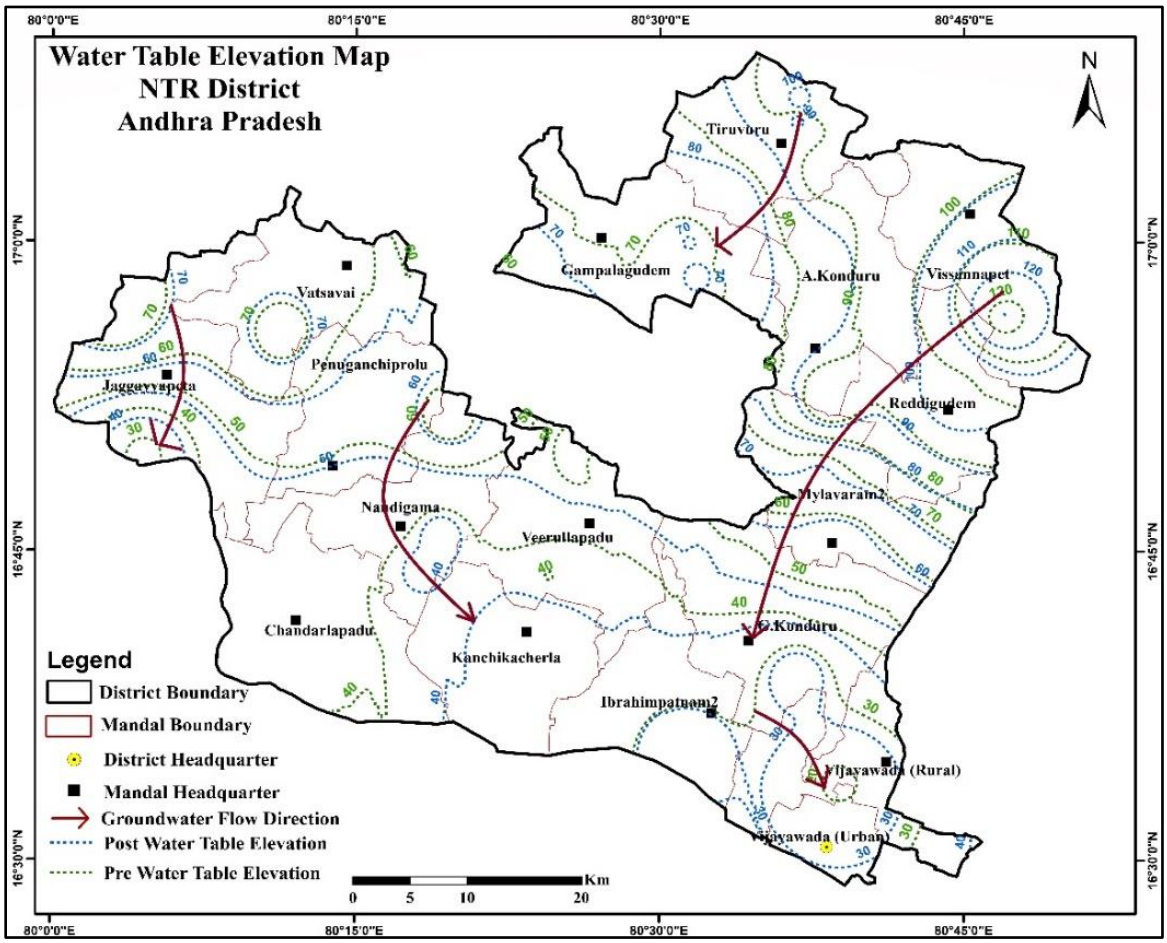


Fig 3.17 Water Table Elevation

3.10 Ground Water Quality

To understand chemical nature of groundwater, total 21 data points is utilized from ground water monitoring wells, exploratory wells and well inventory. The samples were collected during pre-monsoon 2022 and analyzed.

The groundwater quality in the area is generally good. In all the locations, pH is within the acceptable limit and shows mildly alkaline nature. Pre-monsoon: Groundwater is mildly alkaline with pH in the range of 6.98-8.53 (avg: 7.93). Electrical conductivity varies from 390-5370 (avg:2019) µ Siemens/cm. In 62 % of area, EC is within 2000 µSiemens/cm, in 34 % area, it is between 2000-3000 µSiemens/cm and in 4% of area it is beyond permissible limit (>3000 µSiemens/cm). (Fig.3.18 and Fig.3.19). Average concentration of TDS is 1165 mg/L and NO3- ranges from 0.4-307.7 mg/L. Nitrate concentration in 43% of samples is beyond

permissible limits of 45 mg/L. Fluoride concentration varies from 0.18-2.76 **(Fig. 3.20)**with 19% of samples is beyond the permissible limits of BIS and rest is within the permissible limit. The point wise source distribution of Nitrate and Fluoride is given in Fig. 3.21 and Fig. 3.22.

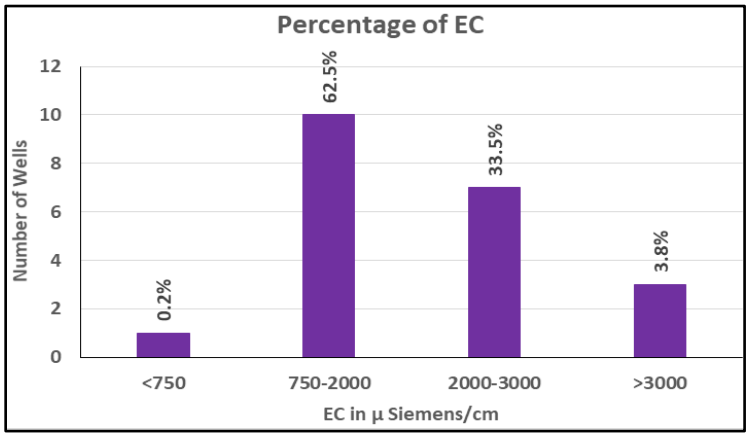


Fig 3.18, Percentage of area EC

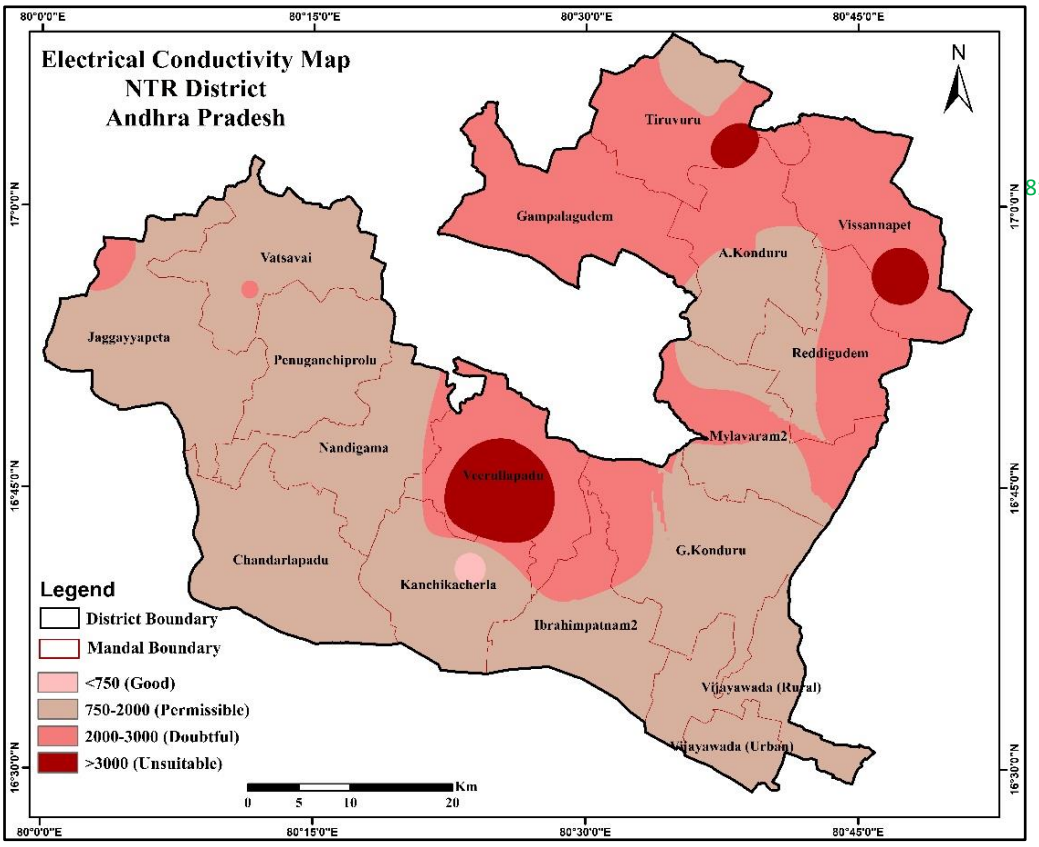


Fig. 3.20 Pre monsoon EC distribution

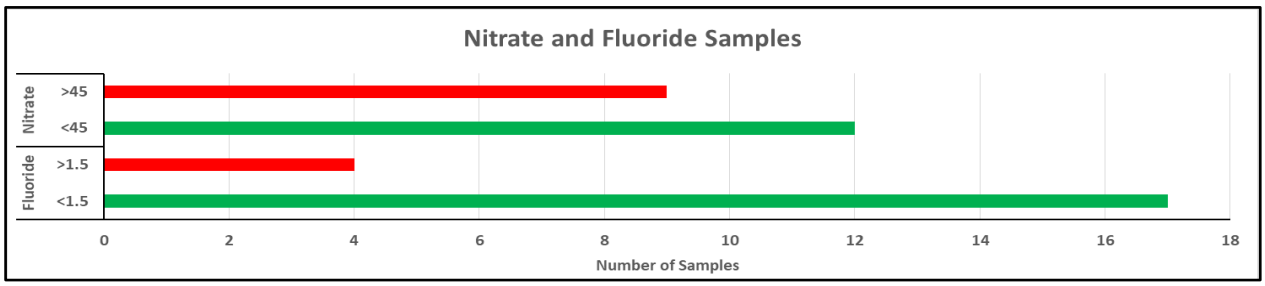


Fig 3..19 Nitrate and Fluoride Samples

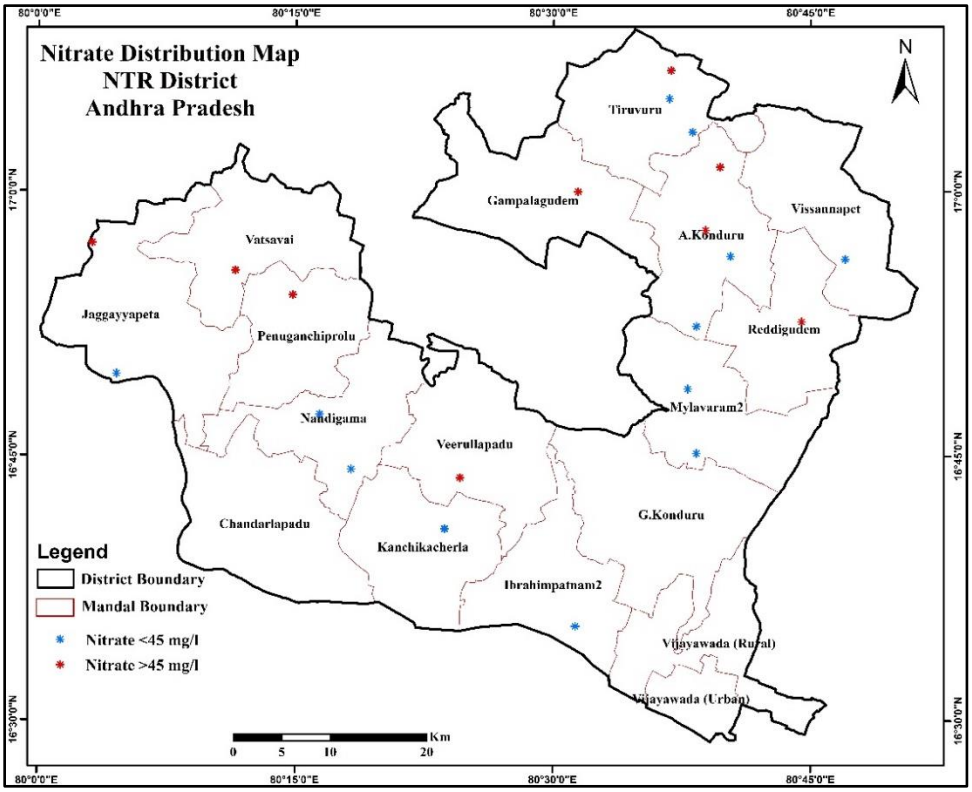


Fig 3.21, Pre monsoon Nitrate distribution

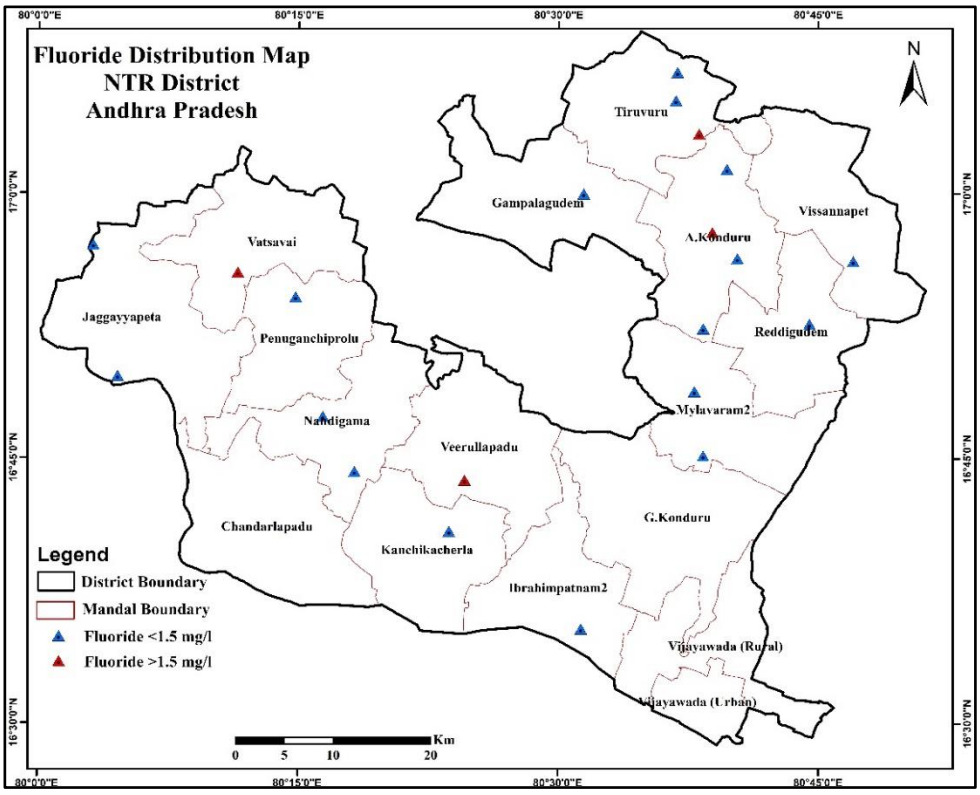


Fig 3.22, Pre monsoon Fluoride distribution

4. Ground Water Resources (2022)

In hard rock areas, for practical purpose it is very tough to compute zone wise (aquifer wise) groundwater resources, because of the weathered zone and fractured zone 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. The mandal wise Dynamic Ground Water Resources as on 2022 of the NTR District is given in **Annexure 1.** The summarized dynamic ground water resources of the NTR District, Andhra Pradesh (2022) given in **Table-4.1**

Table 4.1 Summarized Dynamic Ground Water Resources of the NTR District

Parameters	**Total (MCM)**
Dynamic (Net GWR Availability)	**859.94**
• Monsoon recharge from rainfall	199.61
• Monsoon recharge from other sources	388.18
• Non-monsoon recharge from rainfall	12.15
• Non-monsoon recharge from other sources	305.26
• Total Natural Discharge	45.26
Gross GW Draft	**187.51**
✓ Irrigation	158.14
✓ Domestic and Industrial use	29.37
Allocation of Ground Water Resource for Domestic Utilisation for projected year 2025	18.2
Net GW availability for future use	673.67
Stage of GW development (%)	**23.10**

4.1 Ground Water Recharge: The annual ground water recharge varies from 94.26 MCM (Reddigudem Mandal) to 19.15 MCM (Kanchikacherla Mandal). The gross annual ground water recharge in the district is 905.22 MCM. The net available recharge after leaving natural discharge from monsoon period varies from 89.54 MCM (Reddigudem Mandal) to 18.19 MCM (Kanchikacherla Mandal). The net available recharge in the district is 859.94 MCM**. (Fig 4.1)**

4.2 Ground Water Draft: The ground water draft from irrigation and Domestic /Industrial sources is presented in **Table:4.1.** The Existing Gross Ground Water Draft for all uses varies from 20.29 MCM (Vijayawada Rural Mandal) to 3.49 MCM (Vissannapet Mandal). The Gross Ground Water Draft for All uses in the district is 187.51 MCM. **(Fig 4.2)**

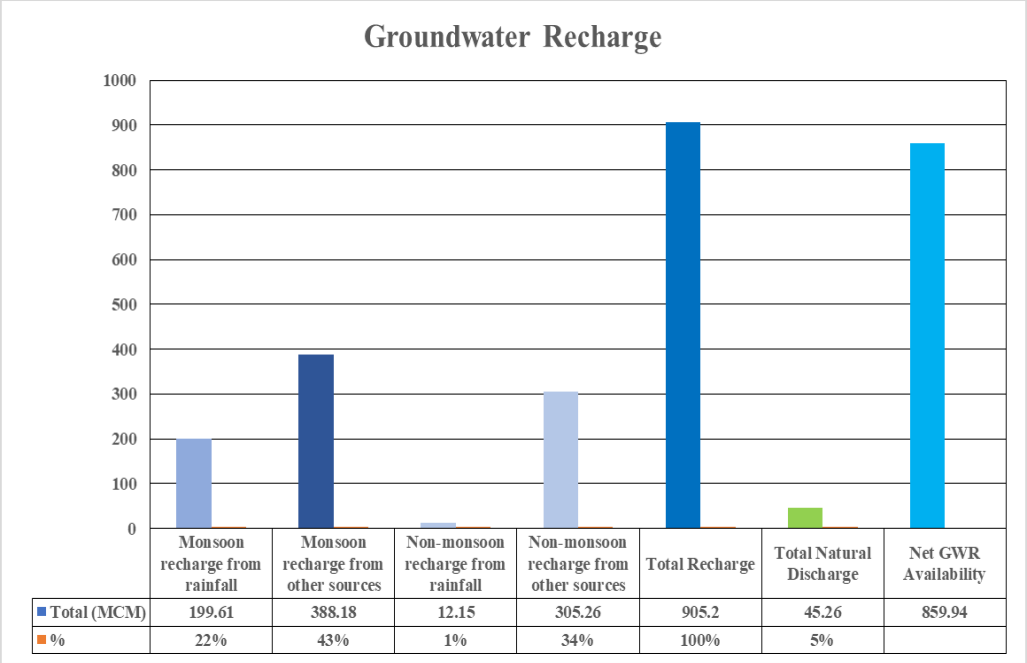


Fig 4.1 Ground Water Recharge

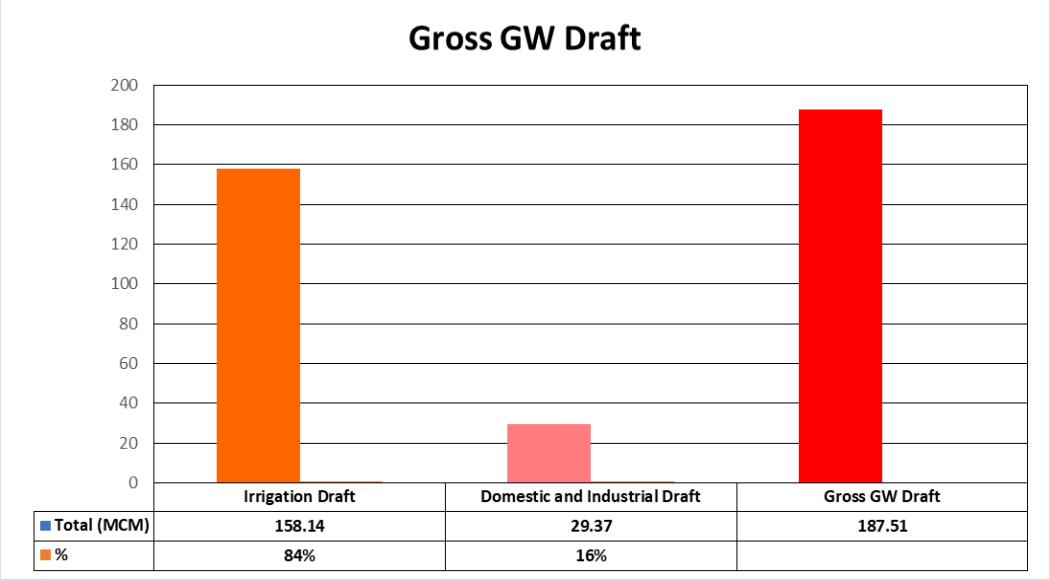


Fig 4.2 Ground Water Draft

4.3 Stage of Ground Water Extraction:

The stage of ground water extraction in NTR district varies from 54.10 % to 7.33 % and all assessment (mandals) units have been categorized as Safe **(Fig 4.3) as per Ground Water Resources Assessment – 2022.** The overall stage of groundwater development of NTR districtis **23.10 %.** The Mandal wise ground water resources and categorization for each assessment unitis presented in table **Annexure 1.**

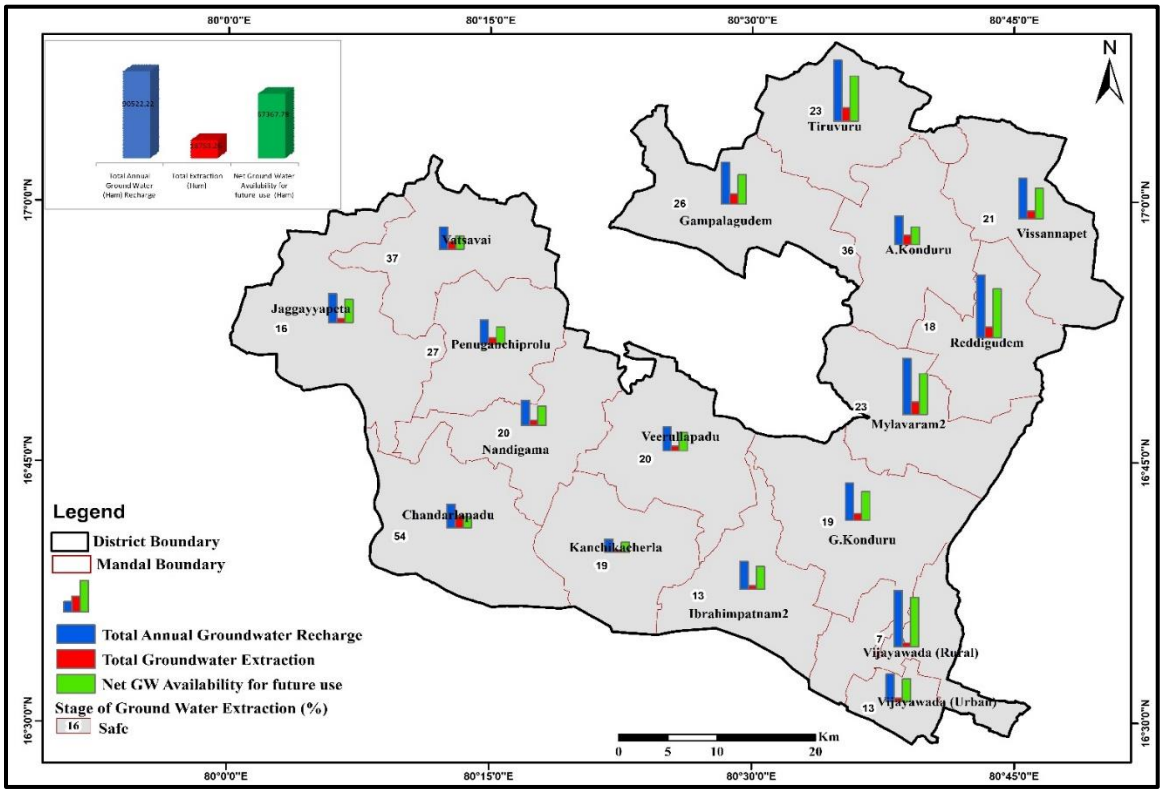


Fig 4.3 Dynamic Ground Water resources -2022

5. Ground Water Related Issues and Reasons

5.1 Deep Water Levels & Declining Trends

- In the north and north western parts of the study area of NTR district comprises Jaggyapet, Vissanapet, Veerullapadu , Tiruvuru and A. Konduru Mandals and the average decadal water level is more than 10m in 11% of the area in pre-monsoon and more than 15% of the area in post-monsoon
- The stage of ground water extraction in the study area is 23%, except Chandralapadu mandal which have SOGWE > 50%, where vulnerability of groundwater resource in future is identified.

5.2 Ground Water Sustainability

Low yield (<2 lps) occurs in 288.8 Sq.km (~9%) is found in many places as the study area is mainly comprises hard rocks such as Charnockites, Khondalites and granite gneiss as per ground water exploration data. The main aquifers being hard rock the yield depends on the thickness of aquifers

5.3 Ground Water Quality (Geogenic & Anthropogenic)

- Higher concentration of Nitrate is observed in 43% of samples. This 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.
- EC is >2000 µ Siemens/cm covering around 1326 sq.kms (40%) observed in parts of encountered in Gampalagudem, Vissannapet , Tiruvuru and Veerullapadu Mandals.
- Higher concentration of Fluoride (>1.5 mg/l) is observed in 4 samples out of 21 samples in localized pockets of throughout the district.

6. Management Strategies

The uneven distribution of groundwater availability and its utilization indicates that a single management strategy cannot be adopted and requires integrated hydrogeological aspects along with socio-economic conditions to develop appropriate management strategy. The study suggests notable measures for sustainable groundwater management.

Management plan

The management plan comprises of two components namely supply-side management and demandside management. The supply side management is proposed, based on surplus surface water availability and the unsaturated thickness of aquifer whereas the demand side management is proposed by use of micro irrigation techniques.

6.1 Supply side management

The supply side management of ground water resources include artificial recharge of available surplus runoff in check dams and percolation tanks. More over repair renovation & restoration of existing tanks will also help in ground water recharge.
The unsaturated volume of the aquifers is estimated based on the average post-monsoon depth to water level (2013-2022) and specific yield. The number of new structures recommended based on the unsaturated volume and existing artificial recharge structures constructed.

Government of Andhra Pradesh had already created a total 586 recharge structure (578 Check dams and 8 percolations tanks: source: (https://emms.ap.gov.in/nregs_ap/Reports/) though MGNREGS and IWMP scheme **(Fig 6.1)**. Mandal wise Existing Artificial Recharge Structures in the study area is given in Table 6.1

Table 6.1 Mandal wise Existing Artificial Recharge Structures in the study Area

Sr No	Mandal	Check Dam	PTs
1	A Konduru	82	2
2	Chandarlapadu	49	1
3	G Konduru	18	0
4	Gampalagudem	64	0
5	Ibrahimpatnam	8	0
6	Jaggayyapeta	54	0
7	Kanchika Cherla	17	0
8	Mylavaram	41	0
9	Nandigama	34	0
10	Penuganchiprolu	23	0
11	Reddigudem	41	3
12	Tiruvuru	21	0
13	Vatsavai	27	0

14	Veerullapadu	55	0
15	Vijayawada Rural	5	0
16	Vijayawada Urban	1	0
17	Vissannapet	38	2
	Total	**578**	**8**

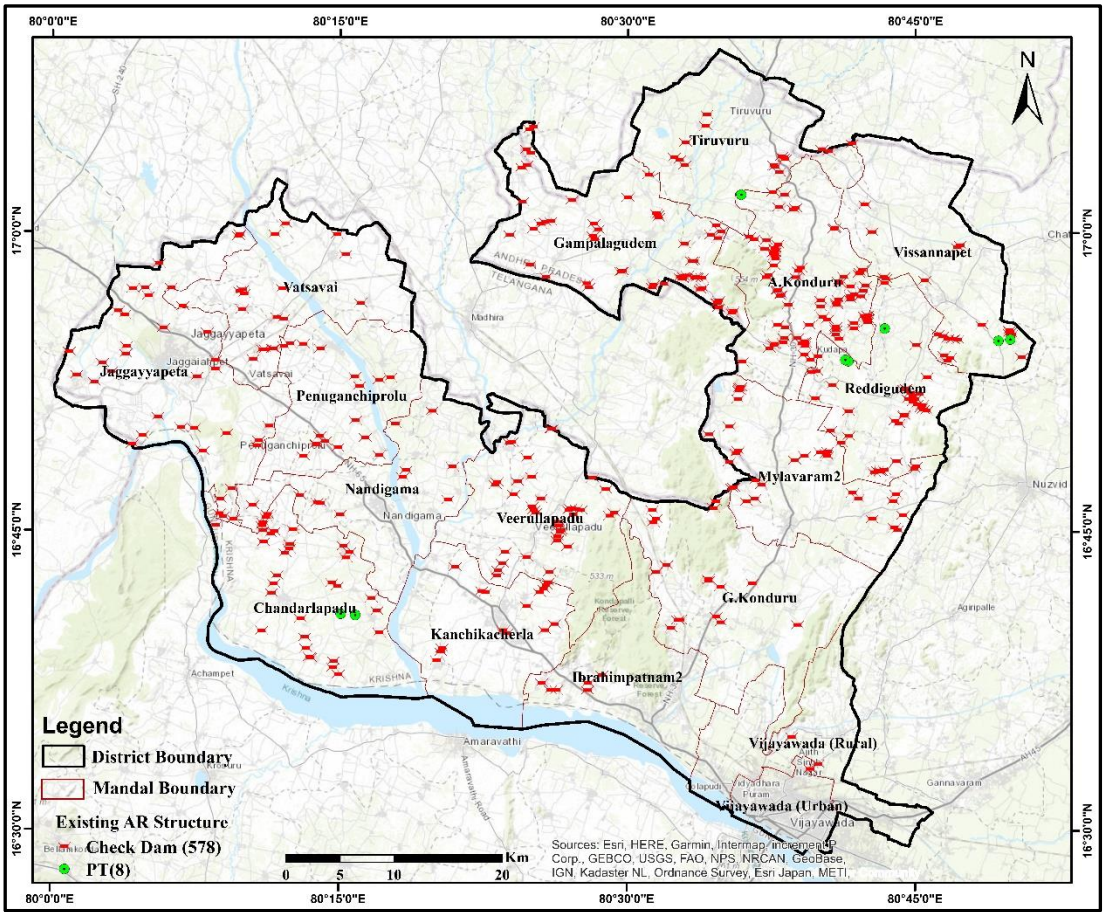


Fig 6.1 Existing Artificial Recharge Structures in the study Area

Considering the stage of Ground water extraction, it is recommended that instead of planning for new artificial recharge structure for the entire study area, it is more viable to propose structures only in areas having SOGWE >50% to regulate further increase in stage of groundwater extraction, where vulnerability of groundwater resource in future is identified and also to consider the desilting and maintenance of existing CD's and PT's.

The availability of sub-surface storage volume of aquifers in each district is computed as the product of area, thickness of aquifer zone between 5 mbgl and the average post-monsoon water level. The recharge potential/sub surface space of the aquifers is calculated by multiplying the sub surface storage volume with 2% specific yield.

- The source water availability is estimated from the rain fall and run off correlations. The runoff was calculated by taking into account of 30 years 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, 20 % run off yield is considered as un-committed yield and for recommending artificial recharge structures in intermittent areas.

- The storage required for existing AR structures by State Govt. departments under IWMP and MNREGS schemes is deducted to find the available surplus run off for recommending the additional feasible AR structures. The recharge and runoff available in the district are given in **Table 6.2** and **Fig 6.2**

Table 6.2: Recharge and Runoff available in the district

Area feasible for recharge (Sq.km)	3315
Unsaturated Volume (MCM)	2217
Recharge Potential (MCM)	44.33
Runoff available (MCM)	15.3
Surplus runoff available for recharge (MCM)(20% of runoff)	3.06

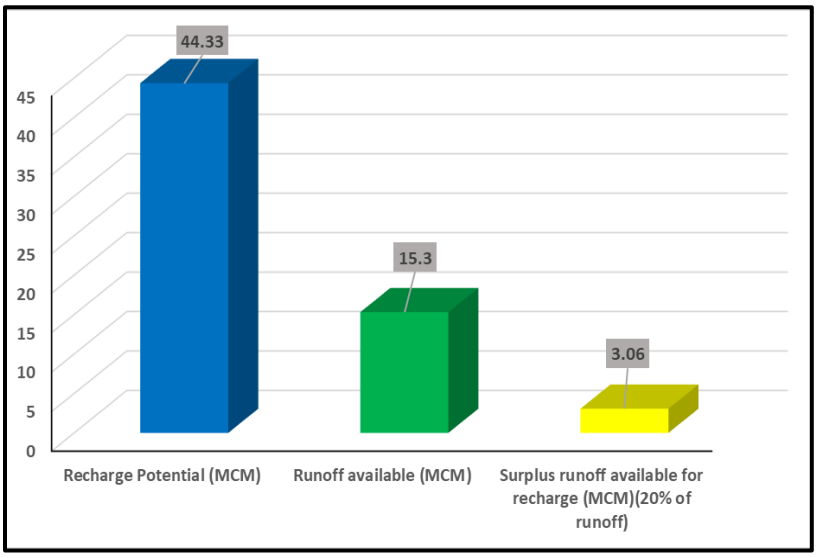


Fig 6.2: The recharge and runoff available in the district

6.2 Roof top and open space rain water harvesting for artificial Recharge in Vijayawada Mandal

Government of Andhra Pradesh is supplying surface water from Krishna River through Prakasam Barrage to Vijayawada city, which will reduce the dependency on ground water. Moreover, the city is having a stage of ground water of 13% only (Vijaywada Urban). Therefore, for maintaining this ground water scenario as the population density is high is to construct, rooftop Rain water Harvesting structure for building with above 200 sq.m as per APWALTA.

6.3 Other supply side measures:

Existing ARS like percolation tanks and check dams and dried dug wells can be de-silted involving people's participation through the Mahatma Gandhi National Rural Employment Guarantee Scheme(MGNREGS). This will also help in sustainable management of groundwater resources.

6.4 Water Conservation Measures (WCM) (Farm Ponds)

The farm ponds are the ideal water conservation structures, which are constructed in the low-lying areas of the farm. The size of farm ponds is 10 x 10 x 3 m. In the district total 443 farm ponds exist and these existing farm ponds can be desilted and maintained so that it will greatly help in ground water augmentation.

6.5 Conjunctive use of surface and ground water

Conjunctive use of surface and groundwater is a strategy that combines the use of both water sources to improve water supply, distribution, and quality, and to reduce the negative effects of each source. The goal is to balance water demand and supply, and to increase the resilience of water supply systems. Conjunctive use can be especially helpful in communities and basins where water availability varies throughout the year.

6.6 Demand side management

- The yield of bore well is <2.0 lps is identified in 288.8 sq.km (9%) of the district. As sustainability of bore well is low, the sprinkler and drip irrigation system with suitable cropping pattern is recommended in those areas where recharge potential is more than the total run off and surplus run off availability.
- In NTR District there are 443 minor irrigation tanks having a registered ayacut of 26958 hectares and actual irrigated area is 17633 hectares. Considering low sustainability of bore wells in the district and limited no. of existing MI tanks, it is recommended for de siltation and cascading of existing MI tanks and filling up MI tanks with surface water schemes. This can result in increase in Ayacut/Irrigation area and sustain the bore well yields and decrease the ground water usage for irrigation.
- A participatory groundwater management (PGWM) approach in sharing of groundwater 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 groundwater may be given to the concerned farmers.
- In urban and rural area, the sewerage line should be constructed to arrest leaching of nitrate.

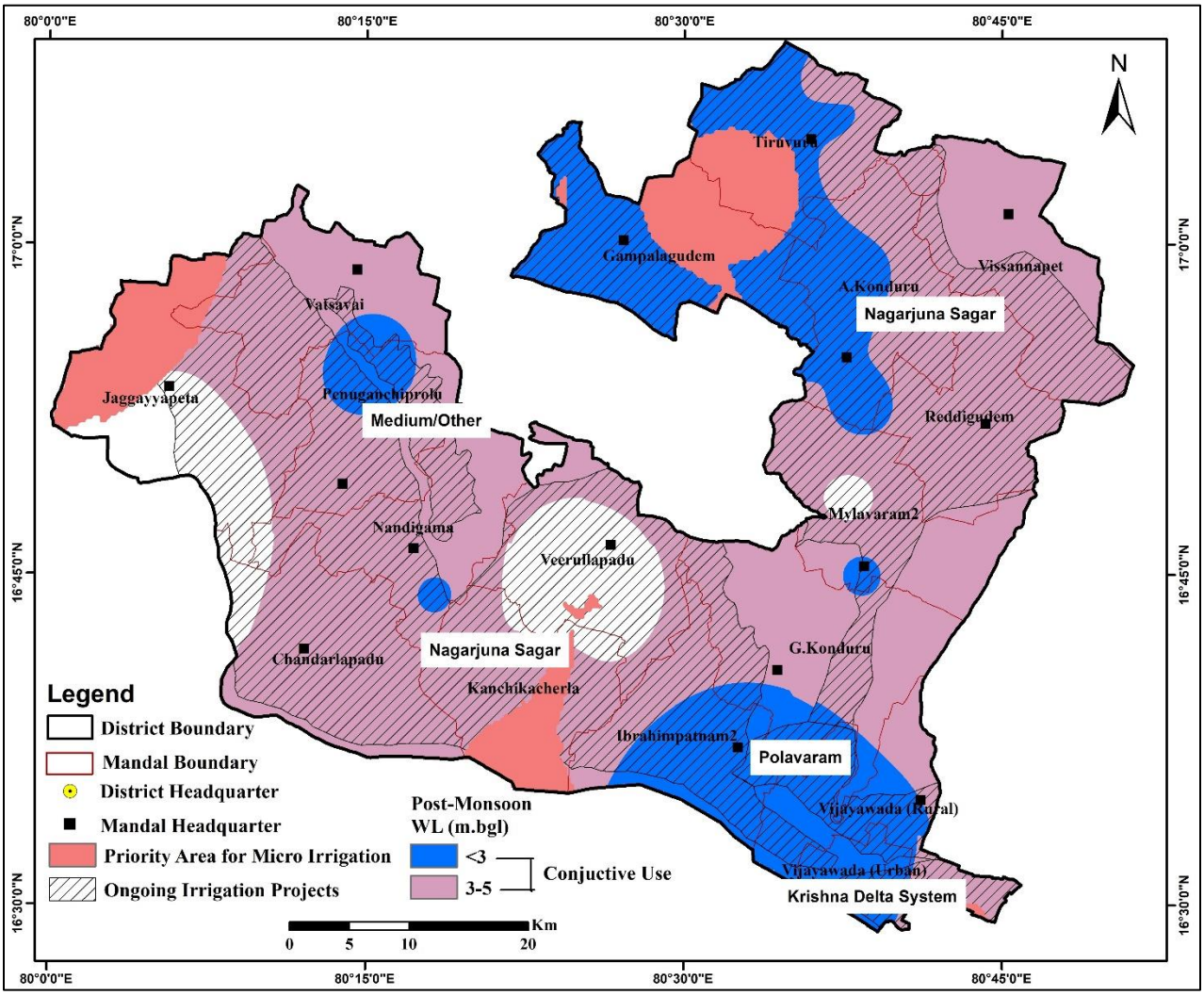


Fig 6.2: Proposed Management Plan

7.Acknowledgment

The author is thankful to Shri. G. Krishnamuthy, Regional Director, CGWB, Hyderabad and Shri Ravi Kumar Gumma, Scientist- 'D' & OIC, CGWB, APSUO, Visakhapatnam for their encouragement, guidance and support. The author is very much delighted to express deep sense of gratitude and support to my colleagues towards Smt Reshma S. Pillai Scientist- 'C', Shri.Bijay Ketan Mohanta Scientist- 'C', Shri. Md. Sarif Khan, Scientist- 'C'and Shri. L.N. Damodara Scientist- 'C' for their valuable help and suggestion during preparation of management plans . The author acknowledges State Ground Water Department, Govt. of Andhra Pradesh for making available of field data.

References:

1. Chief Planning Officer (CPO) (2020) Handbook of Statistics, Krishna district,Government of Andhra Pradesh. Published by Chief Planning Officer, Krishna district.
2. District Survey Report (2021), Krishna district, Department of Mines and Geology, Government of Andhra Pradesh.
3. District Irrigation Plan Krishna District, Water Resources Department, Government of Andhra Pradesh.
4. Dynamic Ground Water Resources of SPSR NTR District (2022), Water Resources Department, Government of Andhra Pradesh.
5. Exploration Report of Andhra Pradesh (2018), Prepared by Sh. G. Bhaskara Rao, Scientist-D, CGWB.
6. Report on Aquifer Mapping for Sustainable Management of Ground Water Resources in Hard rock areas of various districts of Andhra Pradesh, CGWB, Govt. of India. (http://cgwb.gov.in/AQM/AP%20Reportdistrict%20.html)
7. BIS (2012) Drinking water-specification IS: 10500; 1991. Bureau of Indian Standards, New Delhi.
8. Karanth, K.R. (1987) Ground water assessment, development and management. Tata McGraw-Hill Pub. Co. Ltd., New Delhi, 720p.

Annexure-1

Annexure-3 Mandal Wise Ground Water Resources, Availability, Utilization and Stage of Ground Water Development of NTR District (2022)																			
Sr No	Assessment Unit Name	Total area of assessment unit (Ha)	Recharge worthy area (Ha)	Recharge from Rainfall-MON	Recharge from Other Sources-MON	Recharge from Rainfall-NM	Recharge from Other Sources-NM	Total Annual Ground Water (Ha.m) Recharge	Total Natural Discharges (Ha.m)	Annual Extractable Ground Water Resource (Ham)	Irrigation Use (Ham)	Industrial Use (Ham)	Domestic Use (Ham)	Total Extraction (Ham)	Annual GW Allocation for Domestic Use as on 2025 (Ham)	Net Ground Water Availability for future use (Ham)	Stage of Ground Water Extraction (%)	Categorization
1	Reddigudem	19202	18582	959	5059	140	3267	9426	471	8954	1541	21	50	1612	52	7340	18	safe
2	Nandigama	18930	18832	1128	1734	49	857	3770	188	3581	553	52	114	720	119	2856	20	safe
3	Mylavaram (Krishna)	21479	21111	1323	1809	142	5138	8413	421	7992	1669	125	75	1869	78	6120	23	safe
4	Vatsavai	18800	18800	1051	1511	27	754	3344	167	3176	1041	46	76	1163	80	2010	37	safe
5	Vissannapet	20257	19778	1244	2711	91	2036	6082	304	5778	1048	84	70	1202	73	4572	21	safe
6	Kanchika Cherla	16248	15976	882	653	47	332	1915	96	1819	222	48	79	349	83	1467	19	safe
7	Chandarlapadu	22301	22129	1225	1445	81	792	3543	177	3366	1670	53	99	1821	103	1634	54	safe
8	Ibrahimpatnam	11699	10404	1740	1176	139	1144	4199	210	3989	347	84	108	538	113	3446	13	safe
9	Vijayawada Rural	15682	14413	1388	4067	153	2868	8475	424	8052	314	164	113	591	118	7456	7	safe
10	Tiruvuru	18432	18432	1219	4274	21	3747	9261	463	8798	1848	107	74	2029	78	6827	23	safe
11	G Konduru	21600	20252	1304	2718	89	1524	5635	282	5353	834	118	64	1017	67	4334	19	safe
12	Veerullapadu	21049	18715	1317	1685	58	537	3597	180	3417	620	13	59	692	62	2722	20	safe
13	Penuganchiprolu	16325	16325	898	1760	44	938	3639	182	3457	816	59	49	924	51	2531	27	safe
14	A Konduru	20962	18937	1236	1719	15	1409	4378	219	4160	1422	3	52	1477	54	2680	36	safe
15	Gampalagudem	21595	20988	1317	2679	47	2274	6317	316	6001	1403	79	79	1561	82	4437	26	safe
16	Jaggayyapeta	26295	25781	1369	1190	16	1809	4384	219	4164	460	76	141	677	148	3531	16	safe
17	Vijayawada Urban	7268	6869	360	2627	58	1100	4145	207	3938	7	4	499	510	521	3406	13	safe
	Total	**318124**	**306324**	**19962**	**38819**	**1216**	**30526**	**90522**	**4526**	**85996**	**15815**	**1138**	**1801**	**18753**	**1882**	**67368**	**23**	**safe**