केंद्रीय भूमि जल 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

AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES

BHADRADRI KOTHAGUDEM DISTRICT, TELANGANA

दक्षिणी क्षेत्र, हैदराबाद

Southern Region, Hyderabad

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GOVERNMENT OF INDIA
MINISTRY OF WATER RESOURCES, RIVER DEVELOPMENT AND
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REPORT ON
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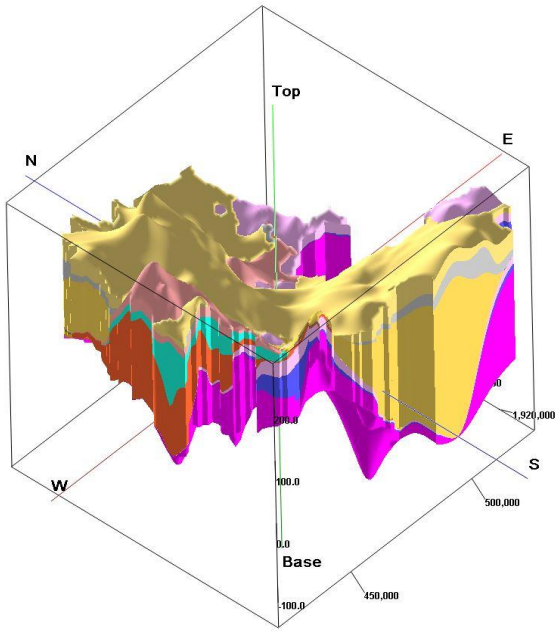

CENTRAL GROUND WATER BOARD
SOUTHERN REGION
HYDERABAD
NOVEMBER 2021

REPORT ON
AQUIFER MAPPING FOR SUSTAINABLE MANAGEMENT OF GROUND WATER RESOURCES IN BHADRADRI KOTHAGUDEM DISTRICT, TELANGANA STATE

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AQUIFER MAPPING FOR SUSTAINABLE MANAGEMENT OF GROUND WATER RESOURCES IN BHADRADRI KOTHAGUDEM DISTRICT TELANGANA STATE

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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	:	Hector
Ha.m	:	Hector 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 Bhadradri Kothagudem district has a geographical area of 7,025 km2, with 23 revenue mandals lies between north latitude 17°11′-18°14′and east longitude 80°12′-81°20'. Administratively the district is governed by two revenue divisions, 377 villages having a population of 10.69 lakhs (2011 census, population density of 152).

The district consists of rock formation from Archaean to Cretaceous age, with some isolated pockets of recent to sub-recent alluvium. About 57% of the area is underlain by Sandstones, 30% area by granite and gneisses occupies and 13% of the area by metasedimentary formations. Pediplains are the major landforms followed by pediment, and structural hills. The district is drained mainly by Godavari and its tributaries. The gross cropped area during 2019-20 is 179288ha. Forest occupies nearly 62% of the area; agricultural land occupies nearly 22% of the area. Remaining area is occupied by water bodies, waste land, built up etc. The area is mainly occupied by fine soil (40%), fine loamy soil (19 %), loamy soil (18%), and loamy skeletal (12%)

The registered ayacut under the medium irrigation Peddavagu project is 2360 acres and Taliperu project is 24700 acres. In the district, there are ~3310 minor irrigation tanks, ~602 PT's and 284 CD's and nearly 9.16 MCM of silt was removed under Mission Kakatiya.

Water level is monitored through 86 wells during pre and post-monsoon season. Water table elevation varies from 47 to 341 m amsl during pre-monsoon season and 52-346 amsl during post-monsoon season. During pre-monsoon, depth to water level varies from 0.85 to 41.4 m bgl. In most of the parts, the water level is in the range of 5 to 10m bgl (69% area). During post-monsoon, depth to water level varies from 0.01-33.15 m bgl. In most of the parts, water level is in the range of 2-5 m bgl (64% area).

All the wells in the state records water level rise during post monsoon season. The seasonal water level fluctuations vary from 0.20 to 16.30 m rise. Trend analysis for the last 10 years (2010-2019) is studied from 30 hydrograph stations of CGWB and SGWD. There is no significant change in water level trend in the district. It is observed that

during pre-monsoon and post monsoon water level trend ranges from -0.02 m/yr to 0.2 m/yr.

Total 194 ground water samples (Pre-monsoon:102 and Post-monsoon:92) were analysed for knowing the suitability of ground water for drinking purposes. In 96 % and 83 % of area EC is in the range of < 1500 µ Siemens/cm during pre and post-monsoon season respectively. During pre-monsoon season, concentration of NO_3 ranges from 0.22-468 mg/L and found that in 36 % samples nitrate is beyond maximum permissible limit of BIS (45 mg/l) and F concentration varies from 0.05-4.09 mg/l and found that in 15% samples it is beyond maximum permissible limits of BIS (1.5 mg/l). During post-monsoon season, concentration of NO_3 ranges from **<1-417** mg/L and found that in 35% of samples it is beyond maximum permissible limit of BIS (45 mg/l). The F concentration varies from **0.03-5.76** mg/l and found that in 8% it is beyond maximum permissible limit of BIS.

On the basis of occurrence and movement of ground water, mainly rock units of the Kothagudem is classified into two categories; hard rocks (Archean crystalline and metasedimentary) formation which occupies 43% of the area and soft rock formation (semi consolidated sedimentary rocks) which occupies 57 % of the area.

In hard rock areas, aquifers are conceptualized in to two namely; 1) weathered zone (~30 m) and 2) fractured zone (30- 195 m). The Weathered zone (~30 m) consisting of upper saprolite (~13 m) and lower sap rock (13-30m.) varies from meagre to 20 m.bgl in archean crystalline and meagre to 30 m. in metasedimentary. Ground water yield of this zone varies from <1-2 lps, specific yield ranges from < 1-2 %. Ground water yield from fractured zone varies from <1 to 5 lps. The transmissivity (T) varies from 1 to 187 m^2/day and storativity varies from 0.00001 to 0.0001.

Five aquifers were demarcated in softrock areas upto a depth of 300m. Aquifer I is the shallowest aquifer, mostly upto a depth of 25 m, consists of weathered residuum where ground water occurs under water table condition. The aquifer II, aquifer-III, Aquifer-IV, and V are deeper aquifers identified in Gondwana Formations. The transmissivity (T) of these aquifers varies from 10 to 367 m^2/day. The Specific Capacity of the wells ranges between 10 and 367 lpm/mdd and Storage coefficient ranges between 2 x 10-4 and 4.64 x 10-4 respectively.

Net dynamic replenishable ground water availability is 807 MCM, gross ground water draft is 301 MCM, provision for drinking and industrial use for the year 2025 is 58 MCM and net available balance for future irrigation use is 514 MCM. The stage of ground water development varies from 8 to 88 % (avg: 37 %).

Major issues identified includes ground water pollution (both anthropogenic (NO_3) and geo-genic (F), deep water levels are > 20 m bgl in 6 % of the area during pre-monsoon season.

The management strategies mainly include both supply side and demand side. The supply side measure includes ongoing work under Mission Kakatiya where ~9.16 MCM of silt has been removed from existing 1197 tanks. This will contribute ~2.29 MCM of ground water by recharge, with this additional ~381 ha land can be brought under irrigated dry (ID) crops in tank ayacut. Under Mission Bhagiratha, there is plan to import ~35.39 MCM of water for drinking purposes which will save the present ~19 MCM of water for drinking and domestic purposes and with this additional ~3166 ha of land can be brought under ID crops.

Construction of 1096 artificial recharge structures (578 CD's and 518 mini PT'in 111 villages) with a total cost of **136** cores are recommended as supply side measures. Under Water conservation measures include, construction of 7540 nos of farm ponds with 19 crores in all villages.

Demand side measure includes 3050ha of additional land that can be brought under micro-irrigation (@50 ha/village in 65 villages) costing about 18 crores (considering 1 unit/ha @0.6 lakh/ha). With this 5.7 MCM of ground water can be conserved over the traditional irrigation practices.

Other measure includes providing good quality seeds, improved procurement facilities, mandatory artificial recharge at every Govt and industrial units. Capacity building in power supply regulation, application of laser levelling technology in irrigated land, providing proper sewerage system and participatory groundwater management (PGWM) are the other measures recommended.

With the above interventions costing Rs 177 crores (excluding the cost involved in Mission Kakatiya and Mission Bhagiratha), the likely benefit would be the net saving of 82 MCM of ground water.

NUMBER OF DATA POINTS USED FOR PREPARATION OF VARIOUS MAPS/FIGS- BHADRADRI KOTHAGUDEM DISTRICT, TELANGANA

S.No.	Data	Aquifer	Total Data Points	Source	
				CGWB	SGWD/SCCL/RWS
1	Panel Diagram (3-D)	Combine	149	Expl:70 VES:45	34
2	Hydrogeological Sections	4 no	149	Expl:70 VES:45	34
3	Fence/ panel Diagrams	1 no	149	Expl:70 VES:45	34
4	Depth of weathering	1 no	116	Expl:37 VES:45	34
5	Depth of fracturing	1 no	116	Expl:37 VES:45	34
6	Groundwater Yield	combined	104	70	34
7	Transmissivity (m^2/day)	combined	20	20	20
8	Depth to Water Level Maps	Combine	86	24	62
9	Water Level Fluctuation	Combine	86	24	62
10	Long term water level trends	Combine	30	10	20
11	Water quality	Combine	Pre:102 Post:92	12 0	SGWD:62 RWS : 28) SGWD:62 RWS : 30)

1. INTRODUCTION

Aquifer mapping is a multidisciplinary scientific approach wherein a combination of geologic, geophysical, hydrologic, and chemical analysis is applied to characterize the quantity, quality, and sustainability of groundwater in aquifers. In the recent past, there has been a paradigm shift from "**groundwater development**" to "**groundwater management**". As large parts of India particularly hard rock aquifers have become water stressed due to rapid growth in demand for water due to population growth, irrigation, urbanization, and changing lifestyle. 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 groundwater management through community participation.

The Peninsular Shield consists mostly of consolidated sedimentary rocks, Deccan Trap basalts, and crystalline rocks. The occurrence and movement of groundwater in these formations are restricted to weathered residuum and interconnected fractures at deeper levels and have limited groundwater potential. The 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 a high level of geogenic contaminants, such as fluoride, rendering them unsuitable for drinking purposes. High utilization of fertilizers for agricultural productions and improper development of sewage systems 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 a suitable groundwater management plan on a 1: 50,000 scale.

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

1. Compilation of existing data (exploration, geophysical, groundwater level, and groundwater quality with geo-referencing information and identification of principal aquifer units.
2. Periodic long-term monitoring of groundwater regime (for water levels and water quality) for creation of time series database and groundwater resource estimation.
3. Quantification of groundwater availability and assessing its quality.
4. To delineate aquifer in 3-D along with their characterization on a 1:50,000 scale.
5. Capacity building in all aspects of groundwater development and management through information, education, and communication (IEC) activities, information dissemination, education, awareness, and training.
6. Enhancement of coordination with concerned central/state govt. organizations and academic/research institutions for sustainable groundwater management.

1.3 Area Details: The Kothagudem district has a geographical area of 7,025 km2, with 23 revenue mandals lies between north latitude 17°11´-18°14´and east longitude 80°12´- 81°20' (**Fig.1.1**). Administratively the district is governed by two revenue divisions, 377 villages having a population of 10.69 lakhs (2011 census, population density of 152).

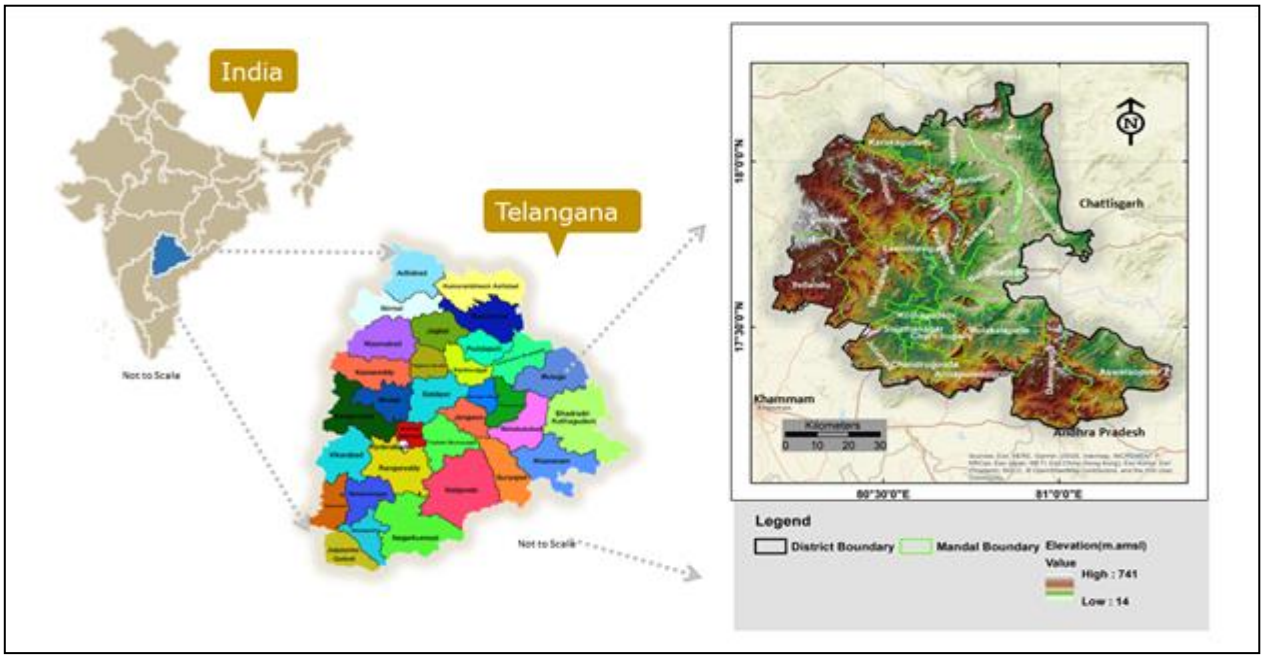

Fig.1.1: Location map of Bhadradri Kothagudem district.

1.4 Climate and Rainfall: The climate of the district is semi-arid and tropical. The district falls under the Central Telangana agro-climatic zone. The Southwest monsoon enters into the district in June and lasts until September and the Northeast monsoon from October to December. Summer starts in March and reaches a peak in May with an average maximum temperature of 40.9°C (for Badrachalam IMD station). A dry, mild winter starts in late November and lasts until early February with the lowest minimum temperature of 16.9°C in December. The annual normal rainfall of the district varies from 984 mm (Allapalli Mandal) to1437.7 mm (Cherla Mandal) with a district normal of 1145.5 mm (Fig. 1.2). The average number of rainy days for a year is around 53 days. Southwest monsoon contributes 89% (902.6 mm), Northeast monsoon by 11% (127.7 mm), and rest 10 % by January to May months of normal annual rainfall. Isohyetal map prepared using annual normal rainfall of mandals shows an increase in rainfall from west to the east direction in the district (Fig.1.2). The district received an annual rainfall of 1943.5 mm (70 % above normal rainfall) during the year 2020 (Jan to Dec) and 1324 mm in 2019 (16 % above normal)**(Table 1.1.)**

Table1.1 Climate data of Bhadrachallam IMD Station (Kothagudem District)

Climate data for Bhadrachallam IMD station (B.Kothagudem district) 1981–2010, extremes 1952–2012													
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Record Extreme temp °C	37.2	40.6	42.8	46.4	48.6	47.5	40.8	38.2	38.6	38.2	36	35.2	48.6
Normal high temp °C	30.8	33.8	37.2	39.3	40.9	36.8	32.7	31.6	32.8	32.6	31.3	30.3	34.2
Normal low temp °C	17	19.9	22.8	25.5	27.4	26.5	24.6	24.4	24.5	22.9	19.3	16.9	22.6
Record low °C	8.4	11.6	14	17	18.6	19.4	20	19.8	19.6	14	10	8.4	8.4
Normal rainfall mm	5.8	6.2	11.2	31.5	41.2	116.4	293.7	292.9	156.6	82.9	19.4	3	1060.8
Average rainy days	0.5	0.4	0.8	1.5	2.6	7	13.3	13	8	4.1	1.5	0.3	52.8
Normal relative humidity (%) (at 17:30 IST)	56	47	44	42	39	56	74	77	77	74	68	63	60
Source: India Meteorological Department													

Analysis of longterm rainfall data of 20 years (2001-2020) shows rise in annual rainfall of 13.3mm/yr. District showing an increasing trend in annual rainfall from 2018. The monthly rainfall trend graph for 20 years shows a rise in rainfall trend in southwest monsoon months from June to September, especially for June (4.5 mm/yr) and August (4.8 mm/yr) months. (**Fig.1.3a & 1.3b**).

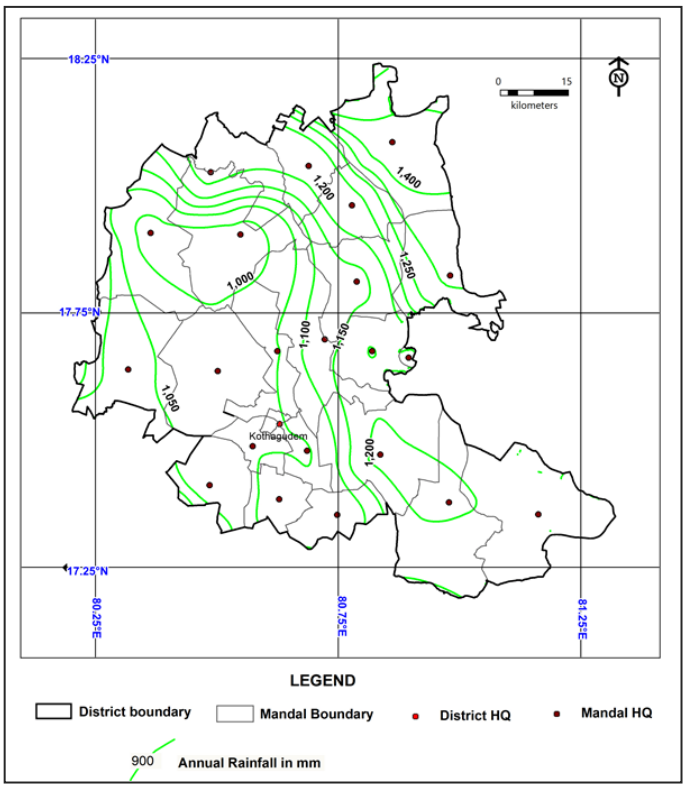

Fig.1.2: Isohyetal map of Bhadradri Kothagudemdistrict

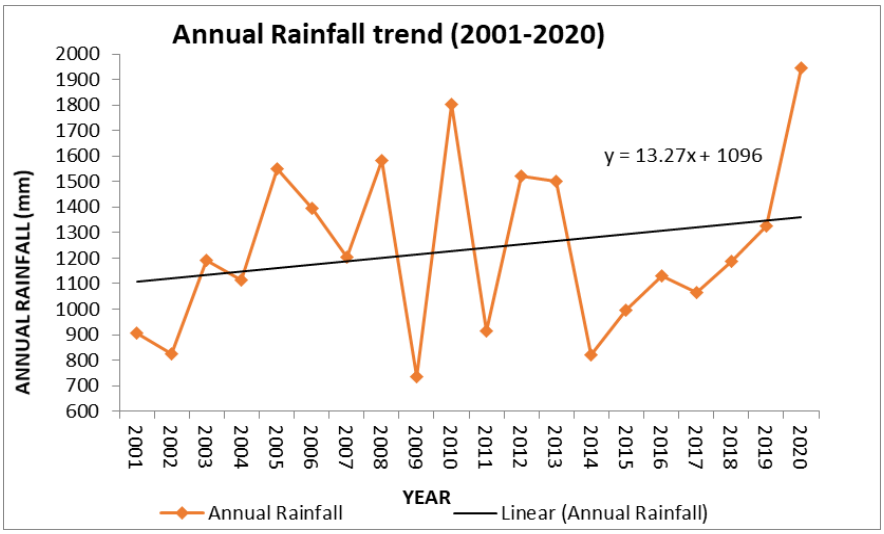

Fig. 1.3a: Annal Rainfall Trend (2001-2020)

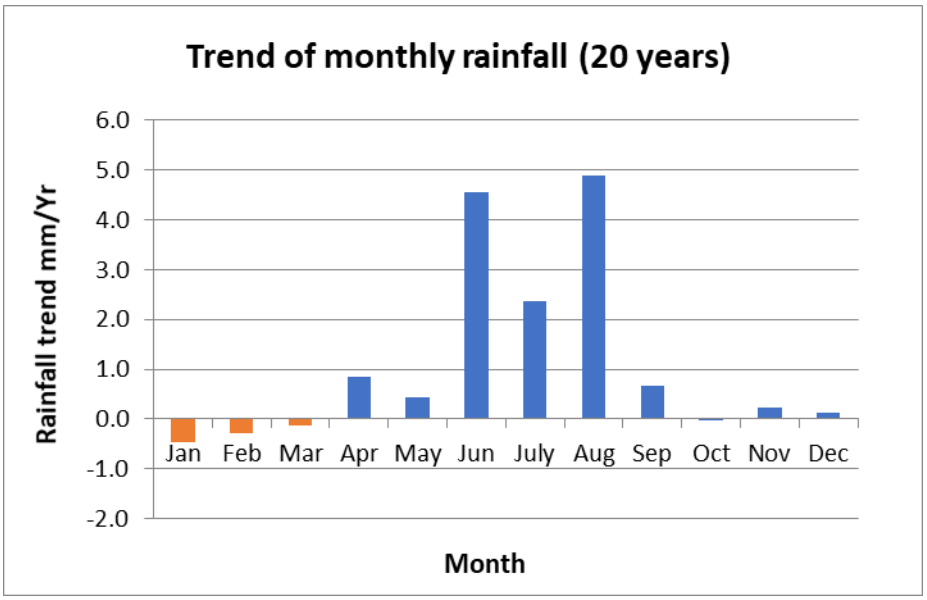

Fig. 1.3b: Trend of Monthly Rainfall

1.5 Geomorphological Set up:

Geomorphologically the study area consists of Pediplain (39% of the area), Pediment (27%of the area), and Structural hills (22% of the area) with a minimum elevation of 14 m.amsl and a maximum elevation of 741m.amsl and regional slope towards the eastern direction (**Fig.1.3**).

1.6 Drainage

The major part of the district is drained by the Godavari River system and the western part is drained by the Krishna river system (**Fig.1.4)**. The Godavari River enters Bhadradri- Kothagudem district from JayaShankar Bhupalapalli district and flows across the district. The drainage system, in general, is controlled by the regional strike of the formations (NNE-SSW).

1.7 Soils:

The area is mainly occupied by fine soil (40%), fine loamy soil (19 %), loamy soil (18%), and loamy skeletal (12%) (**Fig.1.5**).

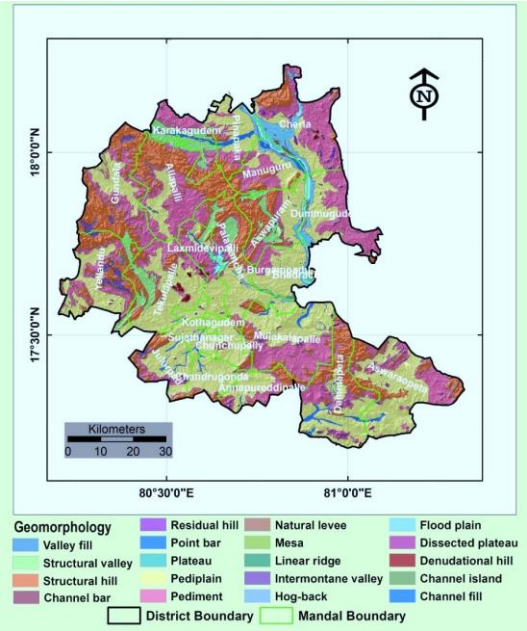

Fig.1.3: Geomorphology map

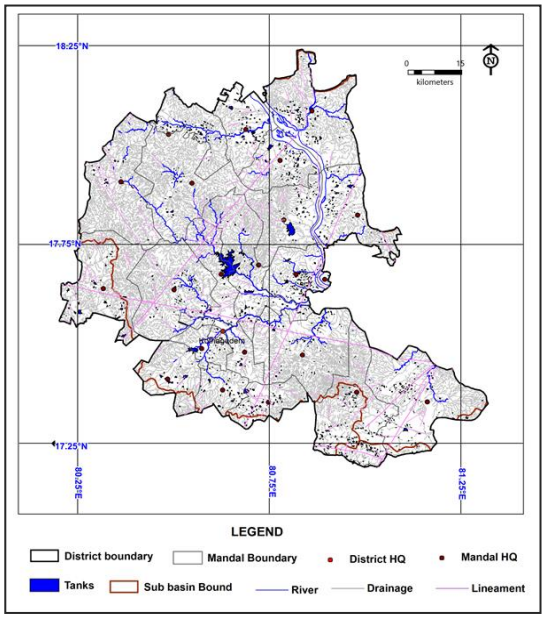

Fig.1.4: Drainage Map

1.8 Land use and cropping pattern (2019-20):

In the district, forest occupies nearly 62% of the area; agricultural land occupies nearly 22% of the area. Remaining area is occupied by water bodies, waste land, built up etc (**Fig.1.6**).The total gross cropped area during the year 2019-20 is 179288 ha and net sown area is 147497 ha. Area sown more than once is 31791 ha.

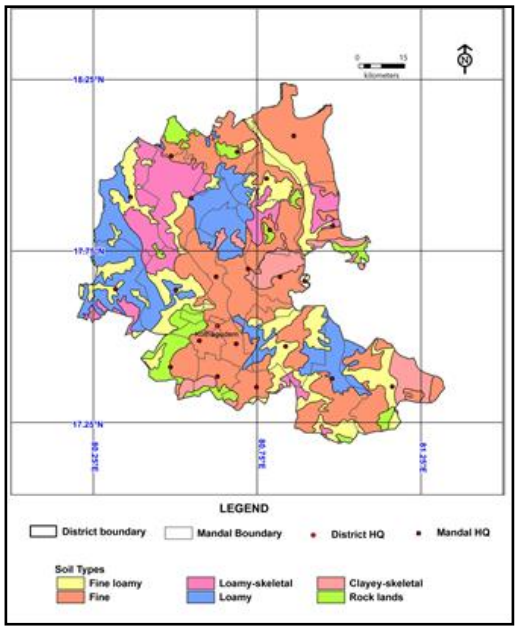

Fig.1.5: Soil map

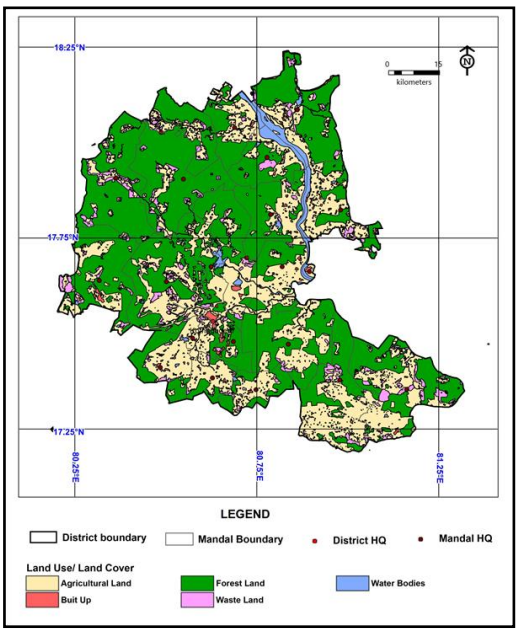

Fig.1.6: Land use and land cover

Major crops grown during khariff season are Paddy, Cereals and millets. Rabi season crops include Paddy, Cotton and Cereals. Paddy is grown in 57972 ha in Khariff season and 22711ha in Rabi season. Season wise cropping pattern is given in **Fig.1.6a** and **Fig.1.6b.**

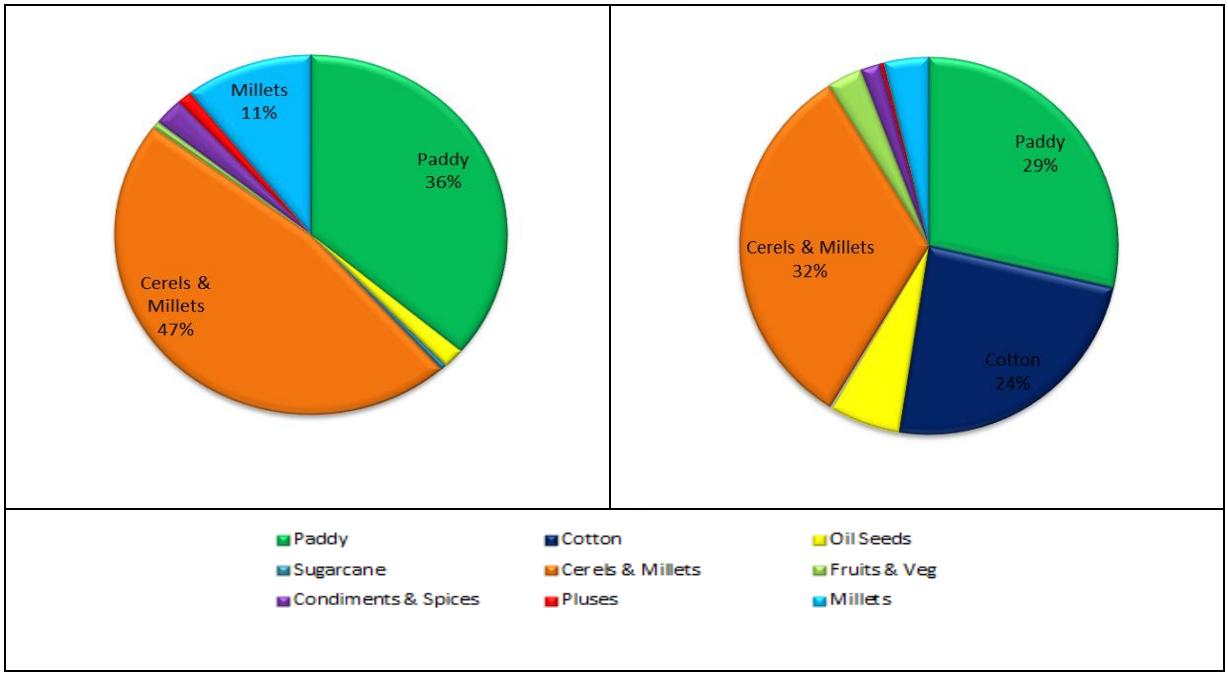

Fig.1.6 a, b Season wise cropping pattern

1.8 Mining and Indutries

The principal mineral deposits of the kothagudem district include coal, Baryte, Dolomite, and sowing sand deposits. The active coal mining area in the district is nearly 60 km2.

The major industries of the district include the Singareni Collieries Company Limited (SCCL), having headquarters at Kothgaudem and Kothagudem Thermal Power Station at Palvoncha, one of the coal-based power plants of Telangana Power Generation Corporation Limited (TSGENCO).

The Singareni Collieries Company Limited (SCCL) is extracting coal from the coal-bearing Gondwana sedimentary formations in the Godavari Valley Coal Field (GVCF). The Gondwana formations consist of sandstones, shales, clays, coal, etc. The major coal mines are in Manguru, Yellandu, Chuchupally, and Tekulapalle mandals (**Fig 1. 7).**

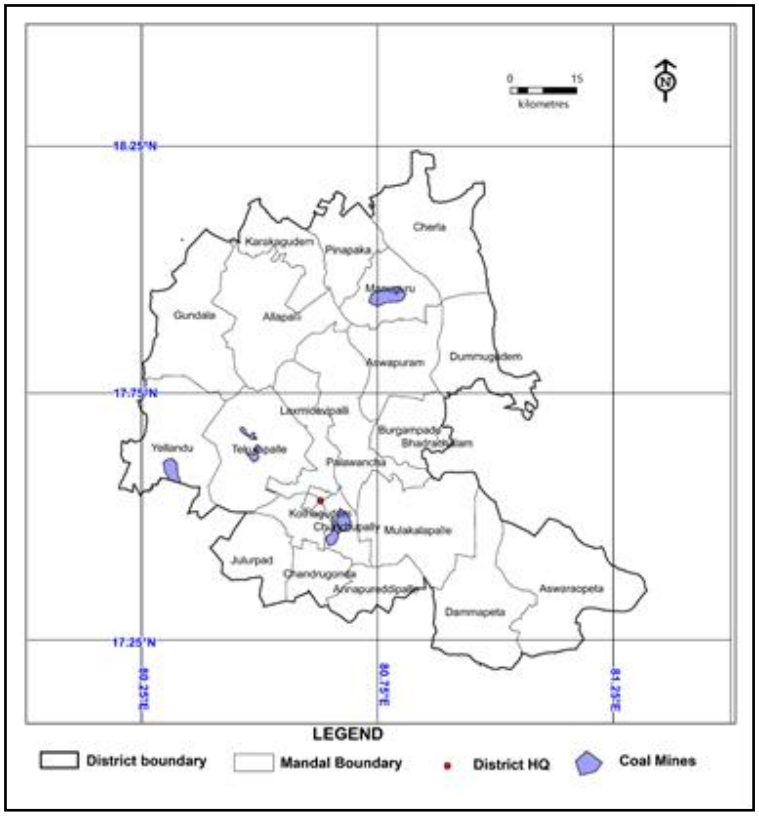

Fig 1. 7 Major Coal mines of Kothagudem District

1.9 Irrigation:

Medium Irrigation Projects:

Peddavagu Project is a Medium Irrigation Project constructed across Peddavagu a tributary of Godavari River in Gummadivally village in Bhadradri Kothagudem district. This Project is having the ayacut of 955 hectare in Bhadradi Kothagudem with an irrigational potential of 955 hectares.

Taliperu is a medium irrigation project across the Taliperu river, a major tributary of the river Godavari, near Peddamidisileru Village), Charla Mandal of Kothagudem with an irrigation potential of 9995 hectares.

The Kinnerasani Project is a medium irrigation project proposed across Kinnerasani River located in Yanambail Village of Palwancha mandal of Kothagudem district. This Project is having the ayacut of 4046 hectares in Bhadradi Kothagudem with an irrigational potential of 4046 hectares. **(Fig 1.8)**

Table 1.2 Commisoned Lift Irrigation scheme

Ditrict	No. of Schemes	Irrigation Potential created in hectares
Bhadradri Kothagudem	112	11342

Table 1.3 Ground Water Schemes (Source: 6th Minor Irrigation Census, 2017-18)

	Number
Villages Covered	377
Dugwell	897
Shallow Tubewell	4246
Medium Tubewell	9924
Deep Tubewell	3062
Total	18129

Tabke 1.4 Minor irrigation tanks

State	No. of Tanks	Ayacut in hectares
Bhadradri Kothagudem	3310	60367

Fig 1.8 Irrigation Projects, Kothagudem

1.11 Prevailing Water Conservation/Recharge Practices

In the district, there exists; ~602 percolation tanks, ~284 Check dams, and ~52 farm ponds with gross storage of nearly 18.4 MCM. Under Mission Kakatiya (Phase 1, 2, 3,4), 1197 tanks have been taken under RRR (Repairs, restoration, and Rejuvenation) schemes.

1.12 Geology:

The district consists of rock formation from Archaean to Cretaceous age, with some isolated pockets of Recent to Sub-recent alluvium. Archean to proterozoic Granite, Hornblende biotite gneiss, occupies 30% of the area. The proterozoic shale, dolomite, quartzite, Arkose of Pakhal, and Sullavai group unconformably overlies the Archean and is exposed in 13% of the area. The Gondwana formation lies unconformably over the Archean and Proterozoic Metasedimentary rocks in 57% of the area. The Gondwana formation includes the lower (1) Talchir Formation (2) Barakar Formation (3) Barren Formation (4) Kamthi Formation, and Upper Maleri, Kota, and Gangpur formation. The lower Gondwana formation lies unconformably over the Archean and Proterozoic Metasedimentary rocks. They are overlain by the Gangpur, Kota, Maleri, and kamthi formations of the Upper Gondwana sequence. It extends generally in the NW-SE trend **Fig.1.9.**

Table 4: Stratigraphy of Bhadradri Kothagudem district

Super Group		**Formation**	**Age**	**Lithology**
Alluvium			Recent	Clay, Sand
Gondwana	Upper Gondwana	Gangpur	Middle Triassic to Cretaceous	Clay and Sand Stone, Calcareous Sandstone, Sandstone
		Kota		
		Maleri		
	Lower	Kamthi	Early Permian to Late	Sandstone, Shale, Ferrugenous Sandstone,

	Gondwana	Barren Measure Baraker	Carboniferous	Calcareous Sst
		Talchir		
……Unconformity……....				
Pakhal		Mulug and Mallampalli	Meso Proterozoic	Shale, Dolomite, Quartzite, Arkose
……Unconformity……....				
Eastern Ghat, Peninsular Gneissic complex, Dharwar			Archean to Proterozoic	Granite, Hornblende biotite gneiss, Gabbro, Dolerite, Charnockite,Proxinite, Chlorite Schist, Migmate gneiss, Khondalite etc.

1.13 Hydrogeology

Hydrogeology is concerned primarily with the mode of occurrence, distribution, movement, and chemistry of groundwater occurring in the subsurface, in relation to the geological environment. Based on the water-bearing property, the rocks of the district can be divided into (i) hard rock comprising crystalline archean granites, gneisses, and metamorphic chlorite schist, mica schist, amphibolite, and Proterozoic metasedimentary Pakhal and Sullavai group of rocks. (ii) Soft rock comprising semi consolidated rocks belonging to Gondwana Supergroup and younger alluvium.

1. **Hard rock (Consolidated formation):** Consolidated rocks are commonly referred to as hard rocks, which include igneous and metamorphic rocks e.g. granites and gneisses of Archaean group and schists, phyllites, shales, and limestones of Pakhal Series. The occurrence and movement of groundwater primarily depend on the degree of interconnection of secondary pores/voids developed by fracturing and weathering. Groundwater occurs in the under

confined to semi-confined conditions in the fractured formation and unconfined conditions in the weathered formation.

2. **Soft rock (Semi-consolidated to Unconsolidated formations):** comprising conglomerates, shales, and sandstones of Lower and Upper Gondwana Supergroup. The occurrence and movement of groundwater in these rocks are controlled by the primary porosity which is in turn affected by the grain size and clay content in sandstone.

The occurrence and movement of water in the subsurface are broadly governed by geological frameworks. It depends on rock type, depth of weathering, and extension of weak zones like fractures, joints, etc., in hard rocks, while in sedimentary rocks it depends on porosity, granularity, cementing matrix, permeability, bedding plains, and faults, etc.

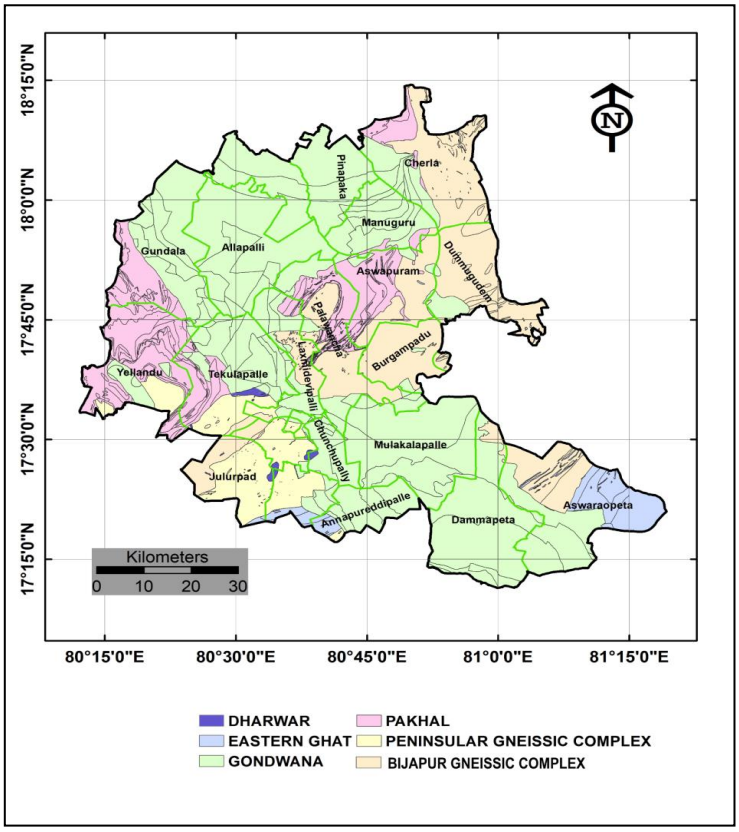

Fig.1.9: Geology of Bhadradri Kothagudem district

2. DATA COLLECTION AND GENERATION

Collection and compilation of data for aquifer mapping studies are carried out in conformity with the Expenditure Finance Committee (EFC) document of XII plan of CGWB encompassing various data generation activities **(Table-2.1)**. 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, along with the data collected from various State and Central government departments.

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

S. No.	Activity	Sub-activity	Task
1	Compilation of existing data/ Identification of Principal Aquifer Units and Data Gap	Compilation of Existing data on groundwater	Preparation of base map and various thematic layers, compilation of information on Hydrology, Geology, Geophysics, Hydrogeology, Geochemical etc. Creation of data base of Exploration Wells, delineation of Principal aquifers (vertical and lateral) and compilation of Aquifer wise water level and draft data etc.
		Identification of Data Gap	Data gap in thematic layers, sub-surface information and aquifer parameters, information on hydrology, geology, geophysics, hydrogeology, geochemical, in aquifer delineation (vertical and lateral) and gap in aquifer wise water level and draft data etc.
2.	Generation of Data	Generation of geological layers (1:50,000)	Preparation of sub-surface geology, geomorphologic analysis, analysis of land use pattern.
		Surface and sub-surface geo-electrical and gravity data generation	Vertical Electrical Sounding (VES), bore-hole logging, 2-D imaging etc.
		Hydrological	Soil infiltration studies, rainfall data

		Parameters on groundwater recharge	analysis, canal flow and recharge structures.
		Preparation of Hydrogeological map (1:50, 000 scale)	Water level monitoring, exploratory drilling, pumping tests, preparation of sub-surface hydrogeological sections.
		Generation of additional water quality parameters	Analysis of groundwater for general parameters including fluoride.
3.	Aquifer Map Preparation (1:50,000 scale)	Analysis of data and preparation of GIS layers and preparation of aquifer maps	Integration of Hydrogeological, Geophysical, Geological and Hydro-chemical data.
4.	Aquifer Management Plan	Preparation of aquifer management plan	Information on aquifer through training to administrators, NGO's, progressive farmers and stakeholders etc. and putting in public domain.

The aquifer geometry for shallow and deeper aquifer has been established through hydro geological studies, exploration, surface and subsurface geophysical studies in the district. The data used for the integration and interpretation includes:

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 70 wells in the district. Out of these, 56 wells were drilled in 2019-20 and 2020-21 based on the data gap analysis carried out in the study area as part of NAQUIM. A total of 104 exploratory borewell data of CGWB (70) and SGWD (34) were used for the hydrogeological studies. 57 wells are located in Semi consolidated Gondwana formation and 47 wells in consolidated granitic and Metasedimentary areas.

2.2 Water Level

Water level monitoring wells of CGWB and SGWD is utilized for the Aquifer Mapping studies. 19 dug wells and 5 Piezometers are presently monitored by CGWB and 62 piezometers by SGWD. CGWB wells are being monitored four times (January, April, August and November) in a year whereas; the monitoring wells of State Ground Water Department (SGWD) are being monitored every month. These groundwater monitoring wells were used in order to understand the spatio-temporal behaviour of the groundwater regime.

2.3 Hydro chemical Studies

Water quality data of CGWB, SGWD and RWS is utilized for understanding the spatial variation of quality in the district. A total of 194 (Pre-monsoon:102(CGWB: 12, SGWD: 62, RWS: 28) and post-monsoon: 92 (SGWD: 62, RWS:30) ground water monitoring well data of Central Ground Water Board, Telangana State Ground Water Department and Telangana Rural Water Supply (mostly tapping combined aquifers Aq-1 and aq-2) is utilized to understand the chemical characteristics of groundwater. 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.

2.4 Geophysical Studies

Geophysical data on VES and profiling are used to extract information on the weathered thickness, fracture depth, thickness of fracture etc of hard rock area. For the interpretation of the aquifer geometry geophysical data in conjunction with the available groundwater exploration data is utilised. The data from 97 Vertical Electrical Soundings (VES) employing the Schlumberger electrode configuration with the maximum electrode separation (AB) of 400 meters is used for the aquifer mapping studies. The data was processed and interpreted by IPI2Win software eveloped by MoscowState University, after marginally modifying the manually interpreted results in corroboration with geology and hydrogeology.

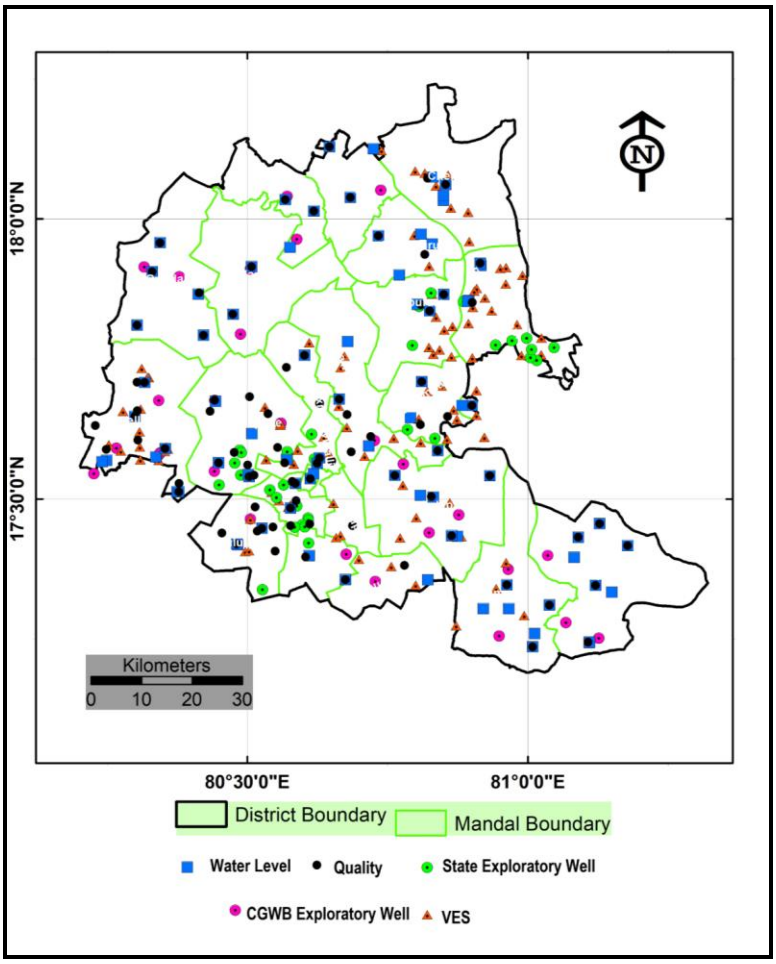

Fig. 2.1: Data availability

3. DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING

3.1. Ground water Level Scenario

3.1.1 Depth to ground water level

Analysis of the pre- and postmonsoon water level data from 86 (CGWB: 24(19 DW, 5 PZ) SGWD: 62 PZ) groundwater monitoring wells shows that depth to water level varies from 0.85 to 41.4 m bgl during pre monsoon and 0.01-33.15 m bgl during post-monsoon season.

Pre-monsoon season: In Majority of the area water level during this season are in the range of 5-10 m (69% of the area), followed by 10-20 m bgl (23 %). Deeper water level in the range of > 20 m bgl occupy about 28 % of the area falling in parts of Dhammapeta, Annapureddipalle, Aswaraopeta and Julurpad mandals (**Fig.2.4**).

Shallow water level <5 mbgl occupy about 2% of the area in parts of Gundala, Dummugudem and Palvancah mandals.

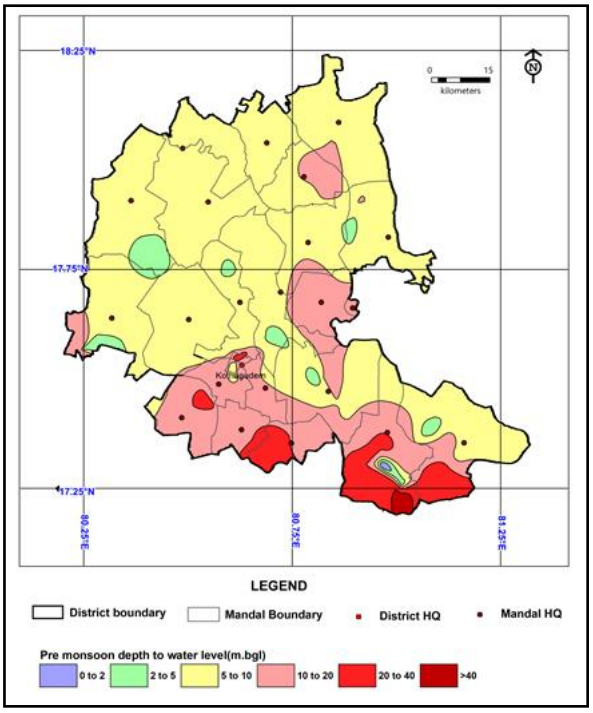

Fig.3.1: Depth to water levels Pre-monsoon

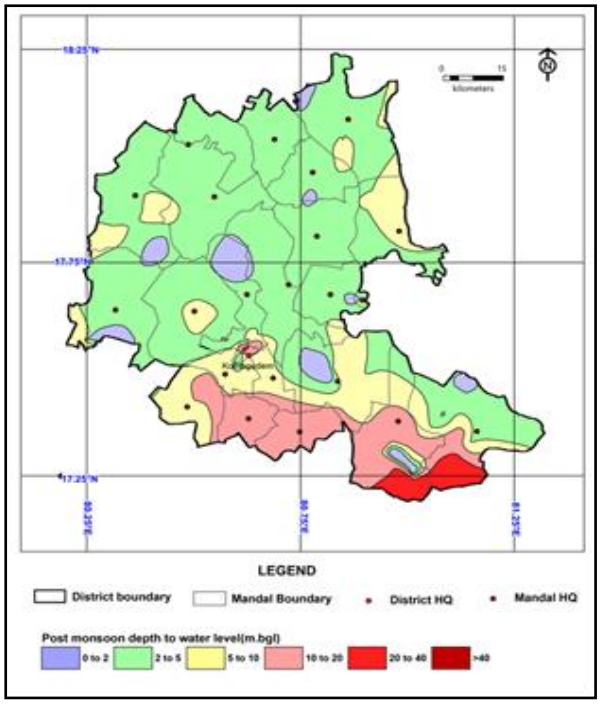

Fig.3.2: Depth to water levels Post-monsoon

Post-monsoon season: Majority of the water level during this season are in the range of 2-5 m covering 64% of the area, 5-10 m bgl in 19 % of the area. (**Fig.2.5**). Shallow water level < 2 mbgl) occupy about 4% of the area in parts mainly in parts of Lakshmidevipalli, Mulakalapalle and Gundala mandals. Deep water level in the range of > 10 m bgl occupy about 13 % of the area falling in parts of Dhammapeta, Annapureddipalle, Chandrugonda, Aswaraopeta and Julurpad mandals.

3.1.2 Seasonal Water Level Fluctuations (May vs. November): All the wells in the state records water level rise. The water level rise varies from 0.20 to 16.30 m in all the wells (Fig.2.6). Rise in water level range of 5-10 m cover majority of area with 48%, followed by 2 to 5 m covering 38% of area. Water level rise in the range of 0 to 2 m is observed Dummagudem, Cherla, Gundala and Aswarempet mandals.

3.1.3 Long term water level trends: Trend analysis for the last 10 years (2010-2019) is studied from 30 hydrograph stations of CGWB and SGWD. It is observed that during pre-monsoon season 7 wells shows falling trend in the range of -0.03 m/yr to -1.1 m/yr and 23 wells shows rising trend 0.01-0.1.16 m/yr. During post-monsoon season

5 wells show falling trend -0.01- to -1.01 m/yr and 25 wells shows rising trends 0.2-1.3 m/yr(**Fig 2.8)**.

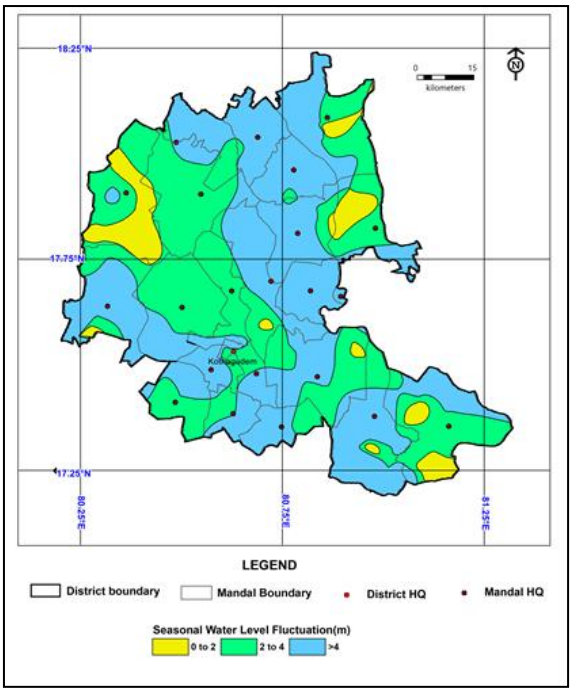

Fig.3.3: Water Level Fluctuation (m) (Nov with respect to May)

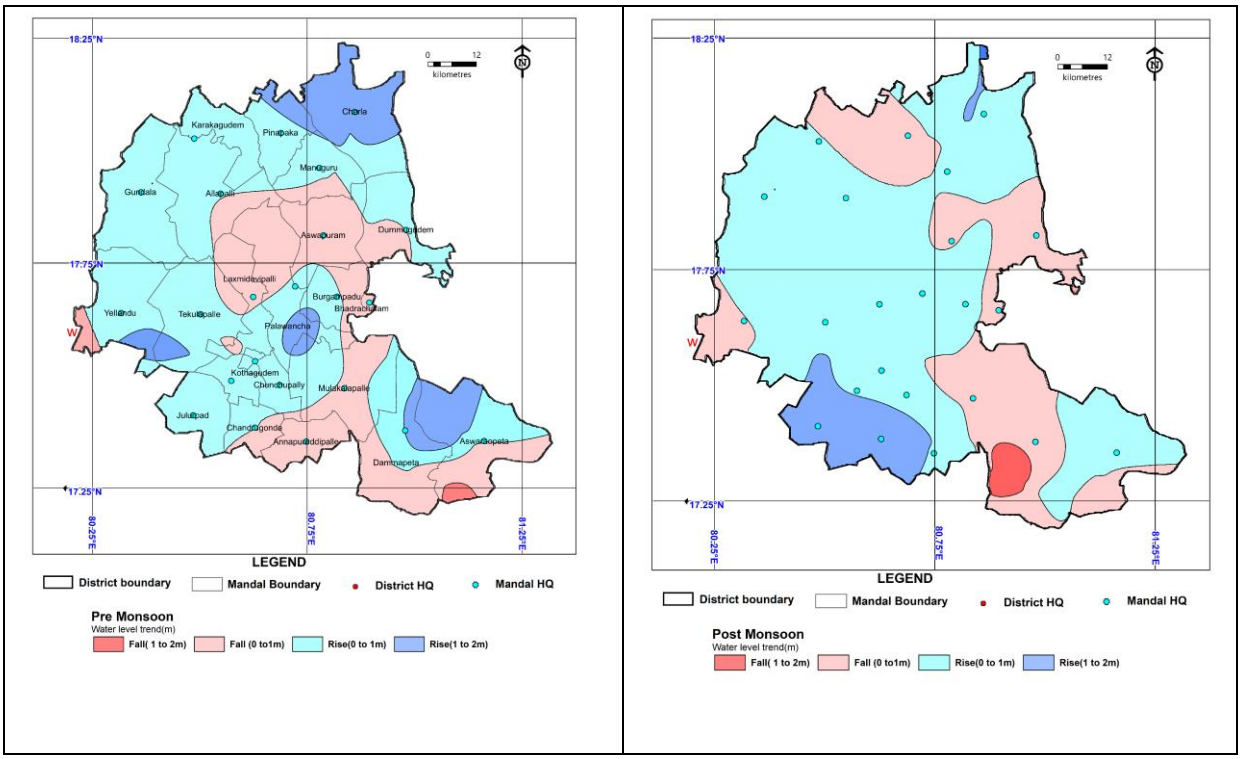

Fig. 3.11a-b: Long-term water level trends (5 yrs)

3.1.4 Water Table Elevation: During pre water-table elevation ranges from 47-341 meter above mean sea level and post-monsoon season 52-346 meter above mean sea level (m amsl). The regional ground water flows mainly towards eastern direction. The ground water flow is towards north to north east direction in the north and southern part of the district. In the central part, the ground water flows is towards east to south east direction. In the southern and western part of the district the contours are comparatively closer indicating the steepness of the terrain thereby the gradient of ground water flow is high in comparison to the other part of the district. The flow of ground water is mostly towards the major drainage suggesting that the base flow is towards the drainage system. (**Fig.2.3**).

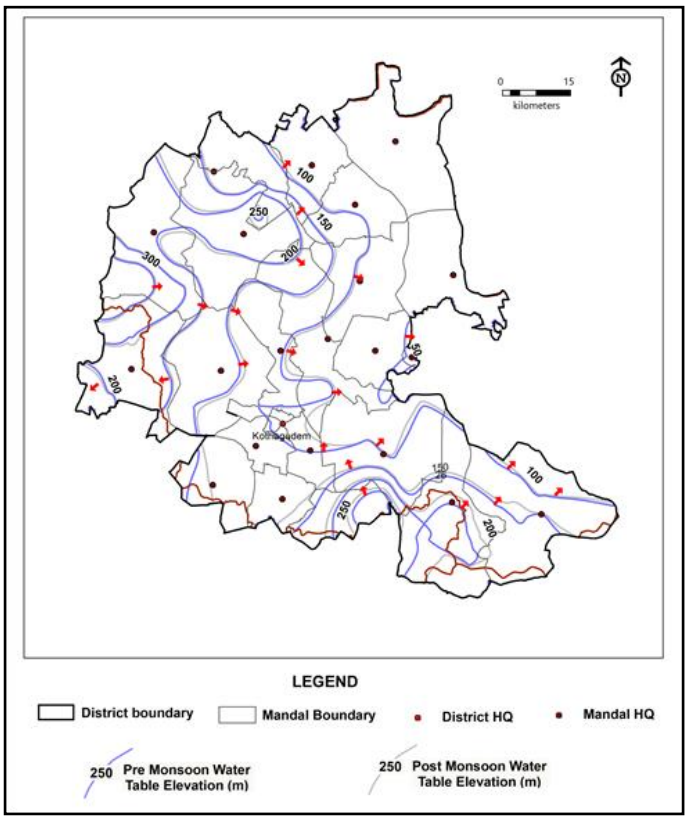

Fig.3.4: Water table elevations (m amsl) during pre and post-monsoon season

3.2 Ground Water Quality

The groundwater quality in the area is generally good for all purposes. In all the locations PH is within the acceptable limit and shows mildly alkaline to alkaline

Pre-monsoon:

Groundwater from the area is mildly alkaline to alkaline in nature with pH in the range of 6.02-9.21 (Avg: 8.03). Electrical conductivity varies from 125-2600 (avg: 794) µ Siemens/cm**.** In 96% of area EC is within 1500 µ Siemens/cm, in 4 % area, it is 1500-3000 µ Siemens. (**Fig.2.8).** Average concentration of TDS is 737 mg/L and NO_3 ranges from 0.22-468 mg/L. Nitate concentration in 36 % of samples is beyond permissible limits of 45 mg/L (**Fig.2.9**). Fluoride concentration varies from 0.05-4.09(**Fig 2.10**) and 85% of samples is within the permissible limits of BIS and rest is beyond the permiss

ible limit of 1.5 mg/L.

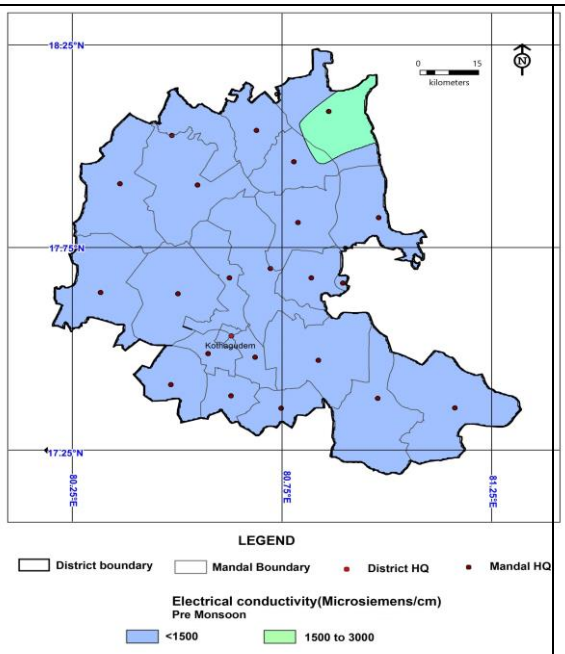

Fig.3.5: Pre monsoon EC distribution

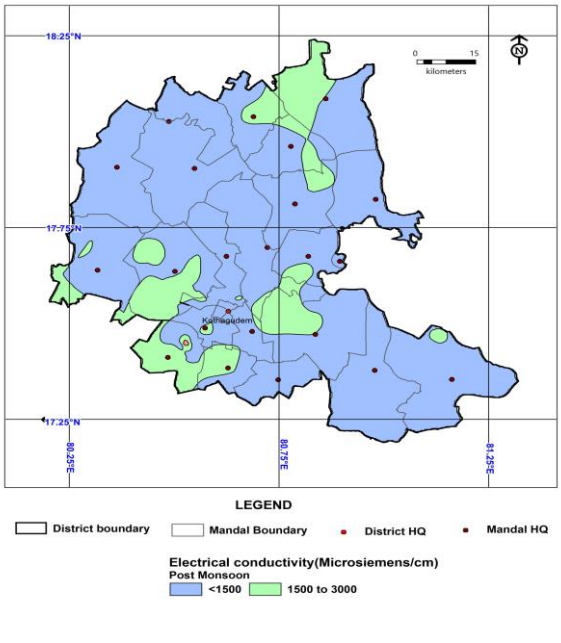

Fig.3.6: Post monsoon EC distribution

Post-monsoon

Groundwater from the area is mildly alkaline to alkaline in nature with pH in the range of 6.68-8.84 (Avg: 7.91). Electrical conductivity varies from 119-2970 (avg: 1175) µ Siemens/cm. In 83% of area EC is within 1500 µ Siemens/cm, in 17% of area EC is 1500 to 3000 µ Siemens/cm**(**Fig.2.11). Average concentration of TDS is 752 mg/L and NO_3 ranges from <1-417 mg/L. Nitate concentration in 35% of samples is beyond permissible limits of 45 mg/L (Fig.2.12). Fluoride concentration varies from 0.03-5.76

(Fig 2.13) and 92 % of area is within permissible limits of BIS and rest is beyond permissible limits of 1.5 mg/L.

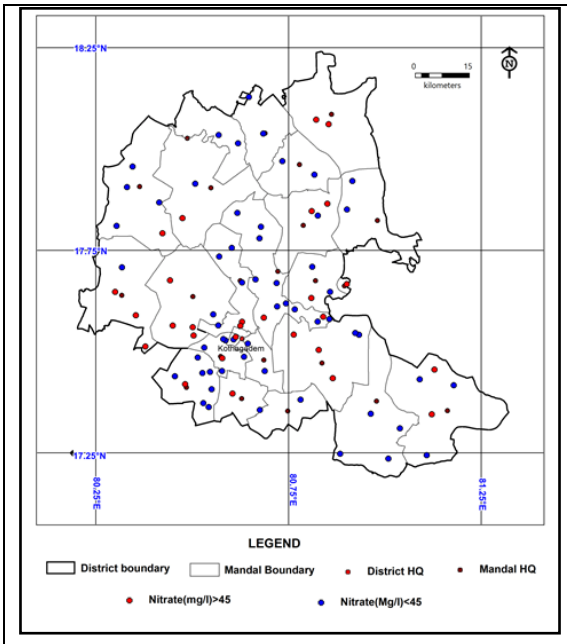

Fig.3.7: Pre monsoon Nitrate distribution

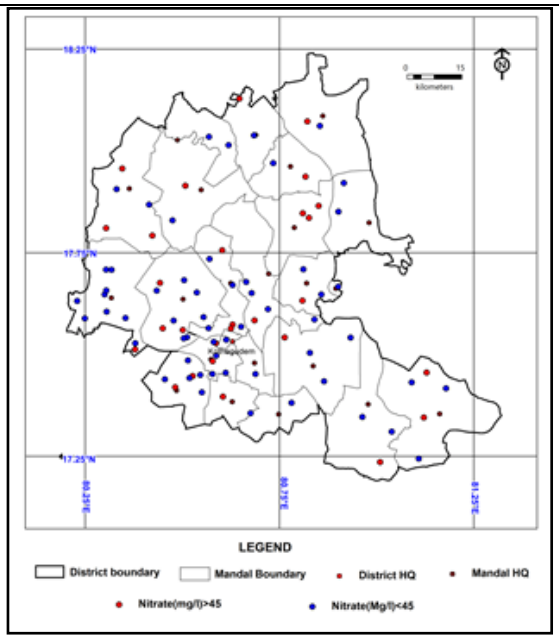

Fig.3.8: Post monsoon Nitrate distribution

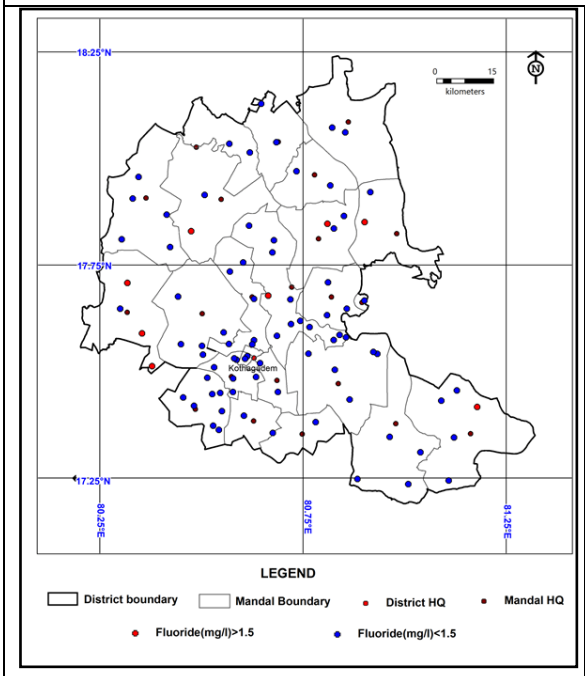

Fig.3.9: Premonsoon Fluoride distribution

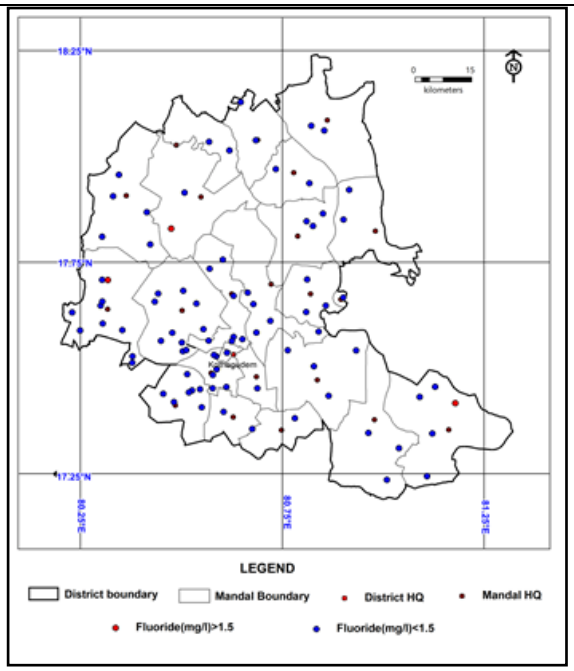

Fig.3.10: Postmonsoon Fluoride distribution

3.3 AQUIFER MAPPING

The aquifer geometry for shallow and deeper aquifer has been established through hydro geological studies, exploration, surface and subsurface geophysical studies in the district. Aquifers were characterized in terms of potential and quality. The aquifer wise characteristics have been delineated and are shown in Table 3.1. Hydrogeology map in the Fig. 3.12 and Depth of occurrence of Aquifer -I is depicted in Fig. 3.13

On the basis of occurrence and movement of ground water, mainly rock units of the Kothagudem is classified into two categories; hard rocks (Archean crystalline and metasedimentary formation) formation which ocuupies 43% of the area and soft rock formation (semi consolidated sedimentary rocks) which occupies 57 % of the area.

3.3.1a. Aquifer system in hard rock areas

Hard rock area consists of consolidated Archean crystalline formation and Consolidated Metasedimentary formations.

a) Aquifer systems of Archean Crystallines

Weathered and fractured granites and gneisses form the aquifer system. The main aquifers constitute the weathered zone at the top, followed by a discrete anisotropic fractured zone at the bottom, generally extending down to 150 m depth. Ground water occurs in weathered formation under unconfined condition is generally tapped through large diameter open wells. And its overexploitation mainly for irrigation purpose resulted in desaturation of weathered zone at many places. The aquifer units identified includes**;**

Shallow Aquifer (Aquifer-I): 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. The average yield of these dug wells range between 20 and 50 m3/day.

Deeper Aquifer in (Aquifer II): The second aquifer 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 145 m bgl (Deepest fracture encountered). The depth of fracturing varies from 25 m to 140m with yield of <1-5lps. The specific capacity of the consolidated formation ranges between 6 and 102 lpm/mdd; transmissivity (T) between 7.8 and 160 sq.m/day.

b) Aquifer systems of Consolidated Metasedimentary formations

These rocks comprising shales, phyllites and silicious limestones occur in parts of Bayyaram, Yellandu and Gundala, Paloncha and Aswapuram mandals. Ground water occurs under water table conditions in the intergranular secondary pores and fractures of weathered rocks.

Shallow Aquifer (Aquifer-I): 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. The depth of weathered zone varies between 4 and 38m bgl and the dug well depths range between 4 to 17m bgl and the depth to water levels range between 2 to 16m bgl. The yields of wells are generally less than 30 m3 /day.

Deeper Aquifer in (Aquifer II): The second aquifer 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 195 m bgl (Deepest fracture encountered). The depth of fracturing varies from 25 m to 195m with yield of <1-5lps. The bore wells have been constructed in the depth range of 30 to 195 m bgl with yield upto 5 lps. The specific capacity of the consolidated formation range between 6 and 87 lpm/mdd; transmissivity (T) between 7.8 and 180 sq.m/day; and Storage co-efficient between 8.4 *10-6 and 8.19*10-3.

3.3.1b Aquifer system in soft rock areas(semiconsolidated to unconsolidated formations)

This group consists of mainly conglomerates, sandstones and shales of Lower and Upper Gondwana members. Groundwater occurs in unconfined and confined conditions in these formations. The sandstones of Upper Gondwana group are very

good aquifers and tube wells constructed in this formation at Mandalapally, Regala and Moddulagudem villages yield, in the range of 26 – 40 lps. The lower Gondwana members are also productive. The yield from lower members of Barakars is in the range of 4 – 10 lps. These formations form very good aquifer systems and groundwater occurs under water table conditions as well as confined conditions in these aquifer units. The shallow aquifers occur down to 25m bgl whereas the confined aquifers occur at different depths ranging from 35 to 300m. A total of 5 aquifers were identified by the expoloratory drilling upto 300m in kothagudem district.

Shallow Aquifer: (Aquifer-I): Aquifer I is the shallowest aquifer, mostly upto a depth of 25 m, 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 ground water occurs under phreatic/unconfined condition.

Deeper aquifers (Auifer II to V)

Unlike shallow aquifer, ground water occurs under confined to semi-confined condition in deeper aquifers (aquifer II, aquifer-III, Aquifer-IV, and V). The occurrence of ground water depends on porosity, granularity, cementing matrix, permeability, bedding plains and faults etc. The deeper aquifer identified upto a depth of 300m. The aquifers are mainly composed of fine to coarse grained sandstone. The thick ness of aquifer increases towards north and south from the centre.

The deeper aquifes are more productive than shallower zones. The tube wells constructed beyond 200m depth have good discharge. Mutiple aquifers are more common in northern part of kothagudem. 5 aquifers were identified in E bayyarm located in the northern part of Kothagudem. While in the southern zone two aquifers were identified. Two distinct perennial auto flow zones in baraker formation have been demarcated in Kumarpodu (Fig 3.14) and KV Rammavaram in Mulkalapalli Mandal.

The Specific Capacity of the wells ranges between 10 and 367 lpm/mdd. The Transmissivity (T) and Storage coefficient ranges between 10 to 367 m^2/day, 2 x 10-4 and 4.64 x 10-4 respectively.

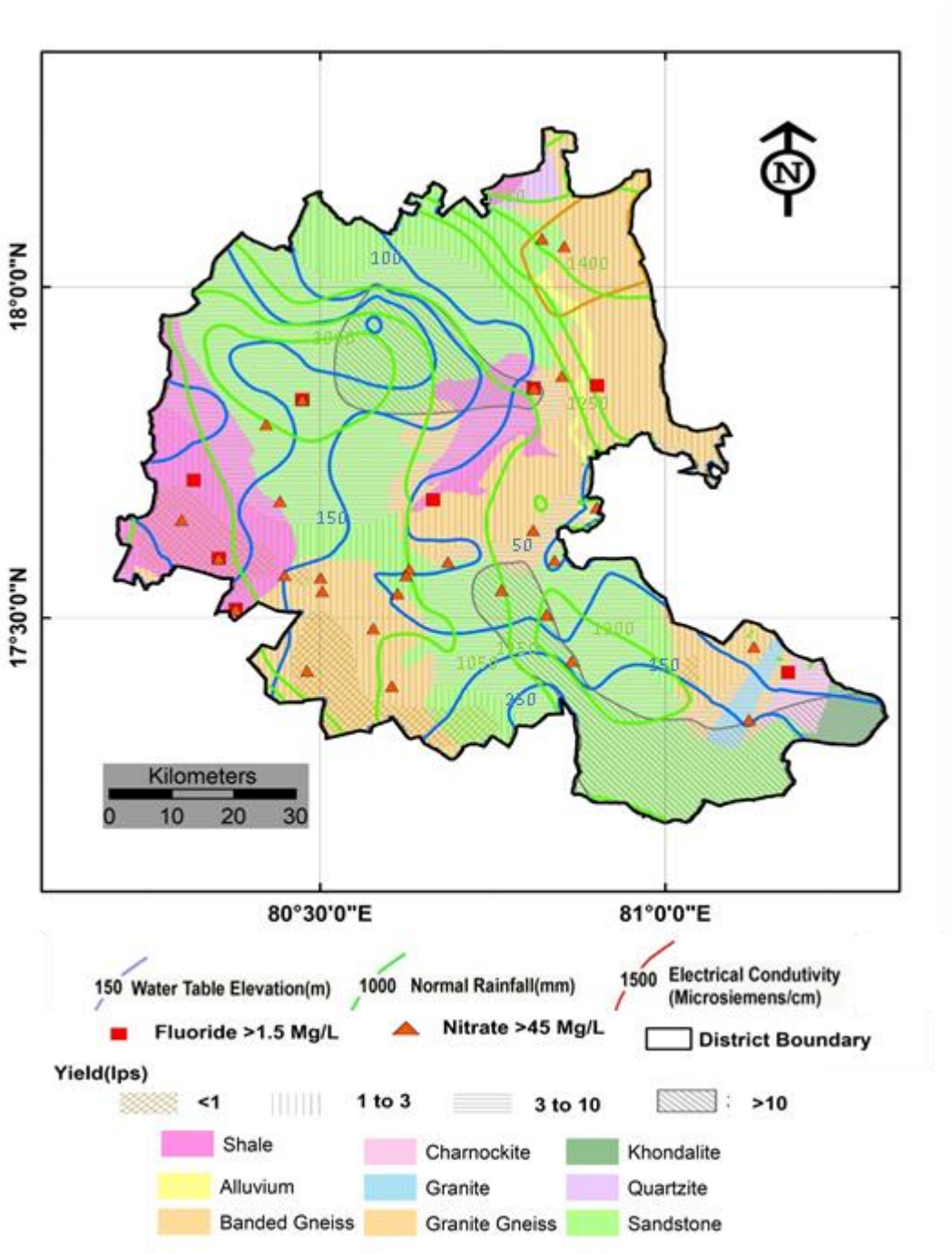

Fig. 3.12 Hydrogeology map

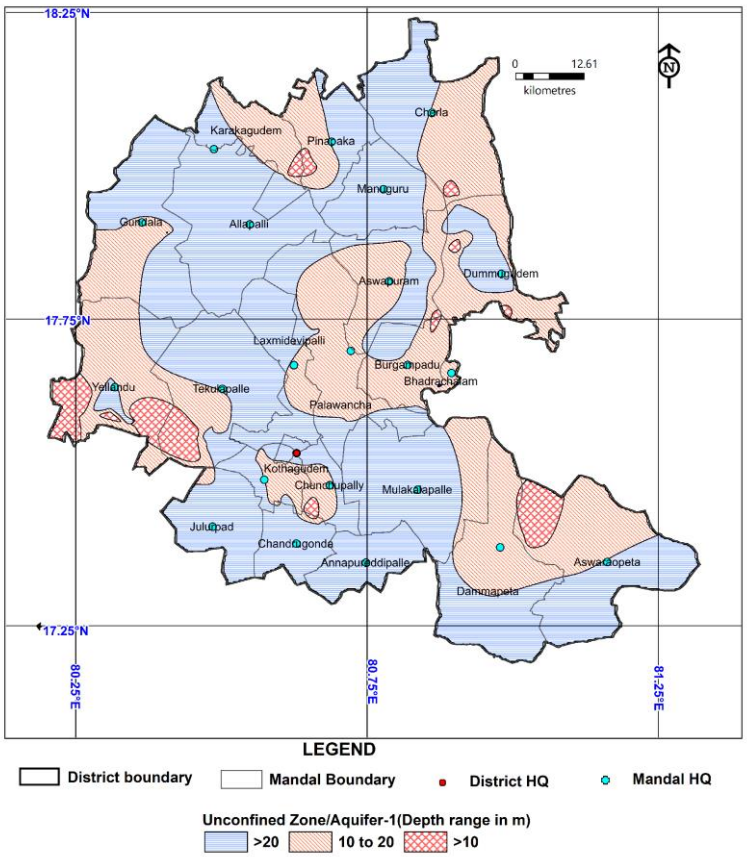

Fig 3.13 Depth of occurrence of Aquifer -I

Fig 3.14:Free Flowing Well- Kumarapodu

Table 3.1. Salient features of Aquifer system in Bhadradri Kothagudem

	Archean Crystalline		Meta Sedimentary		Gondwana Formation	
Prominent Lithology	**Granite, gneiss,**		**Metasediments**		**Sandstone**	
Aquifers	**Aquifer-1 (Weathered Zone)**	**Aquifer-2 (Fracture Zone)**	**Aquifer-1 (Weathered Zone)**	**Aquifer-2 (Fracture Zone)**	**Aquifer-1**	**Aquifer-II to V**
Thickness range	<10-20m	upto 165m	<10 to 30	upto 195m	35m mostly	Aquifer thickness ncludesd ncludes: Aquifer II-Upto 192m, Aquifer III-Upto 228m, Aquifer III-Upto 228m, Aquifer IV-Upto 96m, Aquifer V-Upto 115m
Depth of range of occurrence of fractures	-	86% fracture encountered between 30 to 100m	-	95% fracture encountered between 30 to 150m	-	-
Range of yield potential	<1 to 2	<1 to 5	<1 to 2	<1 to 5	1 to 2	1 to>20
Transmissivity (m2/day)	Upto 160		Upto 187		10 to >367	
Specific Capacity (lpm/mdd)	6 to 102		Upto 87		400	
Quality(Suitability of Irrigation)	Yes	Yes	Yes	Yes	Yes	Yes
Suitabilty of domestic purposes	Yes	Yes	Yes	Yes	Yes	Yes

3.3.2 Aquifer Disposition 3D and 2D

Conceptualization of 3-D hydrogeological model was carried out by interpreting and integrating representative 201 data points (both hydrogeological and geophysical down to 200 m) for preparation of 3-D map, panel diagram and hydrogeological sections. The data (**Fig.2.1**) The lithological information was generated by using the RockWorks-16 software and generated 3-D map for Bhadradri Kothagudem district (**Fig.3.15)** along with panel diagram (**Fig. 3.17a-b**) and hydrogeological sections.

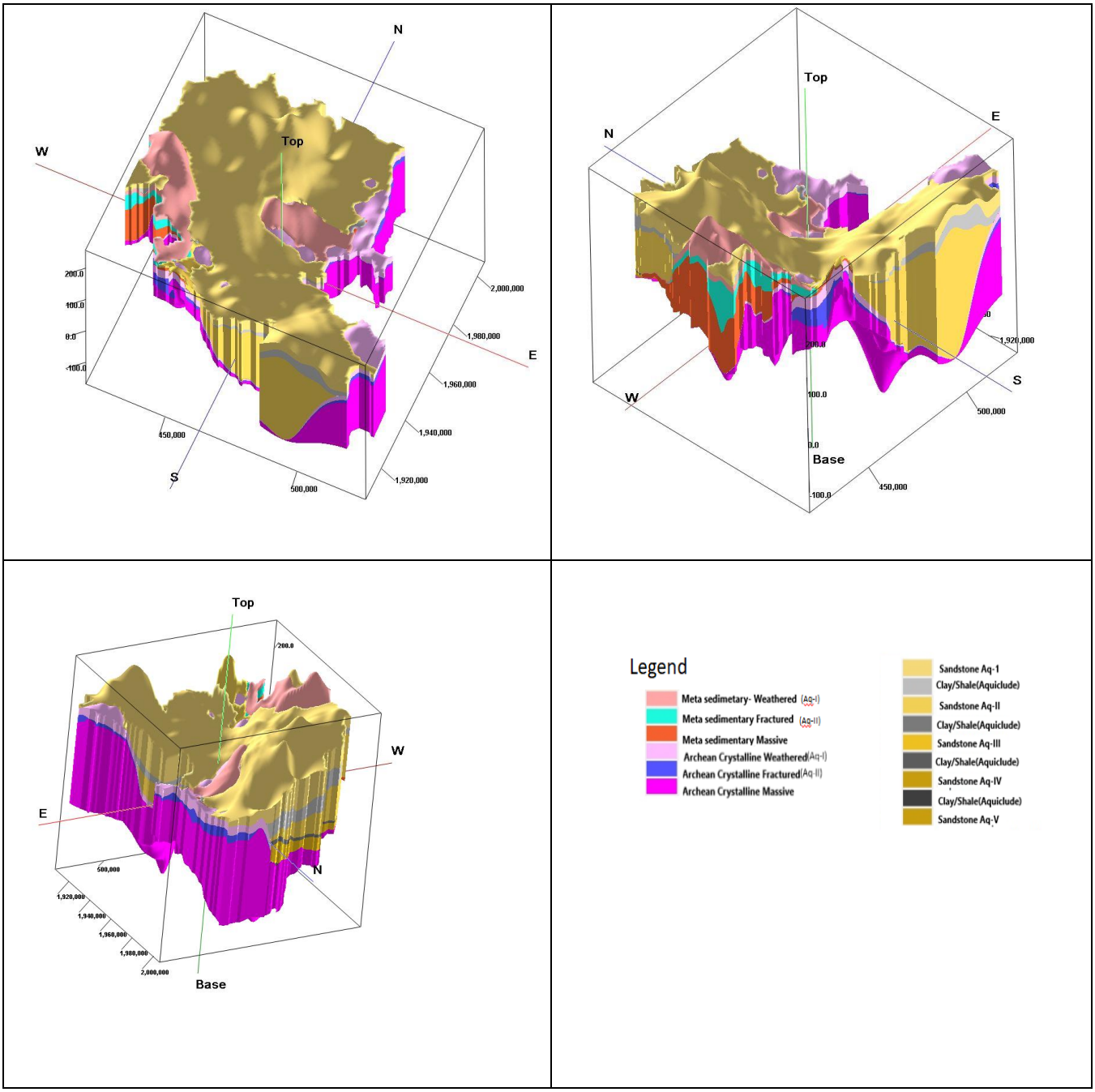

Fig.-3.15:3-D Model for study area

Aquifer Disposition 2D

Three hydrogeological sections are prepared in N-S, W-E and NW-SE directions (**Fig. 3.16**).

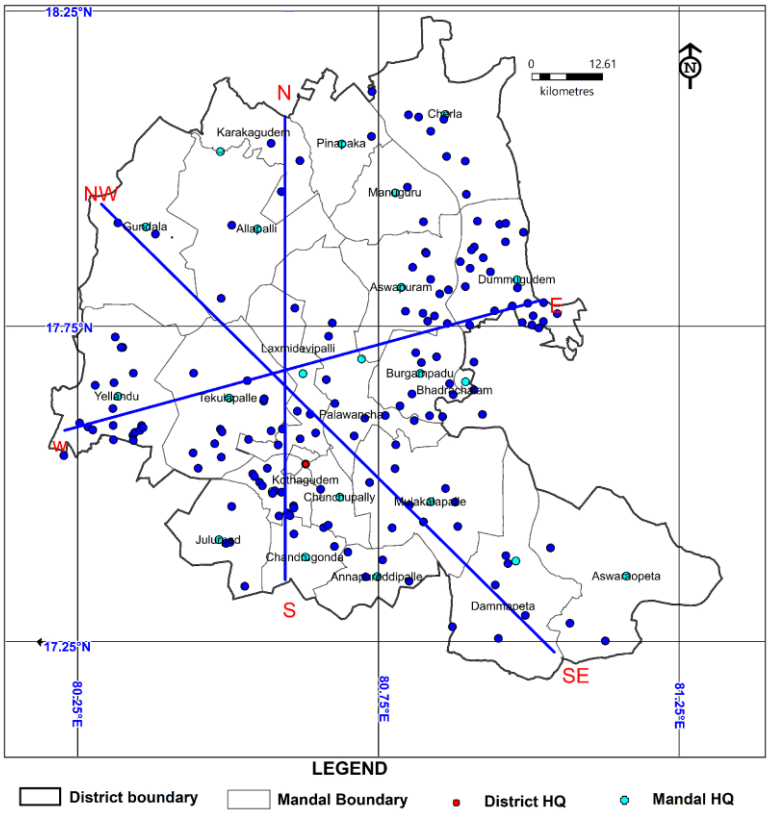

Fig.-3.16: Map showing orientation of various sections.

North and South Section: The section drawn along the N-S direction covering distance of ~110 kms (**Fig.3.17a**). It depicts the layered thick sandstone formations in the north and thin weathered zone and fractured hard rock formation in the middle. Barakar sandstones extend upto 45 km into the district from N boundary. Five aquifers were demarcated in the northern part.

West and East Section: The section drawn along the West -East covering distance of ~75 kms (**Fig.3.17b**). It depicts Meta sedimentary formation in the west and granitic and gneissic formations in the east and sedimentary formation in the centre. Meta sediments overlie the granitic formation in the western part.

North West-South East Section: The section drawn along the North West Direction covering distance of ~120 kms (**Fig.3.17c**). It depicts the layered thick sandstone formations in the North western part and south eastern part. The sediment thickness

reduces in the central part.

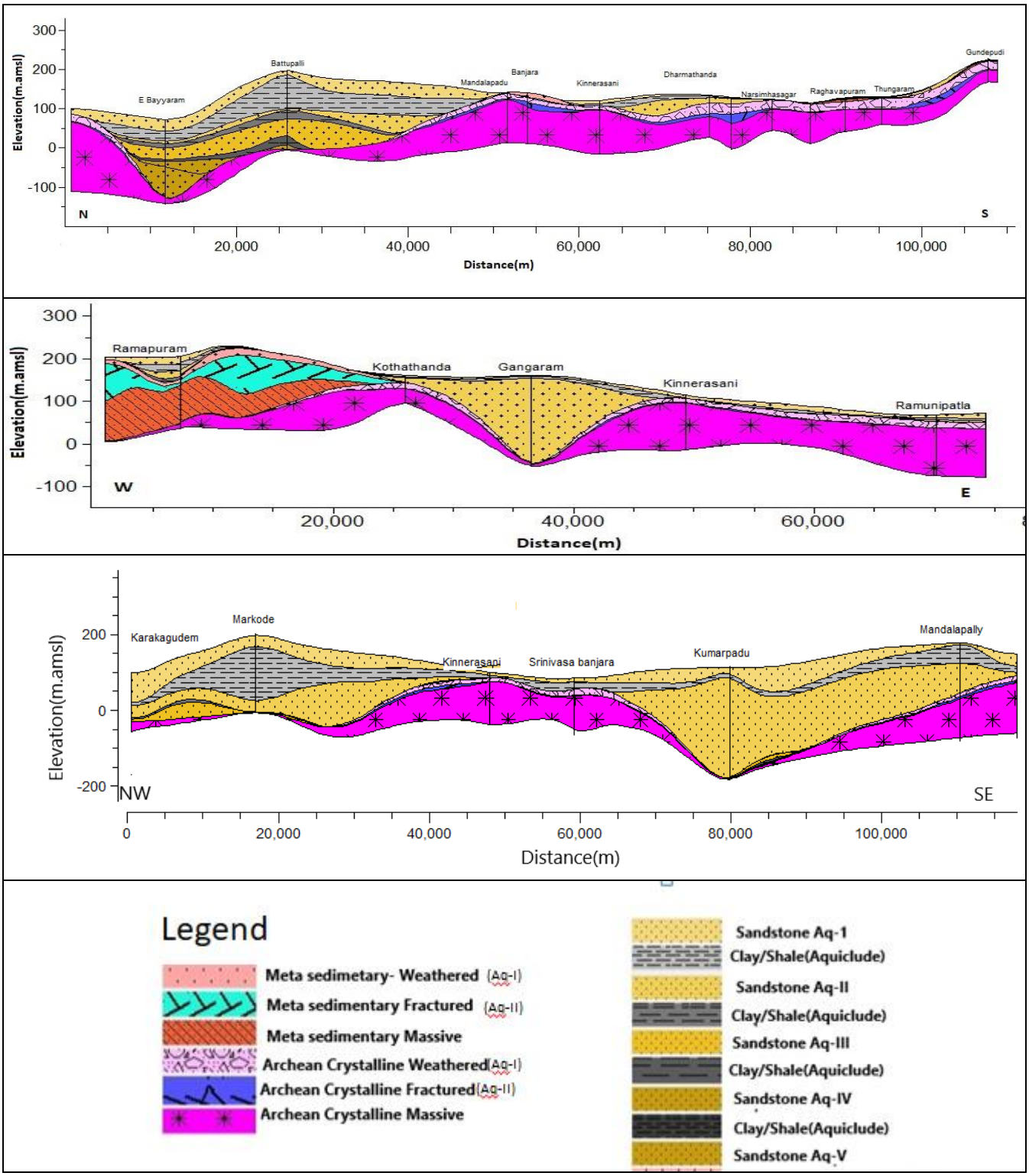

Fig.3.17 (a-c): Hydrogeological profile in different directions in Bhadradri Kothagudem district.

3.4 IMPACT OF MINING IN GROUND WATER

To evaluate the dynamic changes of groundwater storage conditions in the aquifers of Godavari Valley Coal Field, a network of open wells and piezometric wells were constructed around opencast mines for monitoring the depth to water on long term basis by SCCL. Based on the studies carried out, there were no major impacts reported by the mining in the district. Most of the mines are located in forest areas which are safe as per GEC 2020.

The daily Inflow of water into the various SCCL coal mines in Bhadradri Kothagudem District is shown in **table 3.2**

Table 3.2: Impact of mining in Ground Water

Mandal	Sl. No.	Mine	Total quantity of water(m^3/ day)				
			Pumped per day	Mine requirement	Domestic use	For plantation	Let out into the streams
Yellandu	1	JK 5 OC	2350	980	40	100	1230
	2	KOCP-II	2760	620	80	160	1900
Manuguru	1	PK OC- II	5784	1349	0	10	4425
	2	PK OC-IV	2929	1670	0	10	1249
	3	Kondapur UG	703	5	0	0	698
	4	MNG OCP	2929	1670	0	10	1249
Kothagudem/ (Chuchupally)	1	GKOCP	5670	600	0	0	5070
	2	PVK- 5 Incline	11800	2000	5000	3300	1500
Total			34925	8894	5120	3590	17321

The daily pumped water from the mines is used for mine requirement, domestic use and plantation inside the mines. Remaining water is let out into stream. In Yellandu mandal

the let out water from JK-5 OC, Yellandu is being let out into Bugga vagu and the water is being used for irrigation requirement by local communities. The let out water from KPOCP-II, Koyagudem is being letout into Tellavagu cheruvu, lachagudem tank and the water is being meeting the irrigation requirement of local communities.In Manguru mandal**,** the let out water of (PK OC-II and PK OC-IV, Kondapur UG) is being discharged into Gorrepeta vagu and a check dam constructed across which in dip side of PKOC Mine (PK OC-II and PK OC-IV) is feeding waters to tanks viz., 1) Perantala chervu, 2) Peeturuvai cheruvu, 3) Oora cheruvu, 4) Bonthjala kunta, 5) Balamallaiah Kunta and 6) Kummari kunta in Pagideru village. These tanks irrigate an Ayacut area of 902 hectares. The let out water from MNG OCP is being discharged into Peda cheruvu.

In Chuchupally mandal, the let out water from GKOCP is being discharged into Penagadapa and Sitampeta Cheruvu. Through this source about 121 hectares are being irrigated. While the let out water from PVK 5 Incline mine is being discharged into Tella vagu and the water is being used for irrigation requirement by local communities.

4. GROUND WATER RESOURCES (2020)

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. Summarized command/ non-command area and mandal wise resources are given in **Table-4.1 and Annexure-1** respectively.

As per 2020 GEC report, the net dynamic replenishable groundwater availability is 807 MCM, gross ground water draft for all uses 301 MCM provision for drinking and industrial use for the year 2025 is 58 MCM and net annual ground water potential available for future irrigation needs is 514 MCM. Stage of ground water development varies from 8% (Dummagudem mandal) to 88% (Dammapeta mandal).The Awarempeta, Dammapeta, Yellandu, Manuguru, Chuchupalli, Julurpad, Sujathnagar, Kothagudem mandals falls in semi critical category.

Table-4.1: Computed Dynamic, In-storage ground water resources, Bhadradri Kothagudem district.

Parameters	**Total**
As per GEC 2017	MCM
Dynamic (Net GWR Availability)	**807**
• Monsoon recharge from rainfall	623
• Monsoon recharge from other sources	86
• Non-Monsoon recharge from rainfall	87
• Non-monsoon recharge from other sources	92
• Total Natural Discharges (Ham)	82
Gross GW Draft	**301**
• Irrigation	217
• Domestic and Industrial use	84
Provision for Drinking and Industrial use for the year 2025	57
Net GW availability for future irrigation	514
Stage of GW development (%)	37

5. GROUND WATER RELATED ISSUES AND REASONS FOR ISSUES

5.1 Issues

Quality

Few mandals are fluorosis endemic where fluoride (geogenic) as high as 4.09 mg/L during pre-monsoon and 5.76 mg/L during post-monsoon season is found in groundwater. The high fluoride concentration (>1.5 mg/L) occur in 15% and 8 % of the wells during pre-monsoon and post-monsoon season.

High nitrate (> 45 mg/L) due to anthropogenic activities is observed in 36% during pre-monsoon and 35% during post-monsoon season.

Deep water levels

1. Deep water level in the range of > 20 m bgl occupies about 6 % of the area during pre-monsoon season..

2. Sustainability

Low yield (<1 lps) occurs in 6 % of area in the district.

5.2 Reasons for Issues

Geo-genic pollution (Fluoride)

1. 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.
2. Higher residence time of ground water in deeper aquifer.

Anthropogenic pollution (Nitrate)

3. 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.

Deep water levels

4. The deeper water level is observed in part Dammapeta mandal, and part of Aswarompeta mandal, where the Over-extraction for agricultural activities during Rabi season, limited artificial measures etc.

6. MANAGEMENT STRATEGIES

High dependence on groundwater coupled with absence of augmentation measures has led to a fall in water level and desaturation of weathered zone in some parts of the district. The sustainability of existing groundwater structures, food and drinking water security are challenging tasks in the preparation of management plan. Higher NO_3^- 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 groundwater.

6.1 Management plan

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.

In the district 11958 MCM of unstaturated volume (below the depth of 5 m) is avaialable during post-monsoon season, having 238 MCM of recharge potential (2%). This can be utilized for implementing management strategy.

The study suggests notable measures for sustainable groundwater management, which involves a combination of various measures given below.

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

6.1.1 Supply side measures:

Ongoing Projects

6.1.1.1 Repair Renovation and Restoration of existing tanks:

- De-silting of existing 1197 tanks was taken under state Govt. sponsored Mission Kaktiya-Phase-1, Phase-2, Phase-3 and Phase-4 programm and removed nearly 9.16 MCM of silt and this has created additional surface storage. This can contribute nearly ~2.29 MCM of groundwater recharge with this additional ~381 ha land can be brought under irrigated dry (ID) crops in tank ayacut.
- There is need to take remaining tanks (~1199 MI and other small tanks) for de-silting, this will greatly help in stabilisation of tank ayacut and ground water augmentation.

6.1.1.2 Mission Bhagiratha:

- Under Telangana Drinking Water Supply Project (TDWSP) also known as Mission Bhagiratha, All villages are covered under protected drinking water source from surface water (Godavari R) by importing 35.39MCM. It will save the present ~19 MCM of GW and with this additional ~3166 ha land can be brought under ID crops.

To be taken up

6.1.1.3 Artificial Recharge structures:

The area suitable for ground water augmentation through artificial recharge has been demarcated based on the analysis of average post-monsoon depth to water level data of the observation wells for the period of 2011-2020 and the existing data on artificial recharge structures constructed under various schemes of Mahatma Gandhi National Rural Employment Guarantee Scheme (MNREGS) and Integrated Watershed Management Programs (IWMP) by Rural Development department, Govt. of Telangana. 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 m. bgl 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 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 artificial recharge structures by State Govt. departments under different IWMP and MNREGS schemes is deducted to find the available surplus run off for recommending the additional feasible artificial recharge structures.
- 50% of the available surplus runoff is considered for the recommendation of artificial recharge strutcures, as the remaining 50 % is recommended for implementing water conservation measures in recharge areas through MGNREGS.

- The 1825Km^2 area in 111 villages having recharge potential of 238 MCM and Surplus runoff (MCM) of 80.73 MCM.

- 1096 artificial recharge structures (578 CD's and 518 mini PT'in 111 villages) with a total cost of **136** crores can be taken up. (Considering CDS with recharge shafts with 5 fillings with a unit cost of Rs 10 lakhs each and mini PT's with 2 fillings with a unit cost of Rs 15 lakhs each)

    - After effective utilization of this yield, there will be 27.5 MCM of ground water recharge (50 % of total utilizable yield).

Table 6.1 Area Identified for artificial recharge structures

Area Identified for AR (Sq.Km.)	Available Subsurface Space for AR (MCM)	Available Surplus runoff (MCM)	50% of Available Surplus runoff (MCM)	Proposed Numbers of structures		Total volume of water expected to be recharged	
				CD	PT	CD	PT
1962	238	80.73	40.36	578	518	20.23	7.3

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) (NREGA 2005). This will also help in sustainable management of groundwater resources.

- Some of de-silted tanks along river Manjira and river Godavari may be filled up with during lean monsoon period.

6.1.1.4 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 form ponds can be 10 x 10 x 3 m. In the district total 52 farm ponds exist in 5 villages and additional **7540** farm ponds are recommended (20 in each 377 villages) with total cost of **19** crores.

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

6.1.2.1 Ongoing Work

- In the area till date ~4388 ha under ID crops which saved ~7.89 MCM (considering 30% saving) of groundwater from the basin.

6.1.2.2 Proposed Work

- ~3050 ha of additional land that can be brought under micro-irrigation (@50 ha/village in 65 villages) costing about 18.30 crores (considering 1 unit/ha @0.6 lakh/ha). With this 5.5MCM of ground water can be conserved over the traditional irrigation practices (considering 0.006 MCM/ha for ID crops against 0.008 MCM/ha).
    - Change in cropping pattern from water intensive paddy/spices (turmeric) to irrigated dry crops like pulses and oil seeds are recommended, particularly in water stress/Over-exploited/Critical 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 groundwater user should recharge rainwater through artificial recharge structures in proportionate to the extraction.

6.1.3 Other measures

- 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 farmers involved.

- In urban and rural areas the sewerage line should be constructed to arrest leaching of nitrate.

- The other measure includes supplementary calcium and phosphorous rich food to the children in fluoride endemic mandals. Creating awareness about safe drinking water habits, side effects of high fluoride and nitrate rich groundwater, improving oral hygiene conditions are recommended.

6.2 Expected Results and Out come

With the above interventions costing Rs 177 crores (excluding the cost involved in Mission Kakatiya and Mission Bhagiratha), the likely benefit would be the net saving of 82 MCM of ground water.

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