केन्द्रीय 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

Khammam District
Telangana State

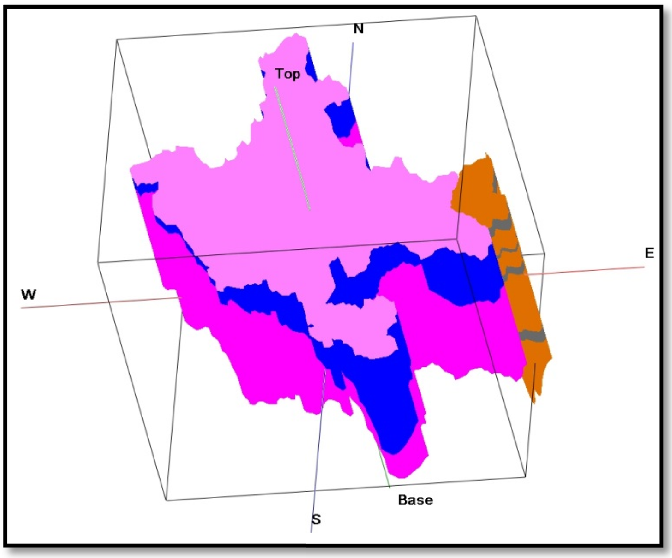
दक्षिणी क्षेत्र, हैदराबाद

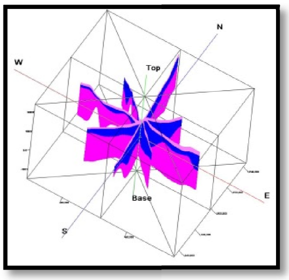
Sourthern Region, Hyderabad

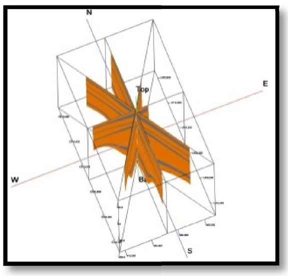
भारत सरकार
जल शक्ति मंत्रालय
जल संसाधन, नदी विकास और गंगा संरक्षण विभाग
केंद्रीय भूमि जल बोर्ड

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

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







CENTRAL GROUND WATER BOARD
SOUTHERN REGION
HYDERABAD
JUNE, 2022

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AQUIFER MAPPING FOR SUSTAINABLE MANAGEMENT OF GROUND WATER RESOURCES IN KHAMMAM DISTRICT, TELANGANA STATE

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AQUIFER MAPPING FOR SUSTAINABLE MANAGEMENT OF GROUND WATER RESOURCES IN KHAMMAM DISTRICT, TELANGANA STATE

Executive summary

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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	:	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 Khammam district having geographical area of 4361 km^2 (mappable area is 4146 km^2) , lies between north latitudes from 16°15'0"N to 17°47'42"N and east longitudes from 79°57'22"E to 80°55'0"E located in the east of Telangana State. Administratively the district is governed by 21 revenue mandals and 380 villages with a population of ~14.01lakhs (2011 census). The density of population in the district is 322.77 per Sq.km.

The majority of district is underlain by oldest Archaean formation and small part by Gondwana formation. About 93% of the area is underlain by Banded Gneissic Complex and 7% area by Sandstones. The basement gneisses and granites constitute the major rock types and found throghout the district. The granites are either biotitic or hornblendic type. A network of the basic dykes of dolerite and epidiorite traverse the granite country. The coal bearing Gondwanas occurring in the district belong to both the lower as well as the upper divisions. The lower Gondwanas include the Talchirs, Barakars, Barren Measures and Kamthis.

Khammam district is characterised by undulating topography with hill ranges, valleys and plains. Pedeplain is the major landform covering about 78% of the area. The other landforms observed are pediment (8%), structural hills (6%), channel Fill (5%), intermontane valleys, channel bar and valley fills The red chalka soils (mostly alfisols and entisols, red and loamy sands, deep, well drained, gravelly clay with low available water content) occupy nearly 49% of the land area while the black clayey soils (vertisols, deep, well drained, gravelly clay with low available water content) occupy about 4.1% of area. The rest of area is covered by Dubba soil .

Out of the total geographical area of 4361 km^2, agriculture and forest are the prominent land use aspects in Khammam district and forms 63.73 % and 11.22 % of total area respectively. The net sown area is 2780.15 km^2 while the gross cropped area is 3850.13 km^2. Paddy is the major crop grown in the district (77%).

The Lankasagar project was constructed across Katlair river, a tributary of Krishna River which is situated near Adavimallela village of Penuballi mandal in Khammam District. It provides ayacut of 7350 Acres in Penuballi and Vemsoor Mandal of Khammam District. The Wyra medium irrigation project was constructed across the Wyra river. This Project was constructed to irrigate an ayacut of 17390 Ha benefiting Wyra, Thallada and Bonakal mandals of Khammam district. The ongoing Bhaktha Ramadasu Lift Irrigation Scheme (For Khammam district) have irrigation potential of 57738 acres. This Project provides irrigation facilities to Marripeda mandal of Mahabubbad district, Thirumalayapalem, Kusumanchi, Nelakondapalli, Khammam rural and Mudigonda m andals of Khammam district. In the district there are of 1,637 minor irrigation tanks, 63,400 irrigation wells (32,006 dugwells and 31,394 borewells), ~810 percolation tanks and 81 check dams exist.

Water level is monitored through 58 groundwater monitoring stations of both CGWB and SGWD (CGWB:19, SGWD: 39) during pre and post-monsoon season. The pre-monsoon depth to water levels ranged between 1.94 m bgl (Bodulabanda) and 32.80 m bgl (Prakashnagar). The post-monsoon depth to water levels ranges between 0.41 m bgl (Banapuram) and 30.01 m bgl (Prakashnagar). The water table elevation ranges from 45 to 170 m amsl during pre-monsoon period and 48 to 174 m amsl during post-monosoon period. The groundwater flow is mainly towards southern direction.

100% (58 no's) of the wells show rise in water level and no wells show fall in water level. The analysis of water level fluctuation data indicates that minimum water level fluctuation was observed at Jakkapally (0.65 m) while maximum water level fluctuation was observed at Lankapalli (8.20 m). Rise in water level range of 0 to 5 m cover majority of area with 78%, followed by 5 to 10 m covering 22% of area in parts of Singareni, Kamapalli, Vemsoor, Madhira and Yerupalem mandal.

Trend analysis for the last 10 years (2011-2020) is studied from 32 hydrograph station (CGWB:17, SGWD:15). The decadal pre-monsoon water level trend analysis indicates that 18 wells show falling trend (>1.0 m: 2, 0-0.5 m: 16 wells) (max fall: 1.33 m/yr) and 14 wells show rising trend (0-0.5: 14 wells) (max rise: 0.52 m/yr). During post-monsoon season 10 wells show falling trend ((>1.0 m: 1, 0-0.5m: 9) (maximum fall: 1.19 m/Yr) and 22 wells shows rising trends (0-0.5 m: 3, 0.5-1.0 m: 19 wells) (max rise: 0.76 m/yr)..

On the basis of occurrence and movement of ground water, rock units of the Khammam district can be broadly classified into two categories: consolidated formation (Archean crystalline and metasedimentary formation) which occupies 93% of the area and semi-consolidated to unconsolidated formation (Sedimentary rock) which occupies 7 % of the area.

In consolidated formations, weathered zone forms the unconfined aquifer. The weathered zone (~28.7 m) consisting of upper saprolite and lower sap rock . Thickness of weathered zone is in the range of 10-20 m in about ~65 % of area, shallow weathering (< 10 m) occurs in 22 % while deep weathering (> 20 m) is seen only in 13% of the area The depth of fracturing varies from 3 m to 184 m (deepest fracture encountered at Adasarlapadu). Ground water yield from fractured granite/gneiss varies from <0.01 to 9.86 lps. The transmissivity varies from 1.50-212 m^2/day and storativity varies from 0.000001 to 0.001

Semiconsolidated formations, which consists of sandstones, shales and clays that makes a thick sequence of sediments. Multiple aquifer systems (1 to 5 aquifers) are found in the sandstone formations with intervening clay beds. The first aquifer is unconfined whereas the deeper aquifers are in semi-confined/ confined condition.Depth of aquifers are decided based on the depth of bottom clay layers. The thickness of Aquifer-I varies from 10-13m. The unconfined zone extend from bottom of the soil layer to top of the first clay layer. Unlike Aquifer-I, ground water occurs under confined to semi-confined condition in Aquifer-II to IV. The deeper aquifers identified upto a depth of 300m. Ground water yield of sandstone aquifers varies from <1 to 18 lps .The transmissivity varies from 146.99 - 570.32 m^2/day and storativity varies from 2.04 x 10^{-4} to 5.50 x 10^{-4}.

Total 235 ground water samples (Pre-monsoon:125 and Post-monsoon:110) were analysed for understanding groundwater quality of the district. In 88 % and 86 % of area EC is in the range of < 3000 μ Siemens/cm during pre and post-monsoon season respectively. During pre-monsoon season, concentration of NO_3 ranges from 0.22-1306 mg/L and found that in 60 % of samples nitrate is beyond maximum permissible limit of BIS (45 mg/l) and F concentration varies from 0.20-4.64 mg/l and found that in 22% samples it is beyond maximum permissible limits of BIS (1.5 mg/l). During post-monsoon season, concentration of NO_3 ranges from 0.40-868.08 mg/L and found that in 54% of samples it is beyond maximum permissible limit of BIS (45 mg/l). The F concentration varies from 0.22-3.44mg/l and found that in 18% it is beyond maximum permissible limit of BIS.

Net dynamic replenishable ground water availability is 1036.51MCM, gross ground water draft is 412.40 MCM, provision for drinking and industrial use for the year 2025 is 53.63 MCM and net available balance for future irrigation use is 605.48 MCM. The stage of ground water development is 39.72 % .

Major issues identified are low ground water potential (< 1 lps) in some 49% of area particularly in consolidated granitic formation, high fluoride concentration (>1.5 mg/L) occur in 22 % and 18 % of the samples during pre and post-monsoon season, high EC concentration (> 3000 micro-seimens/cm) in 12 % and 14% of the area during pre-monsoon and post-monsoon seasons respectively, High nitrate (> 45 mg/L) occur in 60 % and 54 % of the samples during pre-monsoon and post-monsoon season respectively.

The overall groundwater scenario and regime of the district is good except a minor quality issues and few areas of low groundwater potentiality. However, considering the dependency on groundwater and further to maintain the sustainability, few supply side and demand side measures have been recommended. In the granitic area, the artificial recharge structures recommended to improve the overall sustainability and recharge the Aquifer-I which is mainly of weathering part. The sandstone aquifers though potential, the groundwater occurs at depths, which requires high input costs in tubewell drilling and expertise to tap potential zones in Aquifer-II to Aquifer-IV. It is imperative to recommend few artificial recharge structures under supply side to recharge Aquifer-I of Sandstone which is mainly unconfined.

The management strategies mainly include supply side management. The supply side measure includes ongoing work under Mission Kakatiya where de-silting of existing minor tanks (871 no.) was taken under state Govt. sponsored Mission Kaktiya (Phase-1 to 4) to remove silt and this has created additional surface storage and enhance groundwater recharge.

Under Mission Bhagiratha, there is plan to import ~131.67 MCM of water for drinking purposes which will save the present ~79 MCM of water for drinking and domestic purposes and with this additional ~13166.66 ha of land can be brought under ID crops.

As the stage of ground water development in the district is 39.78 % and 16 out of 21 mandals are falling in safe category as per the GEC 2020 estimation, the artificial recharge structures are not proposed for entire district.

To control further increase in stage of ground water development, artificial recharge structures are recommended in 5 semi-critical mandals (i.e., Penuballi, Raghunadhapalem, Sathupalli, Singareni, Thirumalayapalem) and 1 critical mandal (i.e, Vemsoor) only which includes construction of 721 artificial recharge structures (447 CD's and 274 PT's) with a total cost of 128.50cores are recommended as supply side measures. ~2618.82 ha of additional land that can be brought under micro-irrigation (@1000 ha /mandal including existing area in 5 semi-critical mandals (i.e., Penuballi, Raghunadhapalem, Sathupalli, Singareni, Thirumalayapalem) and 1 critical mandal (i.e, Vemsoor) costing about 15.71 crores (considering 1 unit/ha @0.6 lakh/ha). With this 3.93 MCM of ground water can be conserved over the traditional irrigation practices.

In addition to this roof top rainwater harvesting structures should be made mandatory to all Government buildings.

Other measure includes strict implementation of WALTA and participatory groundwater management (PGWM). With the above interventions, the likely benefit would be the net saving of 29.52 MCM of ground water, which can bring down the stage of ground water development by 1 % (from 32 % to 31 %).

1. INTRODUCTION

National Aquifer Mapping (NAQUIM) had been taken up by CGWB to create robust database of hydrogeological information at 1:50,000 scale for sustainable groundwater. Aquifer mapping is a multidisciplinary and a holistic scientific approach wherein a combination of geological, geophysical, hydrological and chemical analysis is applied to characterize the quantity, quality and sustainability of groundwater in aquifers. It had been taken up by CGWB to carry out detailed hydrogeological investigation on toposheet scale of 1:50,000. The vagaries of rainfall, inherent heterogeneity and unsustainable nature of hard rock aquifers, over exploitation of aquifers, insufficient regulation mechanism has a detrimental effect on groundwater scenario of the country in last decade or so. Thus, prompting the paradigm shift from "**traditional groundwater development concept**" to "**modern groundwater management concept**".

Varied and diverse hydrogeological settings demand precise and comprehensive mapping of aquifers down to the optimum possible depth at appropriate scale to arrive at the robust and implementable groundwater management plans. The proposed management plans will provide necessary inputs and recomendations for ensuring sustainable management of groundwater resources of district. The aquifer maps and management plans will be shared with the Administration of Khammam district, TS for its effective implementation.

1.1 Objective and Scope

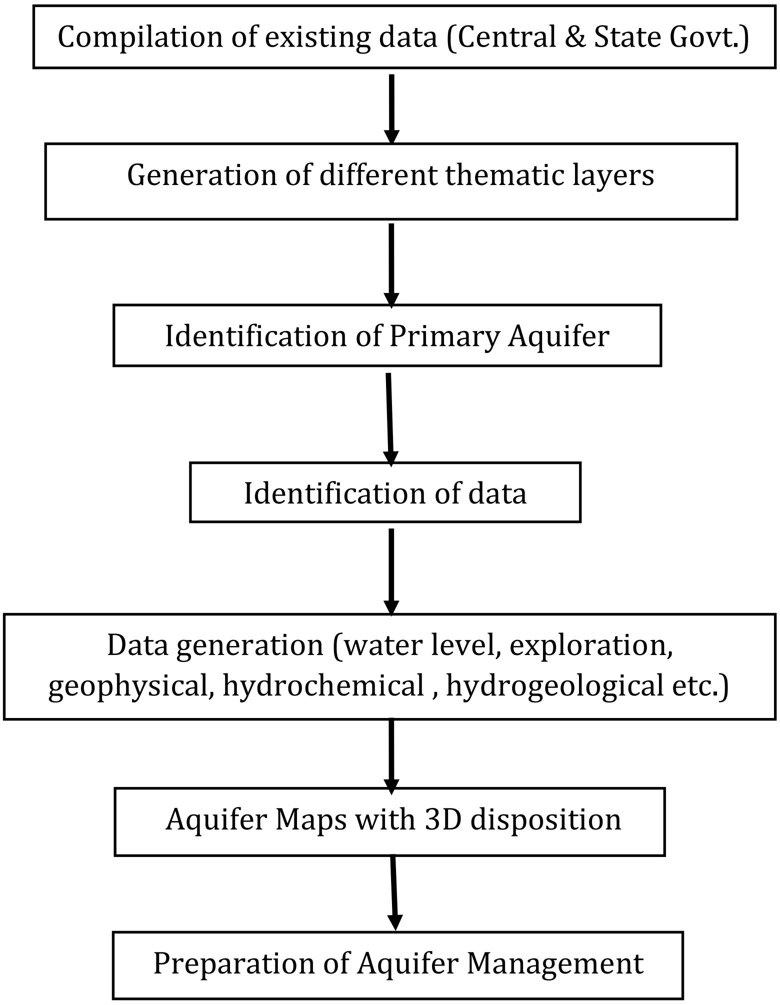
An integrated hydrogeological study was taken up to develop a reliable and comprehensive aquifer map and to suggest suitable groundwater management plan on 1: 50,000 scale. The activities under NAQUIM are aimed at:

- Identifying the aquifer geometry
- Aquifer characteristics and their yield potential
- Groundwater quality
- Aquifer wise assessment of groundwater resources
- Preparation of aquifer maps in 3D and 2D
- Formulate groundwater management plan

1.2 Approach and Methodology

The ongoing activities of NAQUIM include toposheet wise micro-level hydrogeological data acquisition supported by geophysical and hydro-chemical investigations supplemented with ground water exploration down to the depths of 200- 300 meters.

Considering the objectives of the NAQUIM, the data on various components was segregated, collected and brought on GIS platform by geo-referencing the available information for its utilization for preparation of various thematic maps. The approach and methodology followed for Aquifer mapping is as given below:



1.3 Study area

The Khammam district having geographical area of 4361 km^2 (mappable area 4146 km^2) , lies between north latitudes from 16°15'0"N to 17°47'42"N and east longitudes from 79°57'22"E to 80°55'0"E located in the east of Telangana State. The location map of the study area is presented in **Fig.1.1**. The District shares boundaries with (03) Districts i.e., Bhadradri Kothagudem in Eastern side, Mahabubabad in North West side, Suryapet Districts in South-West direction in Telangana State and Krishna, West Godavari Districts in Southeastern side of Andhra Pradhesh State. The District headquarters is located at Khammam Town which is located on the Bank of the Munneru River one of the tributaries to the River Krishna. Administratively the district is governed by 21 revenue mandals and 380 villages with a population of ~**14.01** lakhs (2011 census). The density of population in the district is 322.77 per Sq.km.

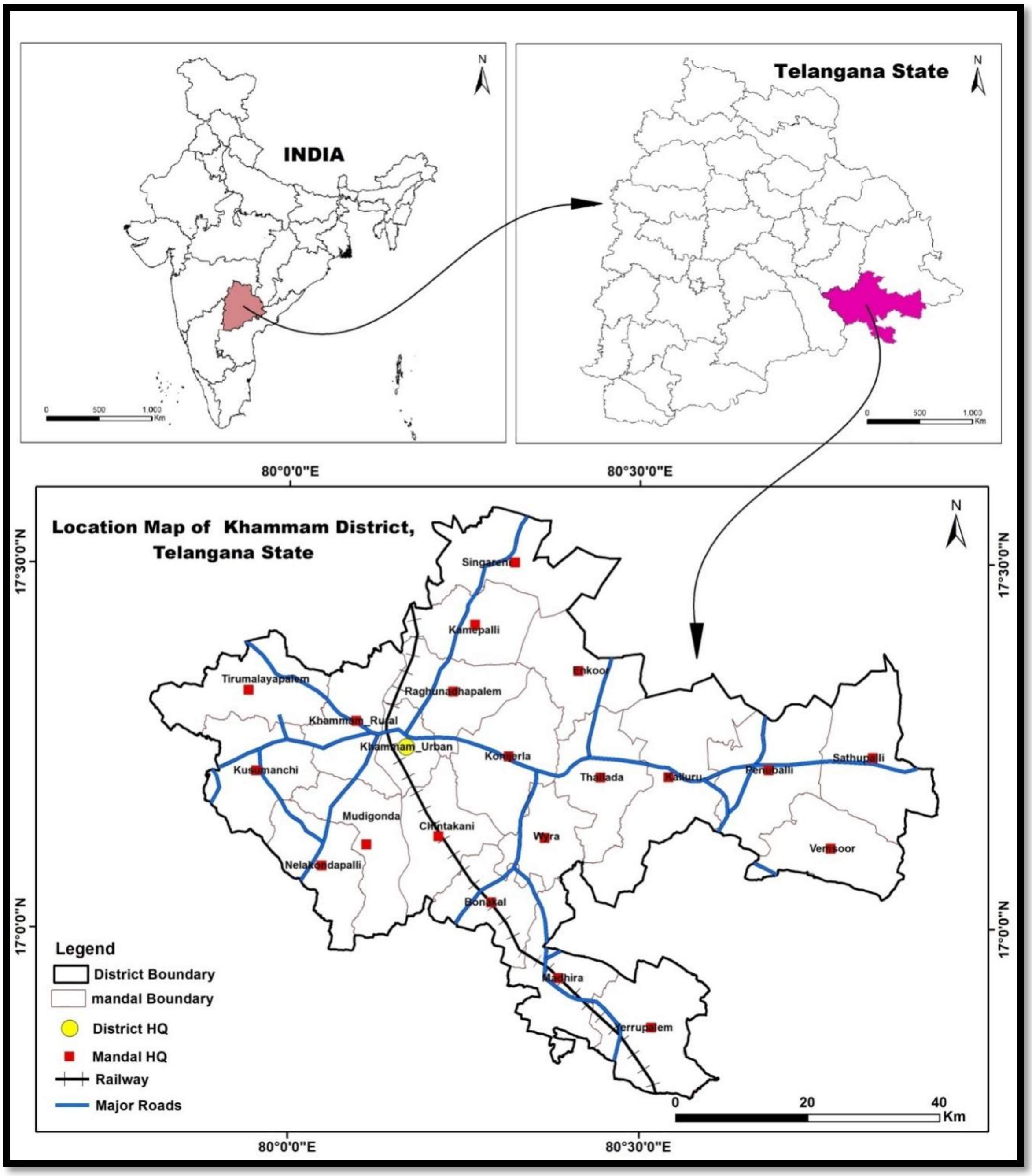


Fig.1.1: Location map of Khammam district.

1.4 Climate and Rainfall

The climate of the district is characterised by hot summer and cool winters with a fairly good amount of seasonal rainfall. The normal mean daily minimum and maximum temperature is 7.6 °C and 48.7 °C. The annual normal rainfall of Khammam district is 1036 mm, which ranges from 969.8 mm at Madhira Mandal to 1160.3 mm at Enkuru Mandal. The area receives more than 80 % of the annual rainfall by southwest monsoon between June and September and the rest during the northeast monsoon from October to November. As per Indian Meteorological Department for the year 2021, it received average annual rainfall of 1175.8 mm (11.89 % more rainfall than normal rainfall). The isohyetal map of the study area is presented in **Fig.1.2a.**

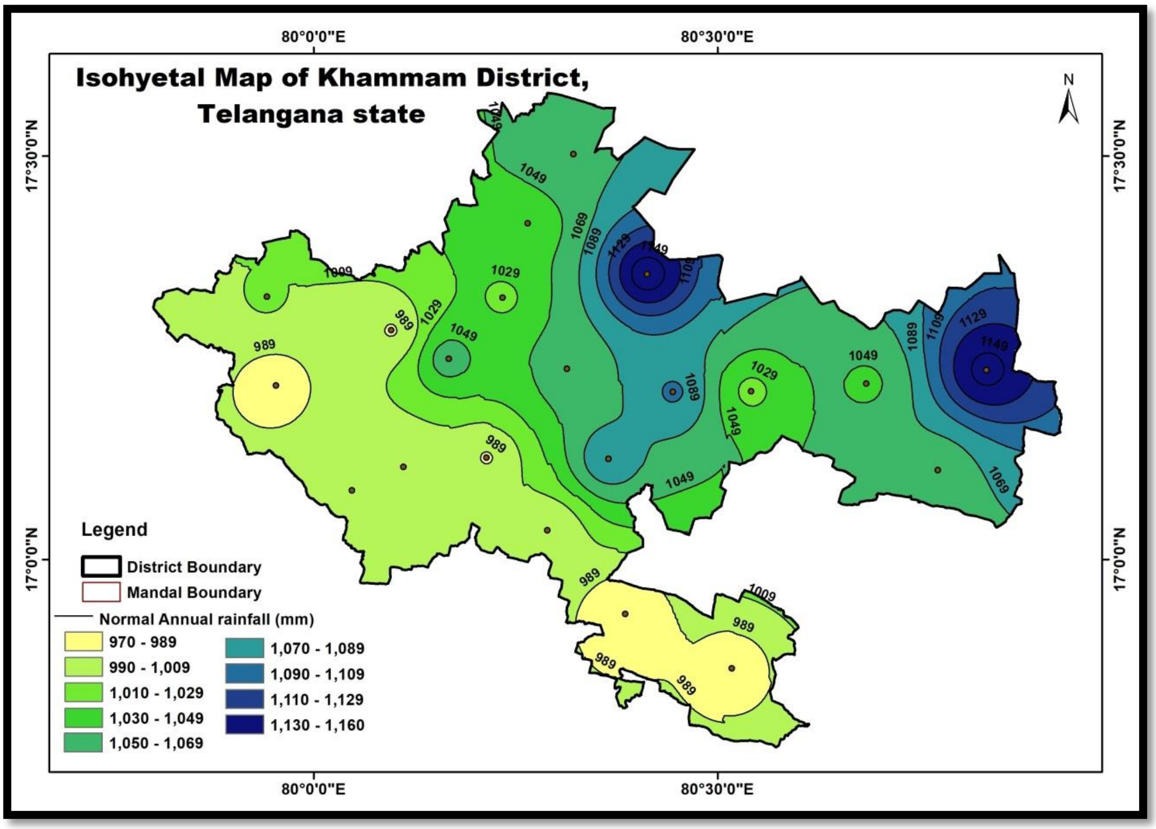


Fig.1.2a: Isohyetal map of Khammam district.

Analysis of long term rainfall data of 17 years from 2005 to 2021 shows decreasing trend in annual rainfall by 7.27 mm/year. District received excess rainfall (+20% and above normal) in 2005, 2008, 2010, 2012 and 2020, deficient rainfall (-20% and below normal) in 2009, 2011 and 2014 and normal rainfall (-19% to +19%) in remaining years (**Fig.1.2b)**. The monthly rainfall time series analysis for 17 years from 2005 to 2021 shows increasing trend in monthly rainfall for January, June, July and December months (0.24, 4.41, 2.67 & 0.25 mm/Year respectively) and decreasing trend for February, March , April, May, September, October, November (-0.67, -2.25, -0.72, -0.11, -7.14, -1.93, -1.29 mm/year) (**Fig. 1.2c**).

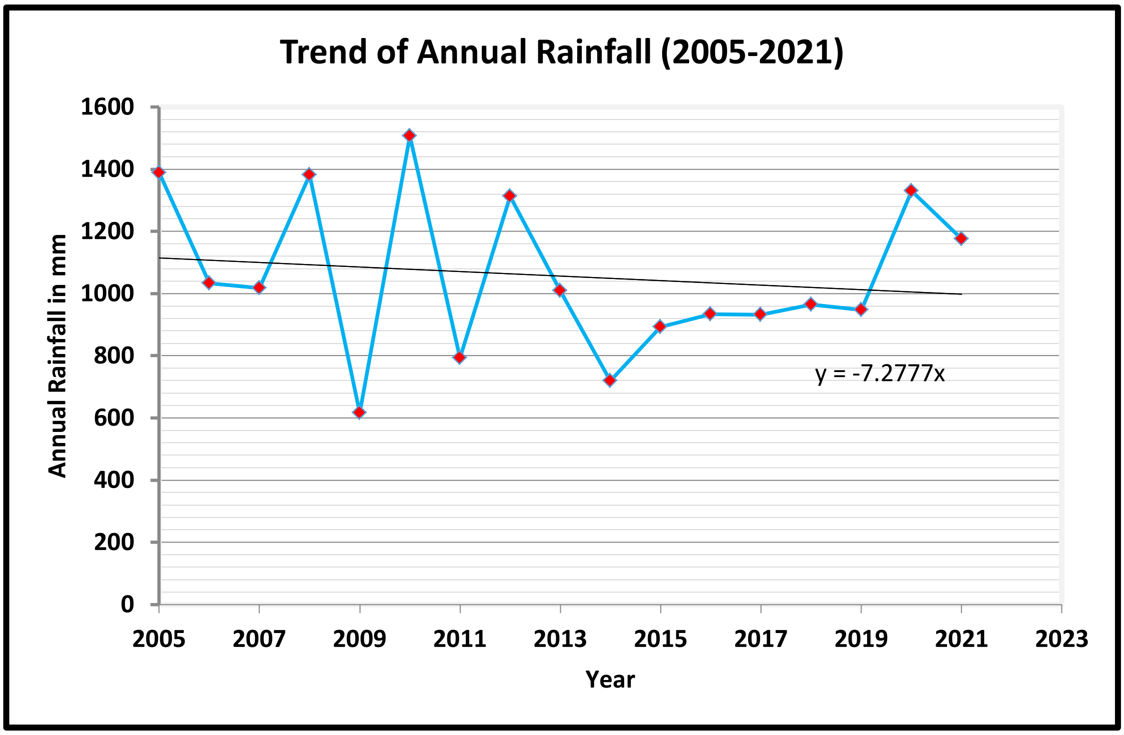


Fig.1.2b: Annual rainfall trend (2005-2021)

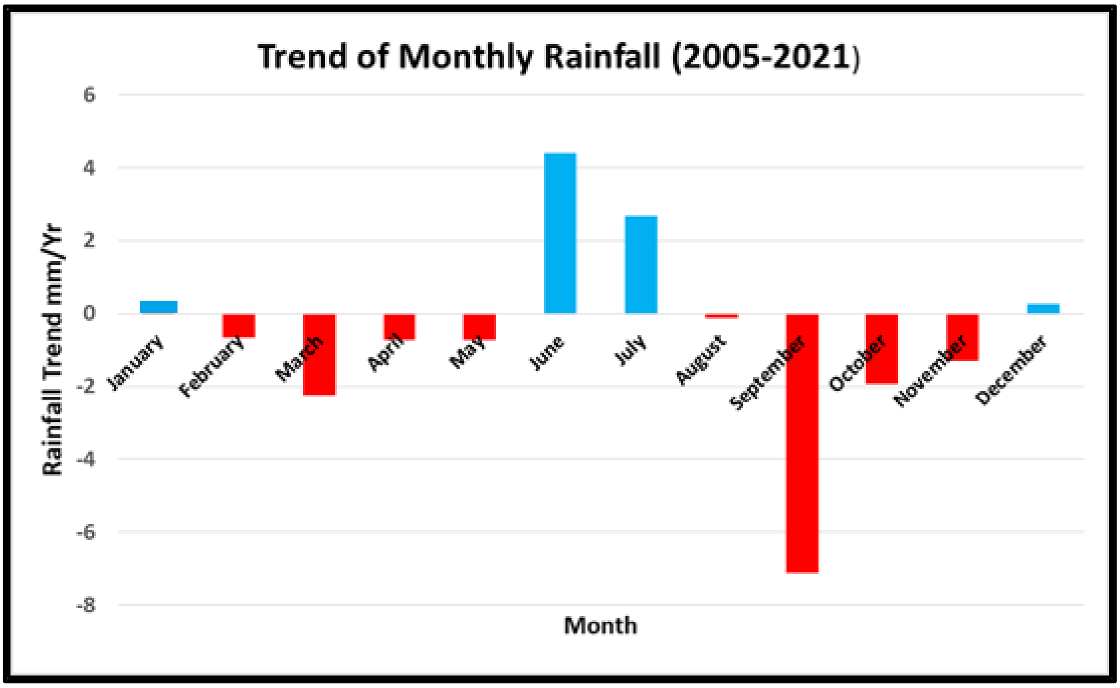


Fig.1.2c: Monthly rainfall trend (2005-2021)

1.5 Geomorphological Set up

Khammam district is characterised by undulating topography with hill ranges, valleys and plains. Pedeplain is the major landform covering about 78% of the area. The other landforms observed are pediment (8%), structural hills (6%), channel Fill (5%), intermontane valleys, channel bar and valley fills .The geomorphology map of the study area is presented in **Fig.1.3**.

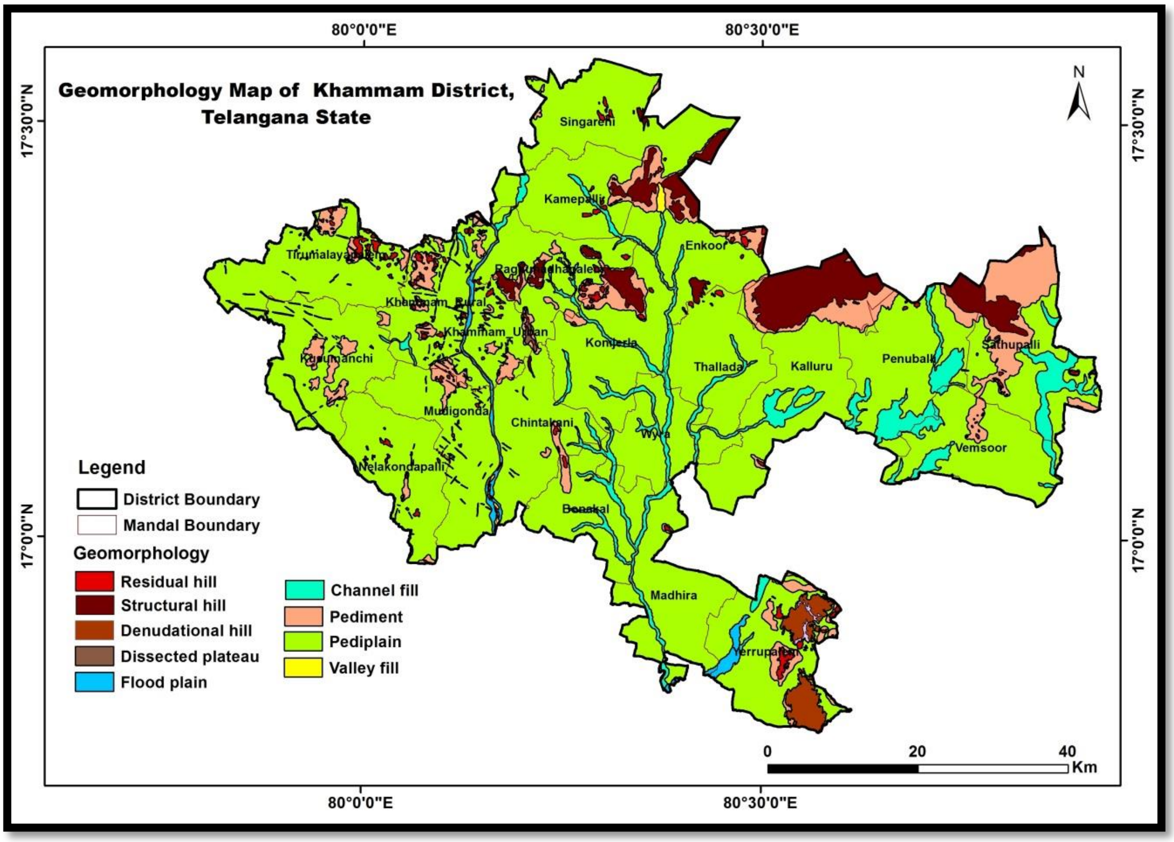


Fig.1.3: Geomorphology map of Khammam district.

1.6 Drainage and Structures

The area surveyed forms a part of Krishna river basin and Muneru, Paler sub basins. The western part of the district is drained by tributaries of Krishna River. The river Muneru rising in the Warangal district flows Southwards passing through Kothagudem and Khammam revenue divisions. The river Akeru, which also rises in Warangal district, flows in the Southeastern direction and joins the Muneru at Tirthala village. The river Paleru flows almost parallel to Munneru and passes through Kakaravai village of Tirumalayapalem. The Wyra river flows in a southerly direction in Madhira mandal to join the paler river in Krishna district. The drainage pattern in the area is dendritic to sub-dendritic in nature. Map depicting drainage, water bodies, and river is presented in **Fig.1.4.**

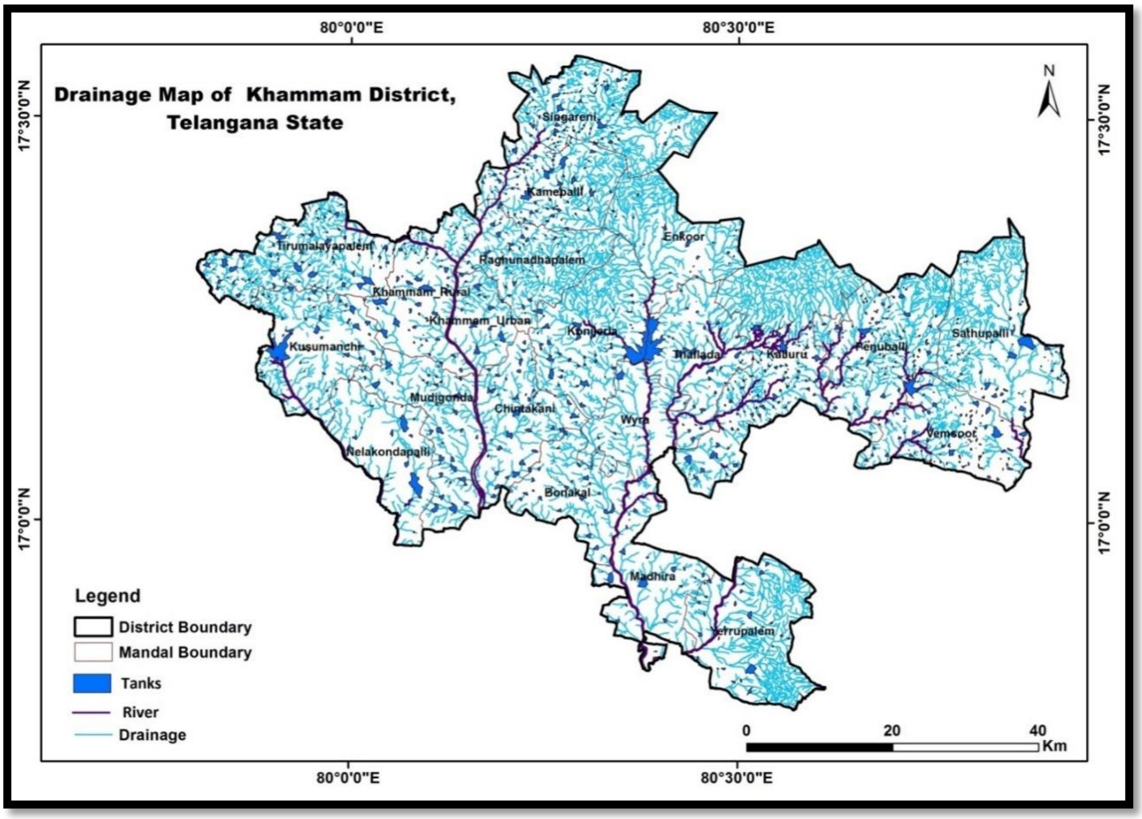


Fig.1.4: Drainage map of Khammam district

1.7 Land use and cropping pattern

Out of the total geographical area of 4361 km^2, agriculture and forest are the prominent land use aspects in Khammam district and forms 63.73 % and 11.22 % of total area respectively. The spatial distribution of land use is presented in **Fig. 1.5.**

The land utilization of Khammam district is given in Table 1.1 and crop distribution is given in table 1.2.

Table: 1.1 Land utilisation in Khammam District

Land Utilisation	Area (in Sq.Km)	%age to Geographical Area
Forest	489.66	11.22 %
Barren and Uncultivable	226.62	5.19 %
Land put to Non-Agricultural uses	477.52	10.95 %
Culturable Waste	20.23	0.46 %
Permanent pasture and Other Grazing lands	64.74	1.48 %
Land under Miscellaneous Tree, Crops, Grovers (Not included in Net Sown Area)	113.31	2.6 %
Current Fallow Land	169.96	3.9 %
Other Fallow Land	20.23	0.46 %

Net Area sown	2780.15	63.73 %
Total Geographical Area	**4361**	**100 %**

The net sown area is 2780.15 km^2 while the gross cropped area is 3850.13 km^2. There are wide varieties of crops grown in the district. Paddy is the major crop grown in the district (77%). Among various crops grown, the climate is most favourable for Maize, pulses and chillies. Other crops grown here include maize, jowar, bajra, red gram, green gram, horse gram, bengal gram, cowpea, ground nut, sesam, cantor, sunflower, chillies, sugarcane and tobacco. Wide range of Horticulture crops like Mango, Banana, Cashew, coconut, palm oil, cocoa, Pepper, Arecanut are also grown.

Table: 1.2 Crop distribution in Khammam district

Crops	Area (Sq.Km)
Cereals and Millets	
Rice	1742.88
Jowar	2.84
Maize	406.23
Total	**2151.97**
Pulses	
Bengal gram	0.10
Red gram	6.72
Green gram	84.13
Black gram	1.84
Horse gram	0
Cow gram	0.65
Other Pulses	0
Total	**93.46**
Total Foodgrains	**2245.43**

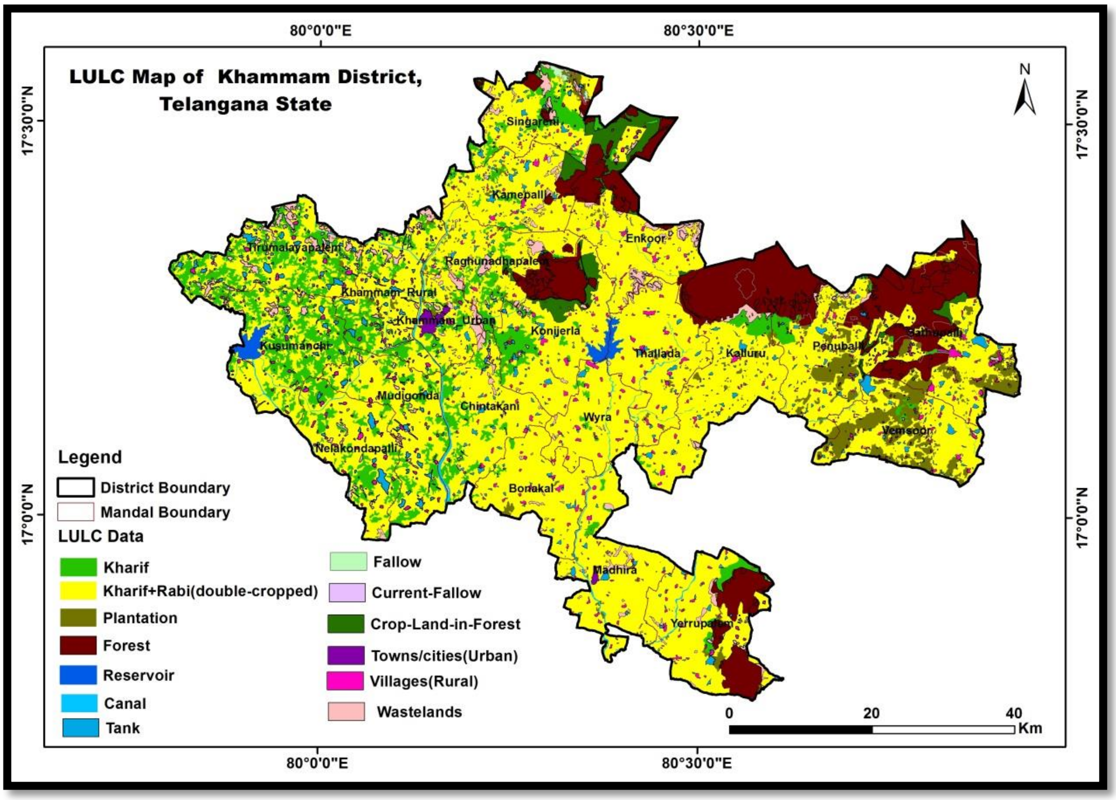


Fig.1.5: Land use and land cover of Khammam district.

1.8 Soils

Khammam district is endowed with a wide variety of soils ranging from less fertile fine mixed (locally called as Dubba soil) to the highly fertile and productive, red and black soils derived from different pedological environments. The red chalka soils (loamy soil, deep, well drained, low available water content) occupy nearly 49% of the land area while the black clayey soils (clayey soil, deep, well drained, low available water content) occupy about 4.1% of area. The rest of area is covered by Dubba soil (Fine mixed soil). The red soils are generally non-saline, non-alkaline and well drained. The black soils are predominant in Madhira and Burugumpadu areas. They are also found as narrow belts on either side of Muneru, Wyra and Katleru. The black soils are very deep and more fertile than the red soils.

The Chalka and Dubba soils are suitable for cultivation of paddy, sugarcane and other wet crops and all dry crops under rainfed and irrigated dry (ID) conditions. As these soils are usually found deficient in nitrogen and phosphrous content, the application of super phosphate as basal dressing and optimum doses of nitrogeneous fertilisers at frequent intervals is recommended for higher yields of crops. The black soils being calcareous, require the application of super phosphate. These soils are particularly suitable for the cultivation of paddy and sugarcane with a provision of surface drains and also rabi dry crops under rainfed conditions (**Fig.1.7**).

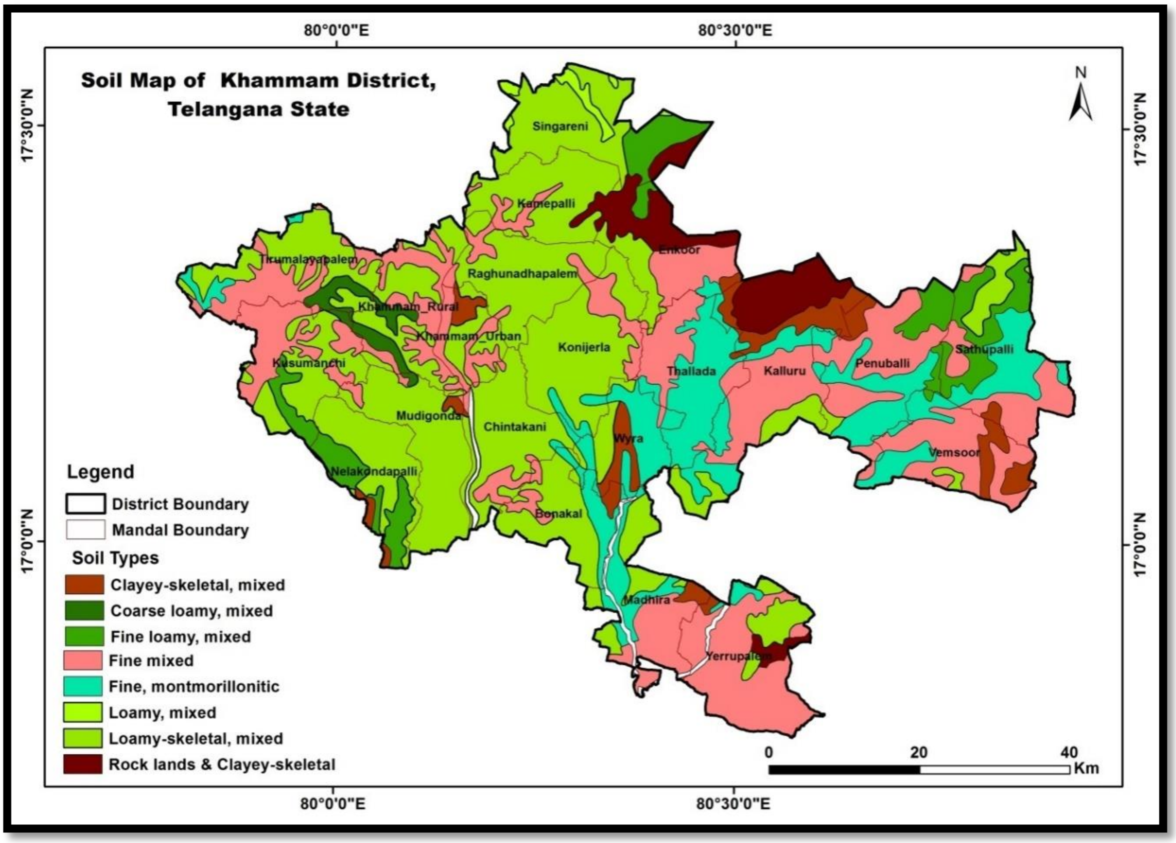


Fig.1.7: Soil map of Khammam district

1.9 Irrigation

Medium Irrigation Projects:

Table: 1.3 Medium Irrigation Project

Name of the Project	IP Irrigation Project) (in Acres)
Wyra Medium Irrigation Project	17390
Lanka Sagar Medium Irrigation Project	7350
Total	**24740**

The Lankasagar project was constructed across Katlair river, a tributary of Krishna River which is situated near Adavimallela Village of Penuballi mandal in Khammam District. It provides ayacut of 7350 Acres in Penuballi and Vemsoor Mandal of Khammam District.

The Wyra medium irrigation project was constructed across the Wyra river. This Project was constructed to irrigate an ayacut of 17390 Ha benefiting Wyra, Thallada and Bonakal mandals of Khammam district. **(Fig 1.8, Table: 1.3).**

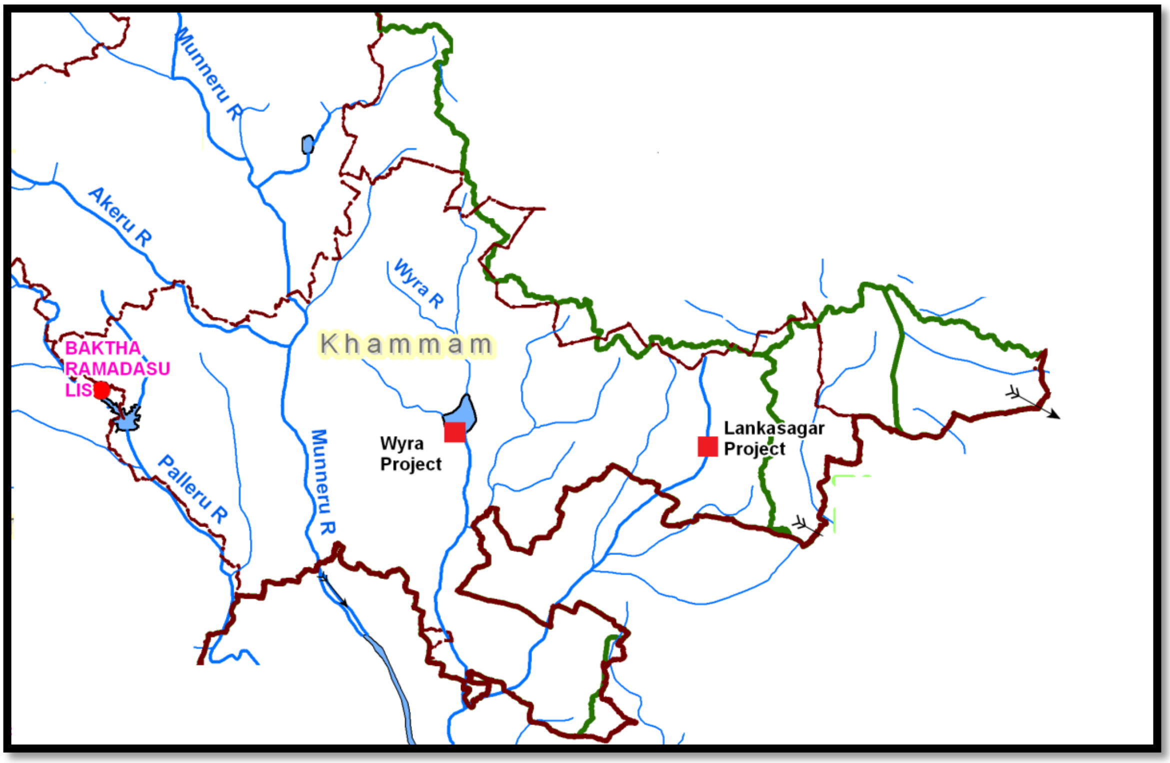


Fig. 1.8 Irrigation project in Khammam district
(Source: https://irrigation.telangana.gov.in/icad/projects)

Lift Irrigation Schemes:

Table: 1.4 Lift Irrigation Scheme

Name of the Project	Irrigation Potential Created (in Acres)
Bhaktha Ramadasu Lift Irrigation Scheme (For Khammam district)	57738

Table: 1.5: Lift Irrigation Scheme distribution in different mandals of Khammam district

Mandal	Ayacut in Acres
Tirumalayapalem	16286
Kusumanchi	23448
Nelakondapalli	2959
Khammam	12605
Mudigonda	2440

This is a major lift irrigation project which provides irrigation facilities to the areas not covered by the Nagarjuna Sagar project left canal. The water is lifted from the Palair balancing reservoir which is on the left main canal of Nagarjuna Sagar project. It lifts 5.5TMC of water from Palair balancing reservoir from an elevation of +128.00 to +187.00 with 2 No.of Pumps each having 275 Cusecs discharge. This Project provides irrigation facilities to Marripeda mandal of Mahabubbad district, Thirumalayapalem, Kusumanchi, Nelakondapalli, Khammam rural and Mudigonda Mandals of Khammam district **(Fig 1.8, Table: 1.4,1.5).**

Minor Irrigation Tanks:

A total of 1,637 minor irrigation tanks exist in the district with an ayacut of 90,117 acres. In the district there are 63,400 irrigation wells (32,006 dugwells and 31,394 tubewells). (Source: Telangana state statistical abstract-2020).

1.10 Prevailing Water Conservation/Recharge Practices

In the district there exists 810 percolation tanks and 81 check dams. Under Mission Kakatiya (Phase 1 to 4), 871 tanks have been undertaken under RRR (Repairs, restoration and Rejuvenation) schemes.

1.11 Geology

The majority of district is underlain by oldest Archaean formation and small part by Gondwana formation. The general geological succession of the area is presented in the **Table-1.6.** About 93% of the area is underlain by Banded Gneissic Complex and 7% area by Sandstones (**Fig1.8**).

Table-1.6: Stratigraphic Succession of Khammam district

Era	Period	Group	Formation	Lithological Description
Mesozoic	Jurassic to Upper Carboniferous	Upper Gondwanas	Chikkialas Kota Maleris	Sandstone, Clay, Grit and Limestone
		Lower Gondwanas	Kamthis Barren Measures Barakars Talchirs	Sandstones, Shales and Clays, Coal seams and boulder beds
Unconformity				
Azoic	Archaeans	Archaeans		Granites and Gneisses

The basement gneisses and granites constitute the major rock types and found throghout the district. The granites are either biotitic or hornblendic type. Veins of quartz and pegmatite traverse through most of the Archaean rocks and Pakhals. A network of the basic dykes of dolerite and epidiorite traverse the granite country. The coal bearing Gondwanas occurring in the district belong to both the lower as well as the upper divisions. The lower Gondwanas include the Talchirs, Barakars, Barren Measures and Kamthis. The Talchirs comprise boulder beds, sandstones and shales. The boulder beds contain, boulders, cobbles and pebbles of different rocks of the Archaean and cemented in arenaceous matrix. The sandstones are brown in colour, medium to coarse grained and feldspathic.

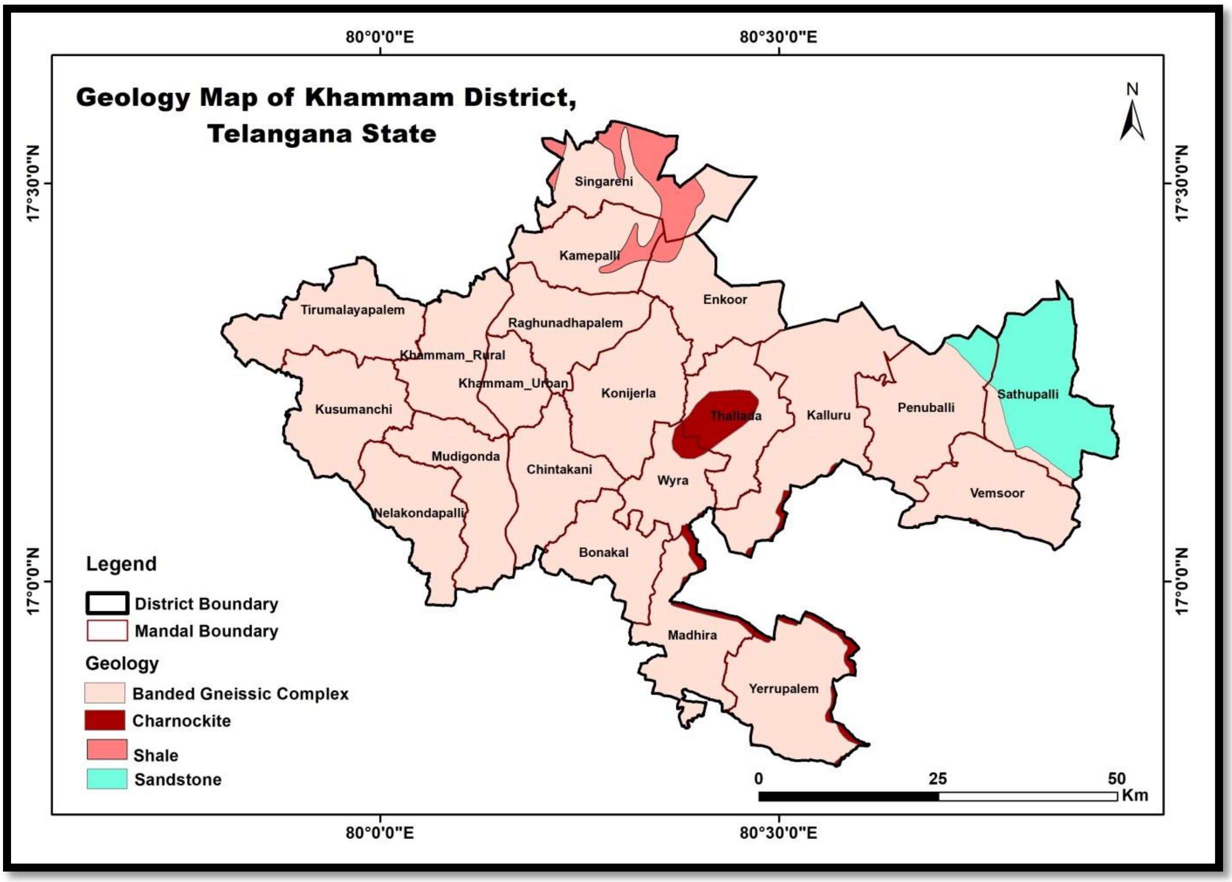


Fig.1.8: Geology map of Khammam district.

2. DATA COLLECTION AND GENERATION

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

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

S. No.	Activity	Sub-activity	Task
1	Compilation of existing data/ Identification of Principal Aquifer Units and Data Gap	Compilation of Existing data on groundwater	Preparation of base map and various thematic layers, compilation of information on Hydrology, Geology, Geophysics, Hydrogeology and Geo-chemical. Creation of data base of Exploration Wells, delineation of Principal aquifers (vertical and lateral) and compilation of Aquifer wise water level and draft data.
		Identification of Data Gap	Data gap in 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.
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 data generation	Vertical Electrical Sounding (VES), bore-hole logging, 2-D imaging.
		Hydrological Parameters on groundwater recharge	Soil infiltration studies, rainfall data analysis, canal flow and recharge structures.
		Preparation of Hydrogeological map (1:50, 000 scale)	Water level monitoring, exploratory drilling, pumping tests, preparation of sub-surface hydrogeological sections.
		Generation of additional water quality parameters	Analysis of groundwater for general parameters including fluoride.
3.	Aquifer Map Preparation (1:50,000 scale)	Analysis of data and preparation of GIS layers and preparation of aquifer maps	Integration of Hydrogeological, Geophysical, Geological and Hydro-chemical data.
4.	Aquifer Management Plan	Preparation of aquifer management plan	Information on aquifer and dissemination 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 by utilising the data generated through various hydro geological, exploration, surface and subsurface geophysical studies in the district. The data used for the integration and interpretation are explained in the following sections:

2.1 Ground Water Exploration

CGWB had constructed 95 bore wells at different depths in the Khammam district (Table 2.2). Out of these, 4 EW were drilled in semi-consolidated/unconsolidated formation and 91 were drilled in consolidated formation. Data analysed from CGWB wells indicates that 5 well of shallow depth (<30 m), 34 nos in the range of 30 to 100 m, 5 nos in the range of 100-150 m, and 49 nos in the range of 150-200 m depth. Deepest fracture was encountered at 184 m.bgl at Adsarlapadu in consolidated granitic formation. The locations of exploratory wells are shown in **Fig. 2.1**.

Table-2.2: Ground Water Exploration wells

Source	Exploratory wells	Observation wells
CGWB	76	19

2.2 Ground Water Monitoring Wells

Groundwater level monitoring wells of CGWB(19 nos.) and SGWD(39 nos.) were utilized for the Aquifer mapping studies. Inorder to understand the groundwater level trend, current and historical water levels along with water level trend data for pre-monsoon and post-monsoon season of 32 borewells (CGWB: 17, SGWD: 15) has been used**.** 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.The data is given in **Table-2.3** and locations of monitoring wells are shown in **Fig. 2.1.**

Table-2.3: Ground Monitoring wells

Source	**No. of wells**
CGWB	19
SGWD	39
Total	**58**

2.3 Ground Water Quality

To understand chemical nature of groundwater, 125 (CGWB: 15, SGWD: 110) and 110 (SGWD: 110) water quality data for pre-monsoon season and post-monsoon season rexspectively were utilized in the analysis (**Table 2.4**.) . 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 and locations of monitoring wells are shown in **Fig. 2.1.**

Table-2.4: Ground Water Sampling wells

Source	Pre-monsoon	Post-monsoon
CGWB	15	-
SGWD	110	110

2.4 Geophysical Studies

Geophysical data on VES and profiling are used to extract information on the weathered thickness, fracture depth and thickness of fractures in 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 128 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 **(Fig. 2.1)**. The data was processed and interpreted by IPI2Win software enveloped by Moscow State University, after marginally modifying the manually interpreted results in corroboration with geology and hydrogeology. The details of resistivity with change for various formations encountered in the district is given in **Table-2.5.**

Table-2.5: Resistivity values for various formations

Formation	**Resistivity range (ohm-m)**	**Thickness (m)**
Weathered granite/Gneiss	5-76	2-25
Fractured/Jointed/Semi-weathered Granite/Gneiss	100-400	30-90
Hard/compact granite/Gneiss	More than 500	

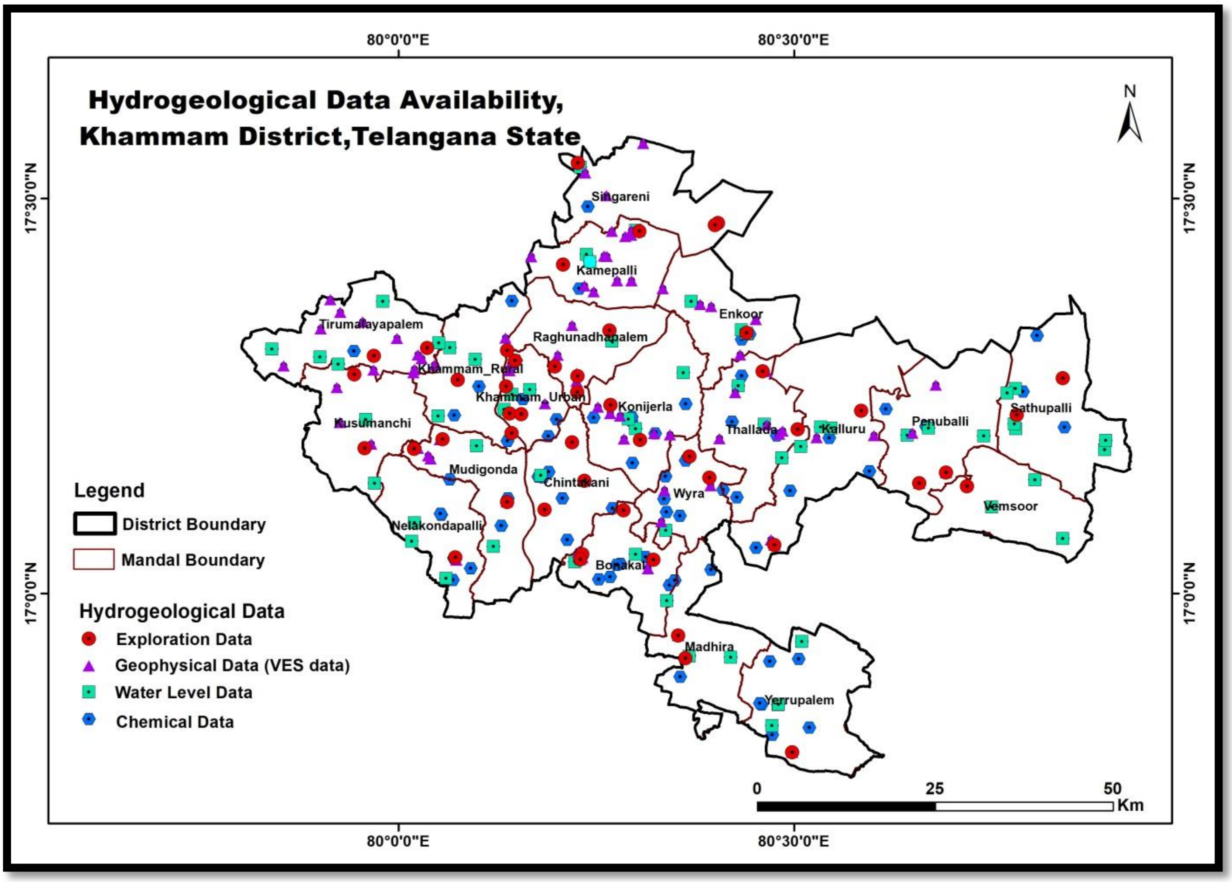


Fig.2.1: Hydrogeological Data availability

3. DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING

The data collected and generated on various parameters viz., water levels, water quality, exploration, aquifer parameters, geophysical, hydrology, hydrometeorology, irrigation was interpreted and integrated. Based on this, various thematic layers such as hydrogeology, water level scenario of both current and long term scenarios, aquifer wise ground water quality, 2-D and 3-D sub surface disposition of aquifers by drawing fence and lithological sections, yield potential, groundwater resources were generated and are discussed in detail in following sections .

3.1 Water Level Scenario

The present depth to water level scenario for pre-monsoon and post-monsoon season was generated by utilizing water level data of 58 (CGWB:19, SGWD: 39) monitoring wells. The pre-monsoon depth to water levels ranged between 1.94 m bgl (Bodulabanda) and 32.80 m bgl (Prakashnagar). The shallow water levels of < 3 m bgl are observed as isolated patches in parts of Nelakondapalli, Mudigonda, Tirumalayapalem and Khammam (Urban) mandal (1.50 % of area), whereas water levels between 3-5 m bgl are mainly observed in Mudigonda, Chintakani, Konijerla, Nelakondapalli, Wyra, Kallur and Bonakal (29 % of area). The water level in the range of 5-10 m bgl is observed in majority parts of the district (58 %). The deeper water levels of >10 m bgl are observed in parts of Madhira, Vemsoor, Sathupalli, Enkoor, Singareni, Kusumanchi and Kamepalli mandal (11.50 % of area). The pre-monsoon depth to water level map is given in **Fig.3.1.**

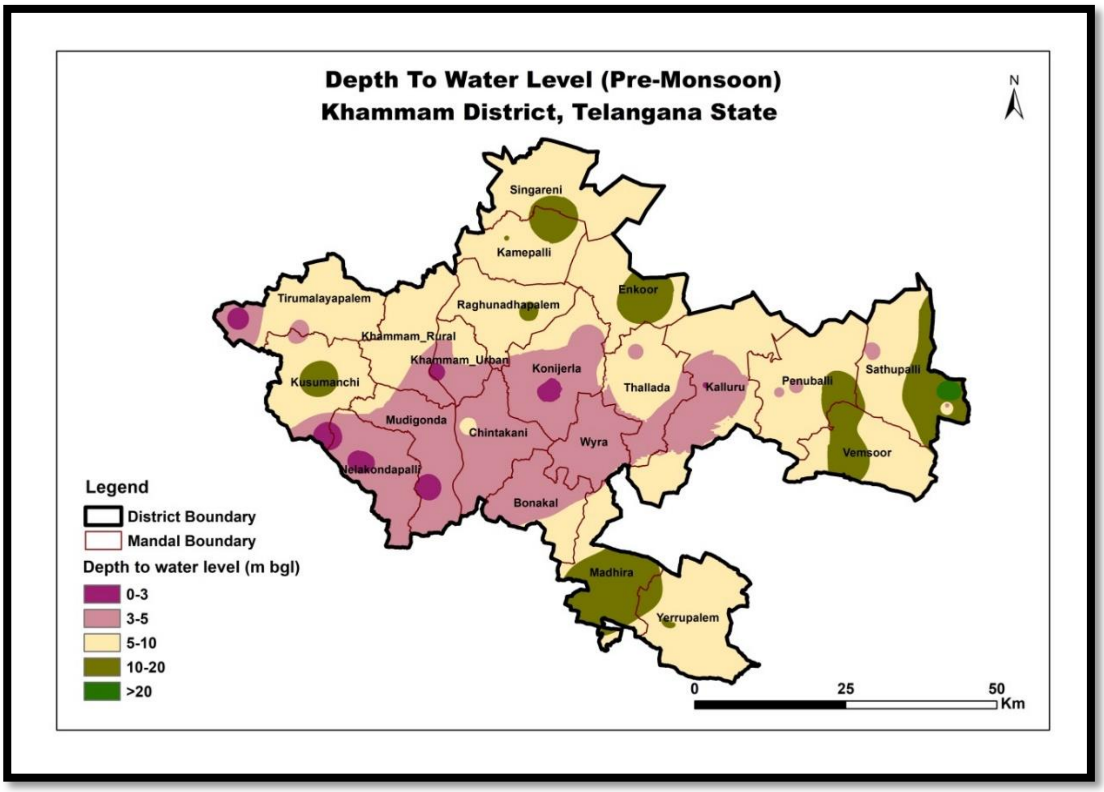


Fig.3.1: Depth to water level map of pre-monsoon season (Average:2011-2020)

The post-monsoon depth to water levels ranges between 0.41 m bgl (Banapuram) and 30.01 m bgl (Prakashnagar). The shallow water levels of <3 mbgl are observed in Nelakondapalli, Mudigonda, Chintakani, Thallada, Kalluru, Konijerla, Bonakal, Wyra and Khammam Urban mandal of the district (38% of area).The water levels between 3-5 m bgl are observed in majority part of the district (43% of area). Moderate water levels between 5-10 mbgl are observed mainly in parts of Kusumanchi, Enkoor, Madhira, Yerupalem and Sathupalli mandal (17% of the area). The deeper water levels of >10 mbgl are observed as isolated patch in Sathupalli mandal (2% of area). The post-monsoon depth to water level map is given in **Fig.3.2.**

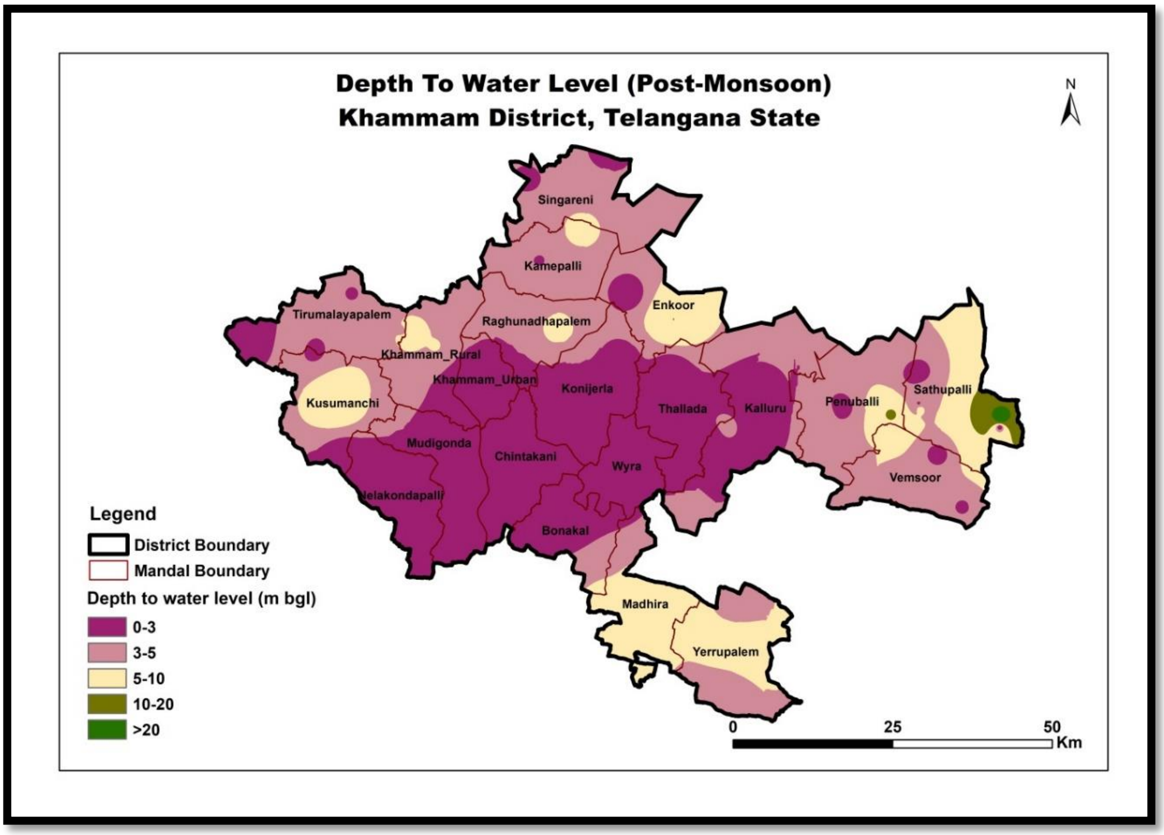


Fig.3.2: Depth to water level map of post-monsoon season (Average: 2011-2020)

3.1.1 Water Level Fluctuation

The water level measured during pre and post monsoon period was used to compute the seasonal fluctuation. 100% (58 no's) of the wells show rise in water level and no wells show fall in water level. The analysis of water level fluctuation data indicates that minimum water level fluctuation was observed at Jakkapally (0.65 m) while maximum water level fluctuation was observed at Lankapalli (8.20 m). The water level fluctuations were grouped under three categories i.e., less, moderate and high and the % of wells in each category was analysed (**Table-3.1**).

Table-3.1: Analysis of Water Level Fluctuation

S. No.	Category	Fluctuation Range	% of area
1.	Less water level fluctuation	0 to 5 m	78%
2.	Moderate water level fluctuation	5 to 10 m	22%
3.	High water level fluctuation	>10m	0%

The analysis indicates that majority of the area (78%) are falling in less fluctuation range indicating good aquifer storage, whereas moderate water level fluctuations are observed in 22 % area and high water level fluctuation of more than 10,m were not observed in the district. The seasonal fluctuation map is presented as **Fig.3.3**, the perusal of map indicates that fluctuation of upto 5 m is observed in major part of the district, whereas moderate fluctuation of more than 5 m is observed in parts of Singareni, Kamapalli, Vemsoor, Madhira and Yerupalem mandal.

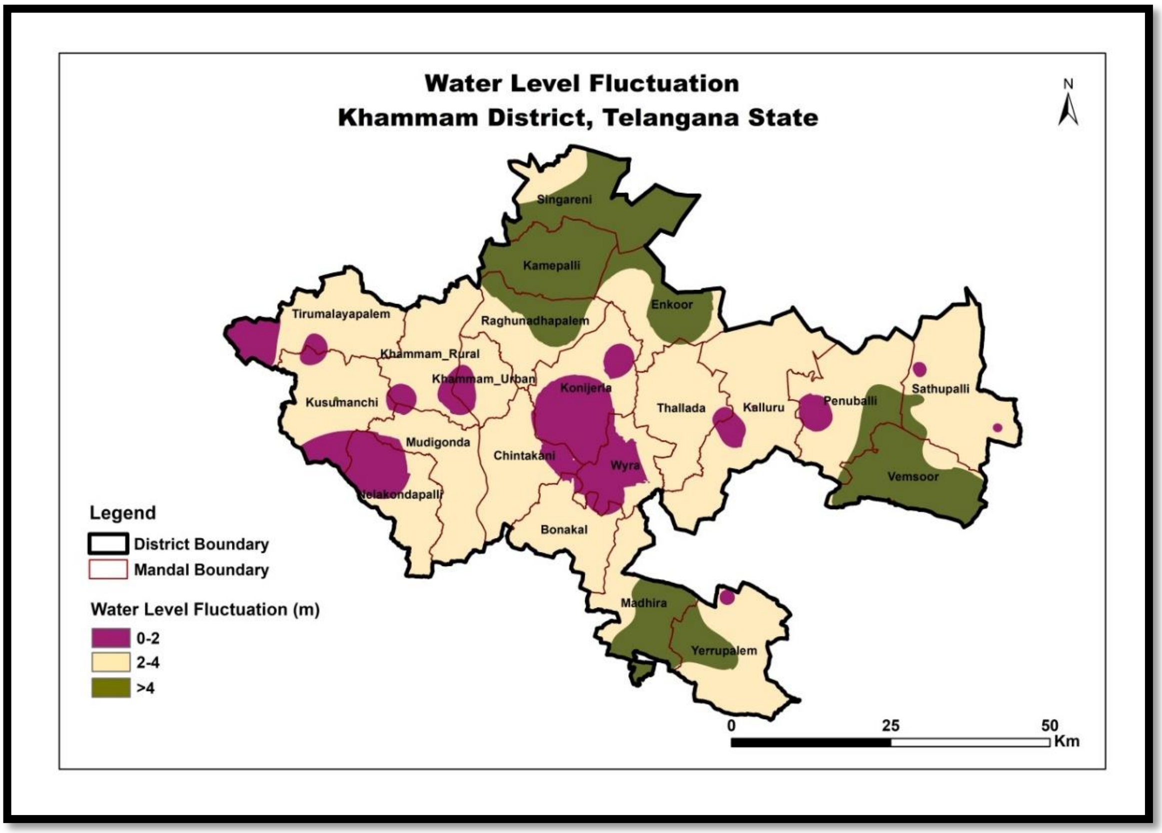


Fig.3.3: Seasonal Water Level Fluctuations (m) (post-monsoon with respect to pre-monsoon (Average:2011-2020))

3.1.2 Water Table Elevation

The water table elevation map for pre-monsoon and post-monsoon period was also prepared (**Fig. 3.4(a), 3.4(b)**) to understand the ground water flow directions. The water table elevation ranges from 45 to 225m amsl during pre-monsoon period and 48 to 228 m amsl during post-monosoon period. The groundwater flow is mainly towards southern direction.

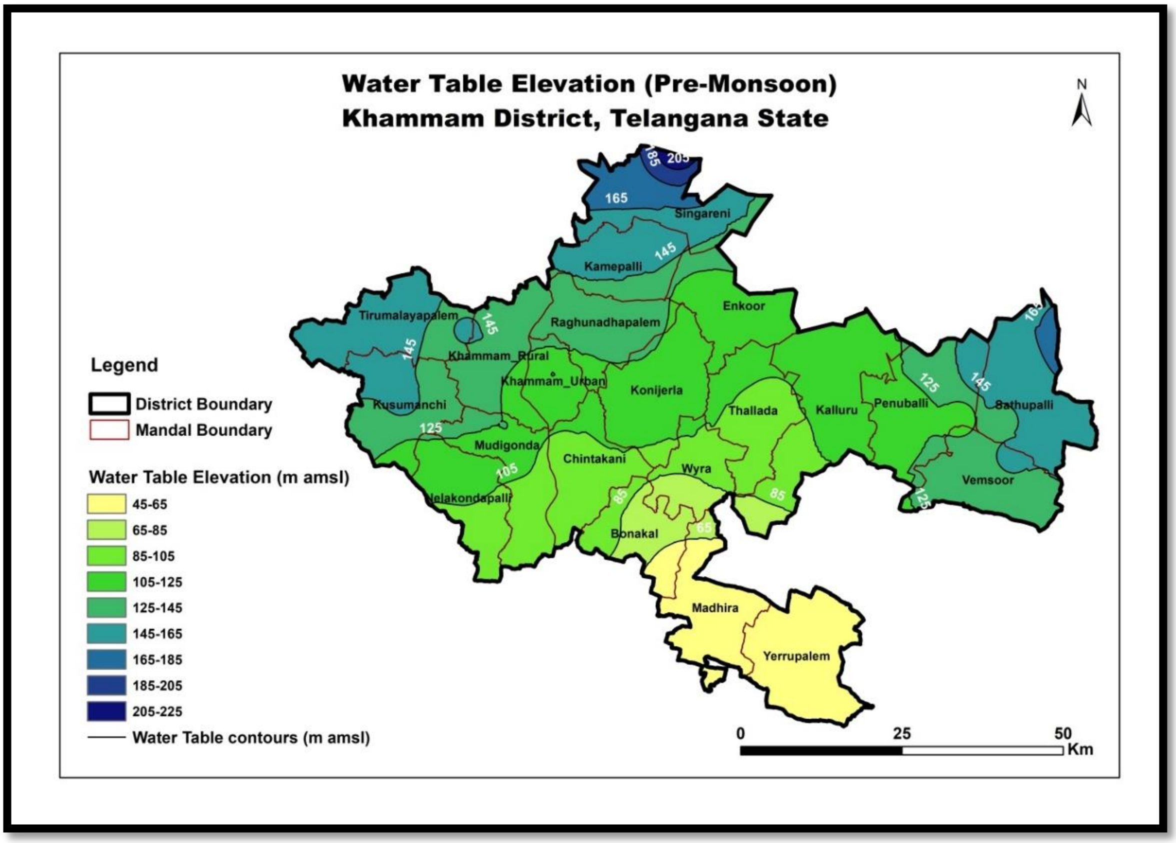


Fig.3.4(a): Water table elevations (m amsl) during pre-monsoon season (Average:2011-2020)

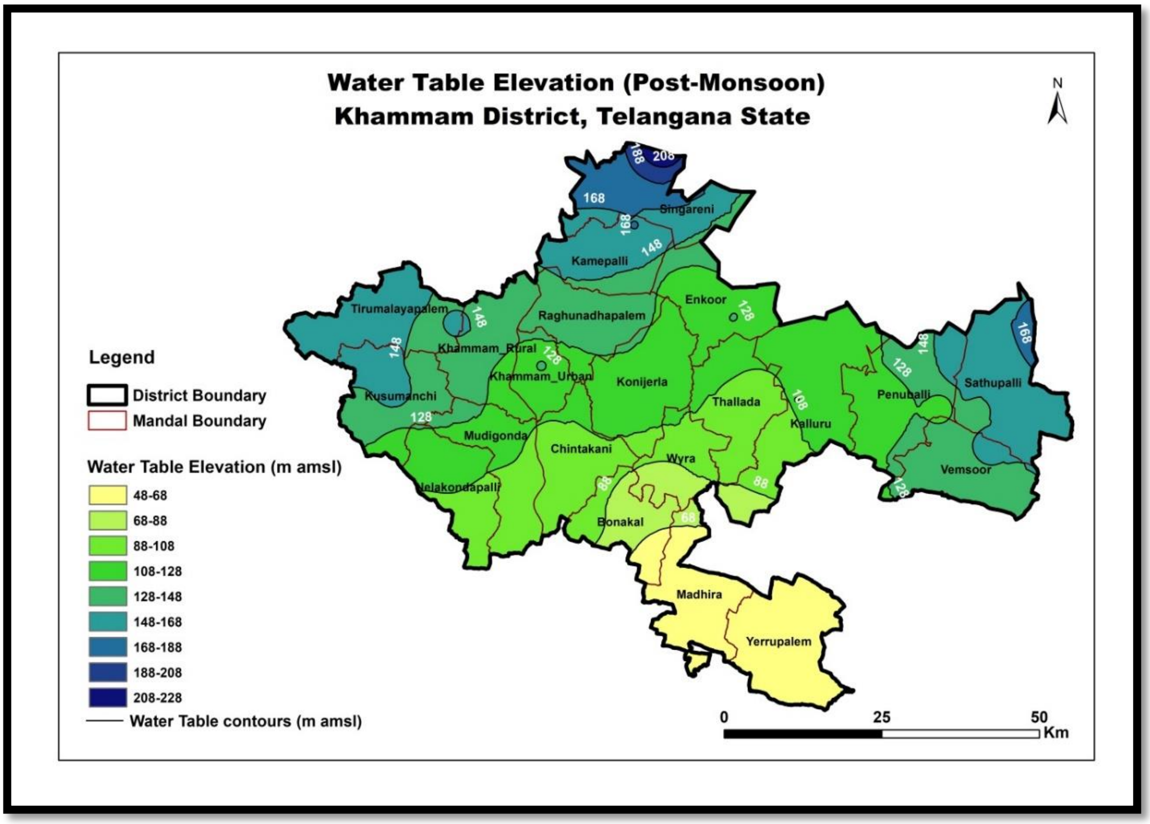


Fig.3.4(b): Water table elevations (m amsl) during post-monsoon season (Average:2011-2020)

3.1.3 Long Water Level Trend (2011-20)

In order to study long term behavior of the water levels and also the effect of various developmental activities with time, the data from 32 hydrograph station (CGWB:17, SGWD:15) for the period 2011-20 have been computed and analyzed. The decadal pre-monsoon water level trend analysis indicates that 18 wells show falling trend (>1.0 m: 2, 0-0.5 m: 16 wells) (max fall: 1.33 m/yr) and 14 wells show rising trend (0-0.5: 14 wells) (max rise: 0.52 m/yr). During post-monsoon season 10 wells show falling trend ((>1.0 m: 1, 0-0.5m: 9) (maximum fall: 1.19 m/Yr) and 22 wells shows rising trends (0-0.5 m: 3, 0.5-1.0 m: 19 wells) (max rise: 0.76 m/yr). The graphical representation of fall and rise is shown in **Fig.3.5** and spatial distribution map is shown in **Fig.3.6** and **3.7.**

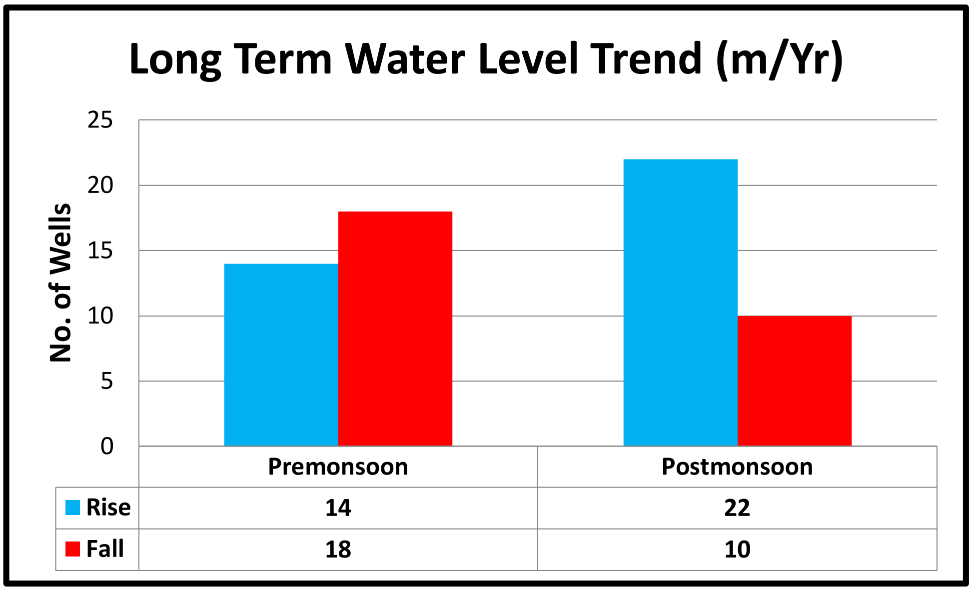


Fig. 3.5: Graphical representation of water level trends (2011-2020)

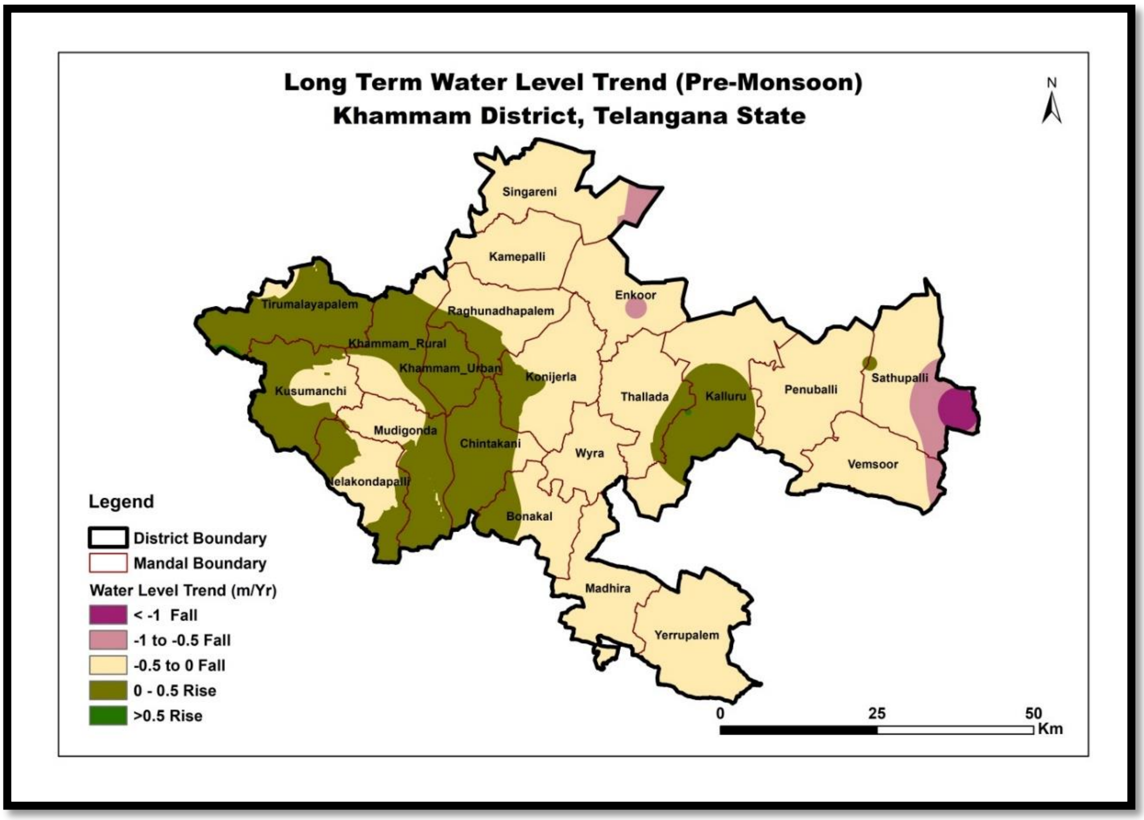


Fig. 3.6: Long-term water level trend, Pre-monsoon (2011-2020)

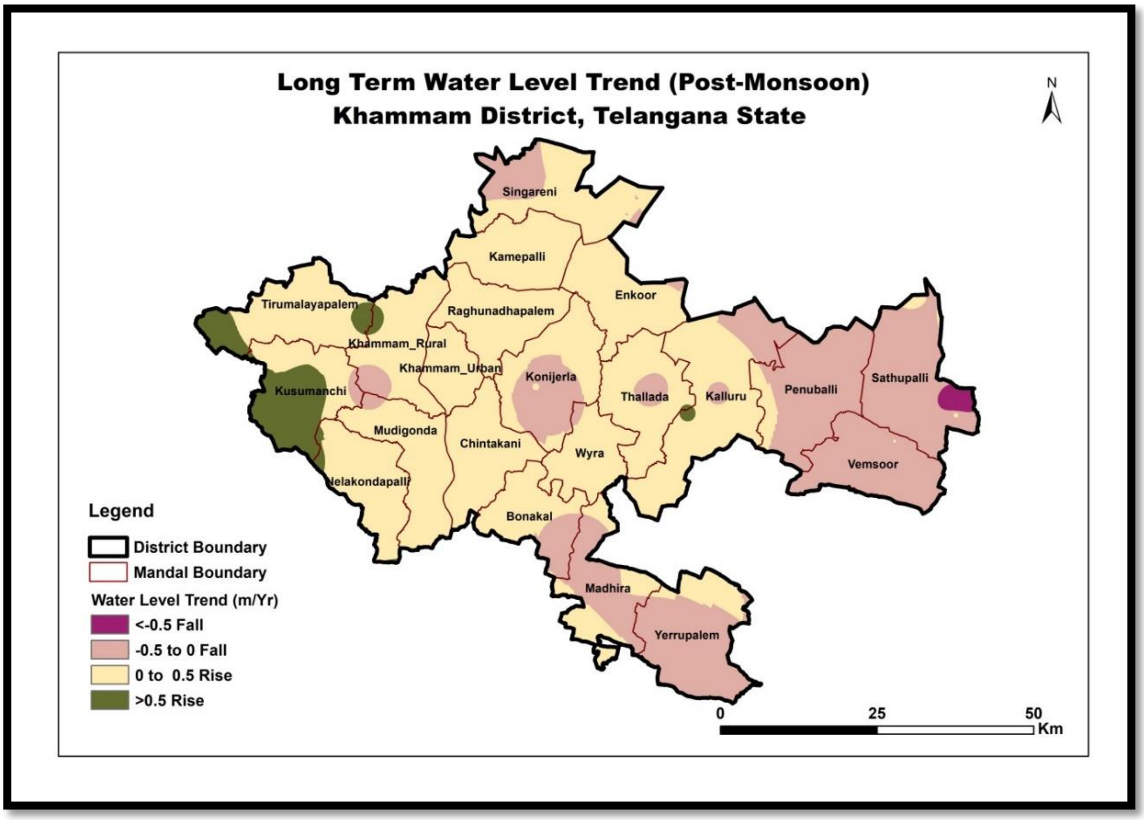


Fig. 3.7: Long-term water level trend, Post-monsoon (2011-2020)

3.2 Ground Water Quality

The suitability of groundwater for drinking/irrigation/industrial purposes is determined keeping in view the effects of various chemical constituents present in water on the growth of human being, animals, various plants and also on industrial requirement. Though many ions are very essential for the growth of plants and human body but when present in excess, have an adverse effect on health and growth. For assessment of ground water quality, 235 samples (Pre-monsoon:125 and post-monsoon:110) were utilised from monitoring wells of CGWB and SGWD. The ground water samples were analysed for major chemical constituents. 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 analysed.

3.2.1 Pre-Monsoon

A total of 125 samples were analyzed (CGWB:15, SGWD:110). Groundwater is mildly alkaline to alkaline in nature with pH in the range of 6.89-8.96 (Avg: 8.12). Electrical conductivity varies from 591-6680 (avg: 1863) µ Siemens/cm. In 88 % of area EC is within 3000 µ Siemens/cm, in 12% of area it is beyond 3000 µ Siemens/cm (**Fig.3.8**). Nitrate concentration varies from 0.22-1306 mg/L and60 %of the samples it is beyond permissible limits of BIS Standard (>45 mg/L) (**Fig.3.9**). High Nitrate concentration is observed in major parts of the district. Fluoride concentration varies from 0.20 to 4.64 mg/L (**Fig 3.10**) and in 22 % of samples it is beyond permissible limits of BIS standard

(>1.5 mg/L). High fluoride concentration is observed mainly in Khammam (Rural), Khammam (Urban), Thallada, Yerrupalem, Konijerla and Wyra mandal.

3.2.2 Post-Monsoon

A total of 110 samples were analyzed (SGWD:110). Groundwater from the area is mildly alkaline to alkaline in nature with pH in the range of 7.06-8.90 (Avg:7.75). Electrical conductivity varies from 350-6540 (avg: 2005) µ Siemens/cm. In 86 % of area EC is within 3000 µ Siemens/cm and in 14% of area EC is beyond 3000 µ Siemens/cm (**Fig.3.11**). Nitrate concentration varies from 0.40-868.08 mg/L and in 54 % of the samples it is beyond permissible limits of BIS Standard (>45 mg/L) (**Fig.3.12**). High Nitrate concentration is observed in majority parts of the district. Fluoride concentration varies from 0.22-3.44 mg/L **(Fig 3.13**) and in 18 % of samples it is beyond permissible limits of BIS standard (>1.5 mg/L). High fluoride concentration is observed mainly in Khammam (Rural), Khammam (Urban), Thallada, Yerrupalem , Tuirumalayapalem, Enkur, Bonakal, Singareni and Wyra mandal .

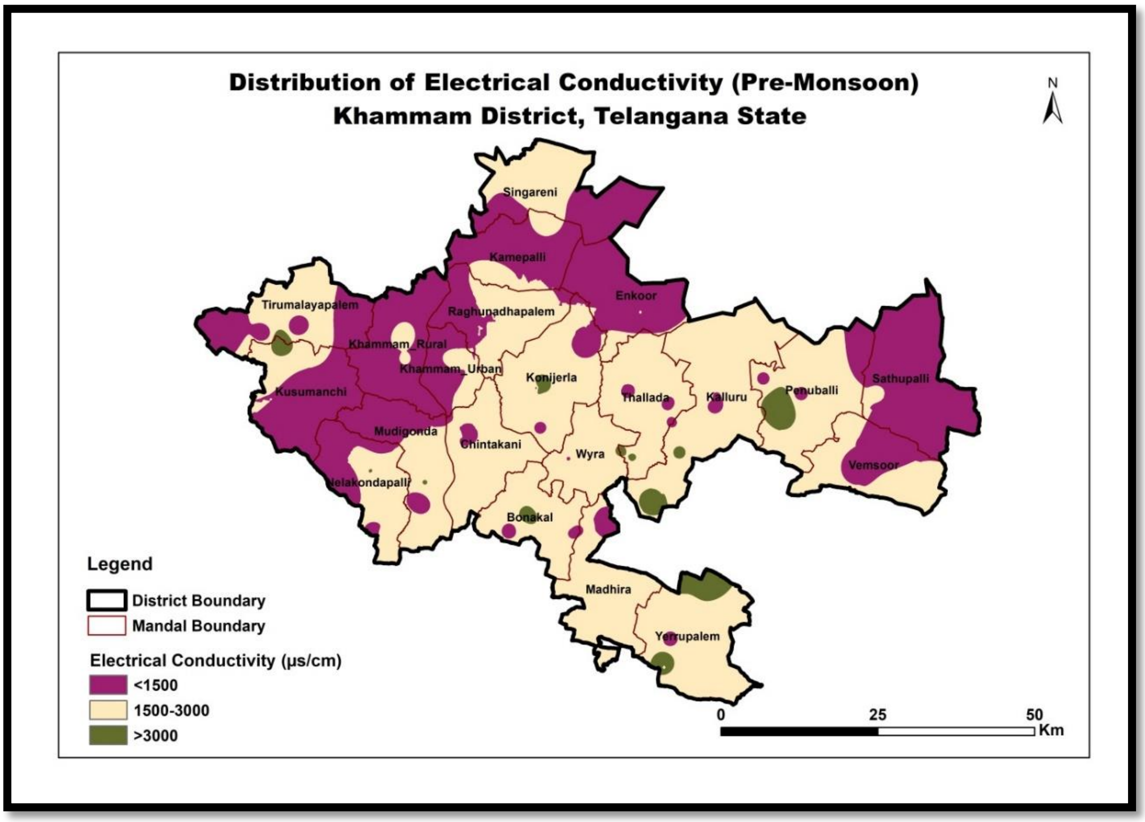


Fig.3.8: Distribution of Electrical conductivity (Pre-monsoon).

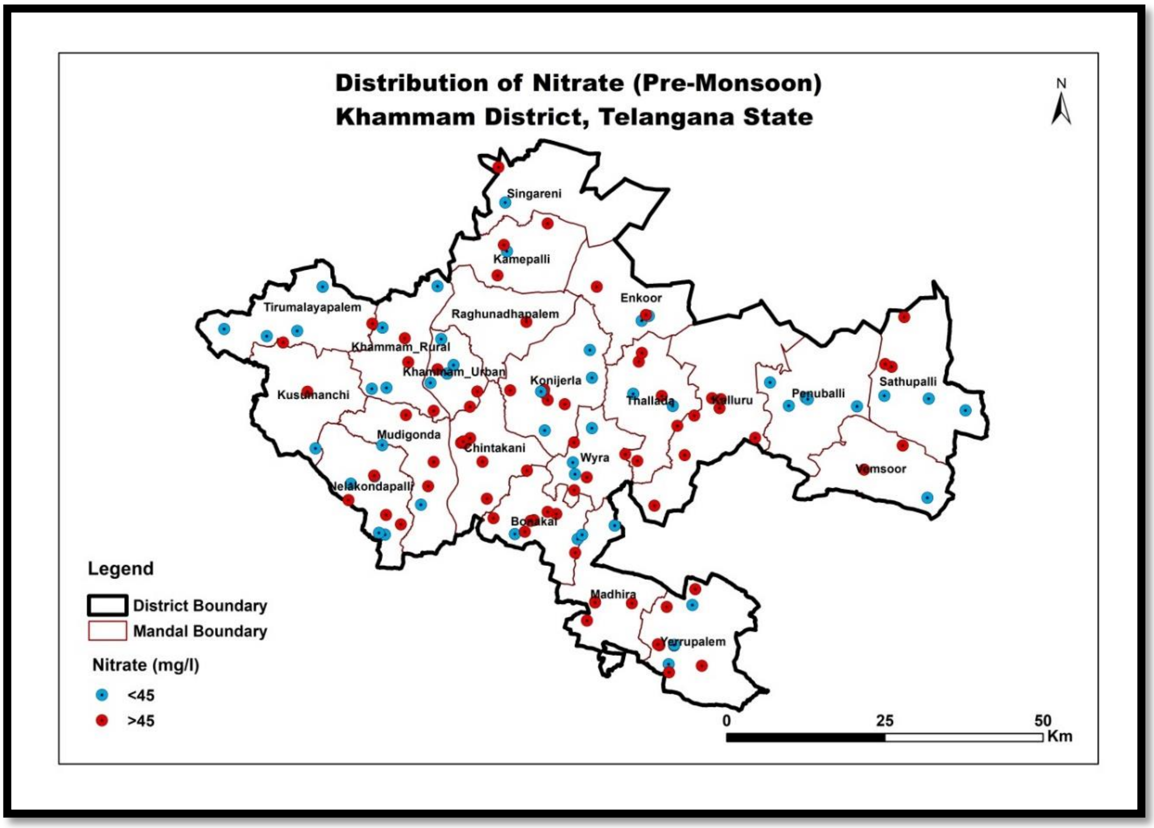


Fig.3.9: Distribution of Nitrate (Pre-monsoon)

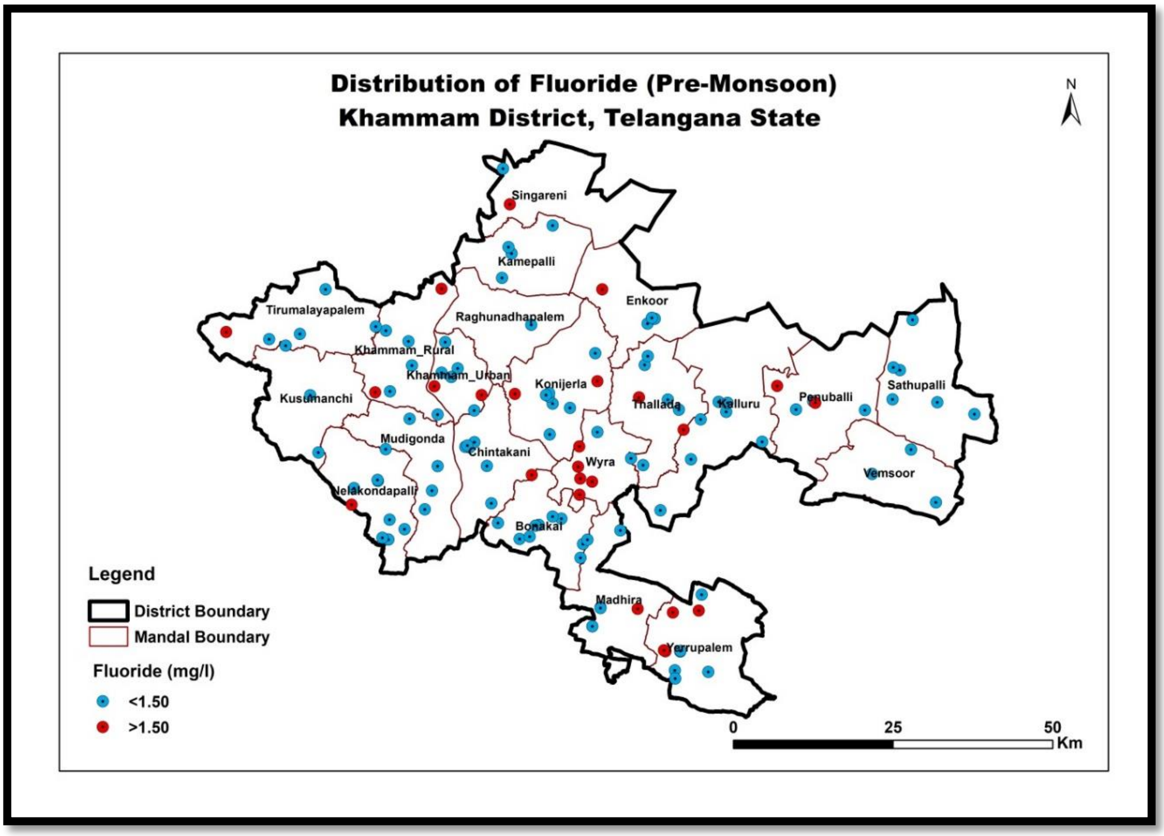


Fig.3.10: Distribution of Fluoride (Pre-monsoon)

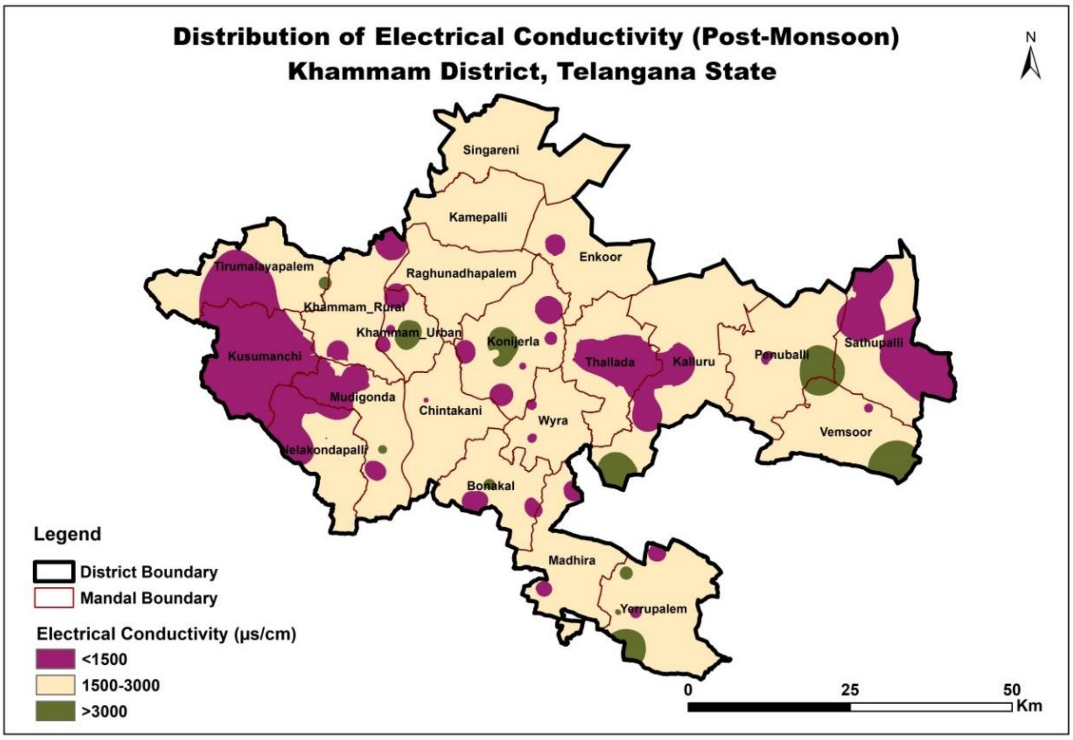


Fig.3.11: Distribution of Electrical conductivity (Post-monsoon)

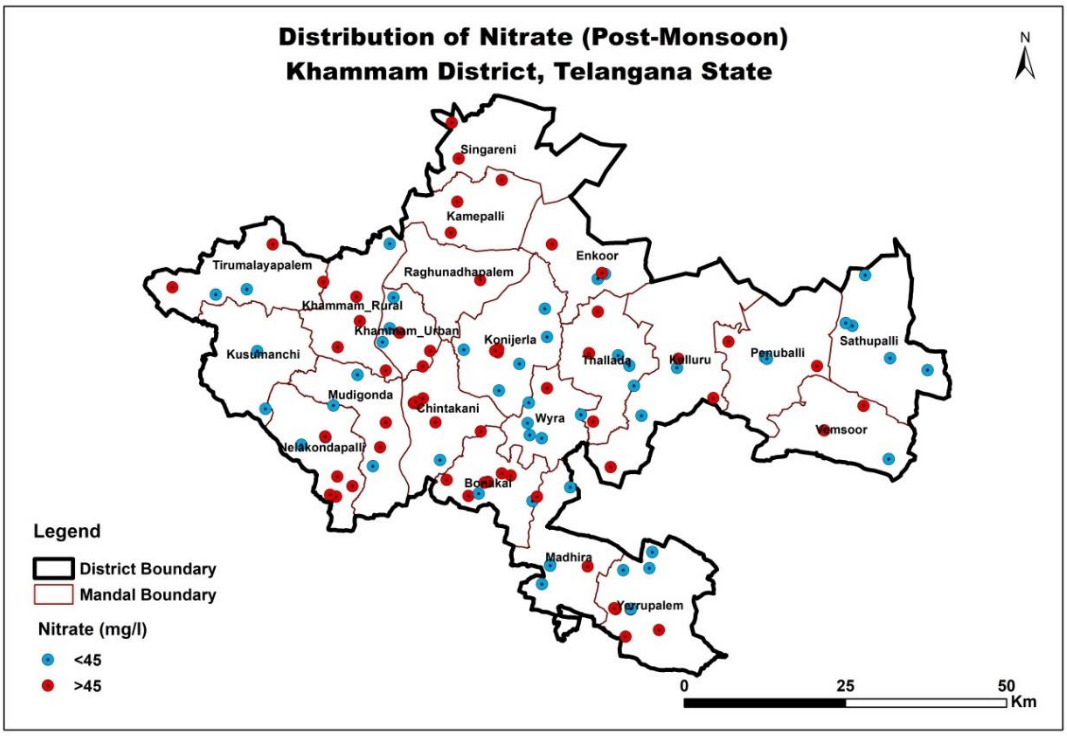


Fig.3.12: Distribution of Nitrate (Post-monsoon)

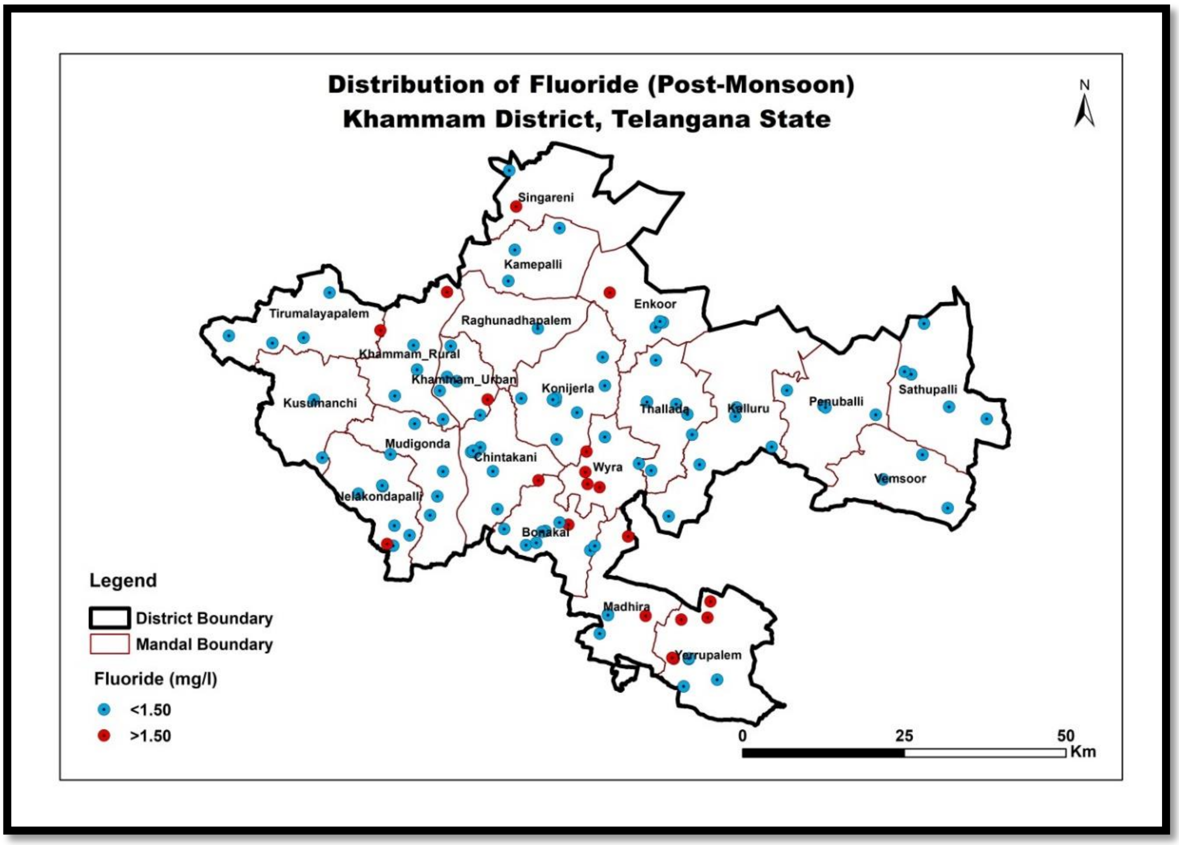


Fig.3.13: Distribution of Fluoride (Post-monsoon)

3.3 Aquifer Mapping

The aquifer geometry for shallow and deeper aquifer has been established through analysing data generated through various hydrogeological, exploration, surface and subsurface geophysical studies in the district. The occurrence and movement of water in the subsurface is 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. Based on 223 hydrogeological data points hydrogeological map is prepared and is presented in **Fig 3.14**.

On the basis of occurrence and movement of ground water, rock units of the Khammam district can be broadly classified into two categories: consolidated formation (Archean crystalline and metasedimentary formation) which occupies 93% of the area and semi-consolidated to unconsolidated formation (Sedimentary rock) which occupies 7 % of the area.

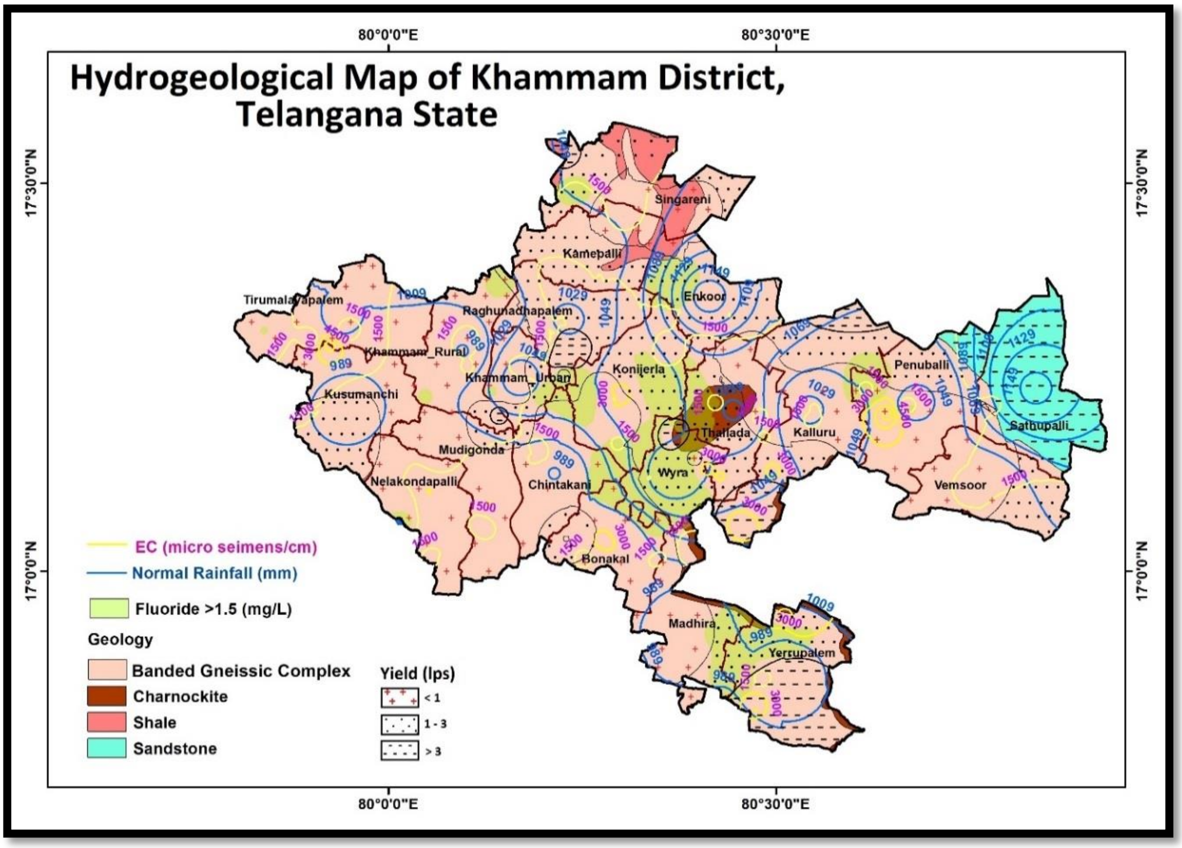


Fig.3.14: Hydrogeological map of Khammam district

3.3.1 Aquifer system in consolidated formation

Consolidated formation consists of Archean crystalline formation comprising crystalline granites and gneisses that are devoid of primary porosity. However, subsequent weathering, fracturing and fissuring developed secondary porosity. These main aquifers possess a weathered zone at the top, followed by a discrete anisotropic fractured/fissured zone at the bottom, generally extending down to 200 m depth.

3.3.1.1 Weathered Zone (Aquifer -I)

It consists of weathered residum where groundwater occurs under unconfined conditions in the intergranular pore spaces of weathered mantle and is mainly developed by construction of dug wells or shallow bore wells with hand pumps. The storage in granite rocks is primarily confined to the weathered zone and it has been used mainly for irrigation purpose, which extends upto depth of 28.70 m in Khammam district. Thickness of weathered zone is in the range of 10-20 m in about ~65 % of area, shallow weathering (< 10 m) occurs in 22 % while deep weathering (> 20 m) is seen only in 13% of the area (**Fig 3.15**).

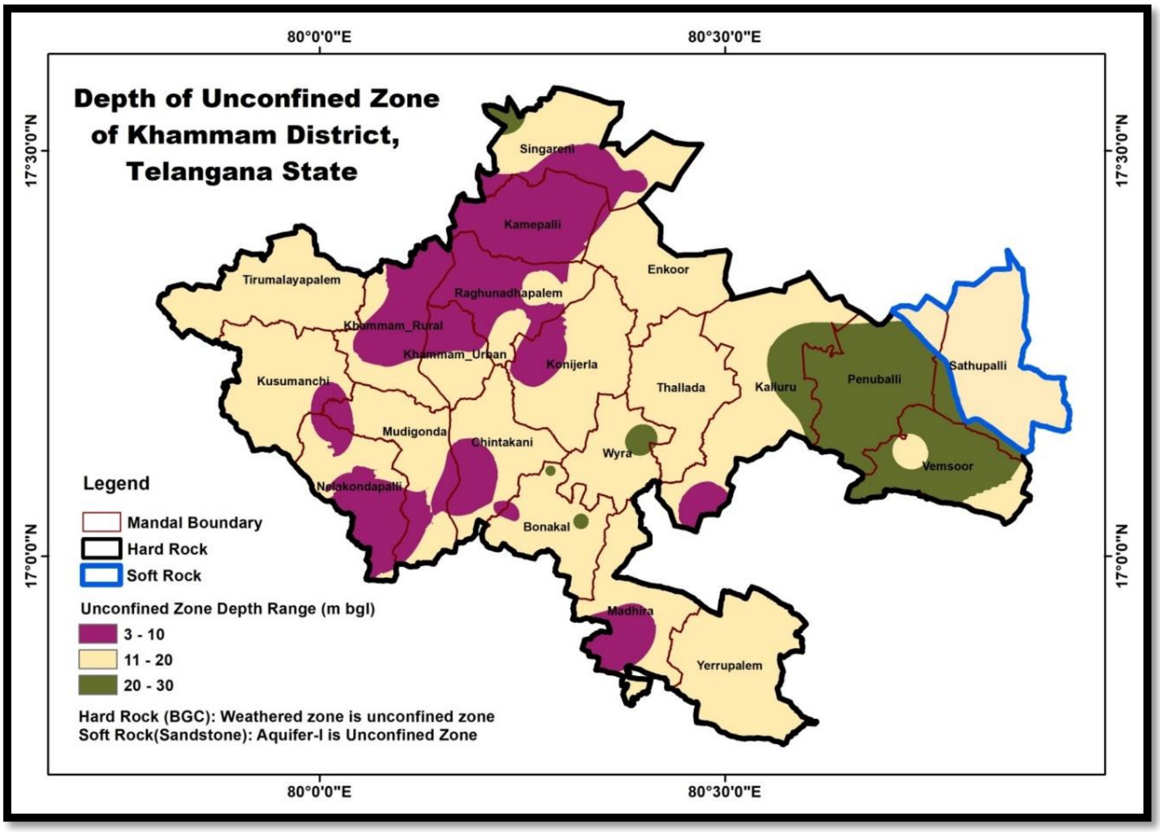


Fig.3.15: Unconfined zone map of Khammam district

3.3.1.2 Fractured Zone (Aquifer -II)

In the fractured zone, groundwater occurs under semi-confined to confined conditions. The fractured zone is considered from bottom of weathered zone to the top of deepest fracture. Groundwater in fractured zone is developed through construction of shallow/deep bore wells and dug-cum borewells. The depth of fracturing varies from 3 m to 184 m (deepest fracture encountered at Adasarlapadu). Ground water yield from fractured granite/gneiss varies from <0.01 to 9.86 lps. The transmissivity varies from 1.50-212 m^2/day and storativity varies from 0.000001 to 0.001 (**Fig 3.16**).

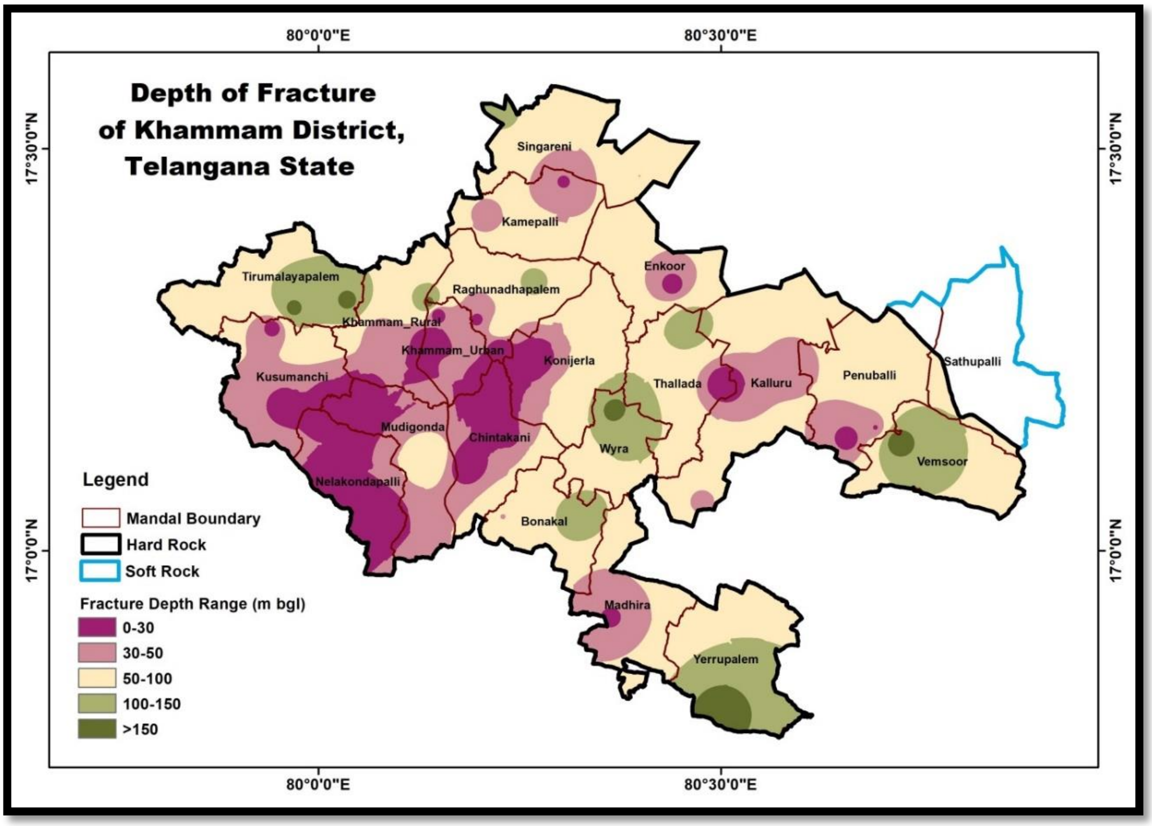


Fig.3.16: Fracture zone map of Khammam district

3.3.2 Aquifer system in semi-consolidated/unconsolidated formation

Gondwana formations represent the semi-consolidated formation, which consists of sandstones, shales and clays that makes a thick sequence of sediments. They are generally bedded deposits with well-defined lithologic units and had undergone structural disturbances. Hence the area shows lateral and vertical variation within short distances, due to which the hydrogeological properties of the formation vary widely. The sandstones are generally medium to coarse, friable and loose due to weathering. The sandstones form the principal aquifers except in areas where thin intercalations of clays exist. The ferruginous kankary material formed on the surface due to weathering augments the infiltration and saturates the underlying sandstones. The groundwater in the Gondwana formations occurs under both water table and confined conditions.

Multiple aquifer systems (1 to 5 aquifers) are found in the sandstone formations with intervening clay beds. The first aquifer is unconfined whereas the deeper aquifers are in semi-confined/ confined condition. Depth of aquifers are decided based on the depth of bottom clay layers.

3.3.2.1 Unconfined aquifer (Aquifer-I)

In the Aquifer-I, groundwater occurs under phreatic/unconfined condition. The unconfined zone extends from bottom of the soil layer to top of the first clay layer. Thickness of the unconfined zone is in the range of 10-13 m in the area.

3.3.2.2 Confined/Semiconfined aquifer (Aquifer-I to Aquifer-V)

Unlike Aquifer-I, groundwater occurs under confined to semi-confined condition in these aquifers. The occurrence of groundwater depends on porosity, granularity, cementing matrix, permeability, bedding plains and faults etc. The deeper aquifers identified upto a depth of 300m and are mainly composed of fine to coarse grained sandstone.

Groundwater yield of sandstone aquifers varies from <1 to 18 lps. The transmissivity varies from 146.99 - 570.32 m^2/day and storativity varies from 2.04×10^{-4} to 5.50×10^{-4}

Table 3.2 Salient features of Aquifer system in Khammam district

	Archean Crystalline		Gondwana Formation	
Prominent Lithology	Granite, Gneiss		Sandstone	
Aquifers	Weathered Zone (Aquifer-1)	Fracture Zone (Aquifer-2)	Unconfined Zone (Aquifer-1)	Semiconfined/ Confined Zone (Aquifer-II to V)
Thickness range	Upto 28.70 m	3-184 m	10 to 13 m	Upto 300 m at different depth ranges
Range of yield potential	<0.01 to 9.86 lps		upto 18 lps	
Transmissivity (m^2/day)	1.50 - 212 m^2/day		146.99 - 570.32 m^2/day	
Storativity	0.000001 to 0.001		1.2 to 0.0001	
Specific Yield	2%		3%	
Quality (Suitability of Irrigation)	Yes	Yes	Yes	Yes
Suitability of domestic purpose	Yes	Yes	Yes	Yes

3.4 3D and 2D Aquifer Disposition

The data generated from groundwater monitoring wells, hydrogeological inventories, exploratory wells and geophysical studies as well as various thematic layers were utilized to decipher the aquifer disposition of the area. This particularly includes the information on 3D geometry of aquifers, panel diagram and hydrogeological information of these aquifers. RockWorks-16 software was used for this purpose. The data is calibrated for elevations with Shuttle Radar Topography Mission (SRTM) data. The 3-D representation of Aquifer disposition is presented in **Fig. 3.15**

The fence diagram indicating the disposition of various aquifers is presented in **Fig.3.16 and Fig.3.17**. In major part of district, granites/gneiss can be seen. The disposition of weathered and fractured zone followed by massive granite/gneiss can be observed in the Fence. In the eastern parts (Sathupalli mandal) multi-aquifers system of sandstone can be seen separated by intervening clay layers.

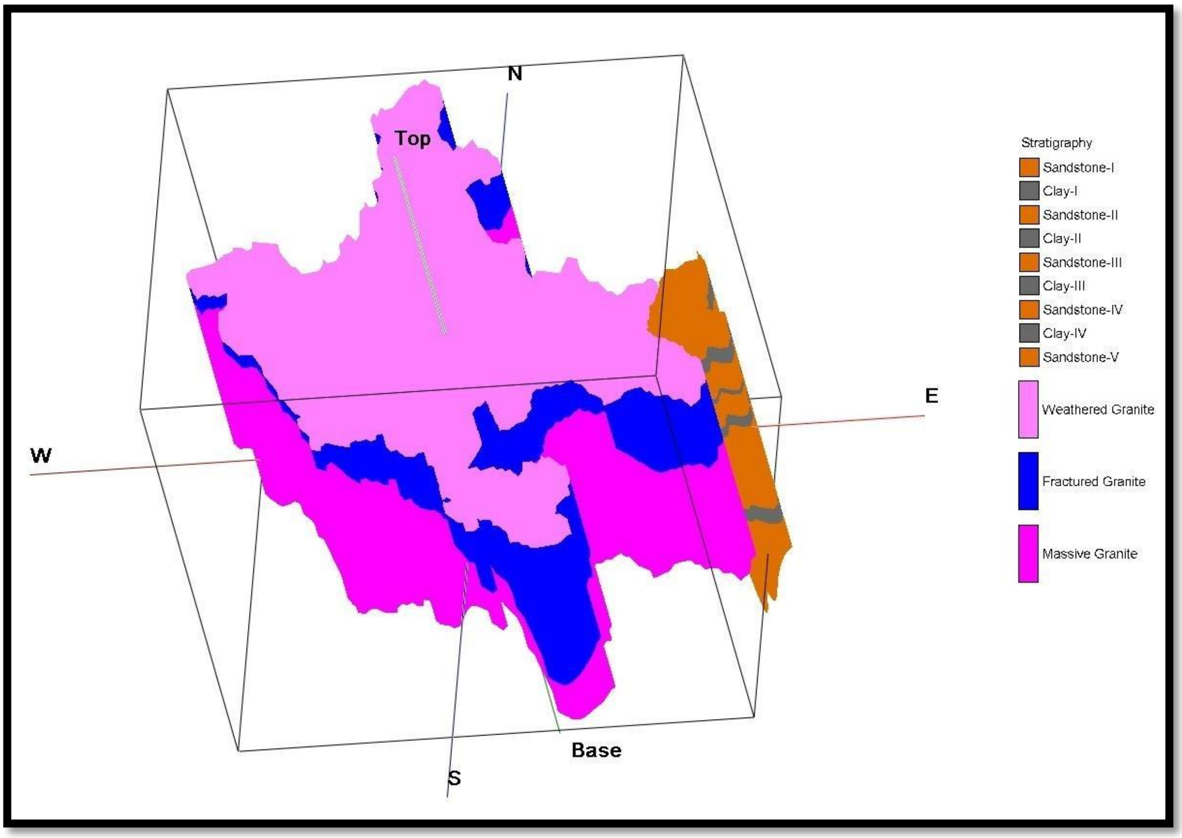


Fig.-3.15: 3-D disposition of Aquifers

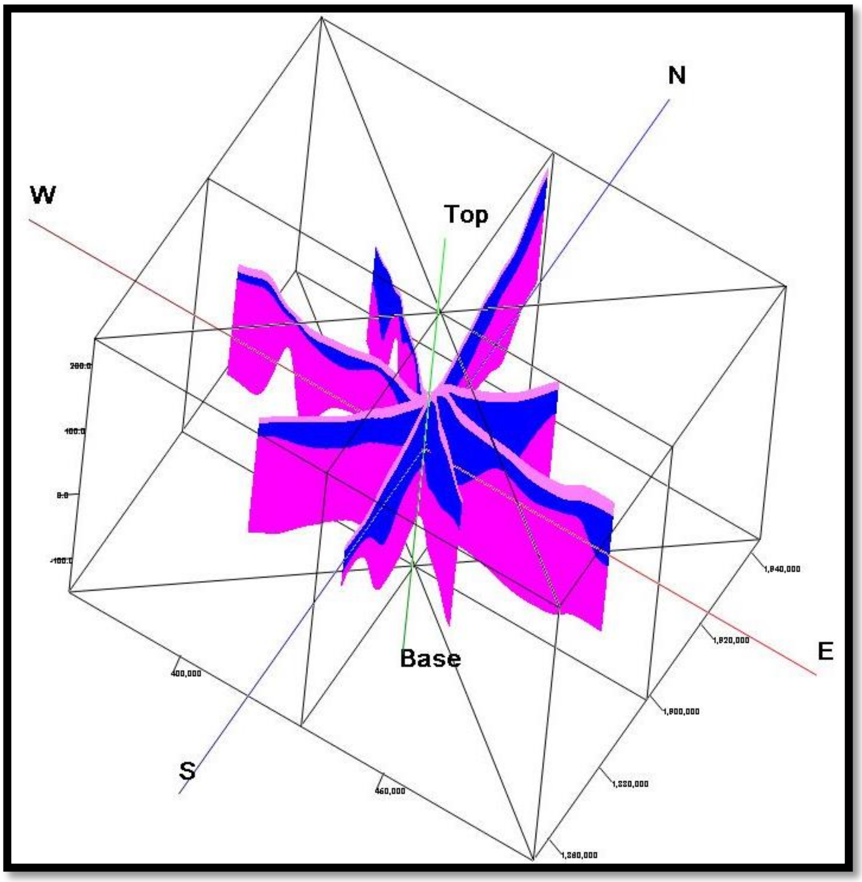


Fig.-3.16: Fence diagram-1

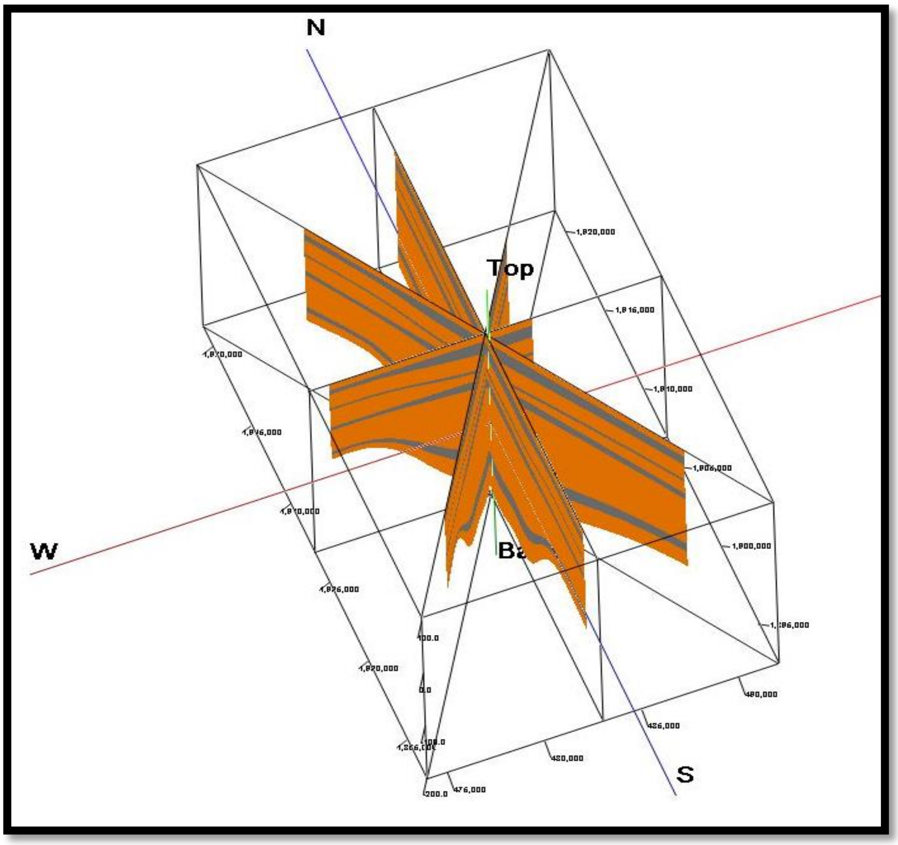


Fig.-3.17: Fence diagram-2

3.4.1 Hydrogeological Cross Sections

To study the aquifer disposition in detail, various hydrogeological cross section indicating aquifer geometry has been prepared viz. NE-SW, NW-SE direction in Granitic area and NE-SW direction in Sandstone area (**Fig. 3.18**).

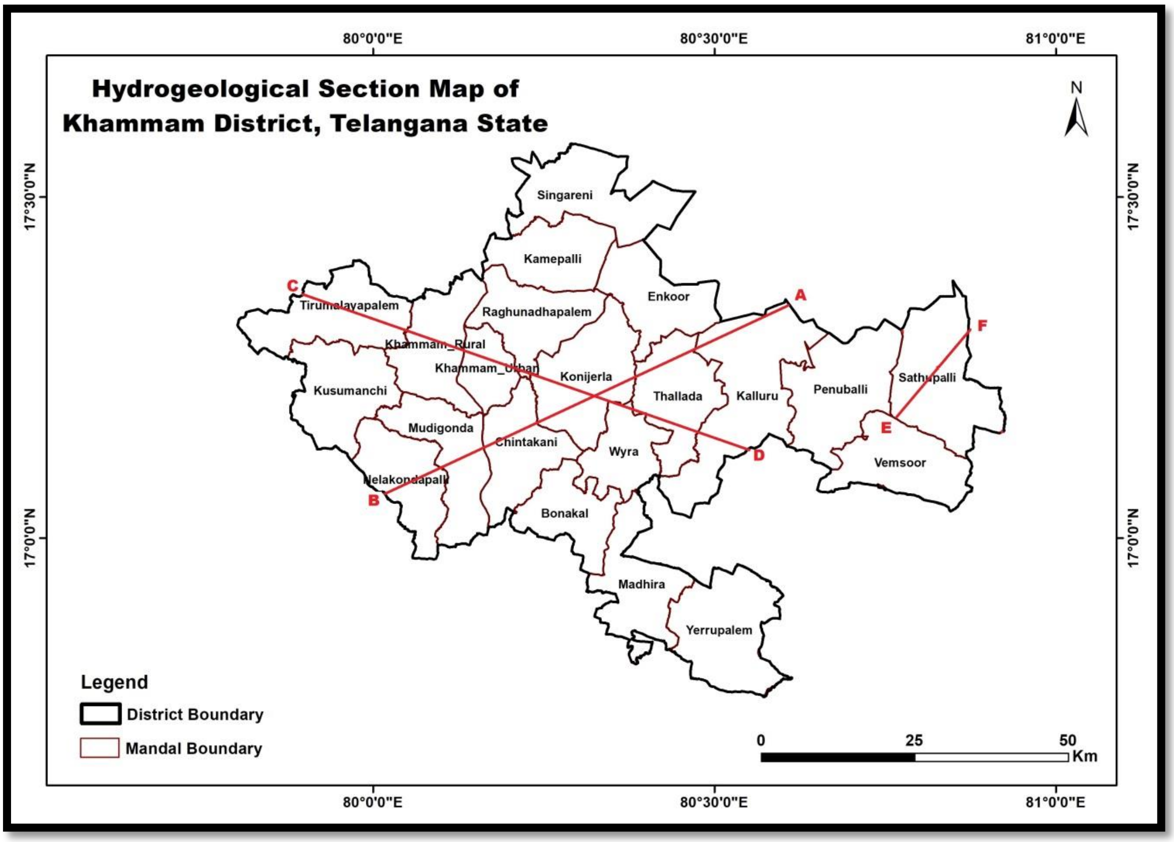


Fig.-3.18: Map showing orientation of hydrogeological sections

3.4.1.1 Hydrogeological Cross Section A-B

Hydrogeological cross section A-B (**Fig.3.19**) represents northeast- southwest direction covering a distance of ~62 kms. It depicts thick fractured zone overlaid by thin weathered zone in granites. As we move from northeast to southwest direction, depth of fracture zone varies from 137 m bgl at Gopalpet to 10.4 m bgl at Cheruvu Madhavaram. The maximum depth of weathering ranging from 14.14 m bgl at Gopalpet to 8.5 m bgl at Cheruvu Madhavaram.

3.4.1.2 Hydrogeological Cross Section C-D

Hydrogeological cross section C-D (**Fig.3.20**) represents northwest–southeast direction covering a distance of ~70 kms. It depicts thick fractured zone overlaid by thin weathered zone in granites. As we move from northwest to southeast direction, depth of fracture zone varies from 175 m bgl at Tirthala to 47 m bgl at Marlapadu. The maximum depth of weathering ranging from 9.56 m bgl at Tirthala to 7.85 m bgl at Marlapadu.

3.4.1.3 Hydrogeological Cross Section E-F

Hydrogeological cross section C-D (**Fig.3.21**) represents northeast–southwest direction in sandstone area covering a distance of ~22kms in Sandstone area. Multiple aquifer systems (1 to 5 aquifers) are found in the sandstone formations separated by 4 intervening clay layers. The thickness of the unconfined aquifer varies from 10 m to 13 m depth. The confined aquifers extend upto depth of 300m.

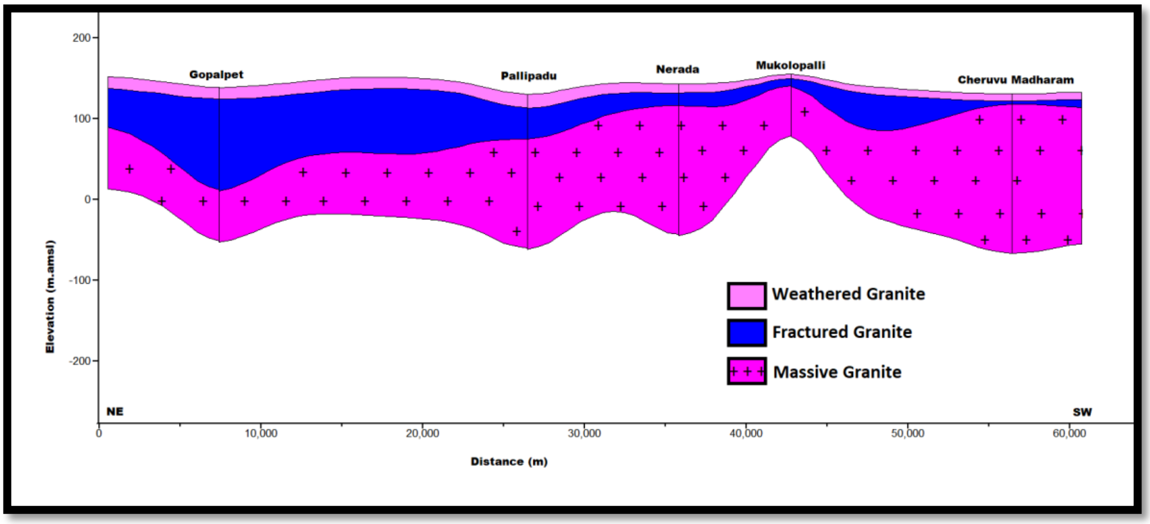


Fig.3.19: Hydrogeological cross section A-B

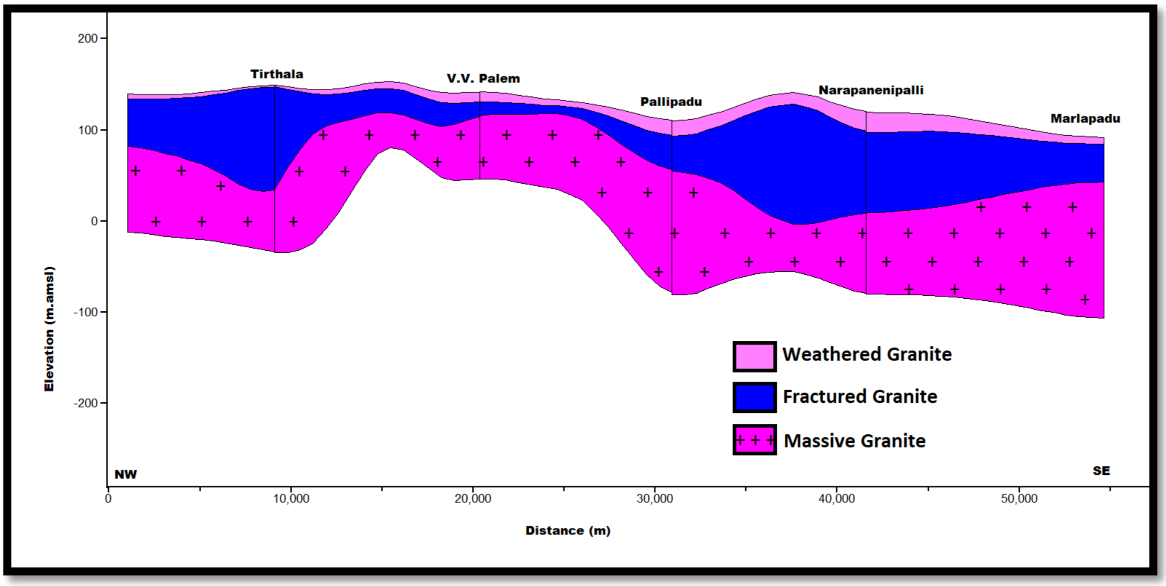


Fig.3.20: Hydrogeological cross section C-D

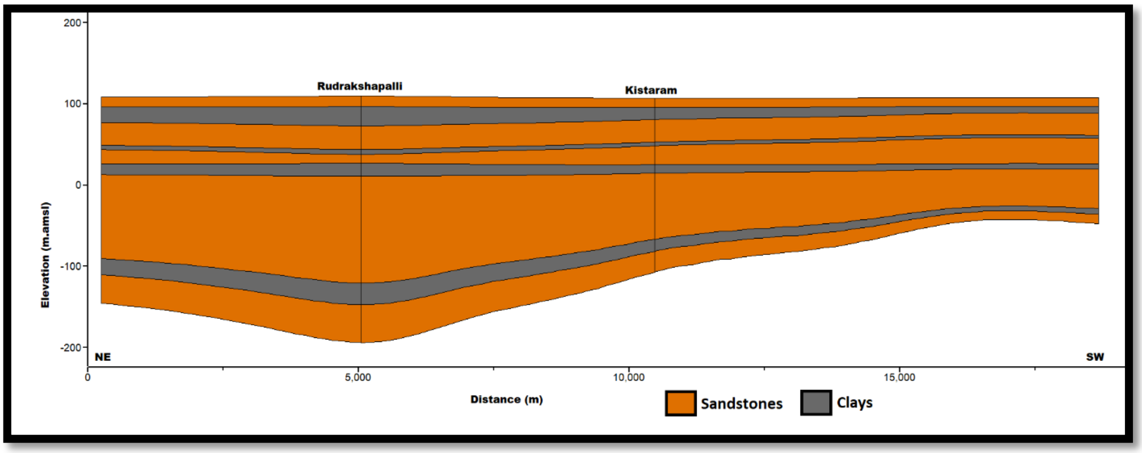


Fig.3.21: Hydrogeological cross section E-F

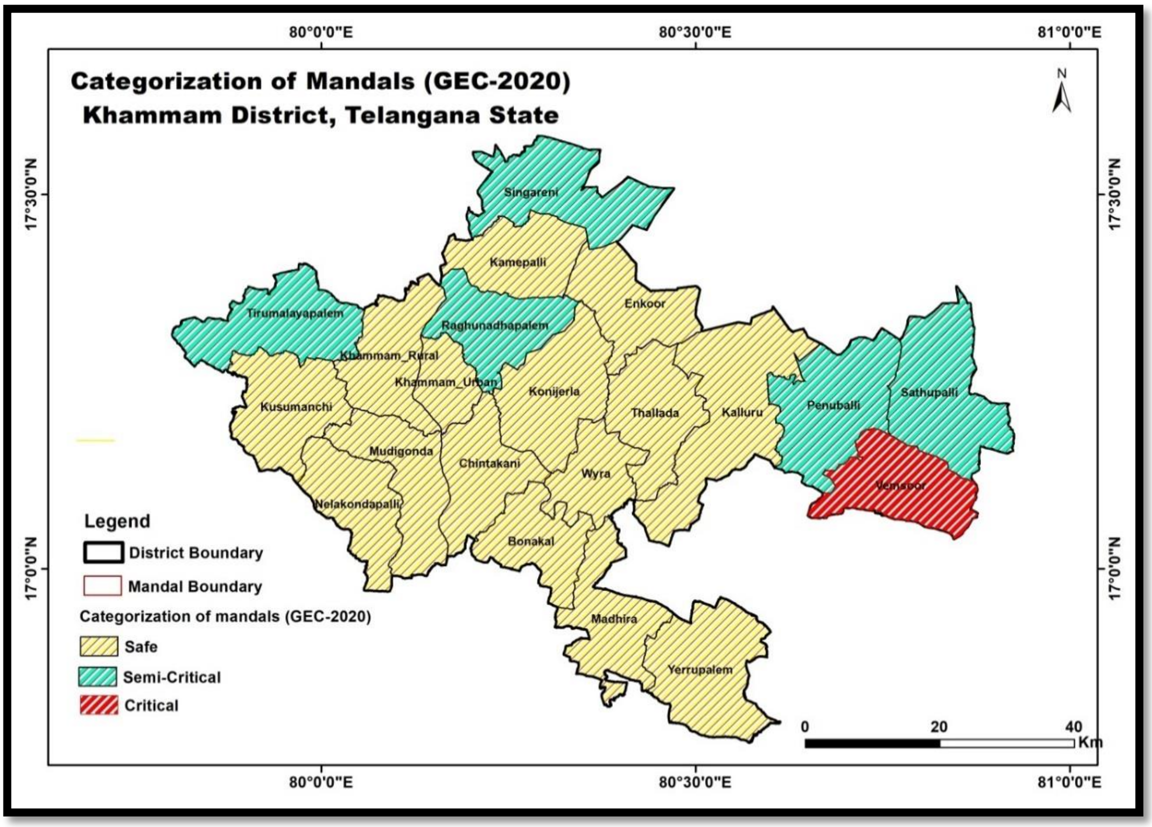


Fig.4.1 : Categorization of mandals (GEC-2020)

4. GROUND WATER RESOURCES

In hard rocks, for practical purpose it is very difficult to compute zone wise (aquifer wise) groundwater resources, because the weathered zone (WZ) and fractured zone (FZ) are inter-connected with fractures/joints and fractured zones get 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 2015 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. Dynamic ground water resources are computed as per the guidelines laid down in GEC-2015 methodology. As per 2020 GEC report, the net dynamic replenishable groundwater resources availability is 1036.51 MCM, gross ground water draft for all uses is 412.40 MCM and net annual ground water potential available for future irrigation needs is 605.48 MCM. Stage of ground water development varies from 15 % at Wyra mandal to 91 % at Vemsoor mandal. Out of 21 mandals, 5 are in Semicritical, 1 in Critical and 15 are in Safe categories. 90 % of gross groundwater draft is utilized for irrigation purpose only. Computed Dynamic groundwater resources of the district is given in **Fig 4.1** and **Table-4.1**.

Table-4.1: Computed Dynamic ground water resources.

As per GEC 2020	MCM
Dynamic (Net GWR Availability)	**1036.51**
• Monsoon recharge from rainfall	300.33
• Monsoon recharge from other sources	345.99
• Non-Monsoon recharge from rainfall	60.23
• Non-monsoon recharge from other sources	431.75
• Natural Discharge	102.56
Gross GW Draft	**412.40**
• Irrigation	373.52
• Domestic and Industrial use	38.87
Provision for Drinking and Industrial use for the year 2025	53.63
Net GW availability for future irrigation	605.48
Stage of GW development (%)	**39.72 %**

5. GROUND WATER RELATED ISSUES

5.1 Low groundwater potential

In Khammam district, low ground water potential (< 1 lps) has been identified in 49% of area in western and southeastern parts mostly due to granitic terrain (absence of primary porosity, negligible development of secondary porosity) and restricted depth of weathering. The occurrence of less rainfall and urbanization also affects the potential. The yield from bore wells have reduced over a period of time and some bore wells which used to yield sufficient quantity of water have gone dry due to low rainfall. Sustainability of the aquifer is limited and the wells normally sustain pumping for 0.5 to 2 hours only.

5.2 Inferior groundwater quality

- Few mandals are fluorosis endemic where fluoride (geogenic) is as high as 4.61 mg/L during pre-monsoon and 3.44 mg/L during post-monsoon season. The high fluoride concentration (>1.5 mg/L) occur in 22 % and 18 % of the samples during pre-monsoon and post-monsoon season.

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

- High nitrate (> 45 mg/L) due to anthropogenic activities are observed in few mandals as high as 1306 mg/L during pre-monsoon and 868 mg/L during post-monsoon season. The high nitrate concentration (>45 mg/L) occur in 60 % and 54 % of the samples during pre-monsoon and post-monsoon season respectively.

  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.

- The high concentration of EC (> 3000 micro-seimens/cm) is observed in 12 % and 14% of the area during pre-monsoon and post-monsoon seasons respectively.

6. MANAGEMENT STRATEGY

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 management plan comprises two components namely supply-side management and demand-side 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 groundwater resources can be done through the artificial recharge by computing surplus runoff available within river sub-basins and also by repairing, renovation & restoration of existing tanks.

6.1.1 Artificial Recharge Structures (To be taken up)

The areas feasible for construction of recharge structures has been demarcated based on the analysis of post-monsoon depth to water level data and existing data on artificial recharge structures constructed under various schemes of MGNREGA and IWMP by Rural Development department, Govt. of Telangana. The availability of unsaturated volume of aquifer was computed by multiplying the area feasible for recharge and unsaturated depth below 3 mbgl. The recharge potential of aquifer is calculated by multiplying the unsaturated volume with specific yield of the aquifers (0.02 for hard rock and 0.03 for soft rock).

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

The storage required for existing artificial recharge structures by State Govt. departments under 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 run-off is considered for the recommendation of artificial recharge structures, as the remaining 50 % is recommended for implementing water conservation measures in recharge areas through MGNREGS. The **Table 6.1** gives the area feasible and volume available for the recharge.

As the stage of ground water development in the district is 39.78 % and 16 out of 21 mandals are falling in safe category as per the GEC 2020 estimation, the artificial recharge structures are not proposed for entire district. To control further increase in stage of ground water development, artificial recharge structures are recommended in

5 semi-critical mandals (i.e., Penuballi, Raghunadhapalem, sathupalli, Singareni, Thirumalayapalem) and 1 critical mandal (i.e, Vemsoor) only.

Table 6.1: Area feasible and volume available for artificial recharge

Total geographical area of district (Sq.km)	4360
Area feasible for recharge (Sq.km) (in 6 mandals)	1429.75
Unsaturated Volume (MCM)	1829.62
Recharge Potential (MCM)	36.59
Surplus run-off available for recharge (MCM)	40.33
PROPOSED ARTIFICIAL RECHARGE STRUCTURES	
Percolation Tanks (@ Rs.20 lakh, Av. Gross Capacity=0.007 MCM*2 fillings = 0.0140 MCM)	274
Volume of Water expected to be conserved / recharged (in MCM)	3.83
Estimated Expenditure (in Crores)	58.00
Check Dams (@ Rs.15 lakh, Av. Gross Capacity=0.007 MCM* 5 fillings = 0.035 MCM)	447
Volume of Water expected to be conserved / recharged (in MCM)	15.64
Estimated Expenditure (in Crores)	70.50
Total volume of water expected to be recharged (in MCM)	19.47
Total Estimated Expenditure for Artificial Recharge (Rs. in Cr.)	**128.50**

The total unsaturated volume (below the depth of 3 m) available for artificial recharge is 1829.62 MCM, having 36.59 MCM of recharge potential (2%). The available surplus run-off can be utilized for artificial recharge through construction of percolation tanks, check dams with recharge shafts at suitable sites. The number of percolation tanks, and check dams are decided based on the number of suitable streams available in the district.

Thus, after taking into consideration all the factors, only 40.33 MCM of surplus water can be utilised for recharge, which is given in **Table 6.1**. This surplus water can be utilized for constructing 447 check dams with estimated expenditure of Rs. 70.50 crores and 274 percolation tanks with estimated expenditure of Rs. 58.00 crores at suitable sites. The amount of recharge from these artificial recharge structures was calculated by considering 0.0140 MCM per percolation tanks and 0.035 MCM per check dam. This intervention would lead to recharge of about 19.47 MCM/year. The details are given in **Annexure-1.**

In addition to this roof top rainwater harvesting structures should be made mandatory to all Government buildings.

6.1.2 State Government Projects

- **Mission Kakatiya (Repair, Renovation and Restoration of existing tanks):**

  De-silting of existing minor tanks (871 no.) was taken under state Govt. sponsored Mission Kaktiya (Phase-1 to 4) to remove silt and this has created additional surface storage and enhance groundwater recharge.

- **Mission Bhagiratha**:

Under Telangana Drinking Water Supply Project (TDWSP), also known as Mission Bhagiratha, all the villages and towns are proposed to be covered from the three water grids with intake from 1) Godavari river (Segment- Godavari-Pusuru), 2)Palair Reservoir (Segment- Palair-Khammam), 3) Wyra Reservoir (Segment-Wyra) to provide protected water from surface reservoirs. The scheme is to enhance the existing drinking water scheme and to provide safe drinking water to 273635 no. of households.

The total water requirement as per 2020 census is 131.67 MCM and this imported water from surface sources will reduce the present utilized ~79 MCM of ground water (considering 60 lpcd). This can be effectively utilized to irrigate ~13166.66 ha of additional land under ID crops.

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.

6.2 Demand side management

In order to manage the available resources more effectively the following measures are recommended.

- In the district, till date 4971 no's drip and sprinklers are sanctioned which has irrigated ~6506.85 ha under ID crops saving ~9.76 MCM (considering 25% saving of 0.006 MCM/ha) of groundwater from the basin. Considering the current scenario of groundwater development, existing number of structures and shallow water levels, demand side intervention such as change in cropping pattern and micro irrigation has not been proposed.
- ~2618.82 ha of additional land that can be brought under micro-irrigation (@1000 ha /mandal including existing area in 5 semi-critical mandals (i.e., Penuballi, Raghunadhapalem, sathupalli, Singareni, Thirumalayapalem) and 1 critical mandal (i.e, Vemsoor)) costing about 15.71 crores (considering 1 unit/ha @0.6 lakh/ha). With this 3.93 MCM of ground water can be conserved over the traditional irrigation practices.
- Change in cropping pattern from water intensive paddy to irrigated dry crops like pulses and millets are recommended particularly in 6 mandals viz, Penuballi,

Raghunadhapalem, Sathupalli, Saingareni, Thirumalayapalem, and Vemsoor where paddy cultivated area is ~ 80% of the Gross cropped area.

- ❖ 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.

6.3 Other Recommendations

- ❖ 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 measures that are recommended include 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.

6.4 Expected results and outcomes

With the above interventions costing Rs 144.21 crores (excluding the cost involved in Mission Kakatiya and Mission Bhagiratha), the likely benefit would be net saving of 98.47 MCM of ground. This will bring down the stage of groundwater development by 3.45 % (from 39.78 % to 36.33%)

Acknowledgment

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Annexure-1

Proposed supply side interventions for ARS

Mandal	Village	Proposed CDs	Proposed PTs	Cost of CDs @ 15 lakhs	Cost of PTs @ 20 lakhs
Penuballi	Adavimallela	2	0	30	0
Penuballi	Bavannapalem	1	0	15	0
Penuballi	Bayyannagudem	3	0	45	0
Penuballi	Chintagudem	2	0	30	0
Penuballi	Chowdavaram	0	0	0	0
Penuballi	Ganeshpadu	1	0	15	0
Penuballi	Gollagudem	12	8	180	160
Penuballi	Gowraram	11	7	165	140
Penuballi	Karaigudem	3	2	45	40
Penuballi	Kondrupadu	1	0	15	0
Penuballi	Kuppenakuntla	4	1	60	20
Penuballi	Lankapalli	16	12	240	240
Penuballi	Lingagudem	6	3	90	60
Penuballi	Mandalapadu	4	2	60	40
Penuballi	Penuballi	5	1	75	20
Penuballi	Ramachandrapuram	6	2	90	40
Penuballi	Tekulapalli	3	1	45	20
Penuballi	Telagaram	2	0	30	0
Penuballi	Thallapenta	12	8	180	160
Penuballi	Thummalapalli	1	0	15	0
Penuballi	Yerugatla	4	1	60	20
Raghunadhapalem	Dareedu	1	1	15	20
Raghunadhapalem	Kamanchikal	1	1	15	20
Raghunadhapalem	Chimmapudi	3	2	45	40
Raghunadhapalem	Erlapudi	23	17	345	340
Raghunadhapalem	Koyachelaka	2	1	30	20
Raghunadhapalem	M. Chintagurthi	2	0	30	0

Raghunadhapalem	Manchukonda	2	1	30	20
Raghunadhapalem	Papatpalli	3	1	45	20
Raghunadhapalem	Raghunadhapalem	4	2	60	40
Raghunadhapalem	Regulachelaka	1	0	15	0
Raghunadhapalem	V.Venkataipalem	3	1	45	20
Raghunadhapalem	Vepakuntla	3	1	45	20
Sathupalli	Ayyagaripeta	18	15	270	300
Sathupalli	Bethupalli	20	17	300	340
Sathupalli	Cherukupalli	9	6	135	120
Sathupalli	Dacharam	1	1	15	20
Sathupalli	Jagannadhapuram	1	0	15	0
Sathupalli	Kakarlapalli	12	10	180	200
Sathupalli	Kistaram	8	5	120	100
Sathupalli	Kominepalli	4	1	60	20
Sathupalli	Ragallapadu	8	6	120	120
Sathupalli	Rejerla	9	8	135	160
Sathupalli	Rudrakshapalli	34	28	510	560
Sathupalli	Sadasivanipalem	2	2	30	40
Sathupalli	Sattupalli	27	22	405	440
Sathupalli	Siddaram	8	7	120	140
Sathupalli	Thumbur	16	14	240	280
Sathupalli	Yatalakunta	2	1	30	20
Singareni	Bajumallaigudem	2	1	30	20
Singareni	Gate Karepalli	6	3	90	60
Singareni	Kamalapuram	2	0	30	0
Singareni	Komatlagudem	1	0	15	0
Singareni	Madaran	6	2	90	40
Singareni	Manikyaram	2	0	30	0
Singareni	Perepalli	5	2	75	40
Singareni	Relakayalapalli	5	2	75	40
Singareni	Singareni	3	0	45	0
Singareni	Usirikayalapalli	18	12	270	240

Singareni	Vishwanathapalli	2	1	30	20
Thirumalayapalem	Bandampalli	2	0	30	0
Thirumalayapalem	Beerolu	3	0	45	0
Thirumalayapalem	Bochodu	1	0	15	0
Thirumalayapalem	Edulachervu	2	2	30	40
Thirumalayapalem	Hasnabad	1	0	15	0
Thirumalayapalem	Hydarsaipeta	0	1	0	20
Thirumalayapalem	Jallepalli	2	1	30	20
Thirumalayapalem	Jupeda	2	1	30	20
Thirumalayapalem	Kakaravai	2	2	30	40
Thirumalayapalem	Laxmidevipalli	1	0	15	0
Thirumalayapalem	Medidapalli	2	0	30	0
Thirumalayapalem	Mohammadapuram	0	1	0	20
Thirumalayapalem	Mujahidpuram	0	0	0	0
Thirumalayapalem	Painampalli	0	0	0	0
Thirumalayapalem	Patharlapadu	2	3	30	60
Thirumalayapalem	Pindiprolu	2	0	30	0
Thirumalayapalem	Raghunadhapalem	1	0	15	0
Thirumalayapalem	Solipuram	0	0	0	0
Thirumalayapalem	Sublaid	1	0	15	0
Thirumalayapalem	Thetlapadu	1	0	15	0
Thirumalayapalem	Tippareddygudem	0	0	0	0
Tirumalayapalem	Kokkireni	5	0	75	0
Tirumalayapalem	Thallacheruvu	0	0	0	0
Tirumalayapalem	Tirumalayapalem	4	0	60	0
Vemsoor	Adasarlapadu	4	2	60	40
Vemsoor	Ammapalem	9	6	135	120
Vemsoor	Bharanipadu	1	1	15	20
Vemsoor	Chowdaram	7	6	105	120
Vemsoor	Duddipudi	3	1	45	20
Vemsoor	Erragunta	3	1	45	20

Vemsoor	Guduru	3	1	45	20
Vemsoor	Kallurgudem	2	2	30	40
Vemsoor	Kandragatlamallela	3	1	45	20
Vemsoor	Kandukuru	3	1	45	20
Vemsoor	Kunchaparthi	5	4	75	80
Vemsoor	Pallevada	9	6	135	120
Vemsoor	Vemsur	6	5	90	100
Vemsoor	Vennachedu	0	0	0	0