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

PRAKASAM DISTRICT, ANDHRA PRADESH

दक्षिणी क्षेत्र, हैदराबाद

Southern Region, Hyderabad

REPORT ON

AQUIFER MAPPING FOR SUSTAINABLE MANAGEMENT OF GROUND WATER RESOURCES IN PRAKASAM DISTRICT (PARTS) ANDHRA PRADESH

CONTRIBUTORS' PAGE

Name		Designation
Principal Authors		
Shri Ravi Kumar Gumma	:	Scientist-C (Sr. Hydrogeologist)
Shri G. Praveen Kumar	:	Scientist-C
Dr. Pandith Madhnure	:	Scientist-D (Sr. Hydrogeologist)
Supervision & Guidance		
Dr. P.N. Rao	:	Supdtg. Hydrogeologist
Shri G.R.C Reddy	:	Scientist –D (Sr. Hydrogeologist)
Shri. D. Subba Rao	:	Regional Director

REPORT ON
AQUIFER MAPPING FOR SUSTAINABLE MANAGEMENT OF GROUND WATER RESOURCES IN PRAKASAM DISTRICT (PARTS) ANDHRA PRADESH

EXECUTIVE SUMMARY

C O N T E N T S

Figures

REPORT ON
AQUIFER MAPPING FOR SUSTAINABLE MANAGEMENT OF GROUND WATER RESOURCES IN PRAKASAM DISTRICT (PARTS), ANDHRA PRADESH
AT A GLANCE

S.No.	Item		Particulars
1	Districts	:	Prakasam
2	Mandals	:	11
3	Revenue villages	:	228
4	Geographical area	:	5851 Km^2
5	Population (2011 Census)	:	6.06 lakhs
6	Locations	:	North Latitude: 15°09´46"- 16°14´47" East Longitude: 78°44´13"- 79°25´17"
7	Rainfall (Normal)	:	726 mm 618 mm to 860 mm
8	Geomorphology	:	Structural hills (35 %), Structural Valleys (18%), Pediplain (25%), Pediment (9%), etc.
9	Major Rivers	:	Krishna and its tributaries
10	Forests	:	~57% (3351 Km^2)
11	Soils	:	Red Clayey and loamy soils
12	Land Utilization (Ha) (2013-14)	:	Total cropped area is 135786 ha (~23%), area sown more than once is 24051 ha (~4%), Forest occupies 335112 ha (~57%), Barren and cultivable land is 43266 ha (7.4%), land put to non-agricultural uses is 38988 ha (6.6%), Cultivable waste is 12760 ha (2.2%) etc.
13	The Total cropped area (Ha) 2014-15	:	1.35 lakh Ha (~28%). Khariff (63 %) and Rabi (37%)
14	Irrigation	:	Major: Veligonda (In-complete) Regisatered Ayacut : 62564 ha Medium: Cumbhum Cheruvu/Tank Registered ayacut of medium irrigation projects: ~2801 ha. But due to non filling of reservoirs it irrigated ~689 ha (24 % only) MI Tanks: 297
15	Water conservation/Recharge practices	:	Artificial Recharge - PT: 610, CD:796. Storage Created : 40.32 MCM Expected Ground Water Recharge: 20.16 MCM (50% of the Storage).
16	Geology	:	Meta sediments comprising of Quartzites (56%), Shales and slates (43%) and Schsits (0.4%)
17	Exploratory Drilling (CGWB and SGWD)	:	APSIDC: 117 bore wells (3 wells are of shallow depth (30 m), 108 nos are of 30-60 m, 06 nos are of 60-100 m depth). SGWD: 20 wells (2 bore wells are <30 m depth, 17 bore wells are of 30-60 m depth and remaining 03 wells are of 60-100 m depth range)
18	Number of ground water structures	:	Irrigation wells: 39585 (7 bore wells/km2).
19	Ground water yield (lps)	:	<1 to 32 lps (Ayyavari peta, Ardhaveedu Mandal).
20	Water Levels (2015)	:	24 PZs of SGWD
20.1	Depth to water Table elevations (m amsl)	:	100 to 250 (m amsl)

20.2	Depth to water levels (m bgl)	:	The DTW varies from meter below ground level (m bgl) during Pre-monsoon period and (average: 37 m bgl) and 9 - 60 m bgl (average: 35) during post-monsoon season of 2016 respectively. Pre-monsoon: 10 to 63 (avg:37) Post-monsoon: 9- 60 (avg:35)		
20.3	Water Level Fluctuations (May vs. November 2015)	:	-13.13 to 37.38 m (Average fall of - 5.03 m and rise of 9.92 m)		
21	Geophysical data	:			
22	Hydrochemistry	:	93 samples pre-monsoon:62, post-monsoon-31		
22.1	Electrical Conductivity (µ Siemens/cm)	:	Pre: 1545-6010 (avg: 2764) µ Siemens/cm. Post: 1062-5078 (avg: 2774) µ Siemens/cm		
22.2	Fluoride	:	1.02 – 4 mg/l with an average of 1.8 mg/l.		
22.3	Nitrate(2015)	:	Pre: 16-456 mg/l and Post: 20-58 mg/l		
22.4	Ground water suitability for drinking	:	70 % samples are not suitable for drinking purpose, during Pre Monsoon and 58% of samples are unfit for human consumptions during post-monsoon season.		
23	Conceptualization		Weathered zone	Fractured zone	
23.1	Aquifer Characterization	:	<10 - 30	10-68 m	
24	Ground water Resources (2013) MCM	:	Command	Non-Command	Total
24.1	Net dynamic groundwater availability	:	0	142	142
24.2	Gross GW Draft	:	0	164.15	164.15
24.3	Provision for Domestic &Industrial (2025)	:	0	18.33	18.33
24.4	Stage of Ground water development (%)		0	115	115
24.5	Net GW Availability for future irrigation	:	0	5.92	5.92
25	Major Ground Water Issues Identified	:	o 7 mandals comprising an area of ~ 4371 Km^2 area (74%) is categorized as over-exploited o Out of the total irrigated area of 66090 ha, GW contributes 55311 ha (83%). o Desaturation of weathered zone and extraction of GW from deeper aquifers. o No assured Surface water irrigation. o Deep water levels (> 20 m bgl) are observed during pre and post-monsoon season in 92 % and 90 % of the area respectively. o Out of 25 wells analyzed, 12 wells (50%) shows fall in water levels (-0.03 to -13.13 m). o The high fluoride concentration (>1.5 mg/L) occur in 70 % of analyzed samples in the study area.		
26	Management Strategies	:	**Supply side measures** **Ongoing Projects (Mission NEERU CHETTU)** 35 minor irrigation tanks are de-silted (0.837 MCM). This contributed ~ 0.42 MCM groundwater recharge and an additional ~139 ha land can be brought under irrigated dry (ID) crops in tank ayacut. Additional storage creation of 6.288 MCM expected ground water recharge is 3.1 MCM and 1050 ha under tank ayacut will be created/stabilized from the proposed desilting of remaining 262 MI Tanks. **To be taken up**		

			Artificial Recharge Structure (ARS) CDS : 128, PTS : 26 The expected GW recharge: 3.02 MCM (CDS : 1.72 MCM and 1.3 MCM for PTS). The total expenditure: 9.0 Cr. Contemplated Projects (Veligonda Project) : ~62564 ha will be irrigated Water Conservation measures (WCM) Farm Ponds Recommended 4560 nos farm ponds with total cost : 11.4 Cr. **Demand side measure** **Ongoing work** A total number of 720 no's drip and sprinklers are sanctioned which has irrigated ~683 ha of land saving ~1.025 MCM of groundwater from the district considering 50% of net savings. **Proposed Work** 13827 ha @ 25% of the area irrigated under ground water (55311 ha) are recomended (@60 ha/ villages) Cost ~82.96 crores (@0.6 lakhs/ha) Will save 39.86 MCM of GW to traditional Irrigation practices. **Other Measures:** Intermittent pumping Regulated power supply Future GW development in rain fed area should be linked with Drip and sprinklers. Effective implementation of AP WALTA Act. Mandatory ARS in every Govt Institutes/buildings. Participatory GW management. Proper sewage disposal
27	Expected Results and Out come	:	**Ground Water** Additional GW Recharge/Conservation: 67.84 MCM. Reduction in Stage of GW Development:37% (from 111 % to 74 %). Expenditure (appx.)of the proposed Interventions: 117.36 cr.

			Additional irrigation benefits/Stabilization Veligonda Project: Irrigation to 62564 ha and Stabilization 55311 ha of GW irrigated area Stabilization of Cumbhum Tank Ayacut: 2801 ha. Desilting of Irrigation Tanks under Neeru-Chettu: 1189 ha stabilization. Farm Ponds: 4560 farm ponds will stabilize the 1845 ha under rain fed irrigation.

ABBREVIATION:

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

EXECUTIVE SUMMARY

The Study area is a western part of the Prakasam district, Andhra Pradesh covering 5851 Km^2 area with 11 mandals and 228 revenue mandals. The population of the district is ~ 6.06 lakh (2011 census). The area receives an annual rainfall of 726 mm.

Structural hills, Valleys, Pediplain and pediments are the major geographic units in the study area. The area is a part of River Krishna There are 1 major, 1 medium and 297 MI tanks and the gross irrigated area 66090 ha. Groundwater contributes ~83% of the net irrigated area and surface water contributes 17%. There are 798 Check dams and ~610 percolation, mini percolation tanks with combine capacity of 40.32 MCM Storage. Till 2015-16, ~ 683 ha area is brought under micro-irrigation practices (Drip and Sprinklers).

Total cropped area of the district is 1.35 Lakh ha (~23%) and forests occupy ~57 % of the area. The main crops during Khariff season are Paddy, Cotton and Chillies etc. During Rabi season, main crops grown are Paddy, maize, oil seeds etc. The other crops are turmeric, jowar etc The soils are mainly clayey skeletal, mixed loamy and loamy types. The area is underlain by Meta sediments comprising of Quartzites (56%), Shales and slates (43%) and Schsits (0.4%) of Cuddapah super group..

Hydrogeological data from 231 Based (Exploration: 139, Geophysical: 20 and well inventory: 54) down to maximum depth explored (1.e. 120 m) are collected and compiled. At present, extraction is mainly through boreholes of 60-100 m depth, with yield between <1 to 11 litres/second (lps). Majority of fractures occur within 100 m depth and deepest fracture is encountered at the depth of 109 m depth (Rayavaram, Yerragondapalem). Ground water yield from weathered and fractured aquifer varies from <1 to 32 lps (Ayyavari peta, Ardhaveedu Mandal).

Water levels are monitored through SGWD PZS (24 No.s) during pre and post-monsoon season of 2015. The DTW varies from 10 to 63 meter below ground level (m bgl) during Pre-monsoon period and (average: 37 m bgl) and 9 - 60 m bgl (average: 35) during post-monsoon season of 2016 respectively.

During pre-monsoon season, majority of the water levels are in the range of 30 to 40 m covers ~ 25% of area, followed by 40-50 m bgl (24% of area). Deep water levels at the range of 50 to 60 m bgl occupy ~6% of area mostly in north central part of the study area.

During Post Monsoon season, 10-20 m (~8 %), 20-30 m (14%), 30-40 m (18%), 40-50 mbgl (38%), 50-60 m bgl (14%) and >60 m bgl (6%)

The water level fluctuations vary from -13.13 to 37.38 m with average fall of - 5.03 m and rise of 9.92 m. Out of 25 wells, in 12 wells (50%) shows fall in water levels (-0.03 to -13.13 m) and 10 wells shows rise in water levels (0.06 to 37.38 m) is observed and 3 wells show neither rising nor fall in water levels.

Total 89 data from Rural Water Supply (RWS) is utilized (Pre: 57 and Post: 32).63 ground water samples. During Pre Monsoon, Electrical conductivity varies from 1545-6010 (avg: 2764) µ Siemens/cm. The Concentration of NO_3 ranges from 16-456 mg/l.. The concentration of Flouride ranges from 1.02 – 4 mg/l with an average of 1.8 mg/l. During Post Monsoon, Electrical conductivity varies from 1062-5078 (avg: 2774) µ Siemens/cm The concentration of NO_3 ranges from 20-58 mg/l The concentration of Flouride ranges from 0.8-2.8 mg/l with an average of 1.6 mg/l.

Aquifers from the area can be conceptualized in to two nos namely, 1) weathered zone (~20 m) and 2) fractured zone (20-120 m). The The Thickness of weathered zone is varies from <10 m to 30 m. The depth of fracturing varies from 10-109 m and deepest fracture is dechiphered through VES study is 109 m (Rayavaram, Yerragondapalem). Weathered zone in most of aquifers has almost gone dry in 11 mandals due to over-exploitation. Ground water yield from weathered and fractured aquifer varies from <1 to 32 lps (Ayyavari peta, Ardhaveedu Mandal). However, in most of the area yield varies from 1 to 5 lps.

The Net dynamic replenishable ground water availability is 142 MCM, gross ground water draft is 164.15 MCM, provision for drinking and industrial use for the year 2025 is 18.33 MCM and net available balance for future irrigation use is 5.92 MCM. The stage of ground water development varies from 73 to 144 % (avg: 115%).

Major issues identified are over-exploitation in 7 mandals covering in an area of 4371 km^2 area covering 07 mandals, pollution (both geo-genic (F) and anthropogenic (NO_3), deep water levels (>20 m) during pre and post-monsoon season in 92 % and 90 % of the area respectively, declining water levels in majority of hydrograph stations and low yields.

The management strategies mainly include both supply side and demand side. The supply side measure includes ongoing work under NEERU-CHETTU where 279 tanks are taken up phase wise which will contribute ~3.52 MCM of ground water by recharge, with this additional ~1189 ha land can be brought under irrigated dry (ID) crops in tank ayacut. Construction of 154 ARS with ~9.0 crores, renovation, repairs and installation of Recharge Shafts in 50% of the existing PTS (610) and CDS (796) are recommenfded with an expenditure estimate of 14.0 cr. This will result in effective utilization of surface storage of 40.32 MCM for GW recharge of 20.16 MCM (50% of the storage). An about 4560 farm ponds with Rs.11.4 crores are recommended.

Under ongoing/contemplated Veligonda project, Govt. of AP is intended to create irrigational facilities to 62564 ha from surface water from river Krishna. Considering 375 MCM crop water requirement for ID crops, after the implementation of the project, the area under rainfed irrigation (69696 ha) in the study area will be brought into the ambit of assured surface water irrigation. Further, if micro irrigation practices are implemented, the crop water requirement for 62564 hectares will be fulfilled within 187.5 MCM. The conserved surface water can be effectively being utilized to supplement irrigation underground water which will reduce the stress on ground water.

Demand side measure includes 13827 ha @ 25% of the area irrigated through ground water (55311 ha) with an estimated cost of 82.96 crores with expected savings of 39.86 MCM of ground water.

Intermittent pumping, Regulated power supply, Future GW development in rain fed area should be linked with Drip and sprinklers, Effective implementation of AP WALTA Act, Mandatory ARS in every Govt Institutes/buildings, Participatory GW management, Proper sewage disposal and Providing calcium, phosphorous rich food along with multivitamin tablets to the children below the age of 14 years in fluoride affected areas along with mid-day meals are also recommended.

With above measures the stage of ground water development will come down by 37 % (from present 115 % to 78%) with one time investment of 117.6 crores. In addition to this, after interventions, the anticipated benefits includes irrigation to 62564 ha and Stabilization 55311 ha of GW irrigated area with Veligonda Project, stabilization of 2801 ha Ayacut under Cumbhum Tank, stabilization 1189 ha through Neeru Chettu desilting, stabilization of 1845 ha under rain fed irrigation through new 4560 farm ponds.

NUMBER OF DATA POINTS USED FOR PREPARATION OF VARIOUS MAPS/FIGS- STUDY AREA, PRAKASAM DISTRICT, ANDHRA PRADESH

S. No.	Data	Aquifer	Total Data Points	Source		
				CGWB	SGW/ APSIDC	Well Inventory
1	Panel Diagram (3-D)	Combine	210	EW 1: VES:21	12/120	56
2	Hydrogeological Sections	3 no	210	EW 1: VES:21	12/120	56
3	Fence/panel Diagrams	AQ-I & II	210	EW 1: VES:21	12/120	56
4	Depth of weathering	AQ-I	210	EW 1: VES:21	12/120	56
5	Depth of fracturing	AQ-II	210	EW 1: VES:21	12/120	56
6	Groundwater Yield	Combined	125	1	12/120	-
7	Transmissivity (m^2/day)	Weathered Z	0	0	-	-
		Fractured Z	0	0	-	-
8	Depth to Water Level Maps (2015)	Combine	24	-	24	-
9	Water Level Fluctuations	Combine	24	-	-	-
10	Water quality (2015) (EC and NO_3) F (historical data of CGWB)	Combine	Pre : 62 & Post : 31 (RWS)	-	62 & 31 (RWS)	-

1. INTRODUCTION

Aquifer mapping is a process wherein a combination of geologic, geophysical, hydrologic and chemical analyses is applied to characterize the quantity, quality and sustainability of ground water in aquifers. In recent past, there has been a paradigm shift from "**groundwater development**" to "**groundwater management**". As large parts of India particularly hard rocks have become water stressed due to rapid growth in demand for water due to population growth, irrigation, urbanization and changing life style. Therefore, in order to have an accurate and comprehensive micro-level picture of groundwater in India, aquifer mapping in different hydrogeological settings at the appropriate scale is devised and implemented, to enable robust groundwater management plans. This will help in achieving drinking water security, improved irrigation facility and sustainability in water resources development in large parts of rural and many parts of urban India. The aquifer mapping program is important for planning suitable adaptation strategies to meet climate change also. Thus the crux of National Aquifer Mapping (NAQUIM) is not merely mapping, but reaching the goal-that of ground water management through community participation.

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

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

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

1. Compilation of existing data (exploration, geophysical, groundwater level and groundwater quality with geo-referencing information and identification of principal aquifer units.

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

1.3 Area details: The Study area consists of 11 mandals with 228 revenue villages located in Western part of Prakasam study area, Andhra Pradesh State having geographical area of 5851 km^2, lies between 15°09´46"- 16°14´47" N latitude and 78°44´13"- 79°25´17" East longitude (**Fig.1.1**). Out of total area, the hilly and forest area about is 3351 km^2 (57%). The list of the mandal and its geographical areas are provided below

S.No.	Mandal	Geographical area (Sq.kms)	Forest/Hilly Area (Sq.kms)	Rainfall (mm) (Normal)	Main Crops	Categorization (GEC-2013)
1	Ardhaveedu	565	352	734.8	Chillies, Castor, Rice	Safe
2	Bestavaripeta	434	195.5	763.1	Bajra,Rice,Chillies	OE
3	Cumbhum	173	45.82	733.3	Bajra,Rice,Chillies	Critical
4	Dornala	950	777.49	859.9	Chillies, Redgram, Castor	OE
5	Giddaluru	863	595.98	636.2	Redgram, Chillie	OE
6	Komarolu	394	179.78	737.6	Chillies, Redgram	SC
7	Markapuram	348	56.18	723.9	Chillies, Redgram	OE
8	Peedaraveedu	379	130.72	711.6	Redgram, Chillies	OE
9	Racherla	320	122.94	618.1	Castor,Redgram	OE
10	Tarlapadu	348	80.03	738.9	Redgram,Chillies	SC
11	Yerragondapalem	1077	814.68	732.4	Chillies, Redgram	OE

The population of the study area is ~6.06 lakhs (2011 census). The density of population is 131 persons/Km^2 (CPO, Prakasam Study area).

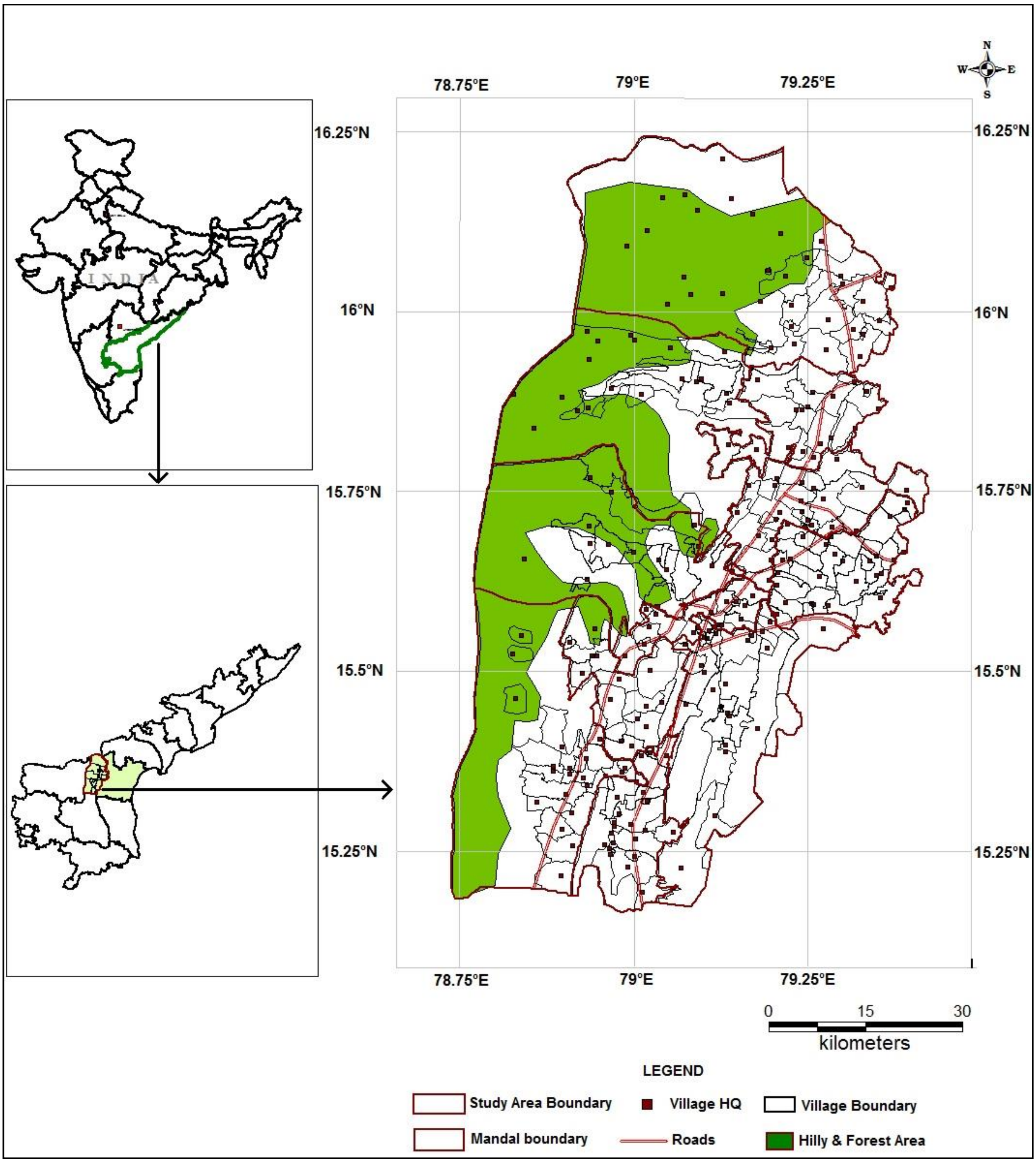

Fig-1.1 Location Map of the Study Area, Prakasam District (Parts), AP

1.4 Climate and Rainfall: The climate of the study area is characterised by hot summer and generally dry weather except during S-W monsoon season. The normal annual rainfall of the study area is 726 mm (Indian Meteorological Department). This varies between 618 mm (Racherla) to 860 mm (Dornala) (**Fig. 1.2**). The South west monsoon contributes ~50 %, North east monsoon contributes ~40%, and remaining by winter season.

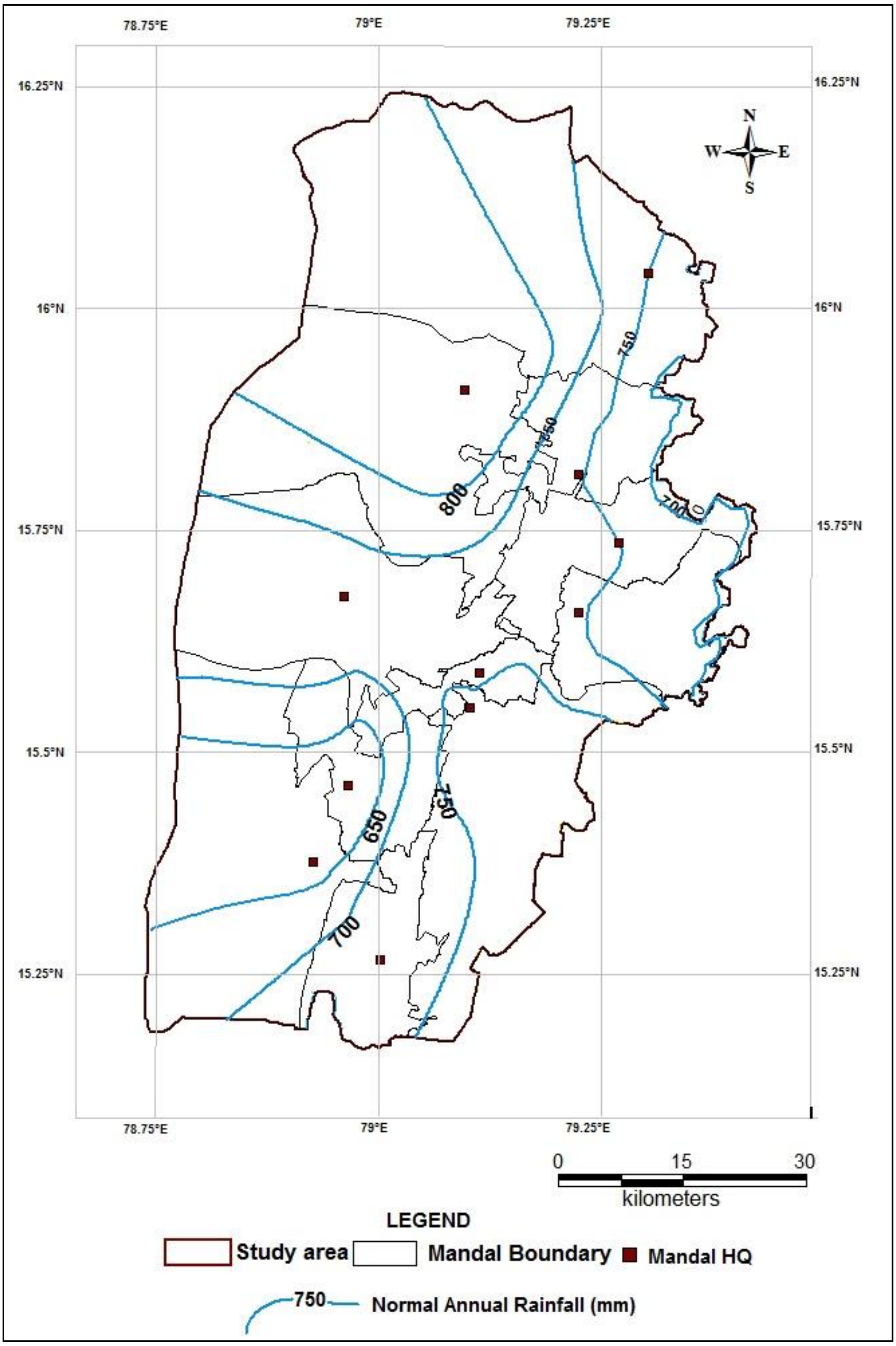

Fig-1.2 Isohytal map of the Study Area, Prakasam District (Parts), AP

1.5 Geomorphological Set up: Structural hills, Valleys, Pediplain and pediments are the major geographic units in the study area. The details and percentage of geomorphological features of the area is given in the table and depicted in Fig-1.3.

Geomorphology	Area (Sq.kms)	%
Structural Hills	2060	35
Structural Valley	1050	18
Pedipalin	1432	25
Pediment	548	9
Dissected Plateus	410	7
Piedmont Zone	200	3
Channel fills	65	1
Others	75	1

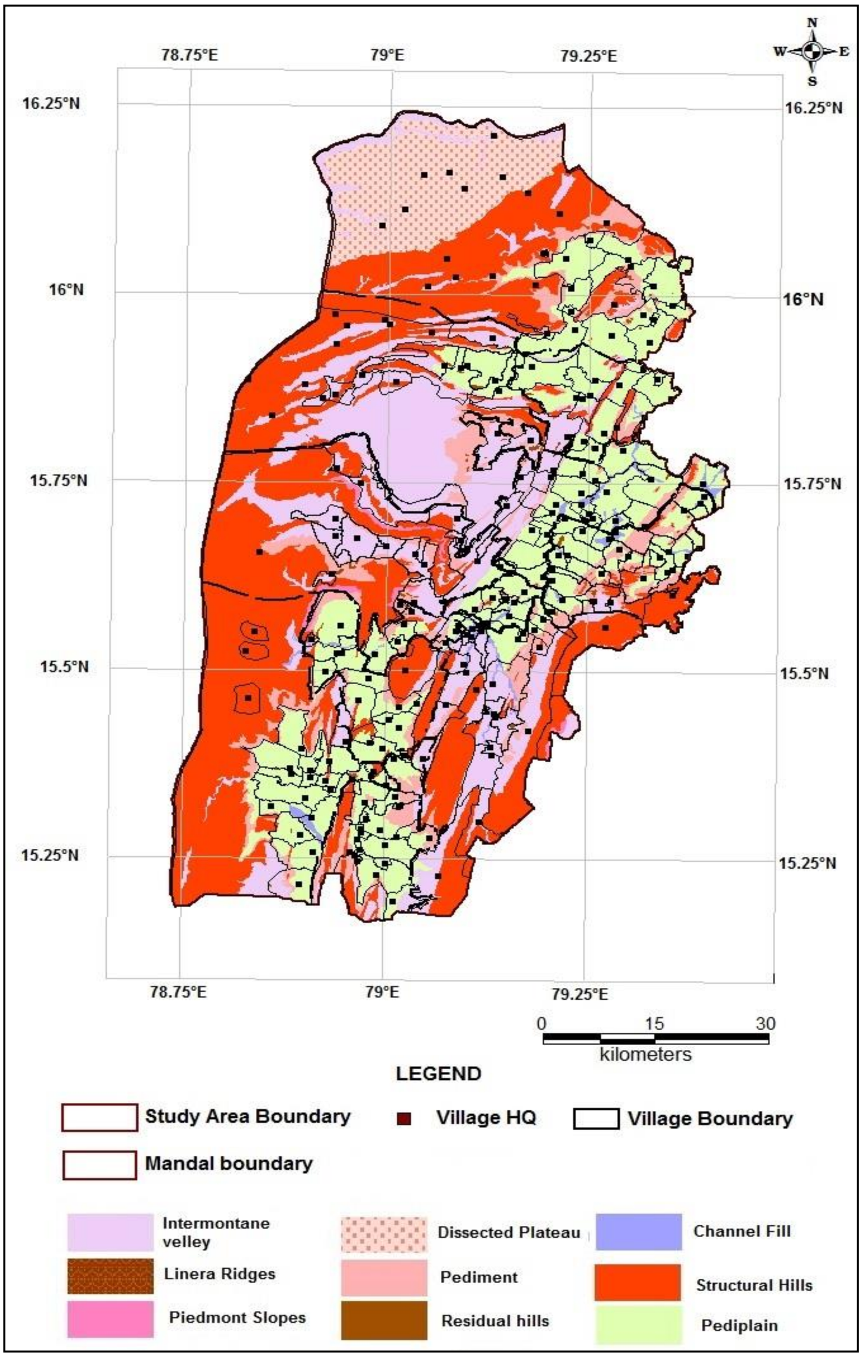

Fig-1.3 Geomorphology of the Study Area, Prakasam District (Parts), AP

1.6 Drainage and Structures: The study area is mainly drained by tributaries of River Krishna and Pennar. The drainage is dendritic and parallel in nature. The Map depicting drainage and water bodies is presented in **Fig.1.4**.

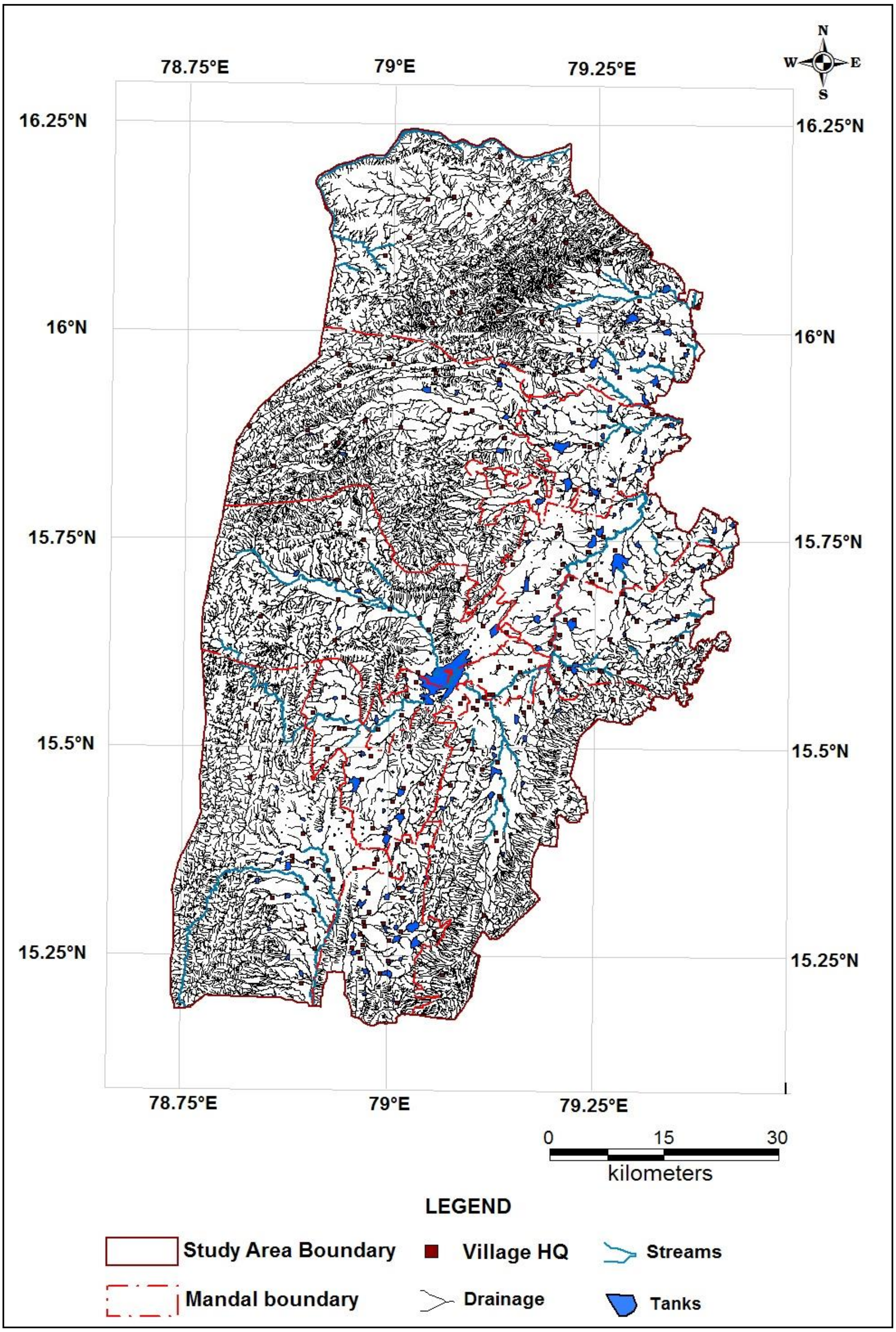

Fig-1.4 Drainage of the Study Area, Prakasam District (Parts), AP

1.7 Land use and cropping pattern (2013-14): Out of the of the total geographical area of 5858 sq.kms, the total cropped area is 135786 ha (~23%), area sown more than once is 24051 ha (~4%), Forest occupies 335112 ha (~57%), Barren and cultivable land is 43266 ha (7.4%), land put to non-agricultural uses is 38988 ha (6.6%), Cultivable waste is 12760 ha (2.2%) etc. During Khariff season, main crops grown are Paddy, Cotton and Chillies etc. During Rabi season, main crops grown are Paddy, maize, oil seeds etc. The other crops are turmeric, jowar etc. Land use and land cover map of the study area is depicted in **Fig. 1.5.**

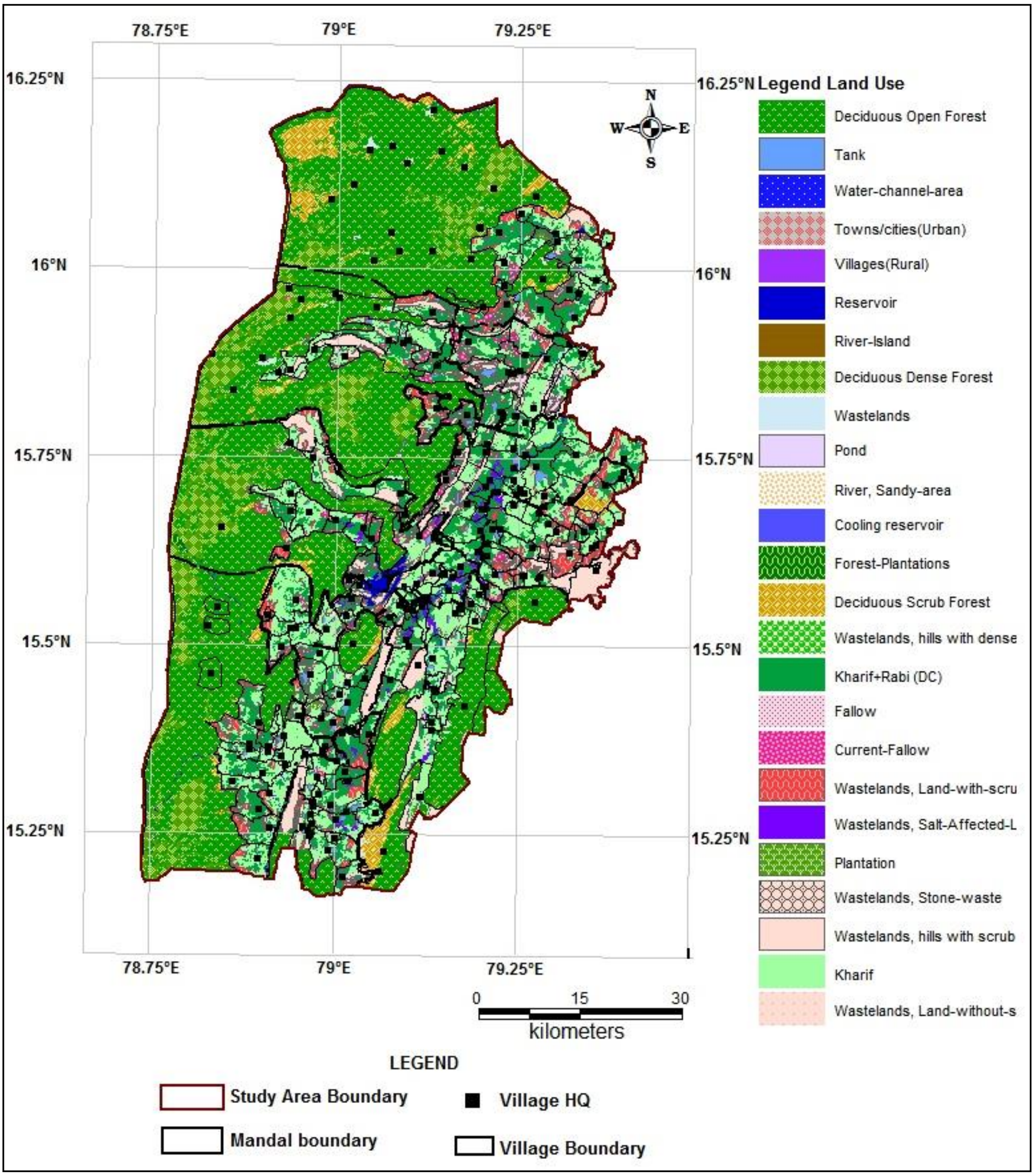

Fig-1.5 Land use map of the Study Area, Prakasam District (Parts), AP

1.9 Irrigation:

The study area is mainly irrigated by ground water. Out of total gross irrigated area of 66090 ha, ~ 55311 ha (~83%) is irrigating through tube wells. The remaining 17% is through 107 minor irrigation tanks (10779 ha).

Veligonda Project is on going irrigation project is located in the study area (Markapuram divison). When completed, the project will provide irrigational facilities to 4,59,000 acres and drinking water to 1.5 million people in 29 Mandals of fluoride and drought affected areas in Prakasam district, Nellore and Kadapa district by diverting 43.5 TMC (1232 MCM) of floodwater of Krishna River from foreshore of Srisailam Reservoir near Kollamvagu and proposed to store in Nallamalasagar Reservoir. The water for the project is drawn through two 18.8 km long tunnels across Nallamala hills. The proposed Veligonda project and its canal network in the study area are shown in Fig-1.6.

1.10 Prevailing water conservation/Recharge practices: In the study area there are **~798** Check dams and ~**610** percolation, mini percolation tanks with combine capacity of 10 MCM. Till 2013-14 ~ 683 ha area is brought under micro-irrigation practices (Drip and Sprinklers).

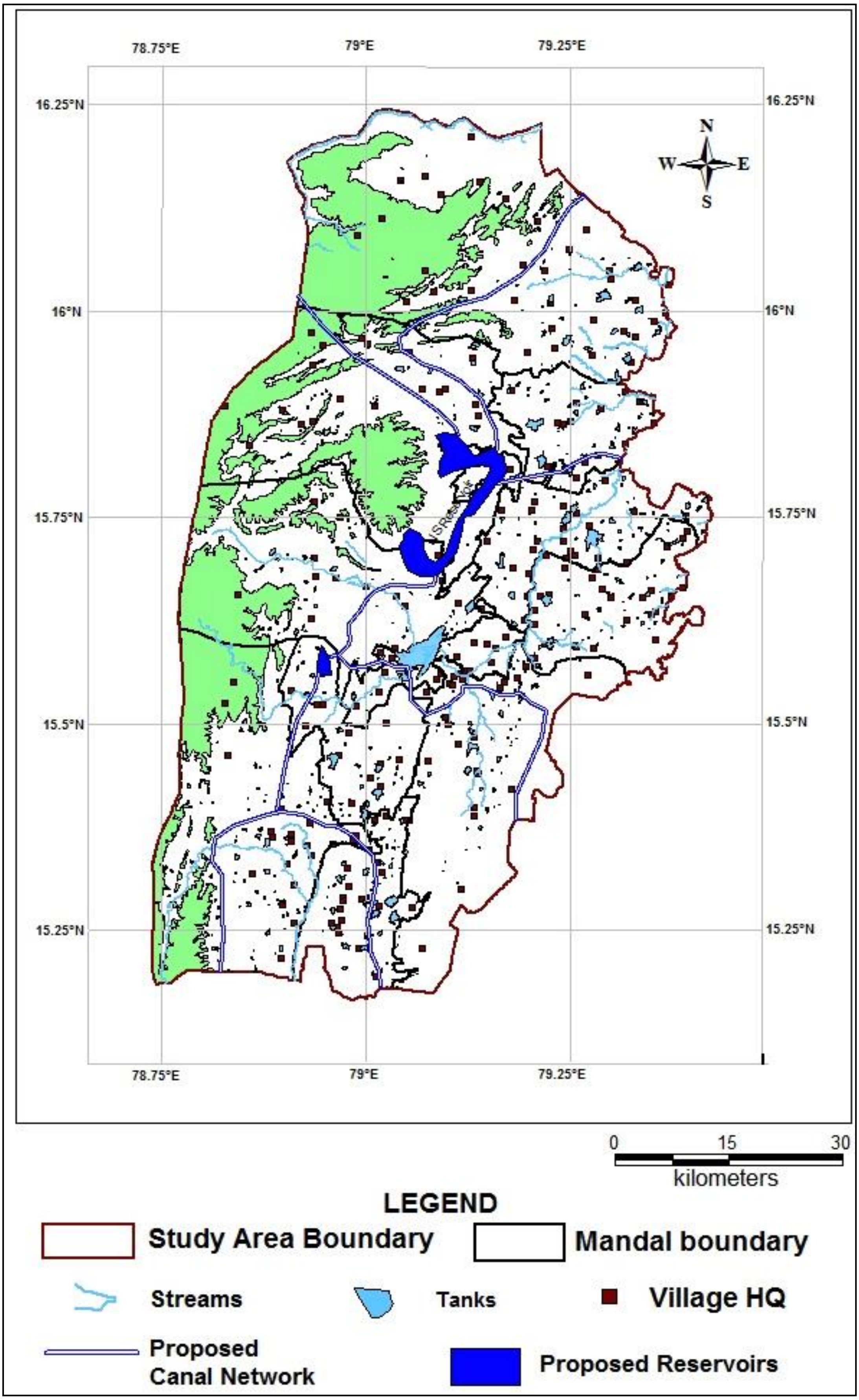

Fig- 1.6 Irrigation Map of the Study Area, Prakasam District (Parts), AP

1.11 Geology: The area is underlain by the Meta Sediments/ Rocks (Shales and Quartzites) belong to Cuddapah super group of Proterozoic age (**Fig 1.7**). The geological succession is shown below

Table- Geological succession of the Study area

Age	**Group**	**Lithology**
Proterozoic	Cuddapah Super Group	Quartzites, Shales, Phyllites, Slates
Archaean	Dharwar Super Group	Schists, Quartzites, Gniesses, Khondalites

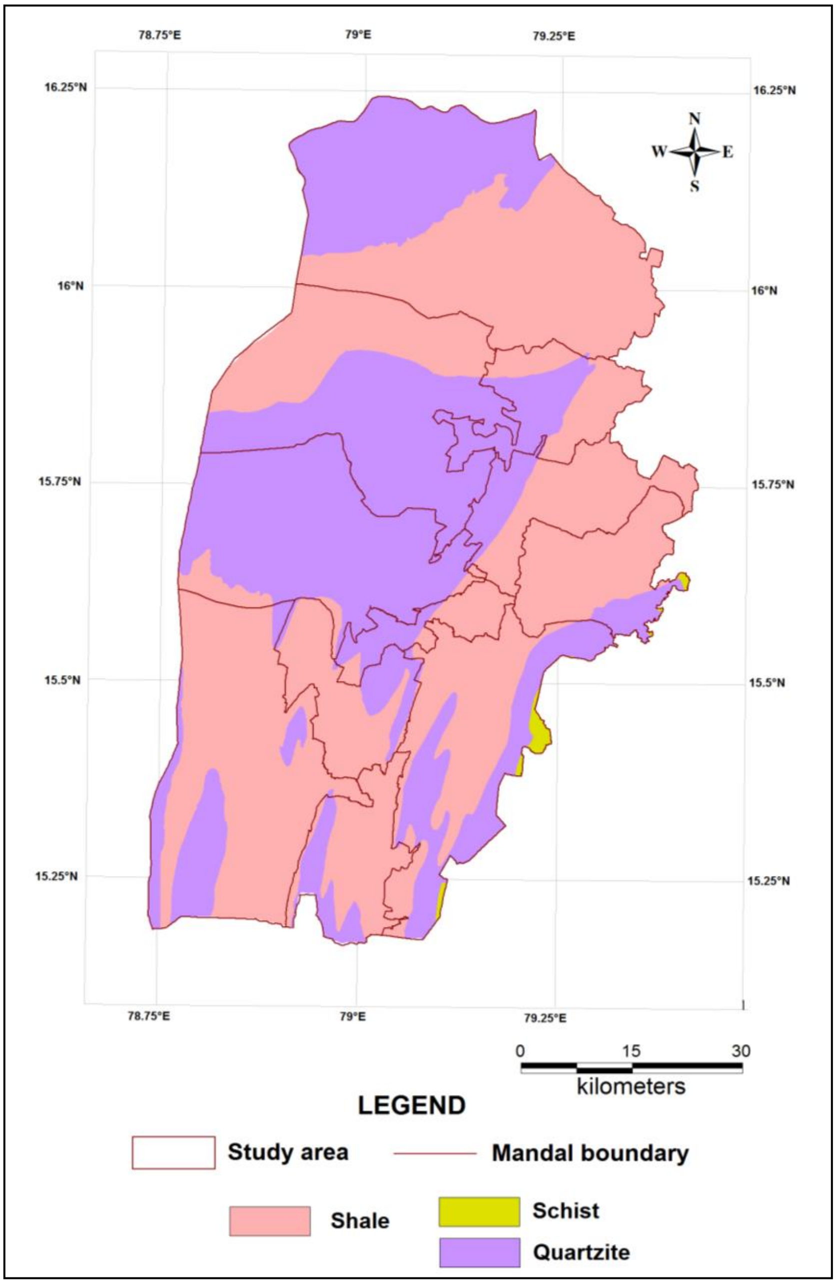

Fig-1.7 Geology Map of the Study Area, Prakasam District (Parts), AP

2. DATA COLLECTION and GENERATION

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

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

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

2.1 Hydrogeological Studies

Hydrogeology is concerned primarily with mode of occurrence, distribution, movement and chemistry of ground water occurring in the subsurface in relation to the geological environment. The occurrence and movement of water in the subsurface is broadly governed by geological frameworks i.e., nature of rock formations including their porosity (primary and secondary) and permeability. The principal aquifer in the area is Meta sediments (Shales and quartzites) and the occurrence and movement of ground water in these rocks is controlled by the degree of interconnection of secondary pores/voids developed by fracturing and weathering. Based on 213 hydrogeological data points (Exploration: 139, Geophysical: 20 and well inventory: 54) hydrogeological map is prepared **(Fig.2.1)**.

2.1.1 Ground water occurrences and movement: Ground water occurs under unconfined and semi-confined conditions and flows downward from the weathered zone into the fracture zone. The main aquifers constitute the weathered zone at the top, followed by a discrete anisotropic fractured/fissured zone at the bottom, generally extending down to 100 m depth. The storage in granite rocks is primarily confined to the weathered zone and its overexploitation, mainly for irrigation purpose, has resulted in desaturation of weathered zone at many places. At present, extraction is mainly through boreholes of 60-100 m depth, with yield between <1 to 11 litres/second (lps). Majority of fractures occur within 100 m depth and deepest fracture is encountered at the depth of 109 m depth (Rayavaram, Yerragondapalem). The hydrogeological map of the area is presented in **Fig. 2.2**.

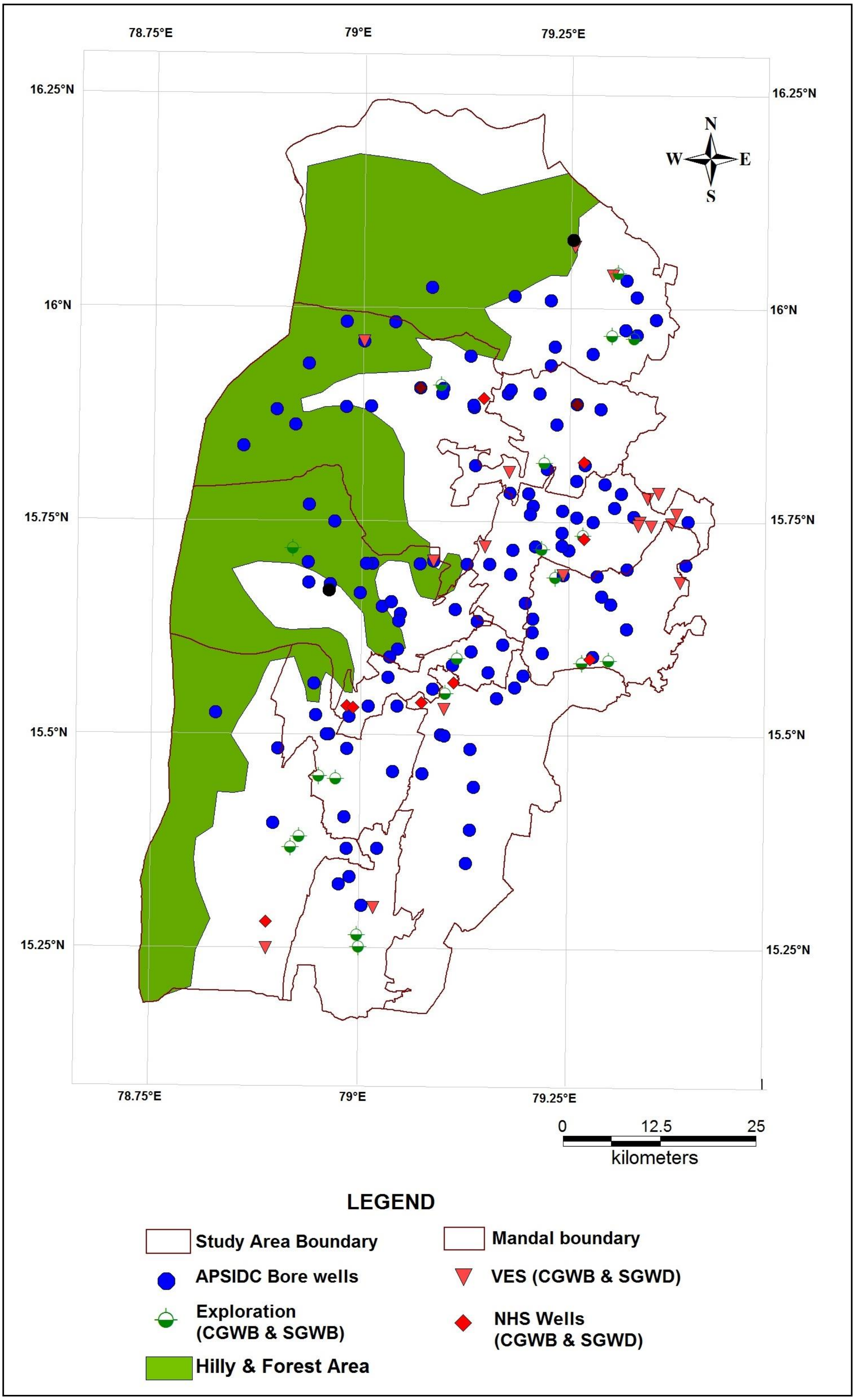

Fig- 2.1 Data used for Aquifer mapping in the Study Area, Prakasam District (Parts), AP

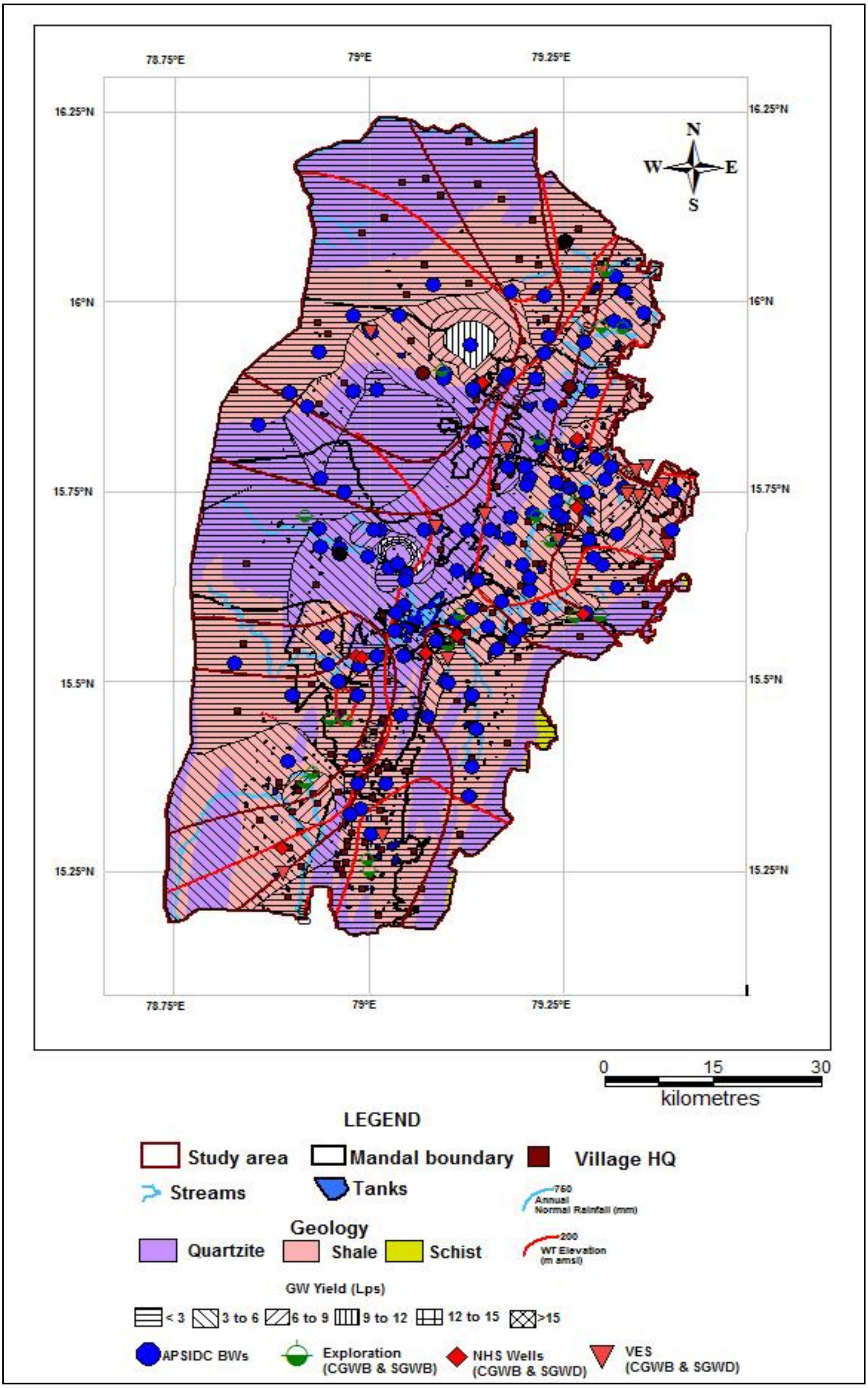

Fig-2.2 Hydrogeology of the Study Area, Prakasam District (Parts), AP

2.1.2 Exploratory Drilling: As on 31/03/2016, APSIDC drilled 117 bore wells (exploratory) and SGWD drilled 20 wells in the study area. Data analysed from APSIDC wells indicates, 3 wells are of shallow depth (30 m), 108 nos are of 30-60 m, 06 nos are of 60-100 m depth**.** An analysis exploratory bore wells drilled by SGWD indicate that 2 bore wells are <30 m depth, 17 bore wells are of 30-60 m depth and remaining 03 wells are of 60-100 m depth range. The depth to the deepest fracture occurred in these formation is 68 m at Giddaluru and deepest fractured dechiphered through VES studies is 109 m (Rayavaram, Yerragondapalem).

2.1.3 Ground water Yield: Ground water yield from weathered and fractured aquifer varies from <1 to 32 lps (Ayyavari peta, Ardhaveedu Mandal). Based on the combined data of APSIDC, CGWB and SGWD yield map is prepared and shown in **Fig.2.3**. In most of the area yield varies from 1 to 5 lps.

2.2 Water Levels (2015): Ground water levels from 24 Piezometers of SGWD are utilized for Water levels of pre-monsoon and post-monsoon season.

2.2.1 Water Table Elevations: During pre and post-monsoon season (May and November) of 2015, the water-table elevation ranges from 100 to 250 (m amsl) respectively and general ground flow is towards NE direction (**Fig.2.4**).

2.2.2 Depth to Water Levels (DTW): The DTW varies from 10 to 63 meter below ground level (m bgl) during Pre-monsoon period and (average: 37 m bgl) and 9 - 60 m bgl (average: 35) during post-monsoon season of 2016 respectively.

Pre-monsoon season: About 4724 mappable area, Water levels are deep in the study area mainly in the range of 30 to 50 m bgl. Majority of the water levels during this season are in the range of 30 to 40 m cover ~ 25% of area, followed by 40-50 m bgl (24% of area). Deep water levels at the range of 50 to 60 m bgl occupy ~6% of area mostly in north central part of the study area (**Fig.2.5**). Shallow water levels (10-20, 20-30 mbgl) occur in the central parts of the study area covering 12% of area.

Post-monsoon season: About 4724 mappable area, the water levels during this season are in the range of 10-20 m (~8 %), 20-30 m (14%), 30-40 m (18%), 40-50 mbgl (38%), 50-60 m bgl (14%) and >60 m bgl (6%) (**Fig-2.6**).

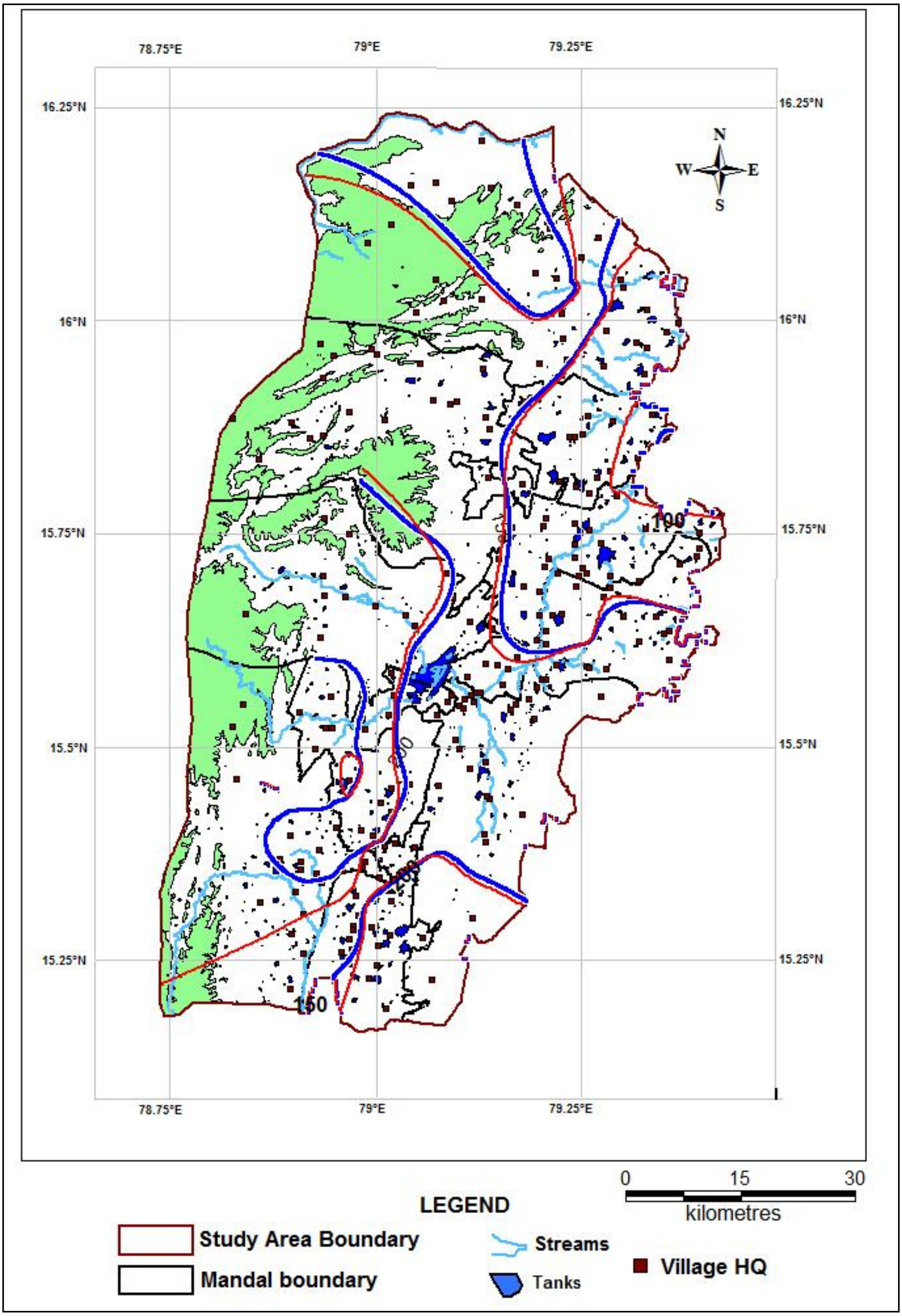

Fig- 2.4 water Table Elevations

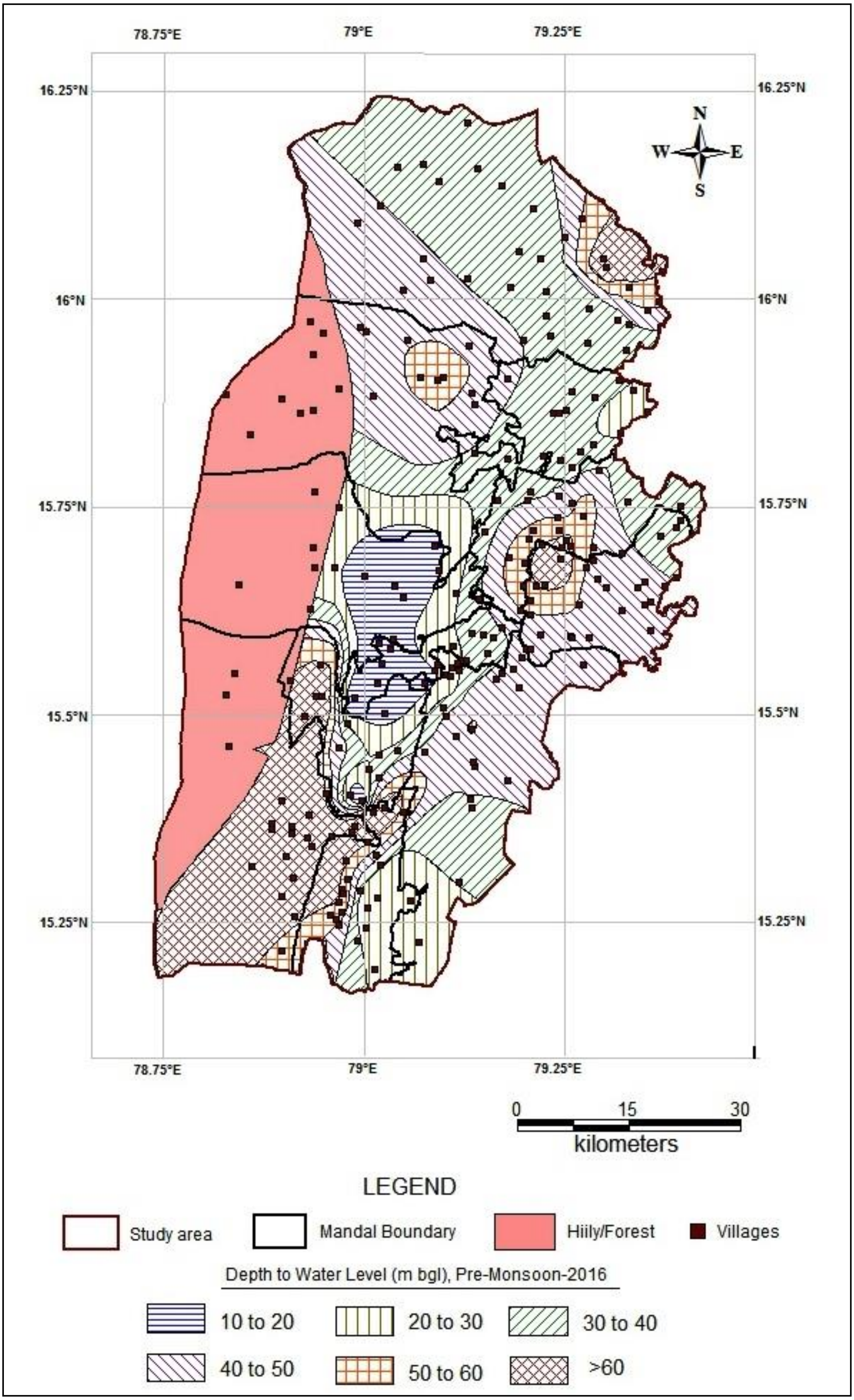

Fig- 2.5 Depth to Water Level (Pre Monsoon- 2015)

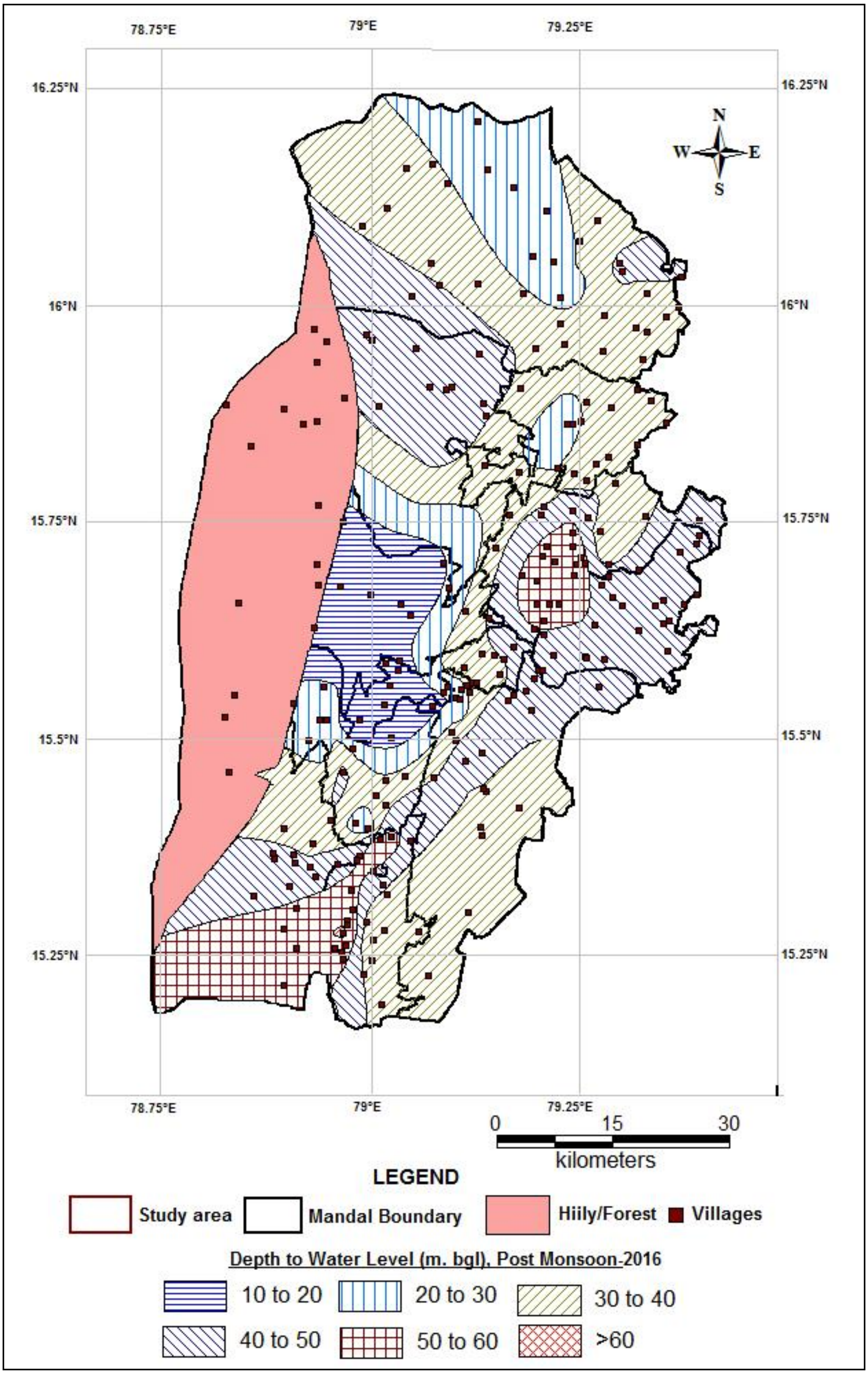

Fig- 2.6 Depth to water Levels (Post Monsoon 2015)

2.2.3 Water Level Fluctuations (May vs. November): The water level fluctuations vary from -13.13 to 37.38 m with average fall of - 5.03 m and rise of 9.92 m (**Fig.2.7**). Out of 25 wells, in 12 wells (50%) shows fall in water levels (-0.03 to -13.13 m) and 10 wells shos rise in water levels (0.06 to 37.38 m) is observed and 3 wells show neither rising nor fall in water levels.

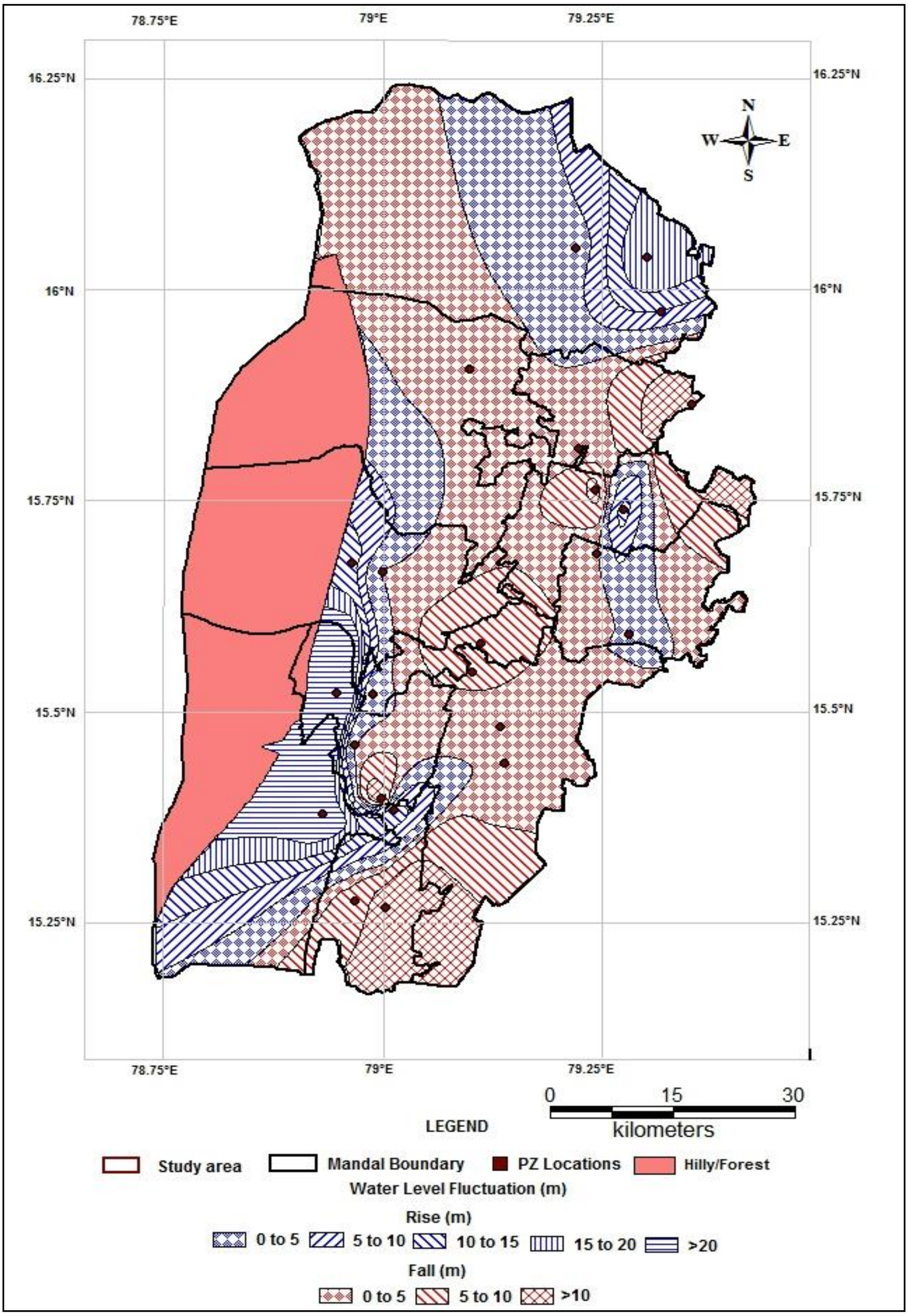

Fig.2.7: Water Level Fluctuations (m) (November-15 with respect to May-2015)

2.4 Hydro-chemical Studies

To understand chemical nature of groundwater, total 89 data from Rural Water Supply (RWS) is utilized (Pre: 57 and Post: 32). From the parameters namely pH, EC (in µS/cm at 25 ° C), TDS and NO_3 and F analyzed by that department ground water quality maps of EC, No3 and F for pre and post monsoon sesons are prepared.

Pre-monsoon (May-2015)

Groundwater from the area is alkaline in nature with pH in the range of 7.4 to 8.9 (Avg: 8.24). Electrical conductivity varies from 1545-6010 (avg: 2764) µ Siemens/cm. In majority of area covering northern, central and south-eastern part (80 %) EC is in the range of 1500-3000 µ Siemens/cm, in 20 % of the area EC is < 3000 µ Siemens/cm covering Parts of Dornala, Markapuram, Tarlapadu and few parts of Ardhaveedu and Racherla mandals. (**Fig-2.9**). The Concentration of NO_3 ranges from 16-456 mg/l. Nitrate concentration =45 mg/l is observed in 16 samples (28 %) and Nitrate concentration >45 mg/l is observed beyond maximum permissible limit of BIS in 5 samples (9%) (**Fig-2.10**). The concentration of Flouride ranges from 1.02 – 4 mg/l with an average of 1.8 mg/l. In 40 samples (70%), F concentration is observed more than the permissible limits (>1.5 mg/l) In 17 (30%) samples F is with in the Permissible range (<1.5 mg/l) (**Fig-2.11**).

Post-monsoon (Nov-2014)

Groundwater from the area is mildly alkaline to alkaline in nature with pH in the range of 7.5-8.8 (Avg: 8.02). Electrical conductivity varies from 1062-5078 (avg: 2774) µ Siemens/cm (**Fig-2.12**). The concentration of TDS varies from 680-3250 mg/l (avg: 1775). Concentration of NO_3 ranges from 20-58 mg/l and in 1 sample it is beyond maximum permissible limits of BIS (>45 mg/l) (**Fig-2.13**). The concentration of Flouride ranges from 0.8-2.8 mg/l with an average of 1.6 mg/l. In 18 samples (58%), F concentration is observed more than the permissible limits (>1.5 mg/l) In 13 (42%) samples F is with in the Permissible range (<1.5 mg/l) (**Fig-2.14**).

2.4.1 Suitability of Groundwater for drinking purpose

Suitability of ground water for different purposes is assessed based on the BIS (2012) standards. It is found that during pre-monsoon season of 2015, 70 % samples (40 out of 57 analyzed) are not suitable for drinking purpose, where F is beyond the maximum permissible limit of BIS. During post-monsoon season of 2015 it is found that 58% of samples (18 out of

31) are not suitable for drinking purposes where F is beyond the maximum permissible limits of BIS.

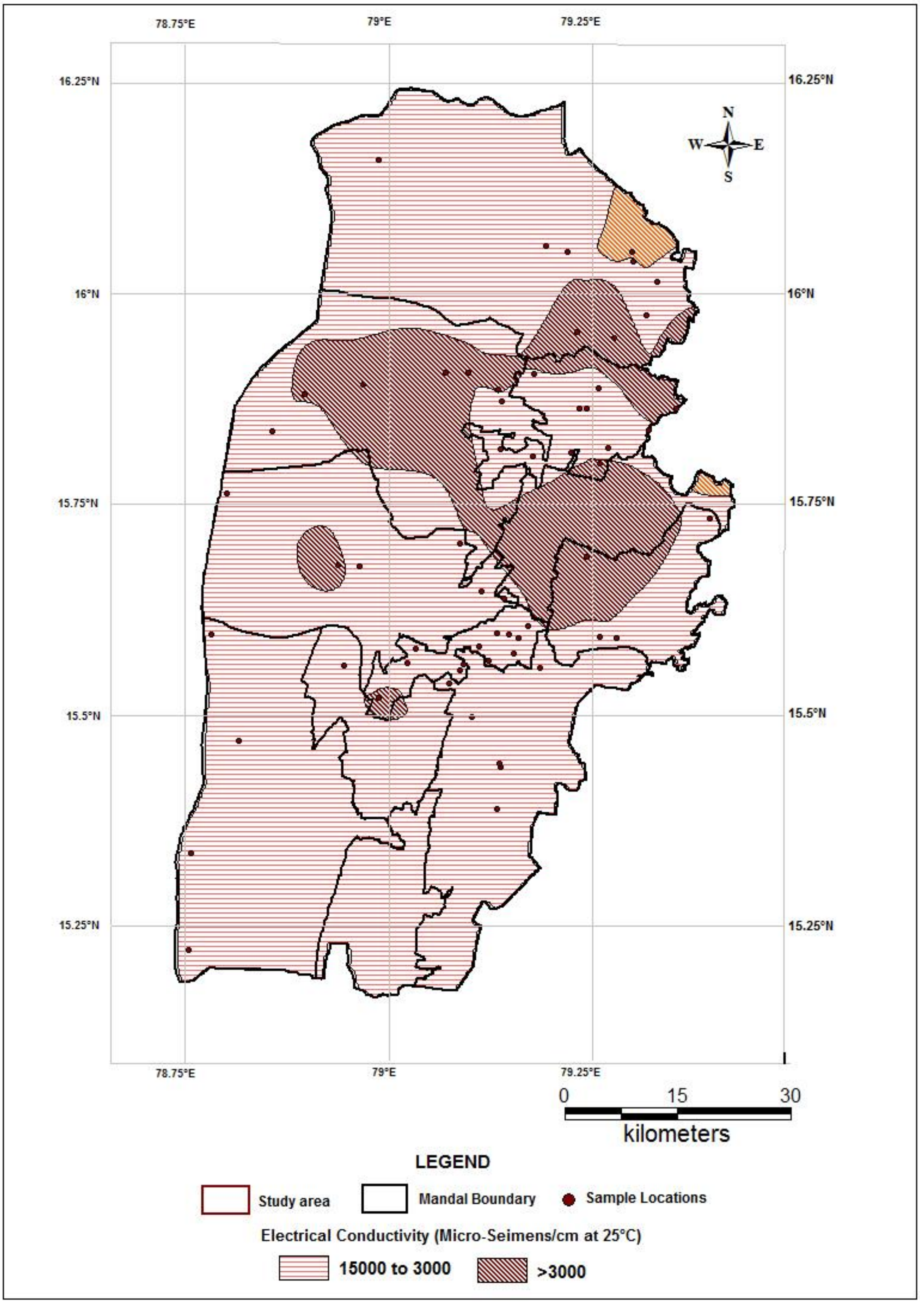

Fig.2.9: Distribution of Electrical conductivity (Pre-monsoon-2015)

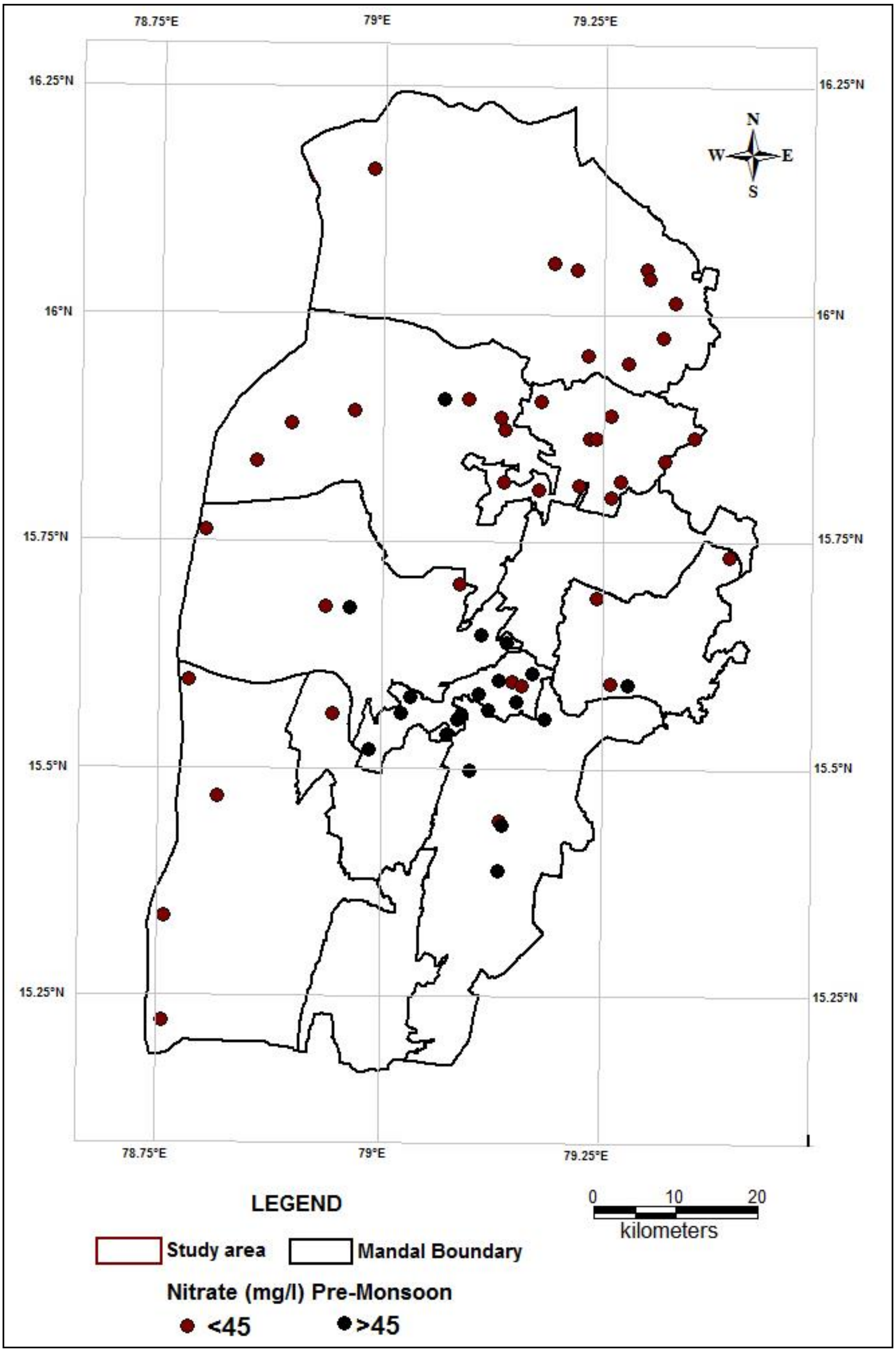

Fig.2.10: Distribution of Nitrate (Pre-Monsoon- 2015)

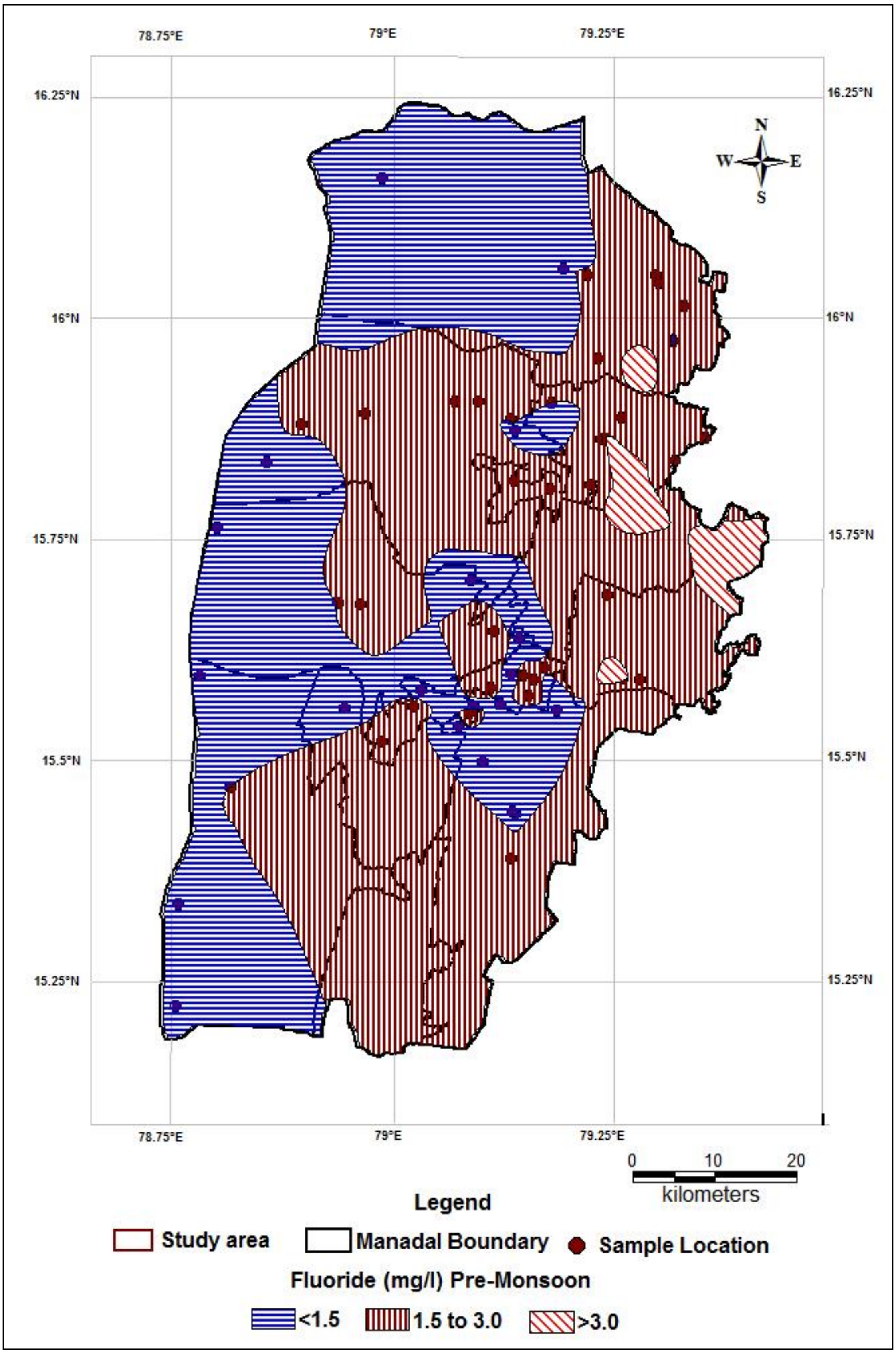

Fig-2.11 Distribution of Fluoride (Pre-monsoon-2015)

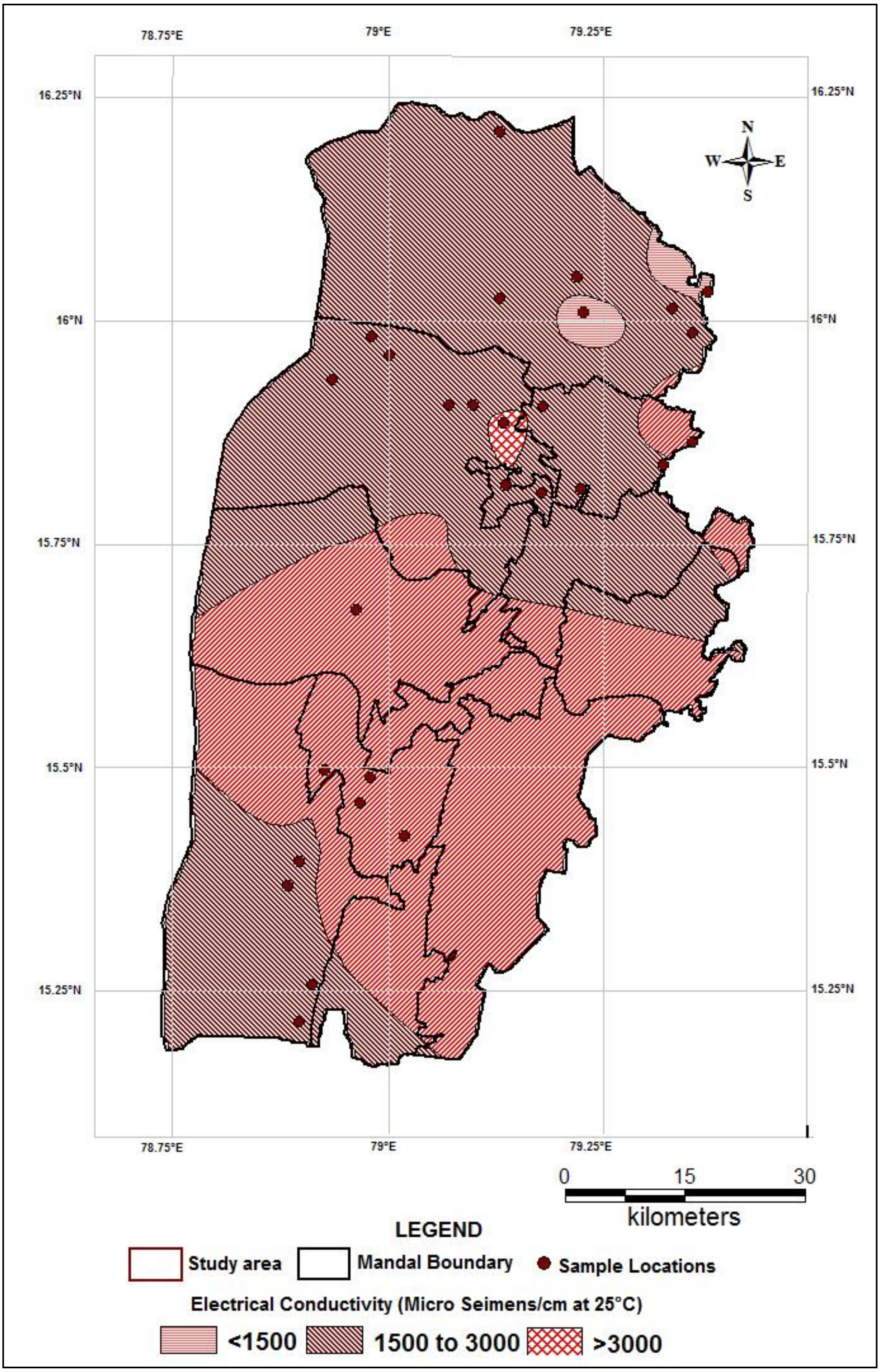

Fig-2.12: Distribution of EC (Post Monsoon 2015)

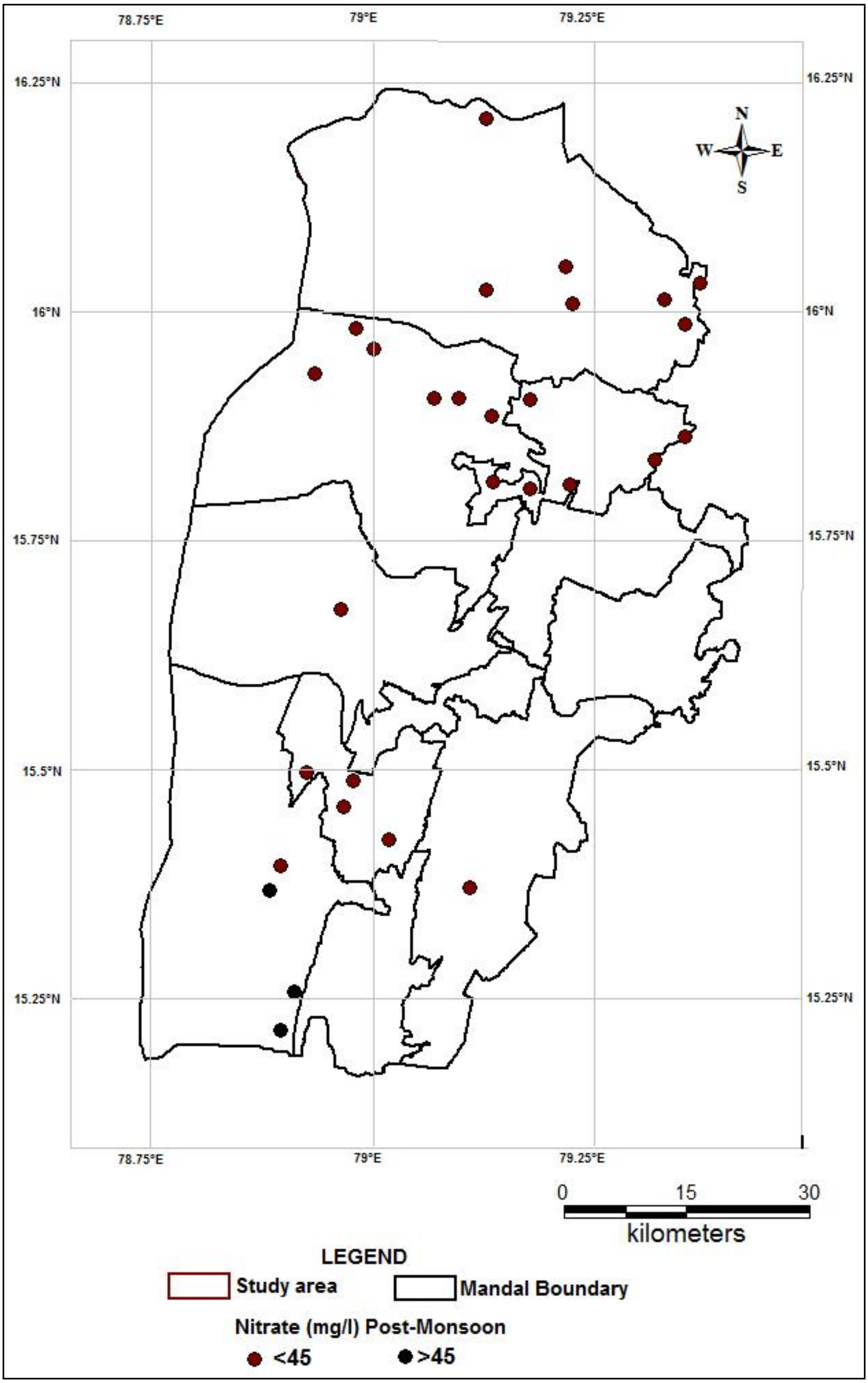

Fig-2.13: Distribution of Nitrate (Post Monsoon- 2015)

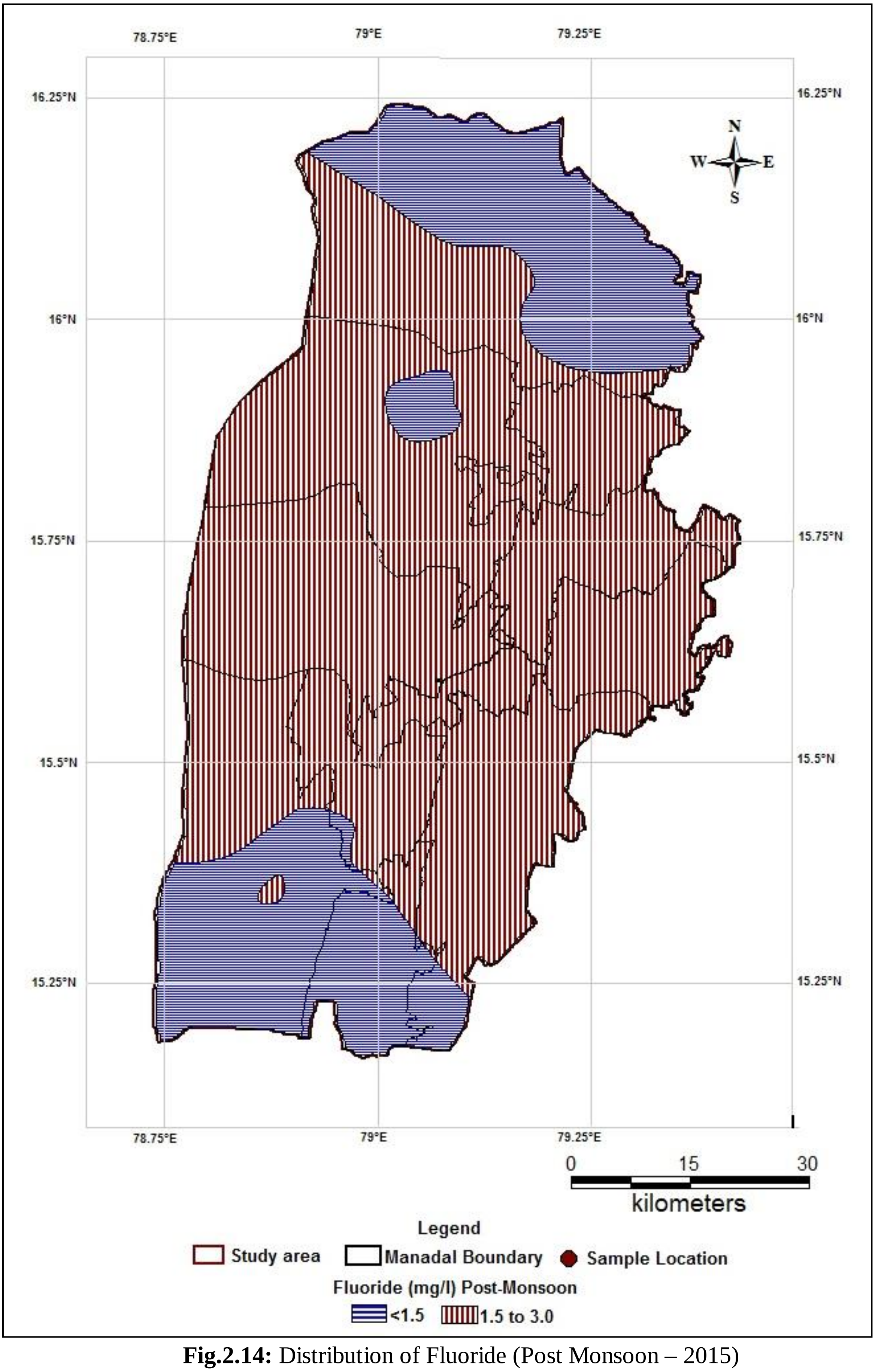

Fig.2.14: Distribution of Fluoride (Post Monsoon – 2015)

3. DATA INTERPRETATION, INTEGRATION and AQUIFER MAPPING

Conceptualization of 3-D hydrogeological model was carried out by interpreting and integrating representative 210 data points (APSIDC Bore wells: 120, SGWD: 12, CGWB:1, Geophysical: 21 and 56 well inventory data) down to 200 m is used for preparation of 3-D map, panel diagram and hydrogeological sections. The data (**Fig.2.1**) is calibrated for elevations with Shuttle Radar Topography Mission (SRTM) data. The lithological information was generated by using the RockWorks-16 software and generated 3-D map for Ananthapuramu study area (**Fig.3.1)** along with panel diagram (**Fig. 3.2**) and hydrogeological sections (**Fig-3.3 and 3.4a-f**).

3.1 Conceptualization of aquifer system in 3D

Aquifers were characterized in terms of potential and quality based on integrated hydrogeological data and various thematic maps. Weathered zone is considered up to the maximum depth of weathering and first fracture encountered (below weathered depth) generally down to ~20 m depth and the fractured zone (fractured granite) is considered up to the depth of deepest fracture below weathered zone (~20-120 m).

3.2 Hydrogeological Sections

Hydrogeological sections (3 nos) are prepared in NNE-SSW, NNW-SSE and W-E directions (**Fig. 3.3**).

3.2.1 NNE-SSW Section: The section drawn along the **NNE-SSW** direction covering distance of ~100 kms (**Fig.3.4a**). It depicts thick fractured zone in NNE parts compared to massive nature of Meta sediments in SSW parts. The weathering is showing uniform thickness in the section.

3.2.2 NNW-SSE Section: The section drawn along the NW-SE direction covering distance of ~100 kms (**Fig.3.4b**). It depicts very thin weathering parts in central part and is hilly. The weathering is showing uniform thickness in the section.

3.3.3 West to East Section: The section drawn along the W-E parts covering distance of ~60 kms (**Fig.3.4c**). It depicts uniform occurrence of weathering and fracture zone in central parts and shows massive nature in West and eastern partrs of the section.

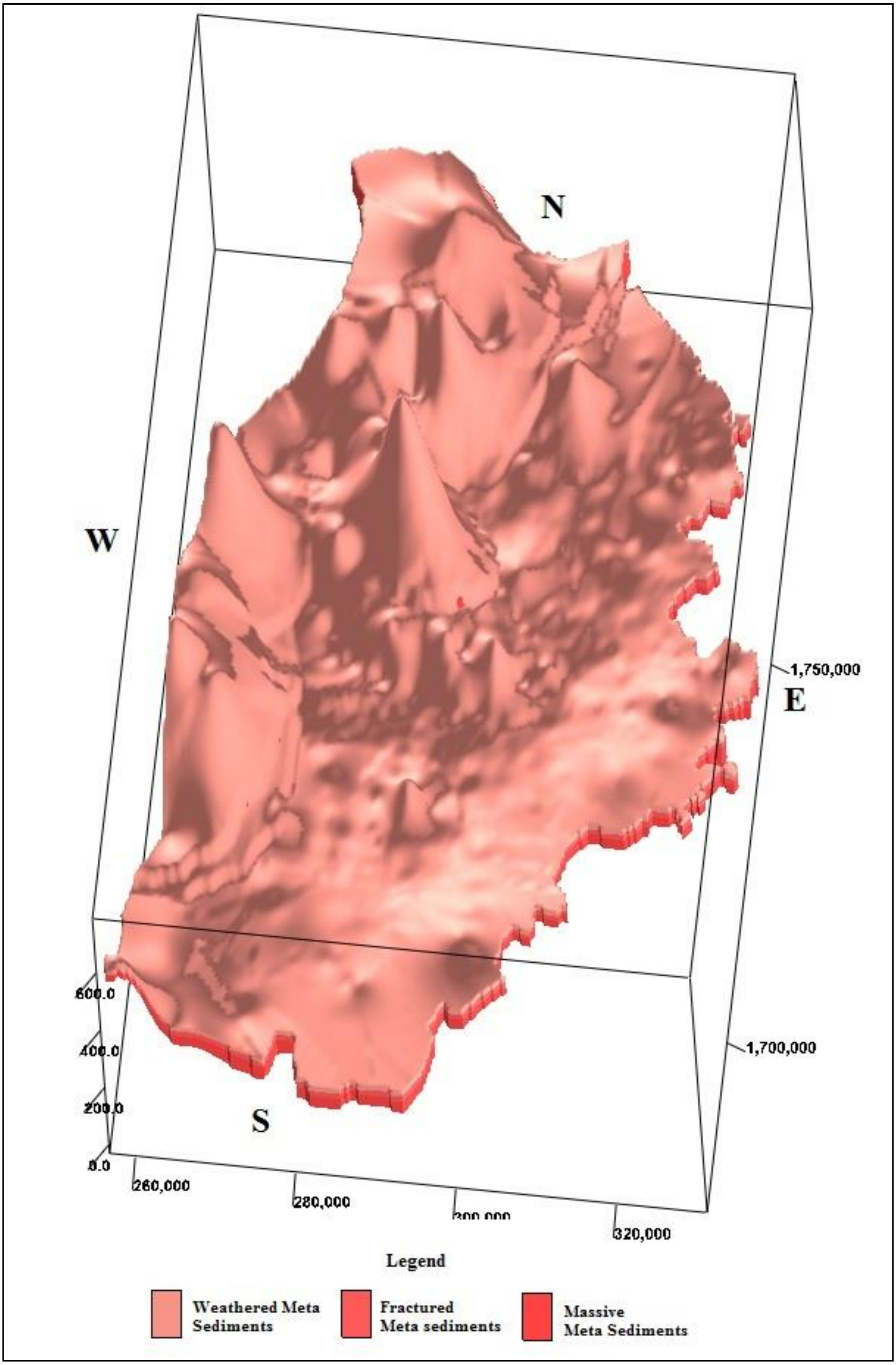

Fig.-3.1: -D Model for Ananthapuramu study area.

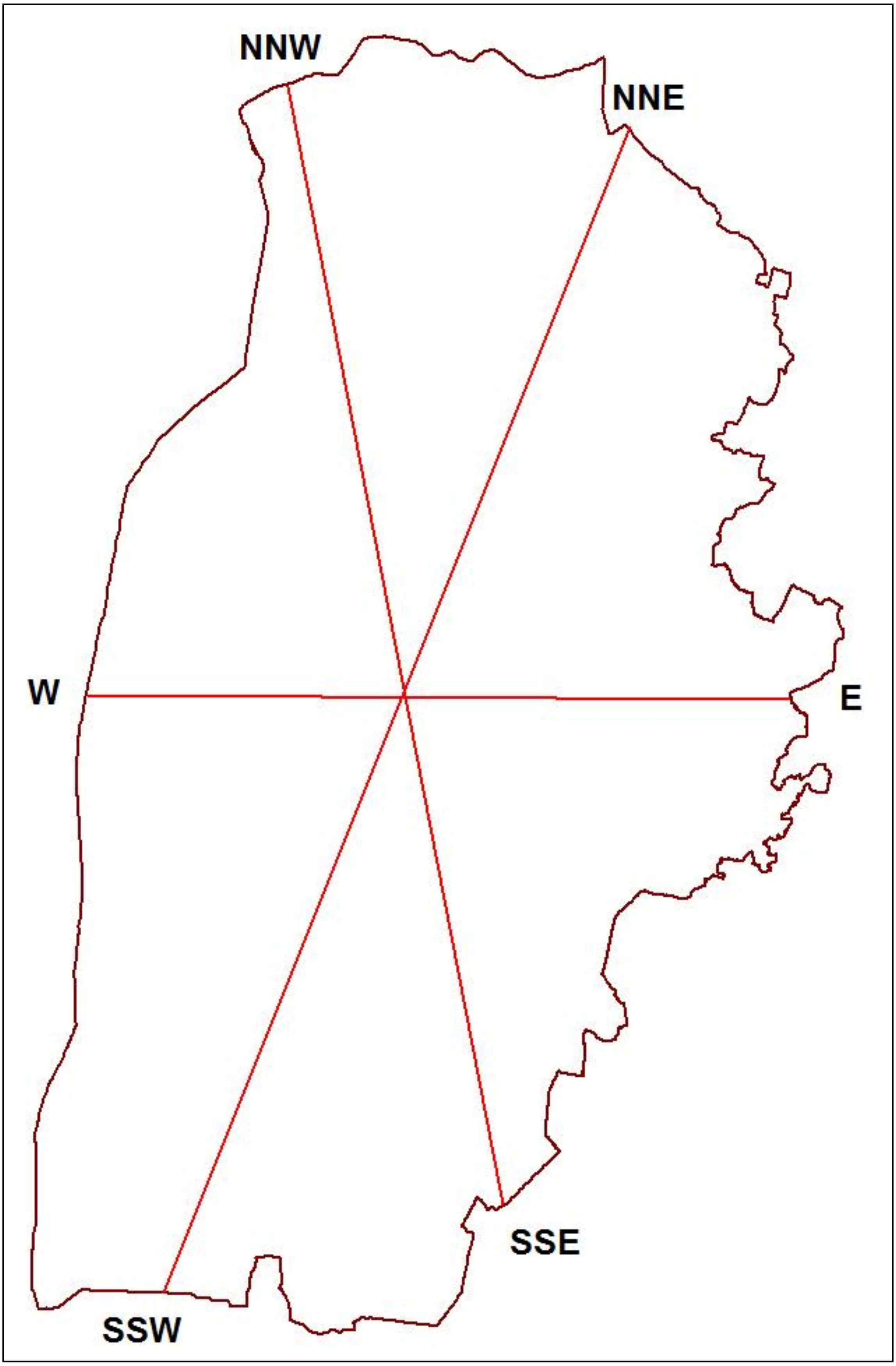

Fig.-3.3: Map showing orientation of various sections.

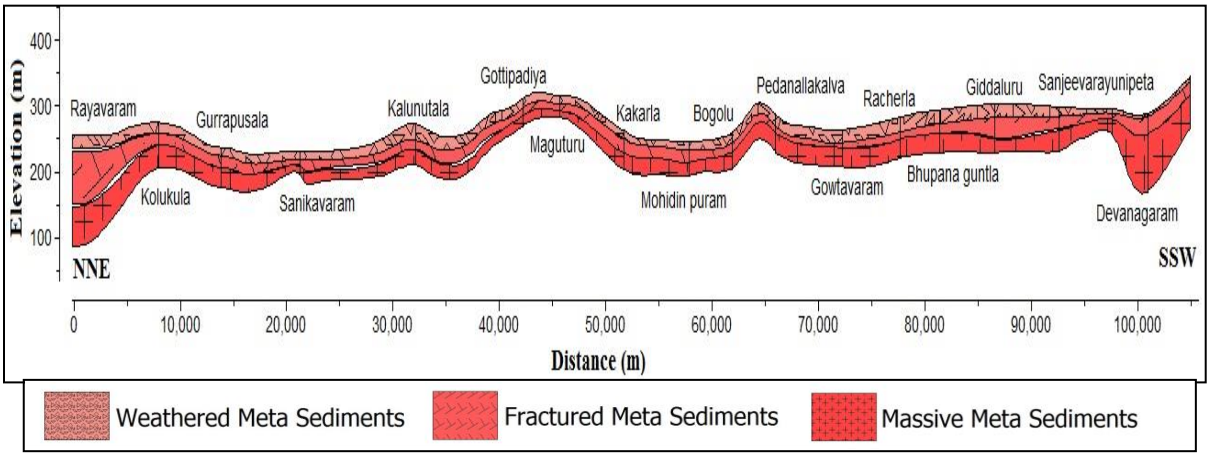

Fig-3.4 a: NNE-SSW Section

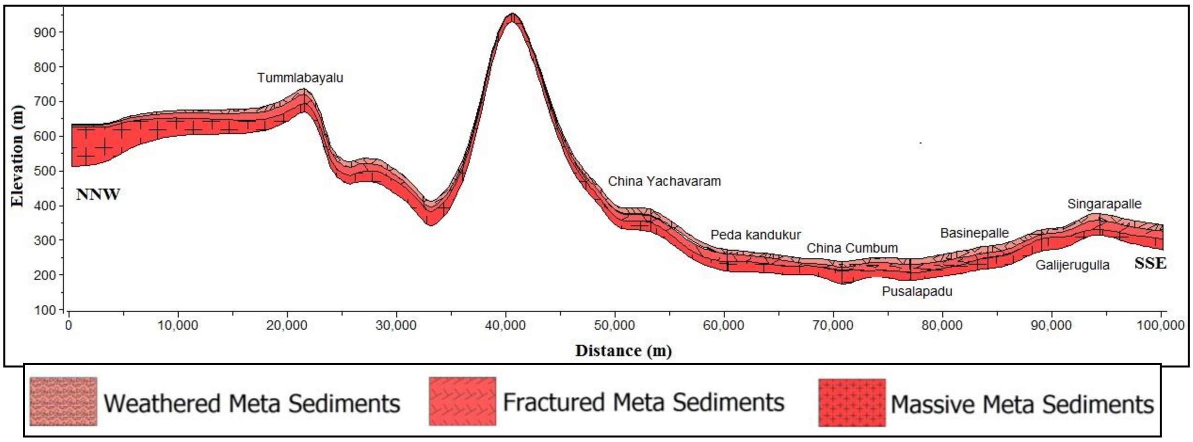

Fig-3.4 b: NNW_SSE Section

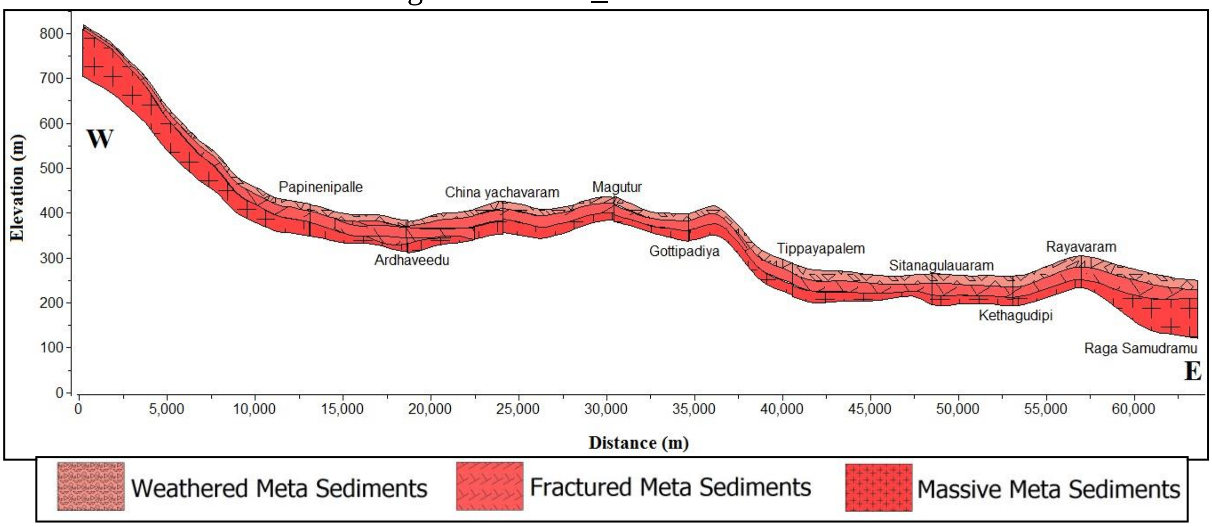

Fig-3.4 c: West-East Section

3.3.1 Weathered zone:

The Thickness of weathered zone is varies from <10 m to 30 m. In most of the study area, the thickness of weathering is in between 10-20 m (75%) in most part of area followed by <10 m Deep weathering (> 20 m) occurs in some parts of Dornala, Racherla, Giddaluru mandals of the study area. The weathered thickness map is presented in **Fig** -)

3.3.2 Fractured zone:

The depth of fracturing varies from 10-109 m and deepest fracture is dechiphered through VES study is 109 m (Rayavaram, Yerragondapalem). The deepest fracture encountered in exploratory drilling is 68 m at Giddaluru, Giddaluru mandal. The yield of the deepest fracture encountered at Giddaluru is 8 lps indicating the potential nature of Second aquifer in the study area. The depth of fracture map is presented in **Fig. 3.6.** ~ All the exploratory wells drilled so far are less than 100 m and the potential fractures occur with in the depth range of 70 m (100%) The ground water yield varies from <1 to 32 lps.

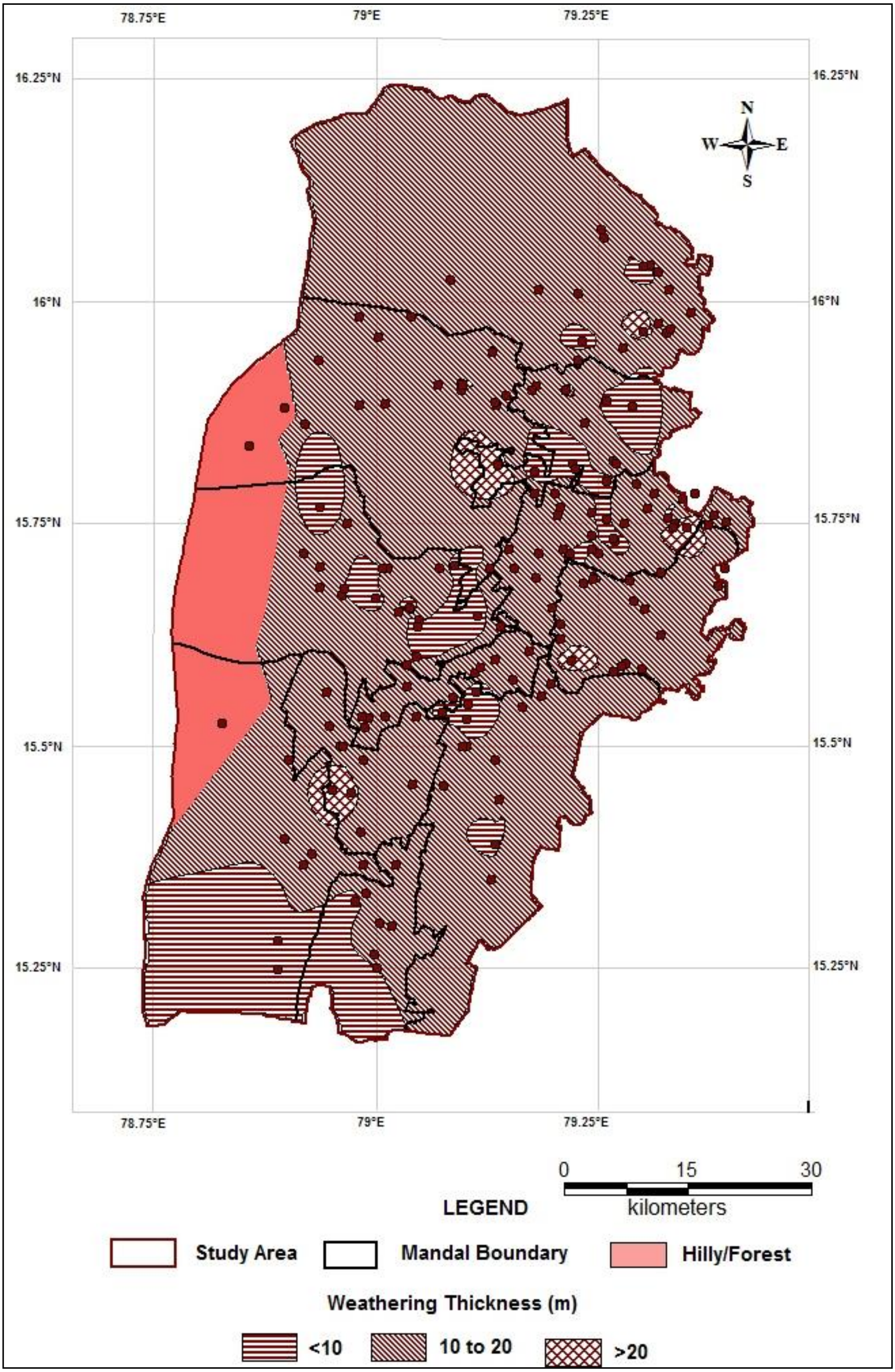

Fig.3.5: Thickness of weathered zone- Study area, Prakasam (Parts).

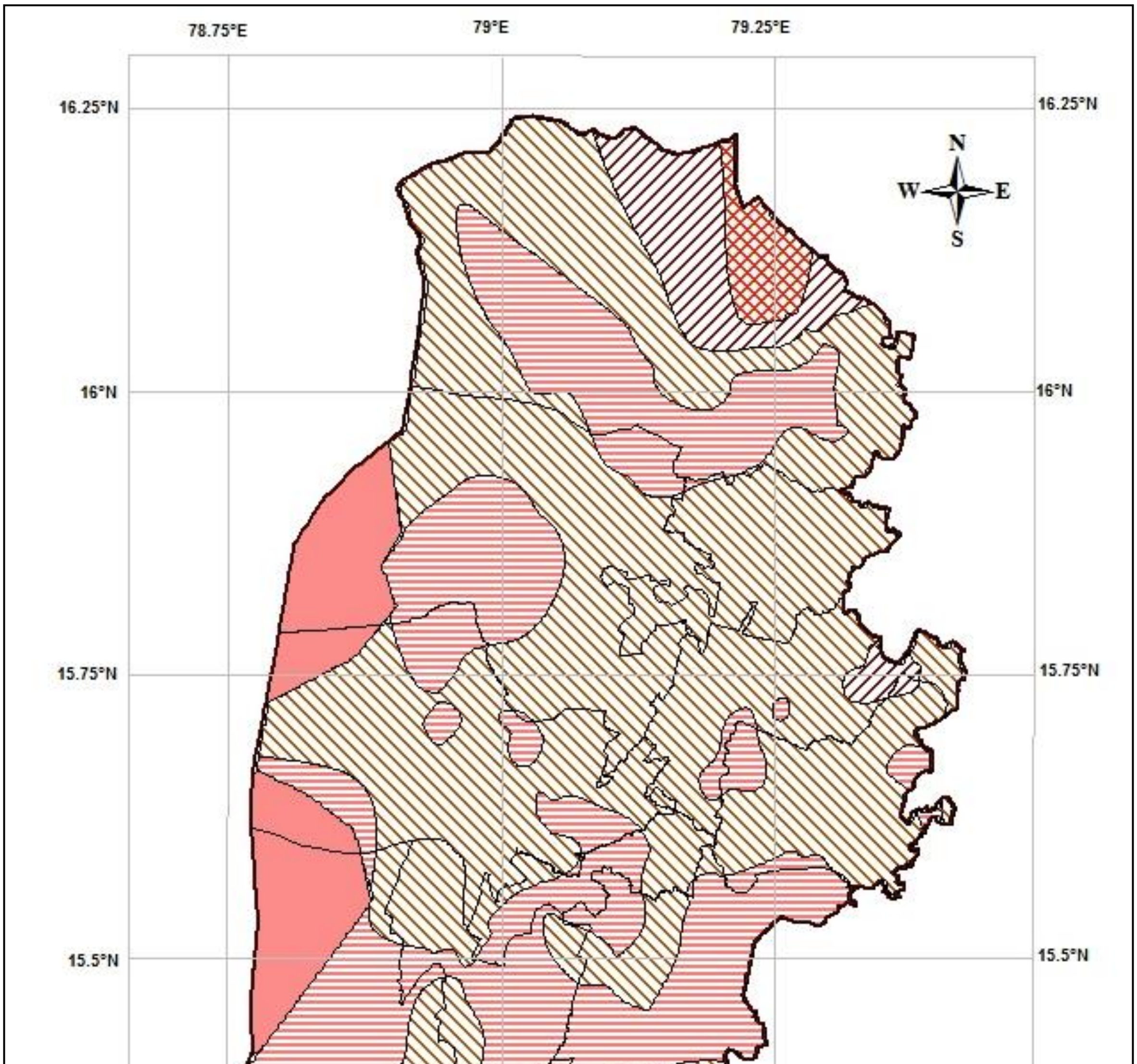

Fig.-3.6: Depth of fractured zone (Maximum depth) (m bgl).

4.0 GROUND WATER RESOURCES (2013)

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

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 2013 GEC report, the net annual groundwater availability is 150.50 MCM, gross ground water draft for all uses **161.84** MCM, provision for drinking and industrial use for the year 2025 is 18.50 MCM and net annual ground water potential available for future irrigation needs is 5.98 MCM. Stage of ground water development varies from 73 % in Ardhaveedu mandal to 144 % in Peddaraveedu mandal (avg: 111 %). Out of 11 mandals 7 mandals falls in over-exploited category (63% of area), 1 in critical category, 2 in semi critical category and 1 in safe category.

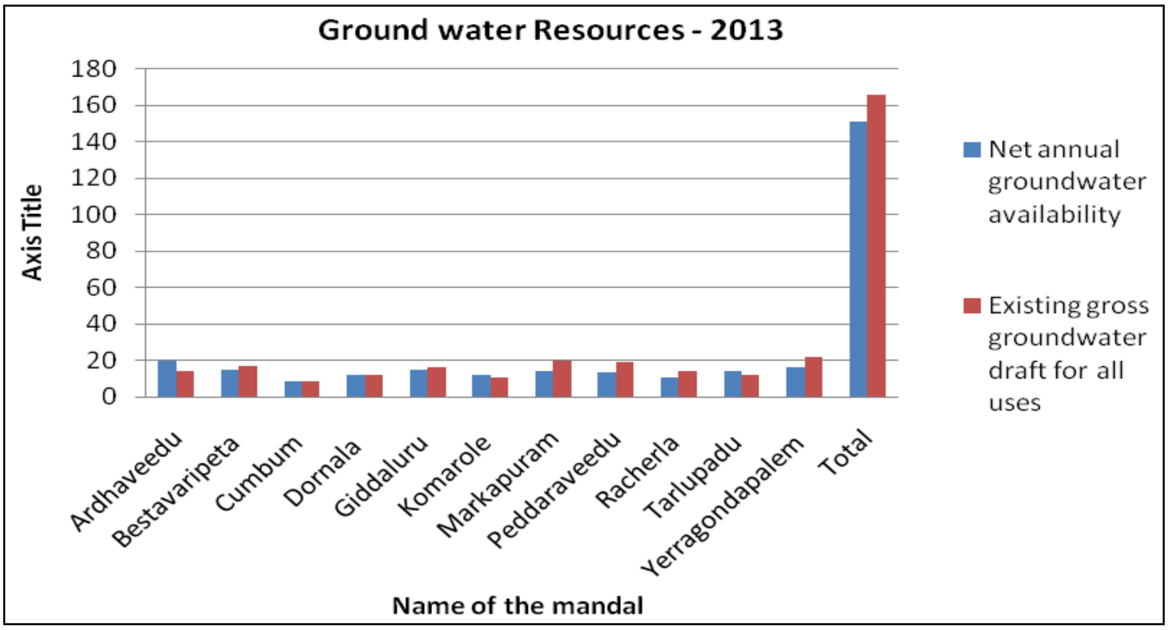

Table-4.1: Ground Water Resources – 2013, Study area, Prakasam district (Parts).

Mandal	**Net annual ground water availability**	**Existing gross groundwater draft for irrigation**	**Existing gross GW draft for domestic and industrial water supply**	**Existing gross groundwater draft for all uses**	**Provision for domestic and industrial requirement supply to 2025**	**Net groundwater availability for future irrigation development**	**Stage of ground water development**	**Category**
Ardhaveedu	19.54	14.13	0.10	14.23	1.14	4.38	73	Safe
Bestavaripeta	14.95	16.04	0.45	16.49	1.54	0.00	110	OE
Cumbum	8.45	8.07	0.24	8.30	1.49	0.00	98	Critical
Dornala	11.60	11.89	0.19	12.07	1.33	0.00	104	OE
Giddaluru	14.97	15.39	0.46	15.85	2.34	0.00	106	OE
Komarole	11.76	10.44	0.37	10.81	1.33	0.00	92	SC
Markapuram	14.30	19.09	0.78	19.87	3.73	0.00	139	OE
Peddaraveedu	12.96	18.50	0.20	18.70	1.32	0.00	144	OE
Racherla	10.25	13.95	0.28	14.23	1.11	0.00	139	OE
Tarlupadu	14.20	11.60	0.28	11.88	1.07	1.54	84	SC
Yerragondapalem	16.20	21.36	0.36	21.72	1.93	0.00	134	OE
Total	**150.50**	**161.84**	**3.74**	**165.58**	**18.50**	**5.98**		

5. GROUND WATER RELATED ISSUES and REASONS FOR ISSUES

5.1 Issues and Resons

Over-exploitation

1. 7 mandals comprising an area of ~ 4371 Km^2 area (74%) is categorized as over-exploited where ground water balance for future irrigation is zero or negative.
2. Out of the total irrigated area of 66090 ha, GW contributes 55311 ha (83%).
3. Desaturation of weathered zone and extraction of GW from deeper aquifers.
4. No assured Surface water irrigation.

Deep water levels

5. Deep water levels (> 20 m bgl) are observed during pre and post-monsoon season in 92 % and 90 % of the area respectively.
6. Out of 25 wells analyzed, 12 wells (50%) shows fall in water levels (-0.03 to -13.13 m).

Pollution (Geogenic and Anthropogenic)

1. Few mandals are fluorosis endemic where fluoride (geogenic) as high as 4 mg/L is found in groundwater. The high fluoride concentration (>1.5 mg/L) occur in 70 % of analyzed samples in the study area.
2. 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 and higher residence time of ground water in deeper aquifer.
3. High nitrate (> 45 mg/L) due to anthropogenic activities is observed in about 10 % samples. This is due to unscientific sewage disposal of treated and untreated effluents in urban and rural areas.Use of NPK fertilizers.
4. EC is < 3000 µ Siemens/cm covering Parts of Dornala, Markapuram, Tarlapadu and few parts of Ardhaveedu and Racherla mandals.

6. MANAGEMENT STRATEGIES

High dependence on groundwater led to a steady fall in water levels and desaturation of weathered zone in almost all mandals of the Study area, raising questions on sustainability of existing groundwater structures, food and drinking water security. The occurrence of fractures in fractured zone are very limited in extent, as the compression in the rock reduces the opening of fractures at depth and the majority of fractures occur within 100 m depth (98 %) (**Fig-3.7**).

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.

- The total run-off calculated in the study area is 160.38 MCM, with an utilizable yield availability of 32.08 MCM.
- In the study area 70903 MCM of unstaturated volume (below the depth of 3 m) is avaialable during post-monsoon season of 2015 having 1418 MCM of recharge potential (considering 2% specific yield).
- DWMA and IWMP had constructed 796 Check damsd and 610 Mini Percolation Tanks in the entire study area except Ardhaveedu mandal. (**Source: www.emuster.in/nregs_ap/reports/index.aspx**).
- The existing storage created through this construction of CDS (33.84 MCM) and MPTS (6.48 MCM) in the Study area is 40.32 MCM by taking into the account of 6 fillings for CDS and 1.5 fillings for PTs. The storage capacity of CDs and MPTs is calculated as 0.007 MCM per structure and expected Ground Water Recharge is 20.16 MCM (50% of the Storage).

The study suggests notable measures for sustainable groundwater management, which involves a combination of supply side and demand side measures

6.1.1 Supply side measures:

Ongoing Projects

Repair Renovation and Restoration of existing tanks (NEERU-CHETTU):

In the study area, 297 MI tanks are existing and renovation of these tanks are taken up by Government of AP under NEERU-CHETTU programme in phase manner. As on 2015, 35 minor irrigation tanks are de-silted and the quantum of desilting is 0.837 MCM of silt) which has created additional surface storage. This contributed ~ 0.42 MCM groundwater recharge (considering 50% of recharge) and with this an additional ~139 ha land can be brought under irrigated dry (ID) crops in tank ayacut.

Desilting of remaing 262 tanks in phased manner will result in additional storage creation of 6.288 MCM (@0.02 MCM per tank approximately) and expected ground water recharge is 3.1 MCM. With this an additional/existing 1050 ha under tank ayacut will be created/stabilized.

Proposed Artificial Recharge structures:

There is no scope for construction of additional artificial recharge structures as the utilizable yield is already being utilizable for the existing Artificial Rechrage Structures (DWMA/IWMP) in the study area except in Ardhaveedu, Cumbum, Komarole and Peddaraveedu mandals.

Table-Run Off and Surplus Utilizable Yield in the Study Area

Mandal	Area suitable for AR (Sq.km.)	Runoff Yield (MCM)	Utilizable Yield (MCM)	No. of CDS (DWMA)	Storgae Created (MCM)	No. of PTS (DWMA)	Storgae Created (MCM)	Total Existing Storage (MCM)	Surplus Yield (MCM)
Ardhaveedu	213	13.9	2.8	0.0	0.0	0.0	0.0	0.0	**2.8**
Bestavaripeta	239	17.5	3.5	79.0	3.4	79.0	0.8	4.2	**-0.7**
Cumbhum	128	8.4	1.7	17.0	0.7	28.0	0.3	1.0	**0.7**
Dornala	173	14.2	2.8	116.0	4.9	36.0	0.4	5.3	**-2.5**
Giddaluru	268	13.7	2.7	137.0	5.8	111.0	1.2	7.0	**-4.3**
Komarole	215	15.8	3.2	19.0	0.8	7.0	0.1	0.9	**2.3**
Markapuram	292	19.1	3.8	133.0	5.7	72.0	0.8	6.4	**-2.6**

Pedda Raveedu	249	16.3	3.3	33.0	1.4	25.0	0.3	1.7	**1.6**
Racherla	198	8.8	1.8	81.0	3.4	132.0	1.4	4.8	**-3.1**
Tarlapadu	268	17.5	3.5	86.0	3.7	62.0	0.7	4.3	**-0.8**
Yerragonda palem	263	15.3	3.1	95.0	4.0	58.0	0.6	4.7	**-1.6**
Total		**160.4**	**32.1**	**796.0**	**33.8**	**552.0**	**6.5**	**40.3**	

As the existing Storage created (40.32 MCM) is more than the surplus utilizable run off (32.08 MCM) in the study area, construction of new artificial recharge structures are not recommended in the Bestavaripeta, Dornala, Giddaluru, Markapuram, Racherla, Tarlapadu and Yerragondapalem Mandals. However, it is proposed for Renovation desilting, Repairs and installation of Recharge Shafts in 50% of the existing PTS (610) and CDS (796). This will result in effective utilization of surface storage of 40.32 MCM for GW recharge of 20.16 MCM (50% of the storage). The expected expenditure will be about 14.06 Cr.

Roof top rainwater harvesting structures should be made mandatory to all Government buildings (new and existing) in the Mandal Head Quarters.

Contemplated Projects:

Poola Subbaiah Veligonda Project comprises of Nallamala Sagar Reservoir which is being formed by constructing CC NOF Dams across the three gaps namely Sunkesula, Gottipadia and Kakarla. It envisages to draw 43.50 TMC (1232 MCM) flood water of Krishna River from the foreshore of Srisailam Project Reservoir through Kollam Vagu (Upstream of Srisailam Reservoir) by twin Tunnels by gravity and thereafter, to impound in Nallamala Sagar Reservoir through a Feeder Canals.

In the study area, Ardhaveedu, Bestavaripeta, Cumbum, Dornala, Komarole, Markapur, Giddaluru, Peddaravedu, Racherla, Tarlapadu and YerragondaPalem mandals are also will be covered under the proposed Veligonda project **(Fig-1.6)** which is contemplated to create additional ~62564 hectare of irrigation potentential. The proposed extention of ayacut under this project is as follows.

S.No.	**Name of the Mandal**	**Extent of Ayacut in Acres**
1	Ardhaveedu	3000
2	Bestavaripeta	11200
3	Cumbum	17300
4	Dornala	6100
5	Giddaluru	10600
6	Komarole	5500
7	Markapur	27700
8	Peddraveedu	21900
9	Racharla	11500
10	Tarlupadu	20000
11	Y. Palem	19800
	Total	**154600 acres/ (62564 ha)**

The crop water requirement for 62564 ha is 375 MCM for ID crops. After the implementation of the project, the area under rainfed irrigation (69696 ha) in the study area will be brought into the ambit of assured surface water irrigation. Further, if micro irrigation practices are implemented, the crop water requirement for 62564 hectares will be fulfilled within 187.5 MCM. The conserved surface water can be effectively being utilized to supplement irrigation under ground water which will reduce the stress on ground water.

The registered Ayacut under Chumbhum Tank is 2801 ha. But due to non filling of Tank, the irrigation is only for ~689 ha (24 %). With the on set of Veligonda project, Chumbhum tank will be stabilized and 2801 ha will be brought under irrigation.

Other supply side measures:

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 farms. Thus, it is recommended to construct 1240 farm ponds with a size of of 5 x 5 x 1.5 m (20 farm ponds per village) in 62 villages in the mandals of Ardhaveedu (240), Cumbhum (280), Komarole (400) and Peddaraveedu (320). The approximate cost will be about **3.1** crores. In the rest of the area (Bestavaripeta, Dornala, Giddaluru, Markapuram, Racherla, Tarlapadu and Yerragondapalem mandals), construction of farm ponds are not recommended keeping in view of the non availability of surplus run off.

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

Ongoing Work

- In the study area till date a total number of 720 no's drip and sprinklers are sanctioned which has irrigated ~683 ha of agriculture land. This resulted in saving of ~1.025 MCM of groundwater from the study area considering 25% of net savings as compared to traditional practice of flood irrigation (4.1 MCM requirement @ 0.006 MCM/ha).

Proposed Work

- It is proposed to brought 13827 ha @ 25% of the area irrigated under ground water (55311 ha). This accounts about 60 ha of agriculture land in each village will be brought under micro-irrigation (228 villages @ 60 ha/village). The estimated cost costing about **82.96 crores** (considering 1 unit/ha @0.6 lakh/ha). With this **39.86 MCM** of ground water can be conserved over the traditional irrigation practices (considering 50% of the water applied is saved through drip and sprinkler irrigation practices or 0.003 MCM/ha)

- Change in cropping pattern from water intensive paddy druing rabi season to other 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.

- As a mandatory measure, every groundwater user should recharge rainwater through artificial recharge structures in proportionate to the extraction.

- 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.

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

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

- The other measure includes providing supplementary calcium, phosphorous rich food along with multivitamin tablets to the children below the ages of 14 years in fluoride endemic villages along with mid day meal scheme. Creating awareness about safe drinking water habits, 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 **109.06** crores (excluding the cost involved in Veligonda project), the likely benefit would be the net saving/recharge of 61.74 MCM of ground water. This will bring down the stage of ground water development by 35 % (from 111 % to 76%).

- 62564 ha will be brought under assured surface water irrigation through Veligonda Project.
- Stabilization of Chumbhum Tank will be resulted in stabilization of irrigation of 2801 ha under tank ayacut.
- The ongoing desilting under Neeru Chettu program will be resulted in irrigation to additional ~139 ha and the proposed desilting from 262 MI tanks will be resultring in irrigation to 1050 ha under tank ayacut.
- The recommended 4560 farm ponds will stabilize the 1845 ha under rain fed irrigation.

Acknowledgment

The authors thank Shri Akhil Kumar, Chairman, and Sri. D. Saha, Member (SAM), Sri. K.C.Naik, Member (ED & MM), of the Central Ground Water Board, Govt. of India and S/Shri D. Subba Rao, Regional Director, and Dr. P. N. Rao, Supdtg. Hydrogeologist and GRC Reddy, Scientist-D of this office for encouragement. The authors acknowledge APSIDC, State Ground Water Department and Rural Water Supply department, Govt of Andhra Pradesh for making available of field data. Authors also thank the Executive Engineer and his drilling crew of CGWB, for carrying out the exploration activity.

References:

1. Chief Planning Officer (CPO) (2014) Handbook of Statistics, Prakasam district, Government of Andhra Pradesh. Published by Chief Planning Officer, Anathapuramu study area.
2. BIS (2012) Drinking water-specification IS: 10500; 1991. Bureau of Indian Standards, New Delhi.
3. Hill, R.A. (1940) Geochemical patterns in Coachella Valley. Trans. Am. Geophys. Union, v.21, pp.46-49.
4. Karanth, K.R. (1987) Ground water assessment, development and management. Tata McGraw-Hill Pub. Co. Ltd., New Delhi, 720p.
5. Piper, A.M. (1944) A graphic procedure in the geochemical interpretation of water analysis. Trans. Am. Geophys. Union, v.25, pp.914-923.
6. US Salinity Laboratory Staff (1954) Diagnosis and improvement of saline and alkali soils. US Department of Agriculture Handbook No. 60, 160p.

7. US Salinity Laboratory Staff (1973) Diagnosis and Improvement of saline and alkali soils. US Department of Agriculture Handbook No. 60, 2nd edition, Washington.
8. Wilcox, L.V. (1955) Classification and use of irrigation waters. U.S. Department of Agriculture, Circ. 969.