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

Visakhapatnam District
Andhra Pradesh

दक्षिणी क्षेत्र, हैदराबाद

Sourthern Region, Hyderabad

भारत सरकार

जल शक्ति मंत्रालय

जल संसाधन नदी विकास एवम् गंगा संरक्षण विभाग

केंद्रीय भूमि जल बोर्ड

GOVERNMENT OF INDIA

MINISTRY OF JAL SHAKTI

DEPARTMENT OF WATER RESOURCES, RD & GR

REPORT ON
AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES IN VISAKHAPATNAM DISTRICT, ANDHRA PRADESH
(AAP-2020-21)

CENTRAL GROUND WATER BOARD

APSUO, VISAKHAPATNAM

JUNE, 2022

REPORT ON

AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES IN VISAKHAPATNAM DISTRICT, ANDHRA PRADESH

(AAP-2020-21)

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AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES IN VISAKHAPATNAM DISTRICT, ANDHRA PRADESH STATE (AAP-2020-21)

AT A GLANCE

S.No.	Item		Particulars
1	District	:	Visakhapatnam
2	Revenue Mandals	:	43
3	Villages	:	3108
4	Geographical area	:	11,343 km^2
5	Mappable area for NAQUIM Studies	:	6574 km^2
6	Hilly Area	:	4769 km^2
7	Population (2021 Census)	:	45.74 lakhs
8	Location	:	Latitude: 17°15´11" - 18°32´46" N Longitude: 81°52´40" - 83°29´27" E
9	Rainfall (Normal)	:	~1202 mm
10	Geomorphology	:	Structural hills, Pediplains, Pediment, Dissected hills, Denudation hills, alluvial plains and Coastal alluvial plains
11	Major Rivers	:	Machkund, Tandava, Varaha, Sarada & Gosthani
12	Land Utilization (Ha)	:	Forest occupies ~42 % of the total geographical area, remaining area is costal lands, barren and uncultivable land, The total cropped area is 318100 ha (209-20). Urban area is 682 sq.km (6% of total area)
13	Soils	:	Red Sandy loams soils and Clayey soils
14	Soil Infiltration rate (cm/hr)	:	Soil Infiltration rate ranges from 1.5 to 3.3 cm/hr, and is soil infiltration capacity is more than rainfall intensity in this area.
14	Cropping Pattern (2019-20)	:	Crops grown are Paddy, Ragi, Bajra and Jowar, Pulses and Sugarcane, groundnut, Niger and Chillies. The other crops are Millets and oil seeds.
15	Irrigation Sources (Ha)	:	Dug wells: 12774 No.s

<table>
<tr><td></td><td></td><td></td><td colspan="3">Tube wells: 20064 No.s
Tanks/Ponds: 30993 ha
Canals: 48507 ha
Other sources: 22694 ha</td></tr>
<tr><td>16</td><td>Geology</td><td>:</td><td colspan="3">Khondalite, Granite Gneiss, Chanrockite, Sandstone/ Quartzite and Alluvium.</td></tr>
<tr><td>17</td><td>Hydrogeological data points</td><td>:</td><td colspan="3">63 Exploratory wells and 35 number of VES data of CGWB & 45 number of wells data from SGWD.</td></tr>
<tr><td rowspan="5">18</td><td rowspan="5">Ground water yield (lps) and Transmissivity (m^2/day)</td><td rowspan="5">:</td><td>Formation</td><td>Discharge (Q = lps)</td><td>Transmissivity (T = m2/day)</td></tr>
<tr><td>Granite Gneiss</td><td>0.3 to 8.4</td><td>1 to 219</td></tr>
<tr><td>Khondalite</td><td>0.12 to 18</td><td>5 to 579</td></tr>
<tr><td>Quartzite</td><td>0.8 to 20</td><td>20 to 400</td></tr>
<tr><td>Charnockite</td><td>0.51 to 1.5</td><td>1 to 20</td></tr>
<tr><td>20</td><td>Water Levels:
Depth to water levels
(m bgl) (Decadal mean data 2010-2019)</td><td>:
:</td><td colspan="3">157 number of monitoring wells (CGWB:49+SGWD:108 no)

Pre-monsoon season: 0.88 to 23.95 m bgl (average: 12.41 m bgl) and majority of areas are in the range of 5-10 m covering 65% of the area, followed by 10-20 m bgl (15%) and 2-5 m bgl (10%). Shallow water levels <2 m. bgl occupy about 5% of the area falling in parts of coastal parts of Visakhapatnam.
Deep water levels here between >20 m.bgl occupy 5% of the area in small parts of Anandapuram, Parwada, Anakapalli and Payakaraopeta mandals.

Post-monsoon: Majority of the water levels during this season are in the range of 5-10 m covering 45% of the area, followed by 2-5 m bgl (40%) and 10-20 m bgl (5%). Deep water</td></tr>
</table>

			levels in the range of >20 m bgl occupy about 2% of the area falling mostly in parts of Devarapalli mandal. Shallow water level <2 m.bgl occupy 8% of the area in small parts of Visakhapatnam urban areas, Bhemunipatnam, Parwada, Anakapalli, Koyyuru, Sabbavaram, Kotauratla, Anandapuram, Padmanabham, Ravikamatam Rambilli and Atchutapuram mandals. **Water table elevations** during pre-monsoon season vary from - 6.8 to 1247 m amsl and during post-monsoon season vary from - 2.21 to 1240 m amsl. Ground water flow maximum areas are north west to south eastern direction.
21	Water Level Fluctuations (May vs. November) (Decadal mean)	:	The water level fluctuations vary from -12.5 to 17.5 m with average rise of 2.5 m. 82% (129 nos) of the wells show rise in water level and 18% (28 nos) of wells show falling fluctuation in water level. Fall in water levels is observed in stations of Lothugadda Purushotampuram, Pendurthi, Gudem and Addaroddu etc.
24	Geophysical data (down to 200 m)	:	35 number of VES, Resistivity is in the range of <28 to 100 ohm (Ω) m for the weathered and fractured granite with an inferred depth of 2 - 70 m, whereas resistivity is in the range of 250 to 4000 Ω m for massive granite with maximum thickness of 50 m to 200 m. The resistivity for the weathered and fractured Khondalite ranges from <2.3 to 90 ohm (Ω) m, while it is in the range of and 106 - 625 Ωm for massive Khondalite with maximum thickness of 90 m to 200 m. Charnockite formations are generally shows high resistivity values more than 500

			Ωm. The resistivity of shear zone aquifers is very low 12 to 30 Ωm.
25	Hydrochemistry	:	Total 342 data used for analysis Pre-monsoon (2019) (CGWB: 59+ SGWD: 138). Post-monsoon (2019) (CGWB: 0+ SGWD: 145).
25.1	Electrical Conductivity (µ Siemens/cm)	:	**Pre-monsoon (2019):** The average EC during pre-monsoon is 1229 µ siemens/cm. In 90% of area, EC is within 2000 µ siemens/cm, in 7% area it is in between 2000-3000 µ siemens/cm and in 3% area is **>**3000 µ siemens/cm. **Post-monsoon (2019):** The average EC during post monsoon is 1269 µ siemens/cm. In 90% of area EC is within 2000 µ siemens/cm, in 6% area is 2000-3000 µ siemens/cm and in 4% area is **>**3000 µ siemens/cm.
25.2	Fluoride mg/l	:	**Pre-monsoon (2019):** Fluoride concentration varies from 0.04 to 3.4 mg/L and 94% of samples are within permissible limits of BIS and rest is beyond permissible limit of 1.5 mg/L. **Post-monsoon (2019):** Fluoride concentration varies from 0.04 to 2.93 mg/L and 99% of samples are within permissible limits of BIS and rest is beyond permissible limit of 1.5 mg/L
25.3	Nitrate mg/l	:	**Pre-monsoon (2019):** Nitrate concentration varies from 0.04-261 mg/L in 14% of samples is beyond permissible limits of 45 mg/L. **Post-monsoon (2019):** Nitrate concentration varies from 0.03-50.50 mg/L in 0.01% of samples (very negligible) is beyond permissible limits of 45 mg/L i.e at location of B.J Palem of Sabbavaram Mandal.
25.4	Iron mg/l		The common problems of presence of high

			Iron concentrations observed in hilly areas i.e Chintapalli, GK Veedi and Paderu areas etc.	
26	Conceptualization Alluvium-Weathered/Fractured/Massive Eastern Ghats type of rocks and followed by basement of Granite Gneiss i.e Weathered/Fractured/Massive types.		Weathered zone (~27 m). **Aquifer-I (~27 m).** As per well data analysis weathering depth observed: 0 to 60 m bgl.	Fractured zone (27-200m) **Aquifer-II (~27-200 m).** As per well data analysis Fractured depth observed: 25 to 200 m bgl.
27	Aquifer Characterization	:	Thickness of weathered zone is in the range of 20 - 40 m occurs in most part of area (70%). Shallow weathered zone i.e <10 m occurs in 3% of the area, 10-20 m in 7% area and deep weathered zone contours (>40 m to max. 60 m depth zone) occurs in rest of the area i.e 20% area.	The occurrence of fractures is in between the depth of ~27 to 200 m bgl and is discrete. Majority of fractures occur at 150 - 200 m depth (40%), followed by 100 - 150 m depth (25%), 50 - 100 m in 15% and fractures occur at <50 m in 20% area.
27.1	Specific Yield	:	< 1.5% to 3%	-
27.2	Storativity	:	-	3.2×10^{-6} to 1.92×10^{-2}
28	Ground water Resources (2020) MCM	:	**Visakhapatnam District (MCM)**	**GVMC and Urban Area**
28.1	Net Dynamic groundwater availability	:	939.61	57.41
28.2	Gross GW Draft	:	255.81	29.19
28.3	Provision for Domestic & Industrial (2025)	:	166.56	38.35
28.4	Average Stage of Ground water development (%)		27%	51%
28.5	Net GW Availability for	:	697.45	32.34

	future irrigation		
28.7	Categorization of mandals		All mandals (43) categorized as Safe
29	Major Ground Water Issues Identified	:	Low yield (<1 lps) occurs in ~60 % of area in the district. Deep water levels in the range of >20 m bgl occupy about 2% of the area, Water-logging is observed in and around Bhimunipatnam, Visakhapatnam urban village coastal areas during postmonsoon seasons. High concentration of Flouride 1.54 to 3.40 mg/L during pre-monsoon season in S. Rayavaram, Rolugunta V. Madugula, Gajuwaka, Anakapalli, Narsipatnam, Bhemili, Visakhapatnam urban, Kasimkota & Kottakota mandals High nitrate (> 45 mg/L) in 10 mandals i.e Koyyuru, G.K Veedi, Dumbriguda, Paderu, Golugonda, Ravikantam, Rambilli, Kotauratla, Visakhapatnam urban and Bhimilipatnam mandals during pre-monsoon in range of 48 mg/L to 200 mg/L. Higher concentration of Nitrate is mainly attributed to unscientific sewage disposal of untreated effluents in urban and rural areas. High use of fertilizers in rural areas. High concentration of trace metals in Parwada and Atchutapuram mandals, Occurrence of GW salinity owing to marine depositional conditions in few pockets near to the coast.
32.	Management Strategies	:	Repair, Renovation and Restoration of existing tanks Desiltation of all existing artificial recharge structures (1091 Check Dams and 301 Percolation Tanks) and water conservation structures for effective utilization of existing structures and storage created through these

			structures. Construction of 1152 artificial recharge structures (576 CDS and 576 PTS) Roof top rainwater harvesting structures for all buildings with more than 200 sq.m area Desilting of all existing 16276 no. of farm ponds and further recommended to construct 17060 farm ponds @ 20 in each village in 853 villages. Recommendation for brining ~42,650 ha that can be brought under micro-irrigation (@50 ha/village in 853 villages) considering 1 unit/ha @0.6 lakh/ha
33.	Expected Results and Out come	:	With the above interventions, the likely benefit would be the net saving of 167 MCM of ground water.

EXECUTIVE SUMMARY

Visakhapatnam district covering an area of 11,343 km^2 and administratively, governed by 4 revenue divisions, 43 mandals with 3108 inhabitated villages. The population of the district is ~45.74 lakhs (2020 census) with average density of 696 persons/km^2.

The district receives an average annual normal rainfall of 1202 mm of which SW monsoon contributes 80% and north-east monsoon contributes 20%. The area is underlain by Khondalites, Granites, Chanrnockites and alluvium. Geomorphologically the district can be divided into three regions, viz. northern hilly terrain with valleys, middle pediplains and alluvial coastal plains. The forest occupies ~42% i.e 4796 sq.km of the total geographical area, remaining is considered as plain. The gross cropped area during 2019 – 2020 during khariff and rabi seasons is 318100 ha. The main crops grown are Paddy during khariff and rabi seasons followed by Sugarcane. The other crops are black gram, green gram, maize, cotton, oil seeds and other vegetables etc. The gross area irrigated during Kharif and Rabi seasons is 36424 ha.

The total area irrigated in the district is 1,13,246 ha, out of which the area irrigated by Surface water is 58521 ha, Ground water is 29369 ha and the area irrigated by other sources are 25356 ha. The total area Irrigated by MI Tanks is 1,23,442 ha. The major irrigation projects completed in Visakhapatnam district are Thandava Reservoir Project is 13229 ha. The ongoing/proposed Polavaram Project and Uttranadhra Sujala Sravanthi Irrigation projects have a proposed ayacuts of 60704 ha and 129904 ha respectively. The proposed ground water irrigation under PMKSY-GWI-HKKP /YSR Jala Kala in the districts is 38123 ha by proposed construction of 37167 no. of bore wells

The district is underlain by geological formations ranging from oldest Archaeans to Recent Alluvium. The Archaean group of rocks includes Khondalites and Charnockites of Eastern Ghat super group and Granitic gneisses of Migmatite group.

CGWB constructed 63 numbers of exploratory wells/ observation wells/ piezometers, whereas State Ground Water & Water Audit department constructed 45 wells in Visakhapatnam district. 35 Geophysical studies have been carried out in the district by CGWB. These data from 108 wells and 35 VES have been used are used in preparation of aquifer maps and management plans.

The Water levels are being monitored through 157 number of monitoring wells by both CGWB (49) and GWD & WA (108). During Pre-monsoon season the water levels vary between <1 m to 24 m bgl with an average water level of 12.41 m bgl. In majority of area, the water levels in the depth range of 5-10 m, followed by 10-20 m bgl and 2-5 m bgl. Shallow water levels <2 m.bgl occupy about 5% of the area falling in parts of Costal parts of Visakhapatnam. Deep water levels here between >20 m.bgl occupy 5% of the area in small parts of Anandapuram, Parwada, Anakapalli and Payakaraopeta mandals.

During post-monsoon period, majority of the water levels during this season are in the range of 5-10 m, followed by 2-5 m bgl and 10-20 m bgl. Deep water levels in the range of >20 m bgl occupy about 2% of the area falling mostly in parts of Devarapalli mandal. Shallow water level <2 m.bgl occupy 8% of the area in small parts of Visakhapatnam urban areas, Bhemunipatnam, Parwada, Anakapalli, Koyyuru, Sabbavaram, Kotauratla, Anandapuram, Padmanabham, Ravikamatam Rambilli and Atchutapuram mandals. Water table elevations during pre-monsoon season vary from -6.79 to 1247.5 m amsl and during post-monsoon season vary from -2.21 to 1240.1 m amsl. Ground water flow maximum areas are north west to south eastern direction. The water level fluctuations vary from -12.49 to 17.41 m with average rise of 2.46 m.

Ground Water quality is being monitored by CGWB from 59 monitoring stations and GWD & WA from 138 monitoring stations. The EC is within 2000 µ Siemens/cm in 90% of area in both pre and post monsoon periods. In 94% of samples shows Fluoride within permissible limits during pre and post monsoon periods. In 14% of samples shows Nitrate concentration beyond permissible limits during pre-monsoon period and >1% samples during post-monsoon. The occurrence of high Iron concentrations observed in hilly areas i.e Chintapalli, GK Veedi and Paderu.

The aquifers of Visakhapatnam district can be conceptualized in to Aquifer-1, weathered and contiguous semi weathered and fractured zone (~27 m) and Aquifer-2, the discrete fracture zone with in the depth of 27- 200 m. However, the thickness of weathered zone is varying and is in the range of 20-40 m in most part of area. The fracture zones are more predominant in depth range of 150-200 m. Specific Yield for weathered zones ranges from < 1.5% to 3%. Storativity ranges from 3.2 x 10^{-6} to 1.92 x 10^{-2}. Transmissivity ranges observed in the weathered zones and fractured zones of hard formation ranges from ~1 to 579 m^2/day.

The annual extractable ground water resource (GWRA-2020) is 939.61 MCM, the gross ground water draft for all uses is 255.81 MCM, provision for drinking and industrial use for the year 2025 is 166.56 MCM and net available balance for future irrigation use is 697.45 MCM. The stage of ground water development varies from 8.9% to 52.9%.

The district has no such major issue in terms of ground water, there are few localized issues i.e., low yield (<1 lps) occurs in ~60 % of area, deep water levels in the range of >20 m bgl occupy about 2% of the area, water-logging is observed in and around Bhimunipatnam, Visakhapatnam urban village coastal areas with areas of ~10 to 15 sq.km during postmonsoon seasons. High concentration of Flouride 1.54 to 3.40 mg/L during pre-monsoon season is found in groundwater at S. Rayavaram, Rolugunta V. Madugula, Gajuwaka, Anakapalli, Narsipatnam, Bhemili, Visakhapatnam urban, Kasimkota & Kottakota mandals. Higher concentration of fluoride in ground water is attributed due to source rock i.e Granite Gneiss and Khondalite, rock water interaction where acid-soluble fluoride bearing minerals (fluorite, fluoro-apatite) gets dissolved under alkaline conditions. Higher residence time of ground water in deeper aquifer may also cause. High nitrate (> 45 mg/L) is observed in 10 mandals i.e Koyyuru, G.K Veedi, Dumbriguda, Paderu, Golugonda, Ravikantam, Rambilli, Kotauratla, Visakhapatnam urban and Bhimilipatnam mandals during pre-monsoon in range of 48 mg/L to 200 mg/L. The presence of iron in ground water in agaency area/Paderu diviosn of the district. In Parwada and Atchutapuram mandals, high concentration of trace metals found in ground water in a few samples due to industrial contamination.

The management strategies mainly include both supply side and demand side measures include repair, renovation and restoration of existing tanks, desiltation of all existing artificial recharge structures 1091 Check Dams and 301 Percolation Tanks and water conservation structures for effective utilization of existing structures and storage created through these structures. Construction of 1152 artificial recharge structures (576 CDS and 576 PTS) in all 43 mandals, roof top rainwater harvesting structures for all buildings with more than 200 sq.m area, desilting of all existing 16276 no. of farm ponds and further recommended to construct 17060 farm ponds @ 20 in each village in 853 villages. Recommendation for brining ~42,650 ha that can be brought under micro-irrigation (@50 ha/village in 853 villages) considering 1 unit/ha @0.6 lakh/ha. With the above interventions, the likely benefit would be the net saving of 110 MCM of ground water. With the above interventions, the likely benefit would be the net saving of 167 MCM of ground water in the district.

NUMBER OF DATA POINTS USED FOR PREPARATION OF VARIOUS MAPS-VISAKHAPATNAM DISTRICT, ANDHRA PRADESH STATE

S. No	Data	Aquifer	Total Data Points	Source	
				CGWB	SGWD
1	Panel Diagram (3-D)	Combine	143	Expl: 63 VES: 35	45
2	Hydrogeological Sections	4 no	143	Expl: 63 VES: 35	45
3	Fence/panel Diagrams	2 no	143	Expl: 63 VES: 35	45
4	Depth of weathering	1 no	143	Expl: 63 VES: 35	45
5	Depth of fracturing	1 no	143	Expl: 63 VES: 35	45
6	Groundwater Potential zones	Weathered zone	132	Expl: 51 VES: 35	46
		Fractured zone	132	Expl: 51 VES: 35	46
7	Transmissivity (m^2/day)	Unconfined to Confined	22	Expl: 22	--
8	Discharge (lps)	Unconfined to Confined	97	Expl: 51	46
9	Depth to Water Level Maps (2019)	Combine	157	49	108
10	Water Level Fluctuation	Combine	157	49	108
11	Long term water level trends	Combine	157	49	108
12	Water quality Pre-monsoon 2019 Post-monsoon 2019	Combine	**342** Pre: 197 Post: 145	 59 0	 SGWD:138 SGWD:145

1. INTRODUCTION

Aquifer mapping is a multidisciplinary and a holistic scientific approach wherein a combination of geologic, geophysical, hydrologic and chemical analysis 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 purposes. 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 at mandal/block level information.

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: Visakhapatnam district is one of the north coastal districts of Andhra Pradesh. The district is lying between the Eastern Ghats and Bay of Bengal. The district is bounded on the south east by the Bay of Bengal, on the north east by Vizianagaram district, on the North West by Orissa state and on the south west by East Godavari district. Howrah - Chennai broad gauge railway line and NH-5 are passing through the district almost parallel to the coastline. The Visakhapatnam district geographical area is 11,343 km^2, lies between north latitude 17°15´11"-18°32´46" and east longitude 81°52´40"-83°29´27". It is falling in part of the lower Godavari subbasin and Nagavali river subbasins. Out of total area, the Command area is 117.94 sq.km and non-Command area is 666.89 sq.km and hilly area is 4769 sq.km (i.e 42%). Administratively the district is governed by 43 revenue mandals with 3108 villages with a population of ~45.74 lakhs (2020 census). The district has aerodrome and natural harbor at Visakhapatnam. Paderu and

Araku in the district are having broad picturesque valleys with an altitude of about 900 m amsl. Araku valley is inhabited by aboriginal tribes with different sects. The Araku valley is famous for its beauty, bracing climate and orchards. The setup of administrative mandal boundaries and base map which shows hilly area and plain-valley areas (area 4796 sq.km and 6574 sq.km respectively) is given in **Fig.1.1**.

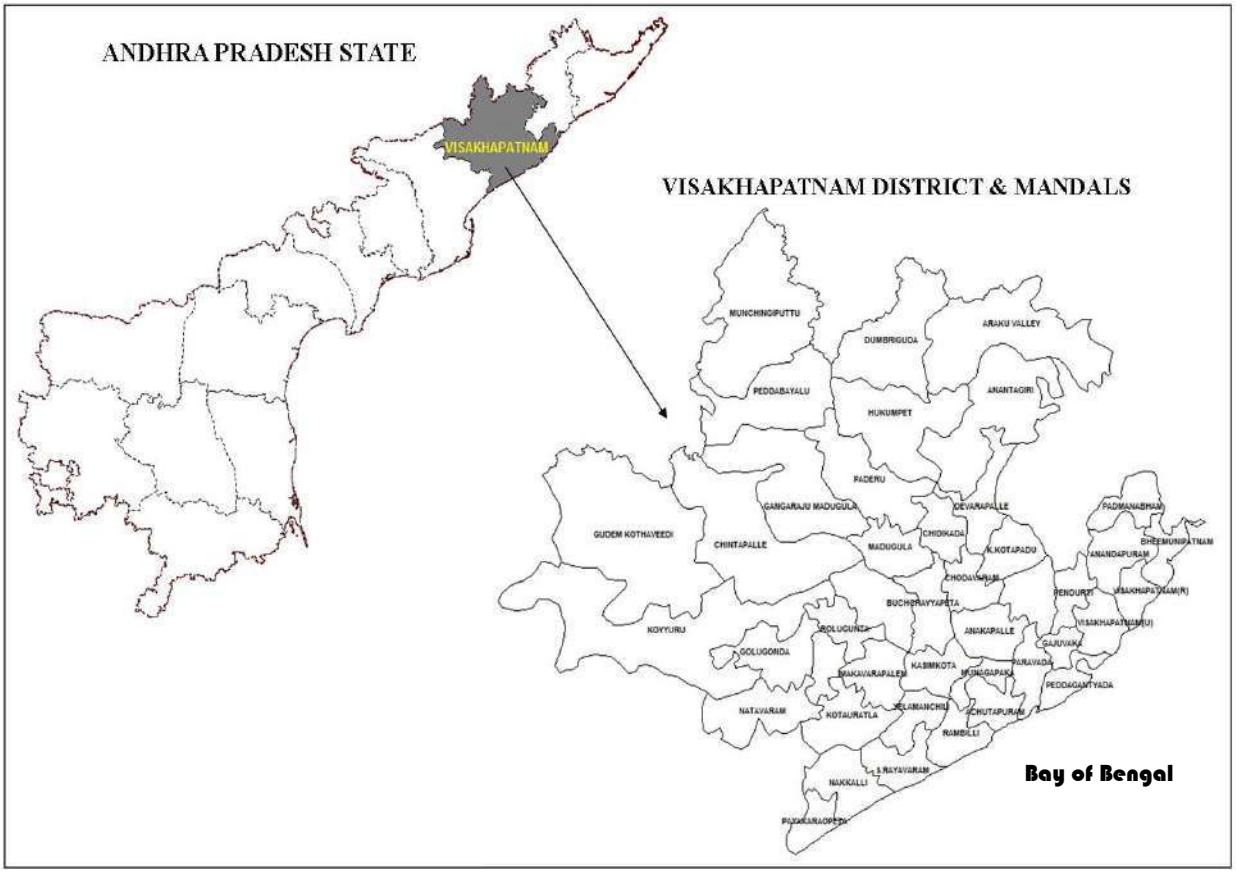


Fig.1.1: Base map of Visakhapatnam district.

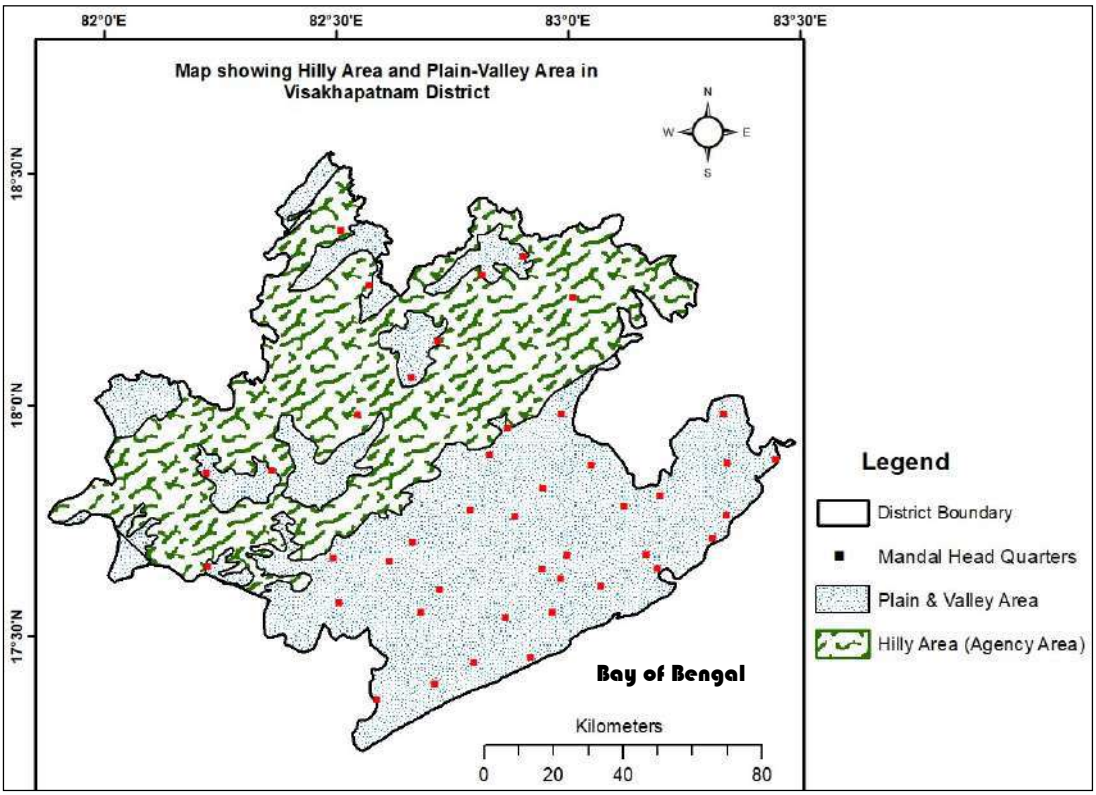


Fig-1.1: Base map of Visakhapatnam District

1.4 Climate and Rainfall: The district experiences tropical sub-humid type of climate with moderate summer and good seasonal rainfall. The temperature variations exist from hilly area to plain area i.e 8°C-25°C to 29°C-36°C respectively. The southwest monsoon sets in the second week of June and lasts till September end. October and November receive rainfall from northeast monsoon. Winter season with cool and fine weather prevails from december to february followed by summer season upto early June. The district receives annual normal rainfall of 1202 mm, of which south-west monsoon accounts for 780 mm of the normal while North-East monsoon contributes 290 mm of the normal rainfall during 2019-20. The rest is shared by summer showers and winter rains. Agency and inland/valley mandals receive larger rainfall from the South West monsoon, while coastal mandals get similarly larger rainfall from North-East monsoon. The mandal wise IMD rainfall data used to prepare the isohyetal map of Viskahapatnam district (**Fig. 1.2**).

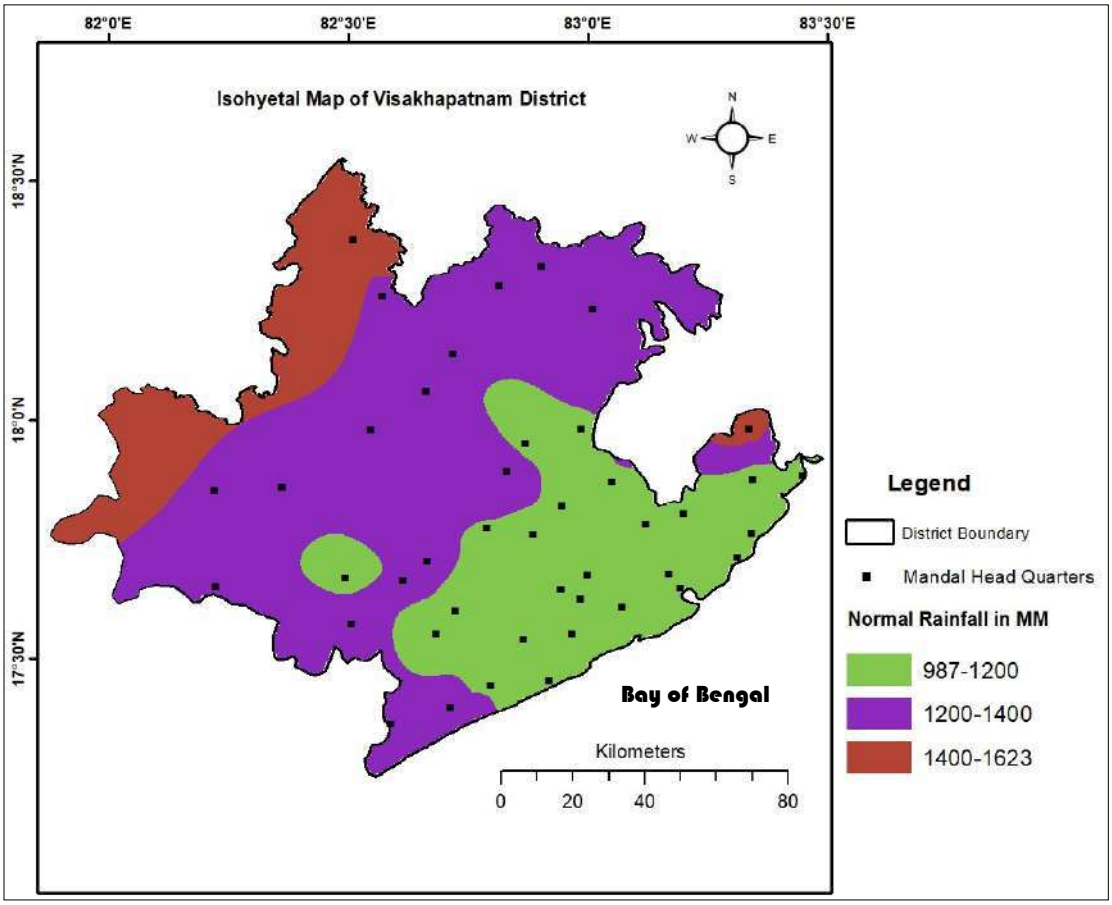


Fig.1.2: Isohyetal map of Visakhapatnam district.

The rainfall distribution of different plain mandals of Visakhapatnam district for all the months of South West monsoon period is shown in **Fig-1.3a** and during the month of September, 2019 15 plain mandals received large excess rainfall and 17 plain mandals received excess rainfall. Though the south west monsoon period the rainfall for entire district is normal, majority of the madals were in deficit rainfall category from June to August [**Fig-1.3a**]. Similar observations were noticed with hilly/agency mandals also [**Fig-1.3b**].

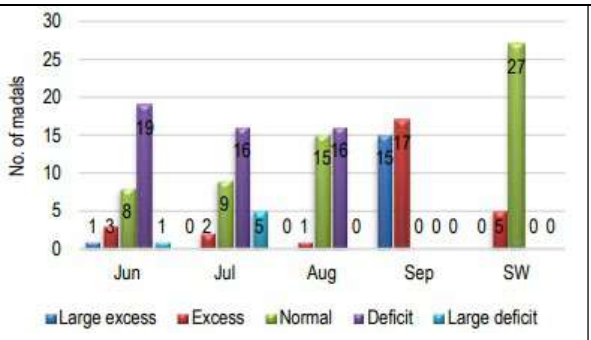


Fig-1.3a: Rainfall distribution in plain area

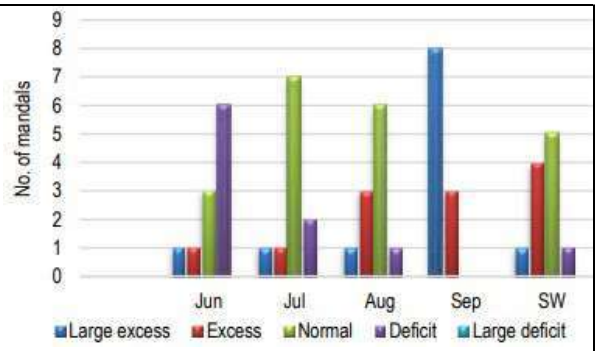


Fig-1.3b: Rainfall distribution in Hilly area

1.5 Geomorphological setup: Geomorphologically the district can be divided into three regions, viz. northern hilly terrain with valleys, middle pediplains and alluvial coastal plains. The northern half of the district is mainly occupied by the structural hills and valleys, which is part of the Eastern Ghats. The hill ranges trends parallel to coast. The average altitude of hills is over 900 m amsl. The hills are densely forested. By virtue of their topography, these hilly terrains largely form recharge run off areas. The valley fills area underlain by weathered formations in the Araku and Paderu areas have high infiltration and high permeability. These areas form good to moderate aquifers depending on their thickness. The hard rock terrain exposed in the Tandava-Varaha-Sarada-Gosthani river basins constitutes the vast denudational pediplains, exhibiting the gradational phase of denudational-residual-inselberg-pediment areas. Pediment is well developed around the khondalite outcrops, whereas in the charnockite outcrops, it is not extensively developed. The pediment area accelerates surface run off with moderate to less infiltration along the jointed and weathered zone. The Tandava, Varaha, Sarada and Gosthani rivers and their tributaries have contributed to the formation of flood plain areas. The district has a coastline of about 132 km. The coastline is broken by a number of bold headlands, which protect the land against constant erosion by the sea. The geomorphology setup of Visakhapatnam district is shown in **Fig.1.4**.

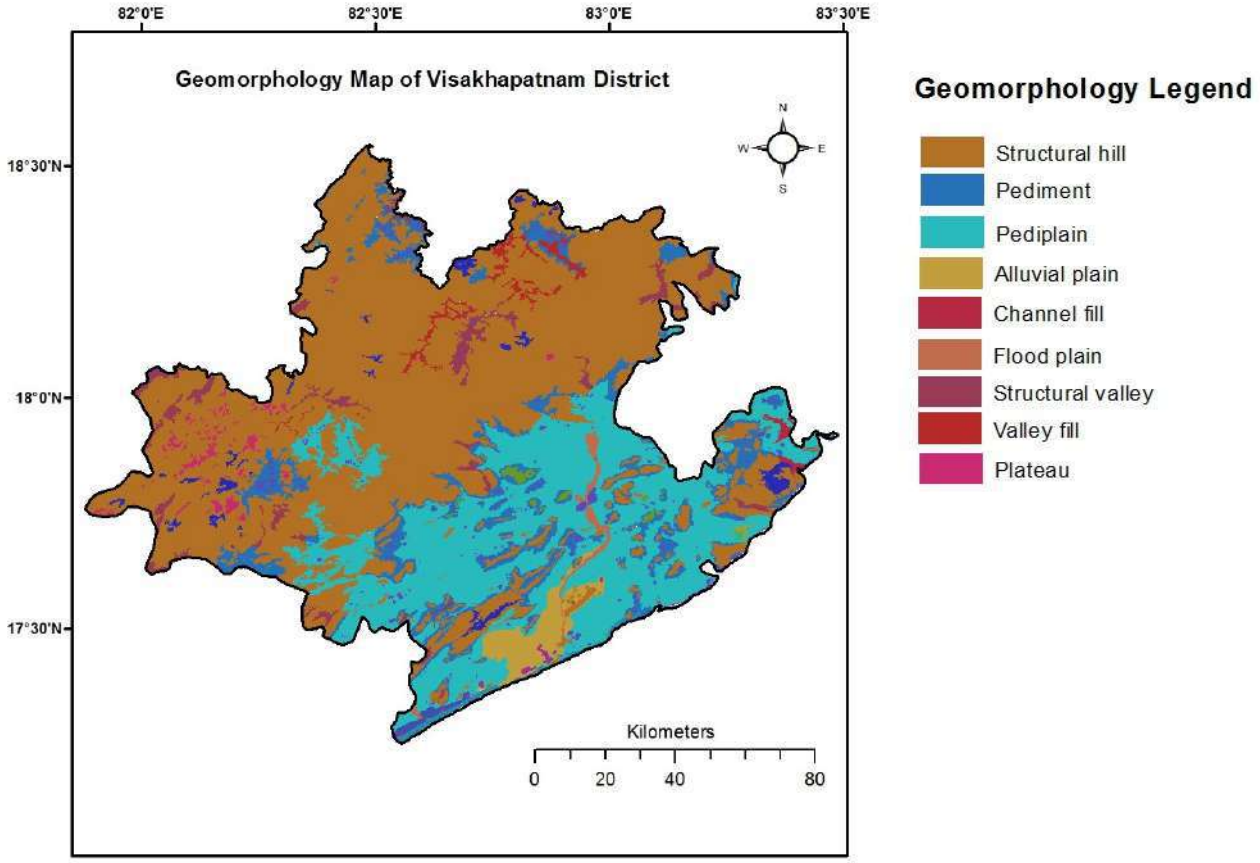


Fig.1.4: Geomorphology of Visakhapatnam district.

1.6 Drainage and Structures: Major part of the district falls under Godavari and Vamsadhara basins and sub-basins are lower Godavari and Nagavali (**Fig.-1.5).**

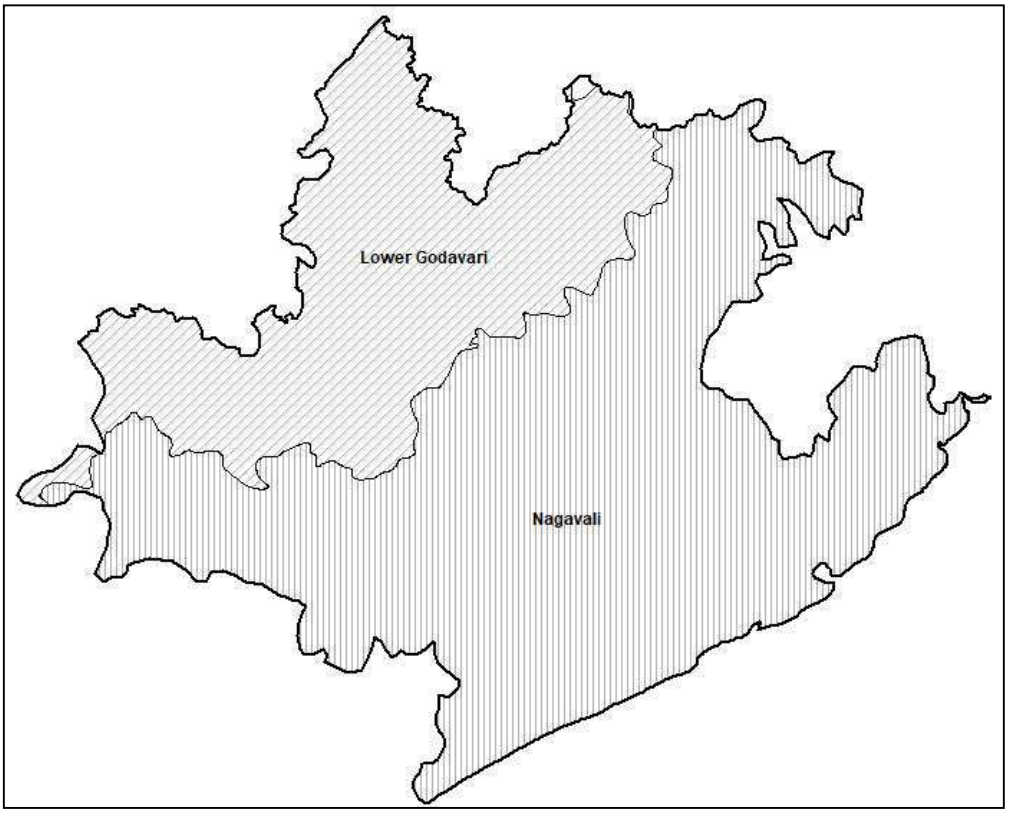


Fig- 1.5: Sub Basins of Visakhapatnam district

The district is divided into five major drainage basins namely Machkund, Tandava, Varaha, Sarada & Gosthani and sub basins of major rivers with their tributaries. No major river/perinial rivers are flowing across the district. The overview of drainage network of Visakhapatnam district is shown in Fig.1.6 and 1.7. The drainage density is less in the plains because of the high infiltration and permeable characteristics of the sediments

The common trend of structural lineaments followed along trending in NE-SW, NW-SE and ENE-WSW directions in this district. The orientitation of structures/lineaments are shown in hydro geological map of Visakhapatnam district (**Fig.2.2**).

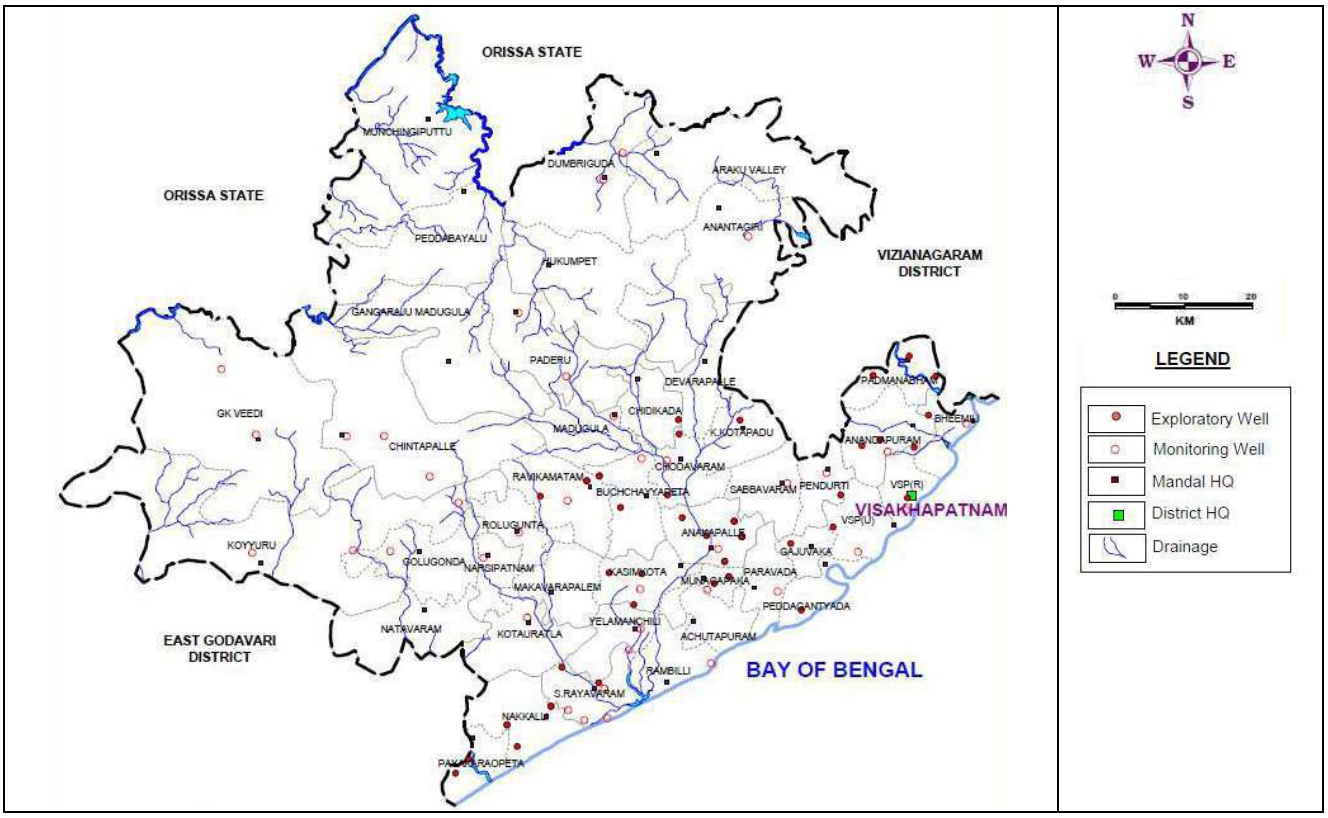


Fig-1.6: Drainage network of Visakhapatnam district.

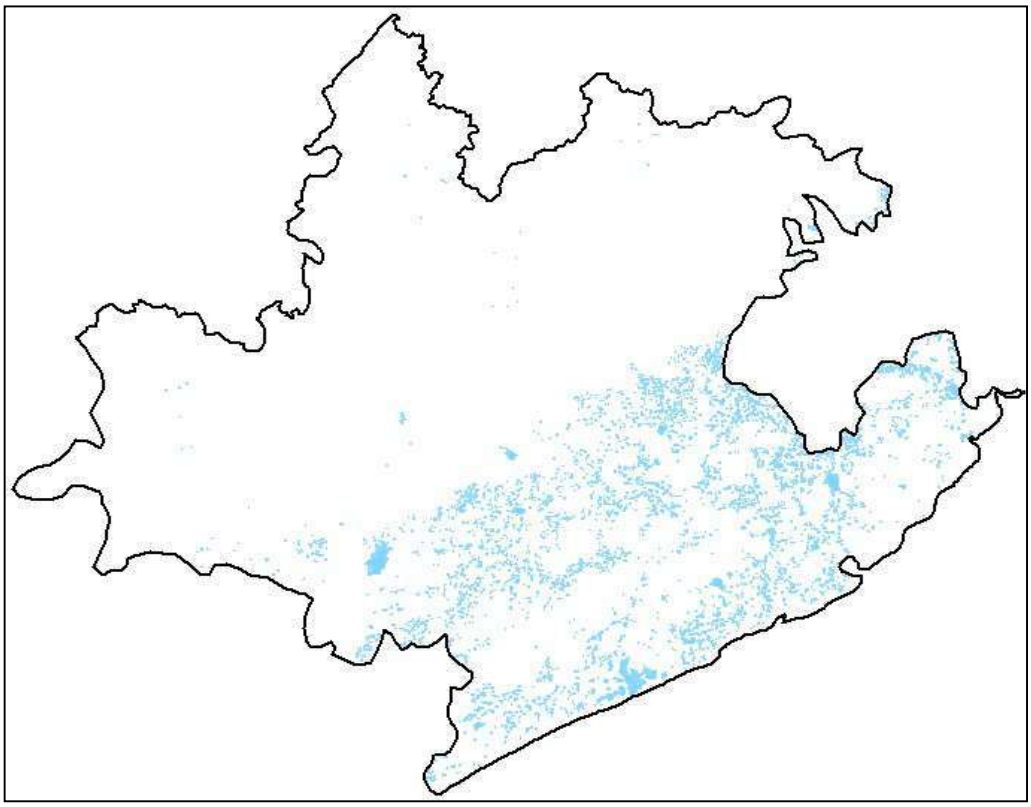


Fig-1.7: Tanks/Ponds in Visakhapatnam district

1.7 Land use and cropping pattern: The forest cover occupies ~42% i.e 4796 sq.km of of the total geographical area and remaining area is considered as plain. The land cover and land use pattern of Visakhapatnam district is shown in Table-1.1 and Fig.1.8.

S.No.	Category	Area (ha)	%
1	Total Area	1116100	100
2	Forests	441200	40
3	Cropped Area	318100	29
4	Barren land	130300	12
5	Cultivable Waste	10600	1
6	Current fallows	78600	7
7	Other fallows	46200	4
8	Others	91100	7

Table-1.1: Land Use pattern of Visakhapatnam District

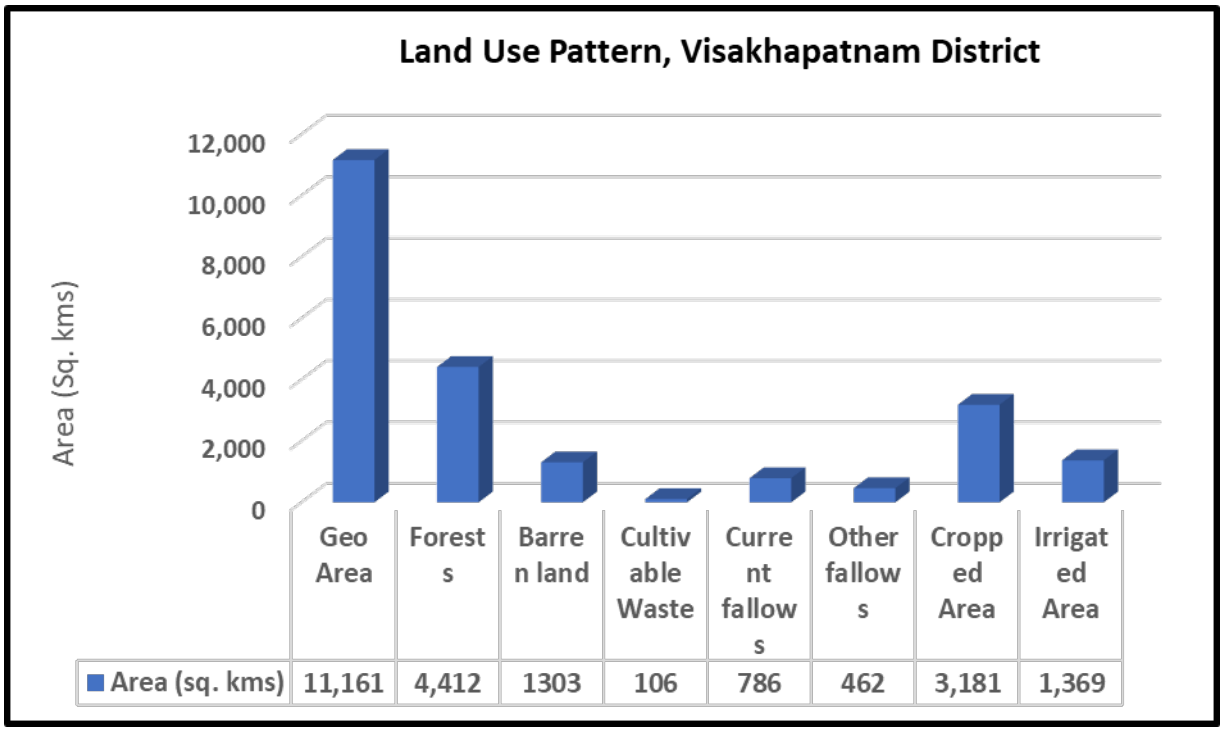


Fig.1.8: Land use and land cover of Visakhapatnam district.

Main crops grown are Paddy during khariff and rabi seasons followed by Sugarcane and other crops are blackgram, greengram, maize, cotton, oil seeds and other vegetables etc.

1.7 Soils:

The soils in the district are red loams, sandy loams, sandy soils and black cotton soils. Red loamy soils are pre-dominant and occupy about 70% in the district. Sandy loamy soils are largely confined to the coastal areas and to certain stretches in the interior mandals of Chodavaram, Narsipatnam, K. Kotapadu and Madugula. Black cotton soils occur in parts of K. Kotapadu, Devarapalli, Chedikada, Paderu and Hukumpeta mandals. Red Loamy soils are poor textured and easily drained. Sandy loamy soils largely confined to the coastal areas (Nakkapalli, Payakaraopeta, S. Rayavaram, Rambilli, Atchutapuram, Paravada, Visakhapatnam, Pedagantyada, Gajuwaka and Bheemunipatnam Mandals) and to certen stretches in the interior Mandals (Chodavaram, Narsipatnam, K. Kotapadu and Madugula). Black cotton soils having sizeable chunks of area (K. Kotapadu, Devarapalli, Cheedikada, Paderu and Hukumpeta Mandals). 45% of the soils in the district are low in organic content and 55% in Phosphorous content. The distribution of soil types in Visakhapatnam district is shown in **Fig.1.9**.

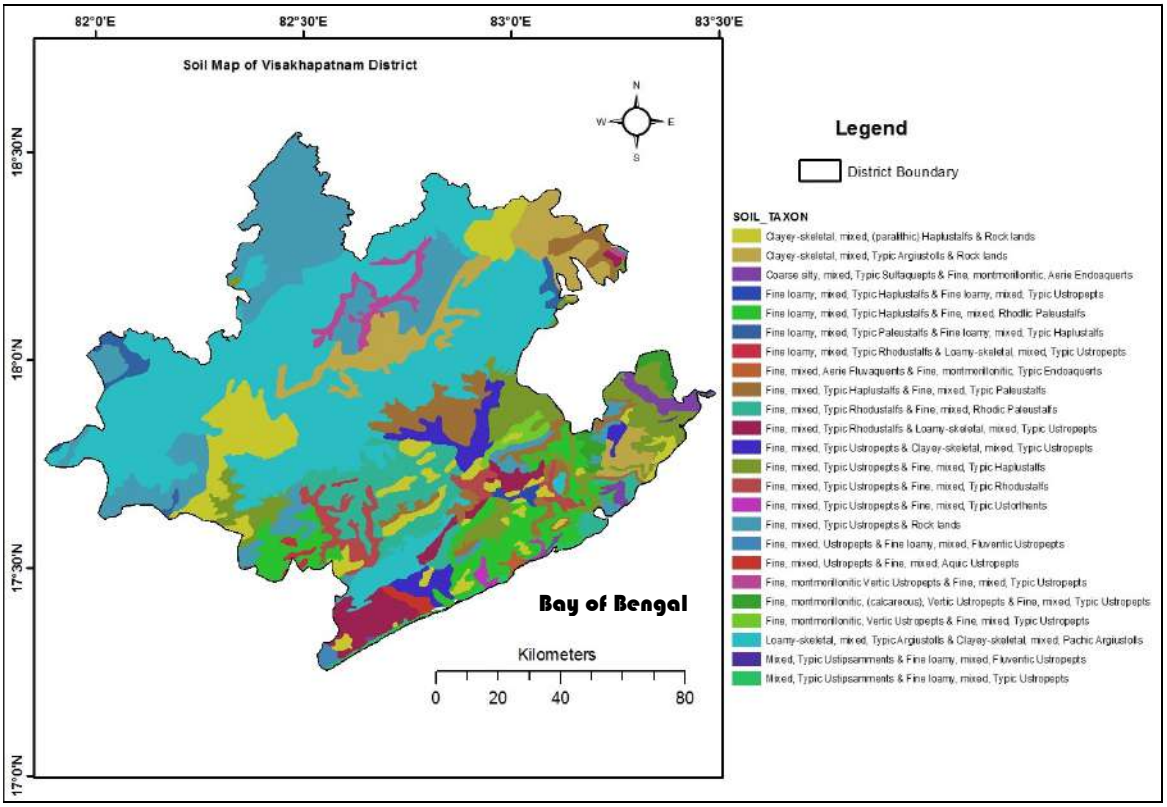


Fig.1.9: Soil map of Visakhapatnam district.

1.8 Soil Infiltration Capacity: Soil infiltration tests were conducted in five different soil types in different locations of Visakhapatnam district to know the infiltration capacity of soils by using double ring infiltrometer at various locations. Depending on the soil types, the basic infiltration rate varies from 1.5 to 3.3 cm per hour, low infiltration rate generally observed in clay and silty type soils and high infiltration rate observed in sandy type of soils. Apart from type of soil, the soil compactness, porosity, permeability and vegetation play an dominant role in the infiltration rate.

Average normal rainfall for monsoon season in Visakhapatnam rural/ urban is ~620 mm for 31 to 33 rainy days. During monsoon, the rainfall intensity is calculated per hour ranges from 0.6 to 0.8 mm/hr, but the regional soils of Visakhapatnam urban and rural area's soil infiltration capacity is measured averagely ~2.5 cm/hour. It indicates that soils infiltration capacity is more than rainfall intensity in this area. The summary of soil infiltration and details of individual soil infiltration test site wise results were given in **Table 2.2** and soil infiltration curve were given in **Fig. 2.10**.

Table-2.1: Summary of Soil Infiltration rate in parts of Visakhapatnam district.

S. No	Village	Mandal	Co-ordinates	Infiltration Rate (cm/hr.)	Soil Type
1	Rishikonda	Visakhapatnam Urban	83º 23' 06'', 17º 47' 39''	3.0	Silty Clay with Sand mixed (Brown colour)
2	Bhemunipatnam	Bhemunipatnam	83º 26' 30'' 17º 54' 14''	1.5	Silty Clay with fine Sand mixed (Brown colour)
3	Adavivaram	Simhachalam	83º 15' 16'' 17º 47' 28''	3.3	Silty Clay with Sand mixed (Brown colour)
4	Gurrampalem	Pendurthi	83º 13' 13'' 17º 50' 04''	2.7	Silty Clay with Sand mixed (Brown colour)
5	Anandapuram	Anandapuram	83º 22' 32'' 17º 53' 21''	1.8	Silty Clay with fine Sand mixed (Brown colour)

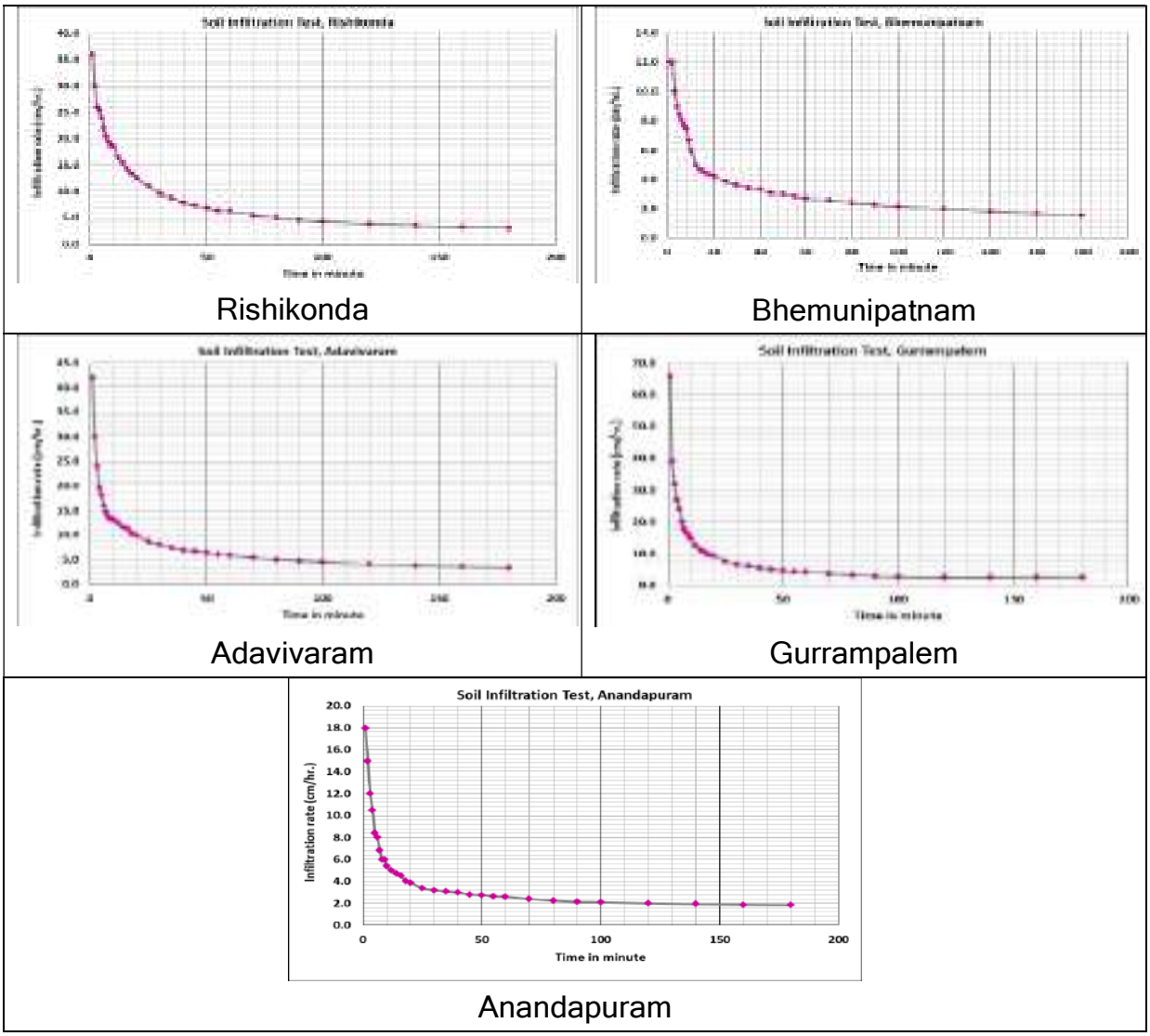


Fig - 1.10: Soil Infiltration curves in different soil types in Visakhapatnam district.

1.9 Irrigation: Agriculture is the main stray of nearly 70% of the households. About 43% of the cropped area is irrigated by major, medium and minor irrigation sources and the rest is rainfed. The major irrigation projects completed in Visakhapatnam district are Thandava Reservoir Project with ayacut area of 13229 ha. Total existing number of bore wells and dug wells in the district are 20,064 and 12,774 respectively. The average depth of bore wells is around 110 m bgl and the average ground water abstraction is for 3-4 hours per day. Out of total irrigated area of 113246 ha, the area irrigated by surface water is 58521 ha (51%), the area Irrigated by ground water is 29369 ha (26%) and the area irrigated by other sources is 25356 ha (23%). The total area Irrigated by Minor Irrigation Tanks and others in the district is 1,23,442 ha. The area irrigated by different sources is provided in fig-1.11

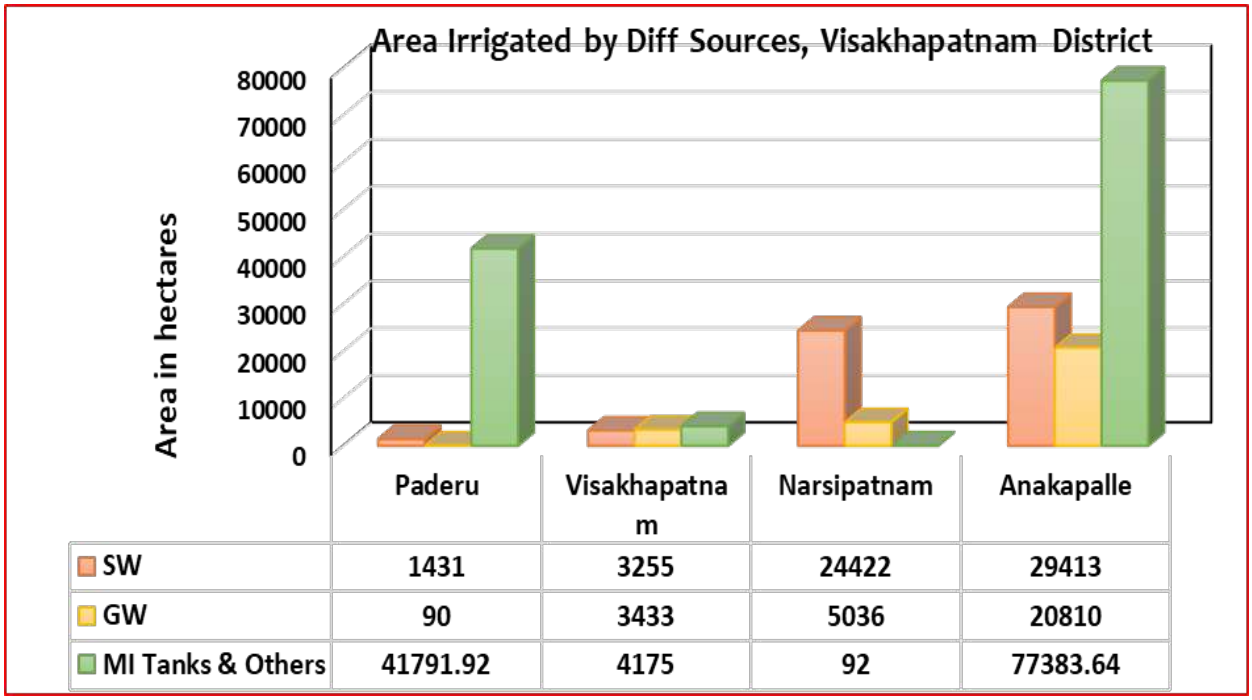


Fig - 1.11 Different sources of Irrigation in Visakhapatnam district

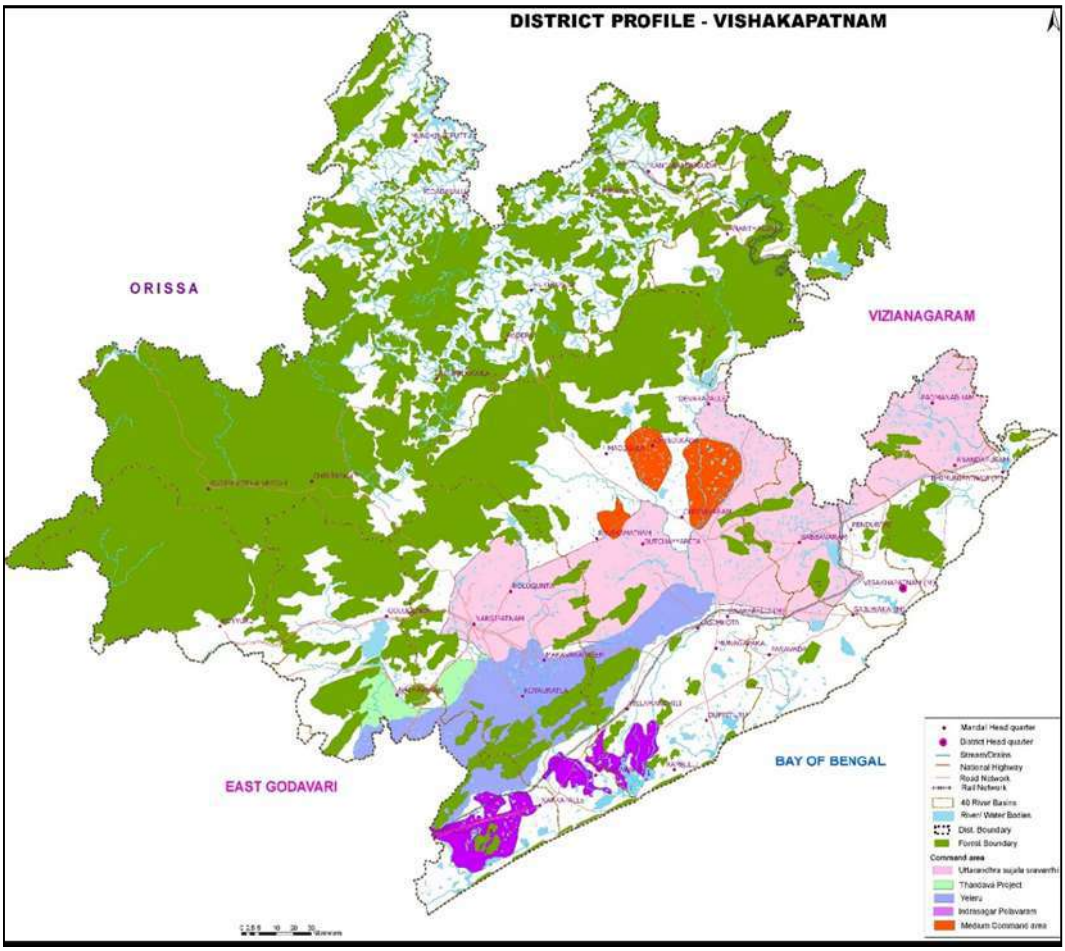


Fig.1.12: Map showing Irrigation Profile of Visakhapatnam District

Future Irrigation Scenario: The ongoing/proposed Indirasagar Polavaram Project and Uttranadhra Sujala Sravanthi Irrigation projects have a proposed irrigation ayacuts of 60704 ha and 129904 ha respectively. The proposed ground water irrigation under PMKSY-GWI-HKKP /YSR Jala Kala in the district is 38123 ha from the proposed construction of 37167 no. of bore wells

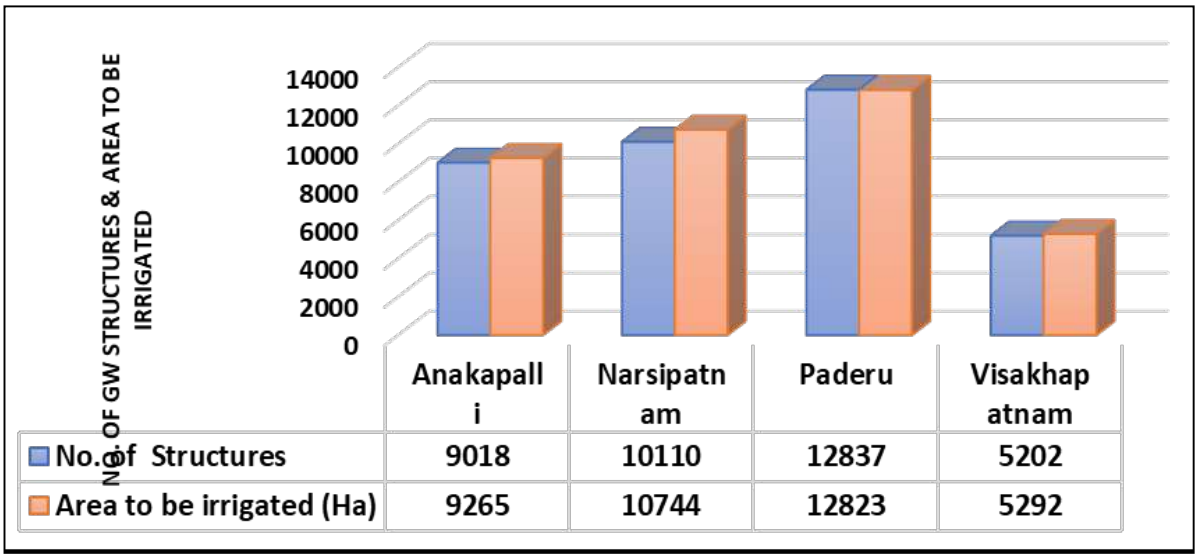


Fig - 1.13 Proposed GW Irrigation - PMKSY/YSR Jala Kala

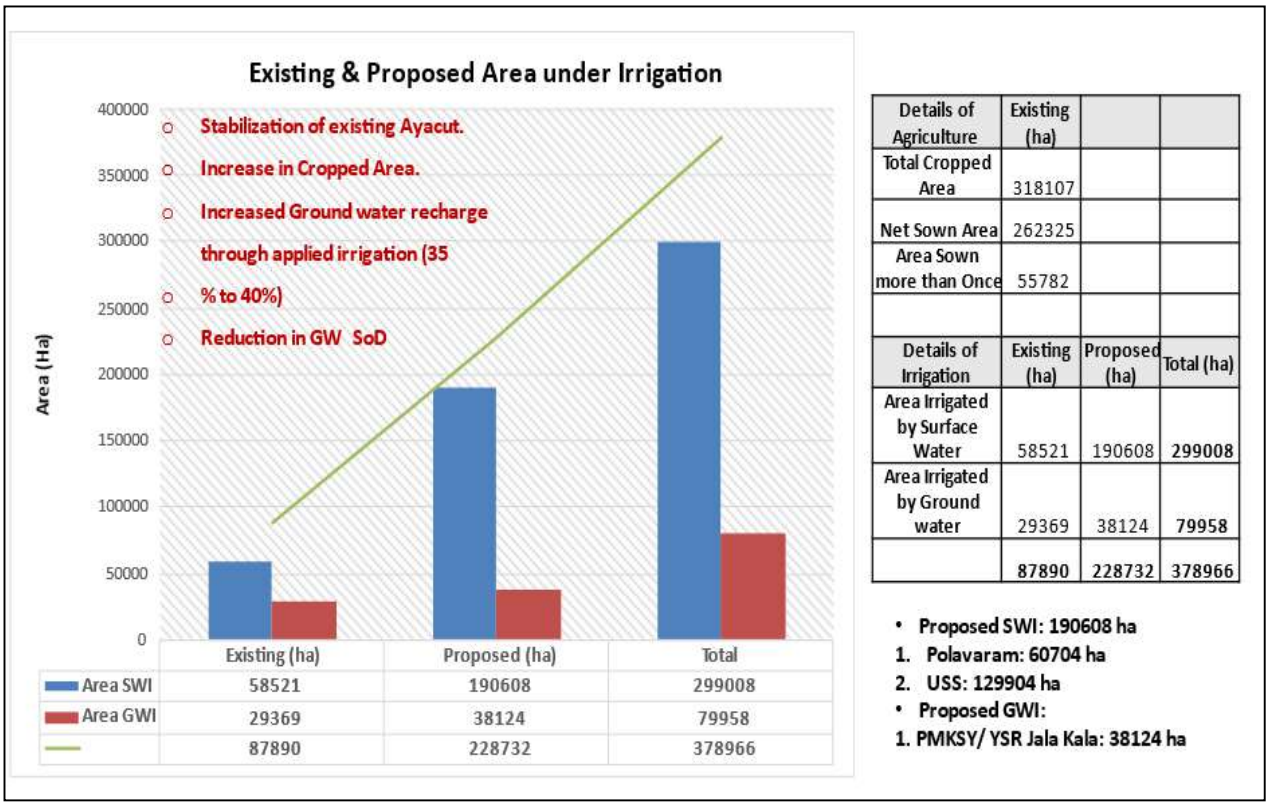


Fig - 1.14 Future Irrigation Prospects, Visakhapatnam District

1.10 Geology:

The district is underlain by geological formations ranging from oldest Archaeans to Recent Alluvium. The Archaean group of rocks includes Khondalites and Charnockites of Eastern Ghat super group and Granitic gneisses of Migmatite group. The recent alluvium is prevalent along the rivers and coastal areas. The stratigraphy of Eastern Ghats Mobile Belt, lithology and basement details are shown in below Table 1.1. The geological map (rock types) of Visakhapatnam district is also show in **Fig. 1.10**.

Table 1.3 Stratigraphy of Eastern Ghats Mobile Belt

Age	Group/ Orogeny	Lithology
950-1100 ma	Eastern Ghat Mobile Belt	Khondalite, Charnockites
	Intrusives	
2600-2800 ma	Charnockites and Granite Gneisses (Basement)	Granite Gneisses

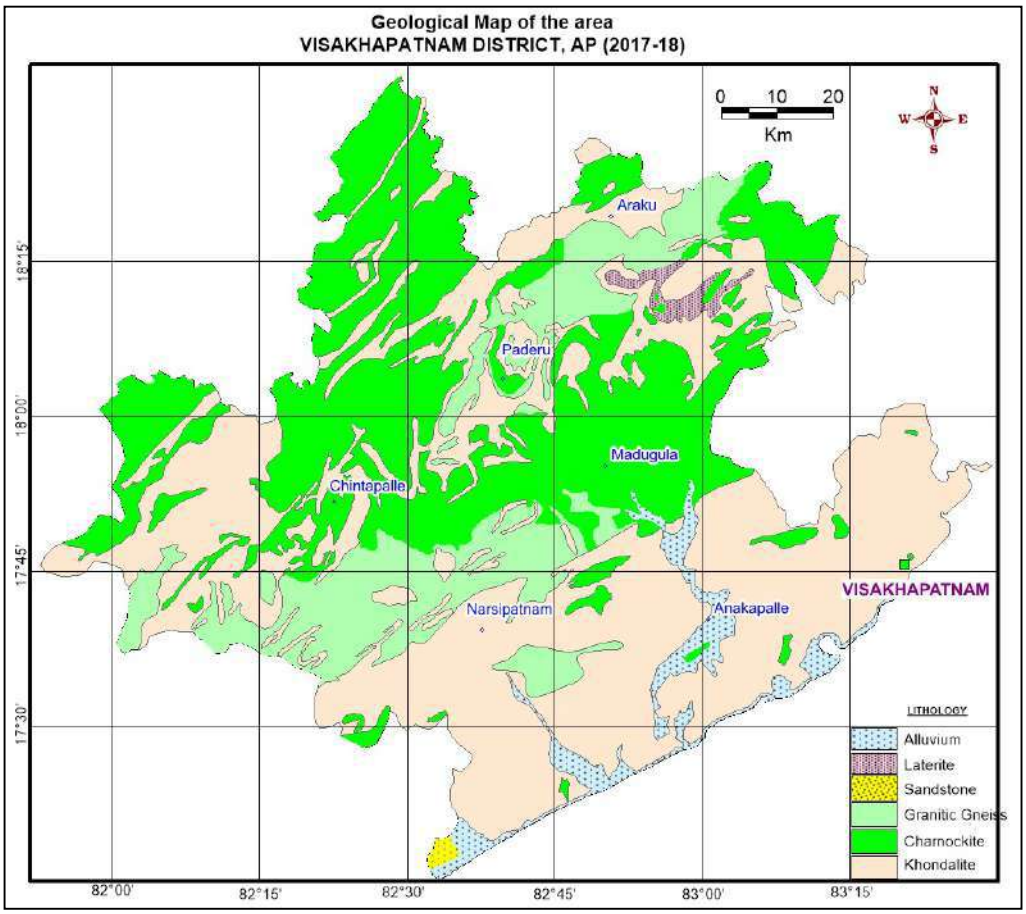


Fig.1.15: Geology of Visakhapatnam district.

2. DATA COLLECTION AND GENERATION

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

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

S. No.	Activity	Sub-activity	Task
1	Compilation of existing data/ Identification of Principal Aquifer Units and Data Gap	Compilation of Existing data on groundwater	Preparation of base map and various thematic layers, compilation of information on Hydrology, Geology, Geophysics, Hydrogeology, Geochemical etc. Creation of data base of Exploration Wells, delineation of Principal aquifers (vertical and lateral) and compilation of Aquifer wise water level and draft data etc.
		Identification of Data Gap and Analysis	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 s1cale)	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 at Mandal/Block level (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 Hydrogeology:

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 aquifers in the Visakhaptanam district can be broadly classified into hard formations (khondalites, charnockites, lyptonites, granitic gneisses etc.) forms the principal aquifer system in the district and soft formations (alluvium and sand stone), which forms a negligible part of the district. Ground water occurs under unconfined to semi-confined conditions in the hard formations.

Various hydrogeological investigations were carried out by Central Ground Water Board (CGWB) and State Ground Water Department (SGWD) in parts of Visakhapatnam district. As a part of ground water exploration studies, CGWB had constructed 63 number of exploratory wells/ observation wells/ piezometers and 45 wells were constructed by SGWD in Visakhapatnam district. These data from 108 wells are used to prepare

aquifer maps in parts of Visakhapatnam district. All 45 numbers of wells of SGWD are below depth of 85 m bgl. The geophysical VES sounding data also used for drawing of aquifer delineation. The locations of exploratory wells of CGWB, wells of SGWD and VES are shown in **Fig.2.1**.

The bore wells drilled in the hard formations, generally tap the weathered zone considered as potential zones and whereas fractured, fissured zones also considered as secondary potential zones for tapping of aquifers for irrigation and domestic utility. The Transmissivity ranges observed in the weathered zones and fractured zones of hard formation ranges from ~1 to 579 m^2/day. Sandstones are exposed in the small isolated places around Nakkavanipalem and Elamanchili which are potential aqufiers. Generally, in these formations, ground water occurs in both unconfined and confined conditions. The maximum depth of dug wells/ filter points in alluvium formations ranges from depth of ~4 to 25 m bgl. Hydrogeological map of Visakhatnam district is prepared and shown in **Fig. 2.2**.

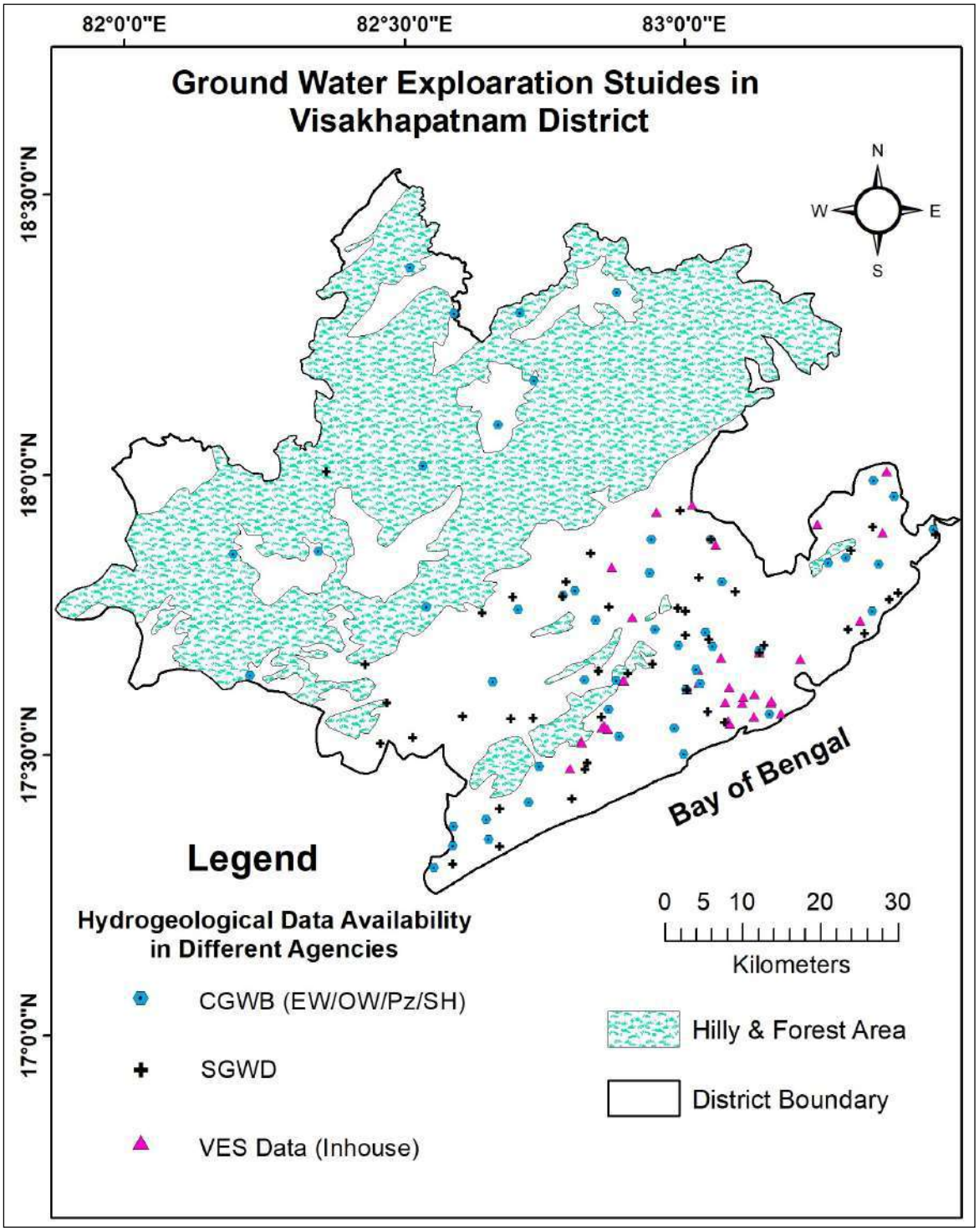


Fig. 2.1: Hydrogeological data availability in Visakhaptanam District.

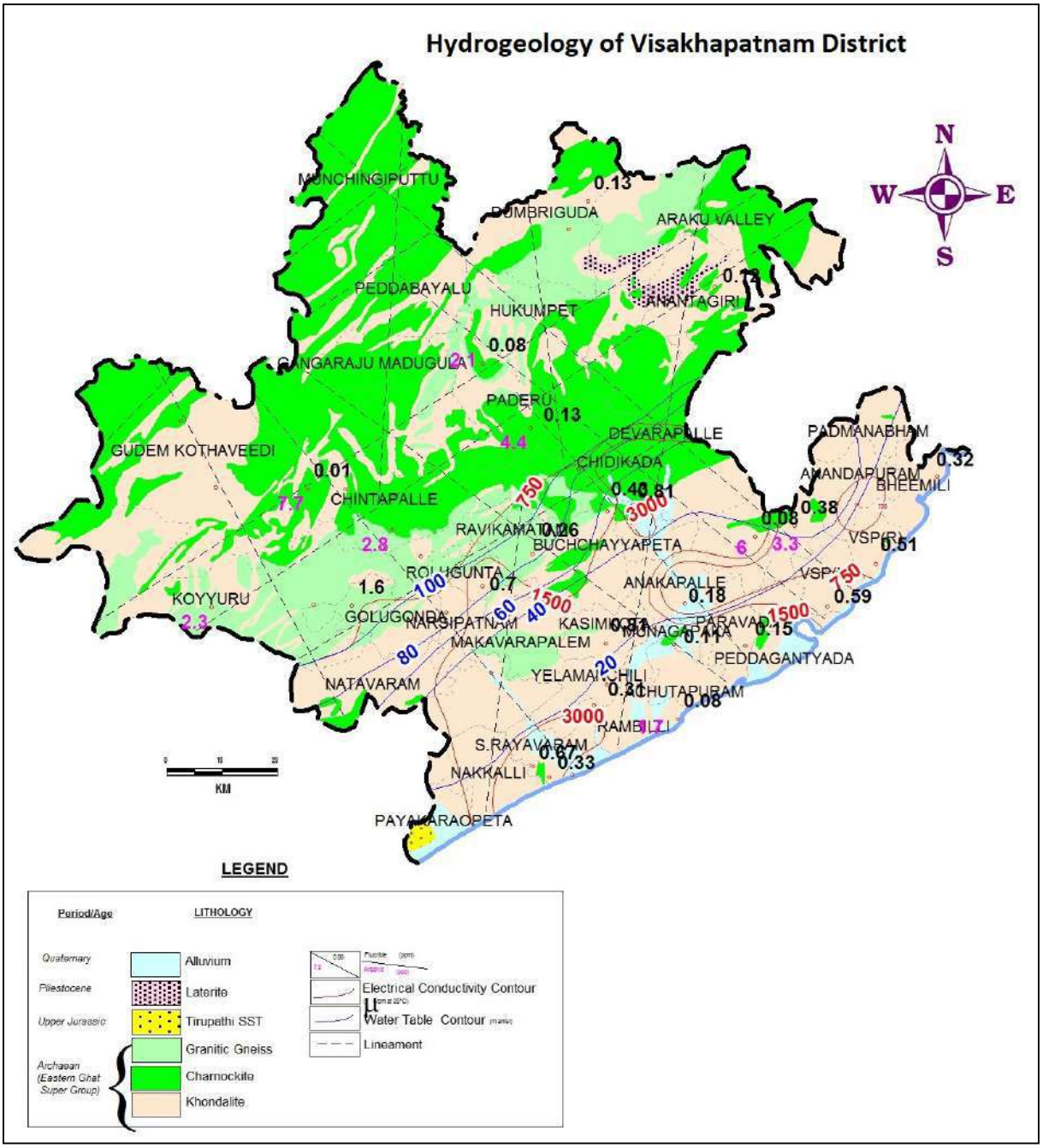


Fig-2.2: Hydrogeological map of Visakhapatnam district.

2.1.1 Ground water occurrences and movement: Ground water occurs in unconfined conditions and also in semi-confined/confined conditions. The ground water flows from the weathered zone into the fracture zone in hard rock area, where as in alluvial/soft rock formations thr ground water flows follws simply reciprocate to topography. The main aquifers constitute the weathered zone at the top, followed by a discrete anisotropic fractured/fissured zone at the bottom, generally extending down to 200 m

depth. At present, ground water extraction is mainly through boreholes of approximately ~15 to ~60 m depth.

2.1.2 Ground Water Yield: Ground water yield vary from < 1 to > 5 lps. Wells located in the command area have higher yield (1-5 lps) and sustain for more hours of pumping when compared to non-command area where yields are relatively low with sustainability for 2-4 hrs (**Fig.2.3).**

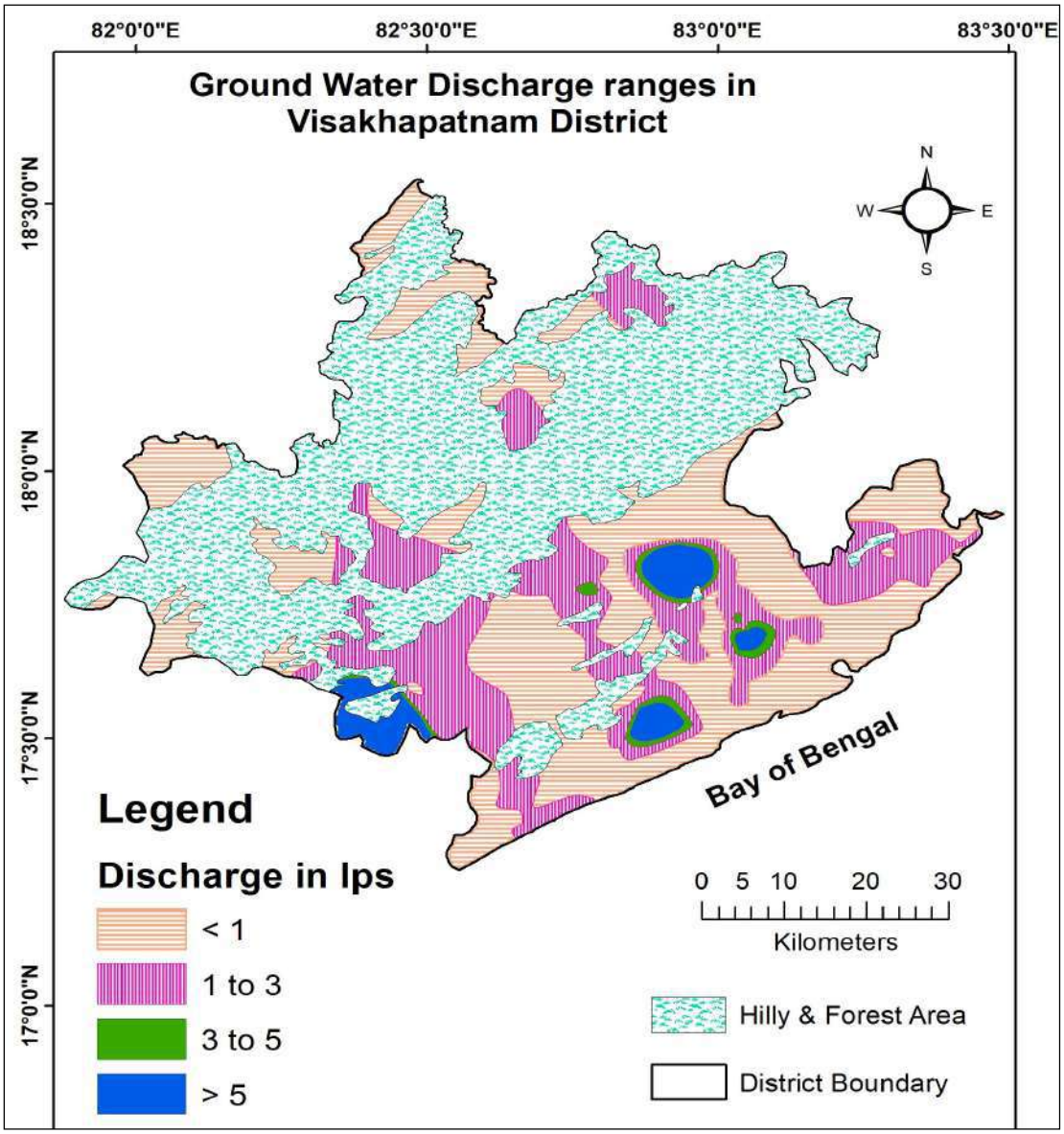


Fig. 2.3: Ground water yield potential map in Visakhapatnam district

2.2 Water Levels: Ground water levels are monitored from 157 numbers of hydrograph network stations in which 49 monitoring stations by CGWB and 108 wells by SGWD. The water level data of 10-year average (2010 to 2019) were used for preparation of depth to water level maps for pre-monsoon and post-monsoon seasons

2.2.1 Depth to Water Levels (DTWL): The average DTWL of 10 years (2010 to 2019) for pre-monsoon and post-monsoon were analysed. The avg. DTWL varies from 0.88 to 23.95 meter below ground level (m bgl) (average: 12.41 m bgl) and 0.27 - 21.80 m bgl (average: 11.03 m bgl) during pre and post-monsoon seasons respectively.

Pre-monsoon season: Majority of the water levels during this season are in the range of 5-10 m covering 65% of the area, followed by 10-20 m bgl (15%) and 2-5 m bgl (10%). Shallow water levels <2 m.bgl occupy about 5% of the area falling in parts of coastal parts of Visakhapatnam (**Fig.2.4**). Deep water levels here between >20 m.bgl occupy 5% of the area in small parts of Anandapuram, Parwada, Anakapalli and Payakaraopeta mandals.

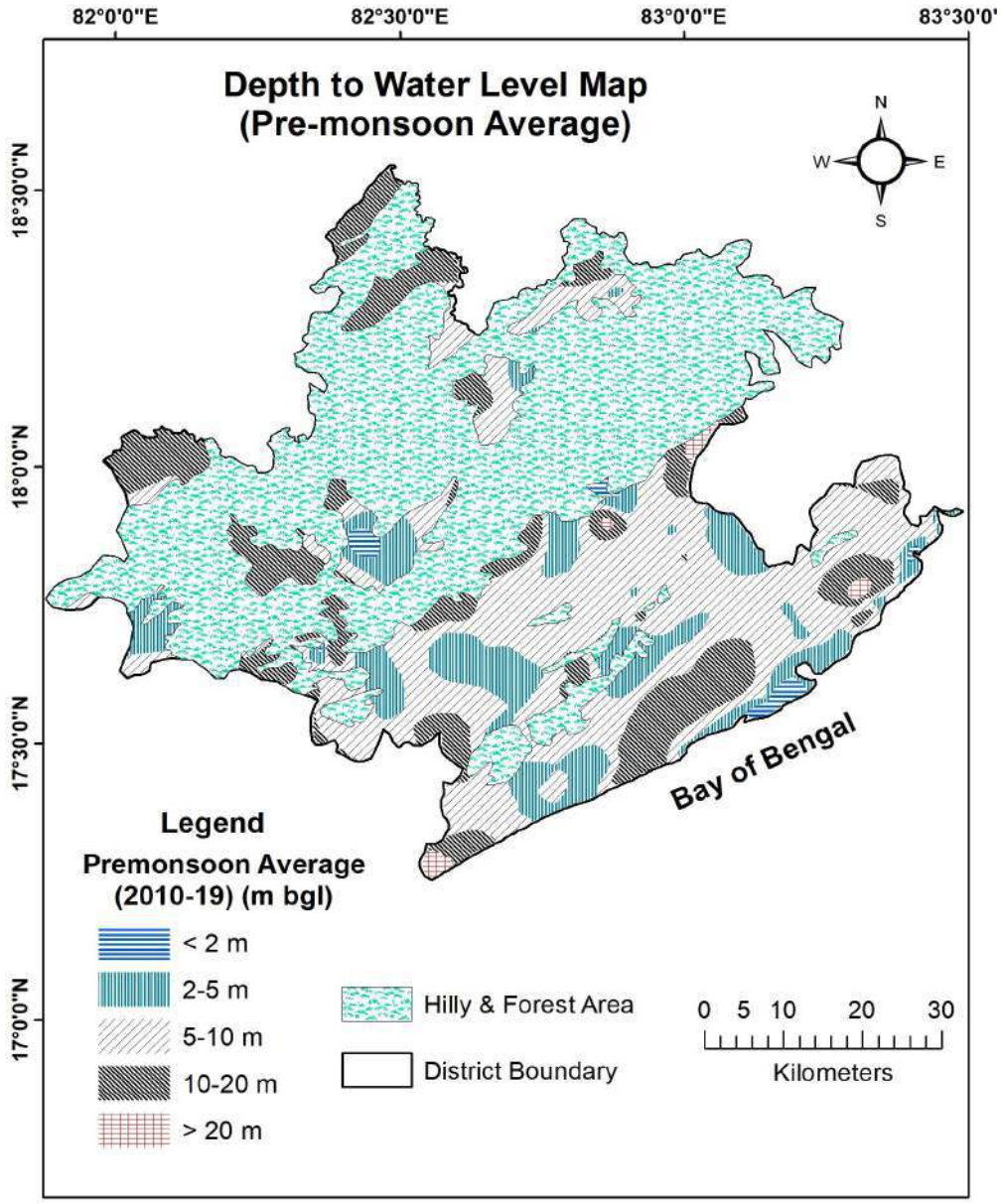


Fig.2.4: Depth to water level map, Pre-monsoon (Decadal)

Post-monsoon season: Majority of the water levels during this season are in the range of 5-10 m covering 45% of the area, followed by 2-5 m bgl (40%) and 10-20 m bgl (5%). Deep water levels in the range of >20 m bgl occupy about 2% of the area falling mostly in parts of Devarapalli mandal (**Fig.2.5**). Shallow water level <2 m.bgl occupy 8% of the area in small parts of Visakhapatnam urban areas, Bhemunipatnam, Parwada, Anakapalli, Koyyuru, Sabbavaram, Kotauratla, Anandapuram, Padmanabham, Ravikamatam Rambilli and Atchutapuram mandals.

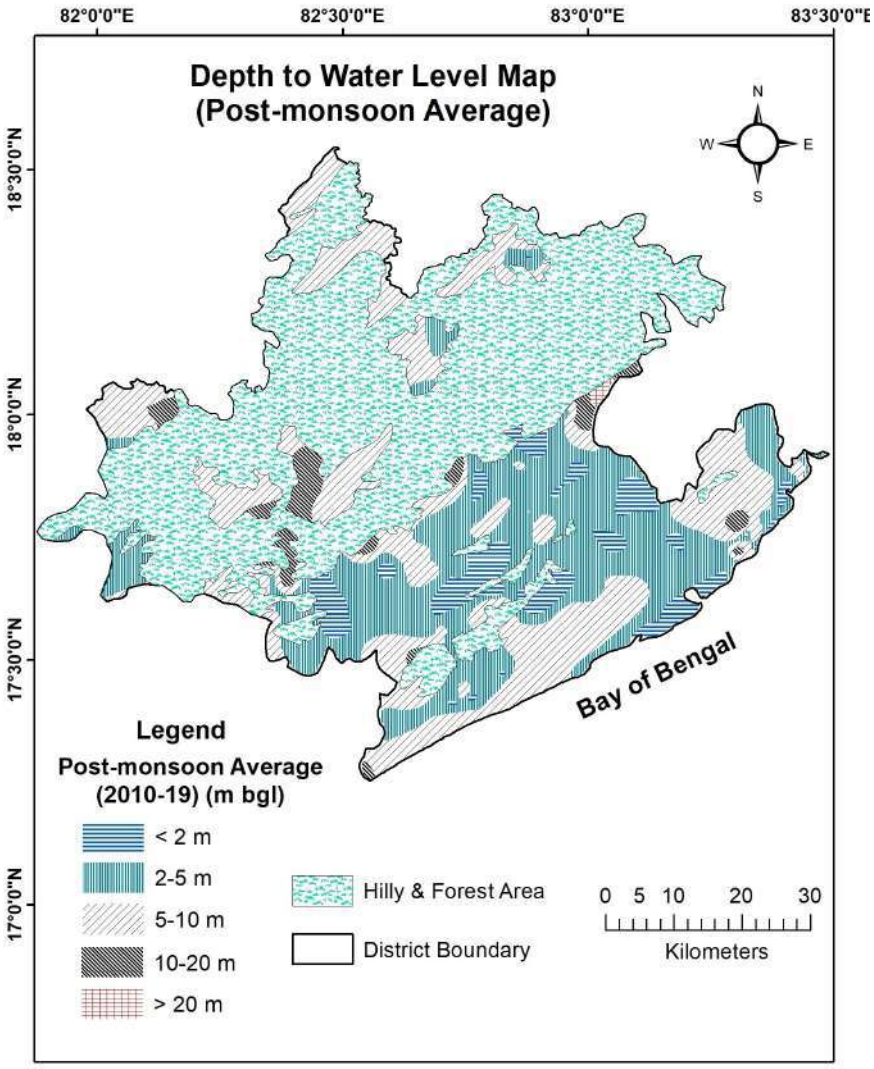


Fig. 2.5: Depth to water level map, Post-monsoon (Decadal)

2.2.2 Water Level Fluctuations (May vs. November): The water level fluctuations vary from -12.49 to 17.41 m with average rise of 2.46 m (**Fig.2.6**). 82% (129 nos) of the wells show rise in water level and 18% (28 nos) of wells show falling in water level. Fall in water level is recorded only in 10% of the area, whereas rise in water levels is observed throughout the distict covering 90% of area. Rise in water level range of 2 to 5 m occurs in majority of the area (55%) followed by 0 to 2 m rise in 30% area, 5 to 10 m rise in 10% area and >10 m in 5% area. Rise of water levels >10 m is observed only in few locations - Arilova, Rambilli, Edatam, Kannurupalem and Donkada. Falls of water levels <-5 m is observed in stations of Lothugadda jn, Purushotampuram, Pendurthi, Gudem and Addaroddu etc.

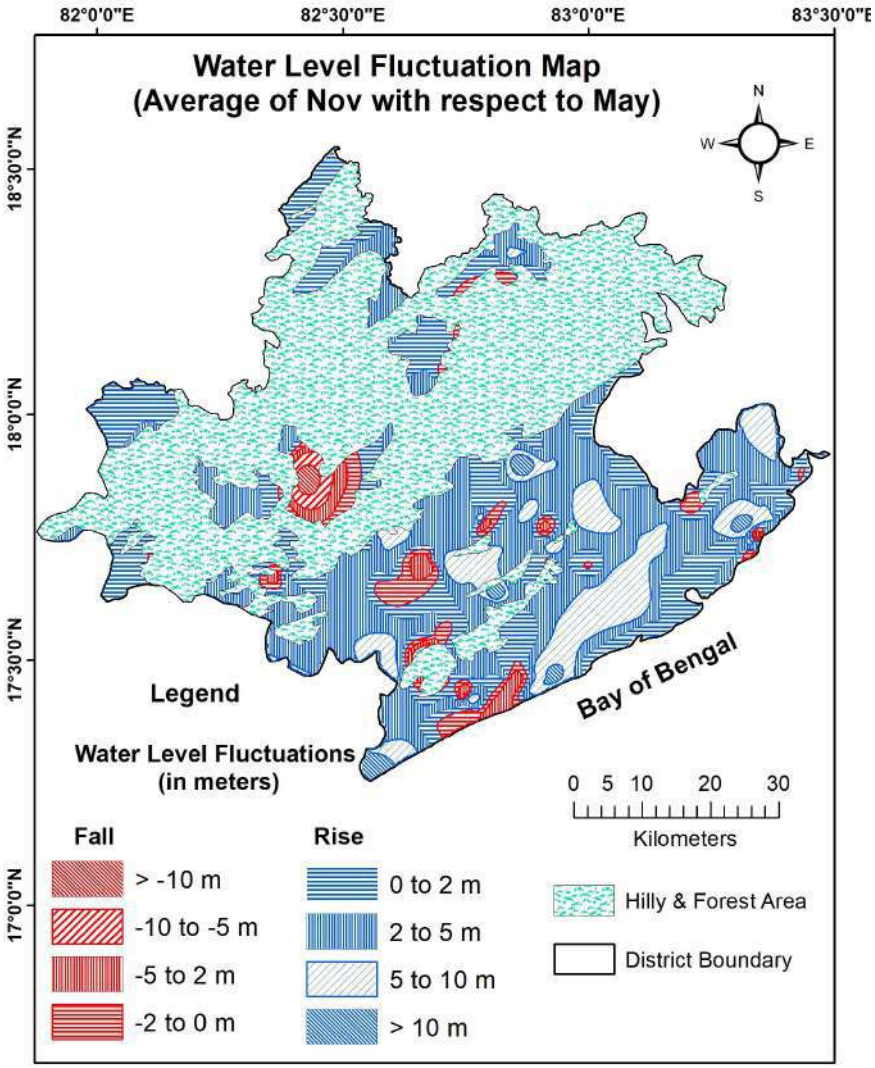


Fig.2.6: Water Level Fluctuations (Nov with respect to May).

2.2.3 Water Table Elevations: The water-table elevation ranges from -6.79 to 1247 during pre monsoon and -2.21 to 1240 meter above mean sea level (m amsl) during post monsoon seasons. The general ground flow is towards towards NW to SE in the southern parts of the district (90% of area) and in some parts of the hilly area and northern part of the district, ground water flows in W, NW directions (**Fig.2.7)**.

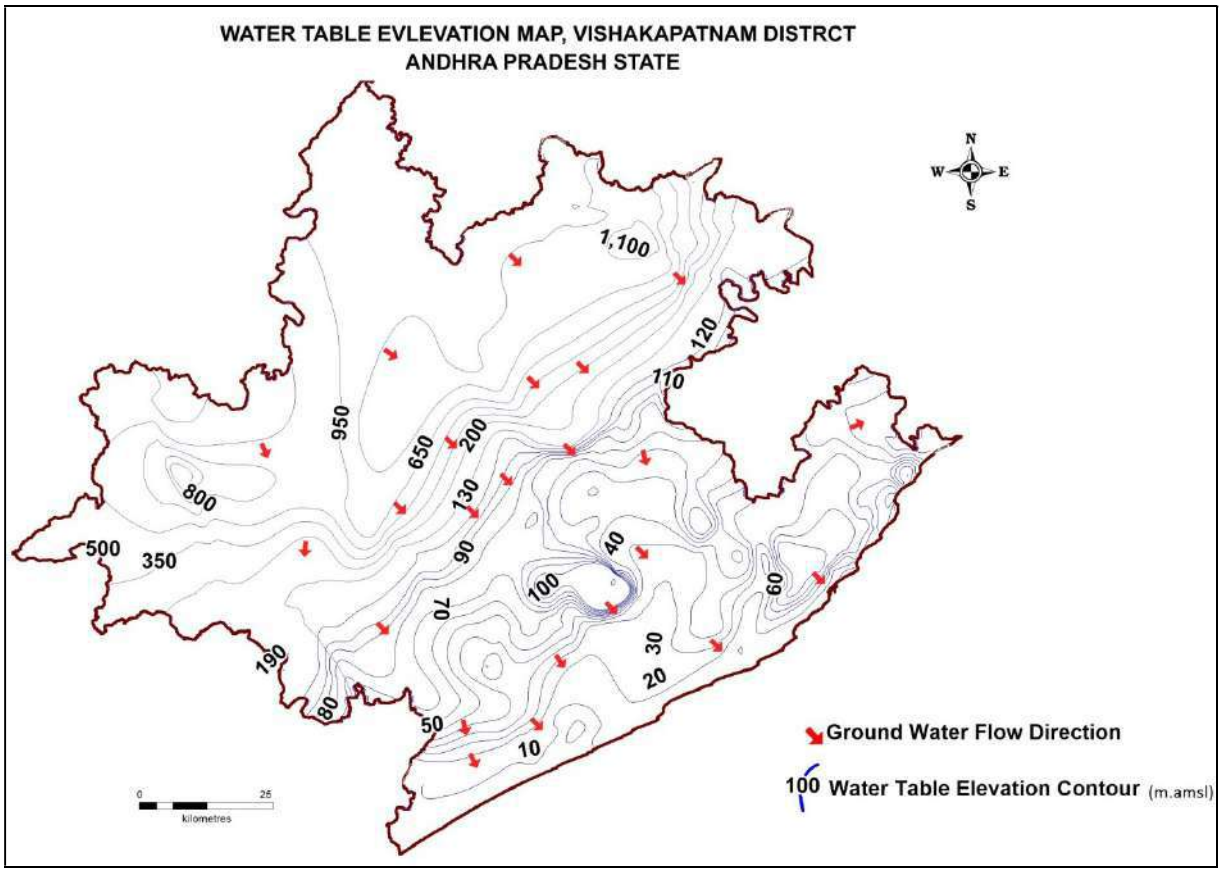


Fig.2.7: Water table elevations (m amsl) during pre monsoon season

2.2.4 Long term water level trends: The long term ground water trend analysis for the last 10 years (2010-2019) is analyzed from 48 hydrograph stations of CGWB. It is observed that during pre-monsoon season 25 wells shows falling trend (0-1 m: 25 wells) (max fall: -0.76 m/yr) and 23 wells shows rising trend (0-1 m: 13 wells) (max rise: 0.64 m/yr). During post-monsoon season 20 wells show falling trend (0-1 m: 20 wells) (maximum fall: -0.7 m/Yr) and 28 wells shows rising trends (0-1 m: 28 wells) (max rise: 0.73 m/yr). The spatial distribution of ground water level trend map is drawn and shown in **Fig 2.8** and also hydrographs of typical stations are also shown in **Fig 2.9.**

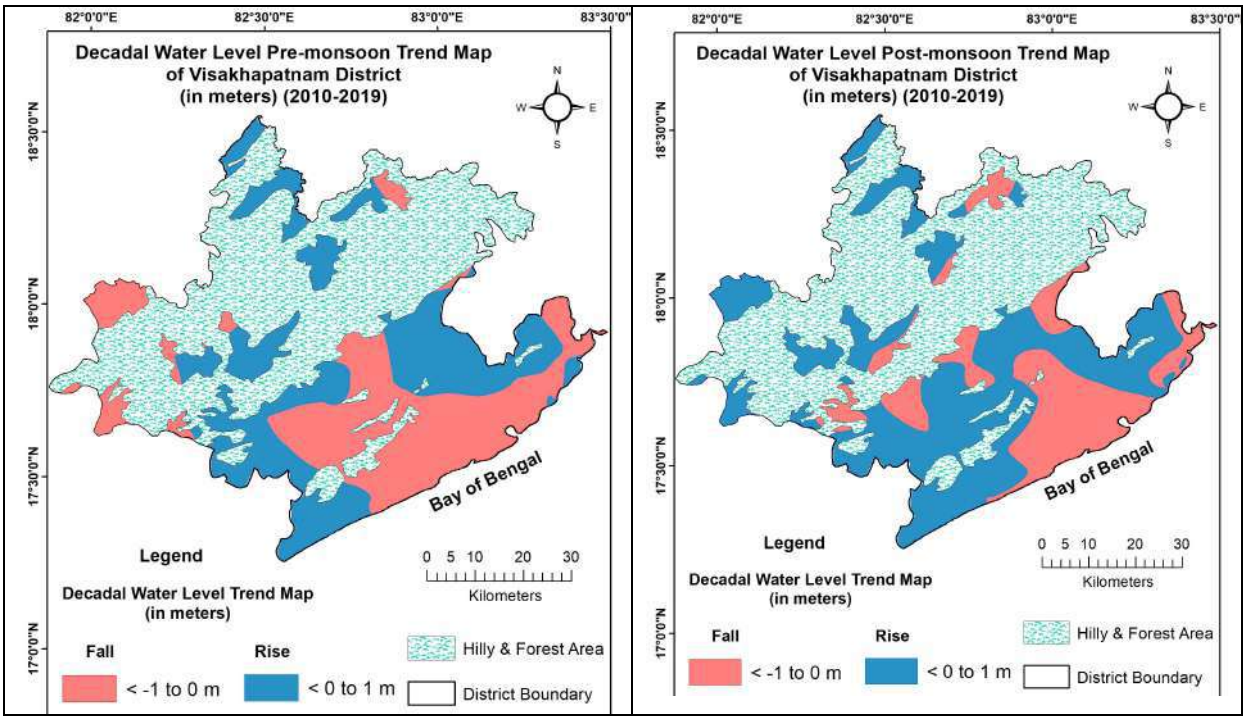


Fig. 2.8 : Long-term water level (Pre & Post monsoon) trends

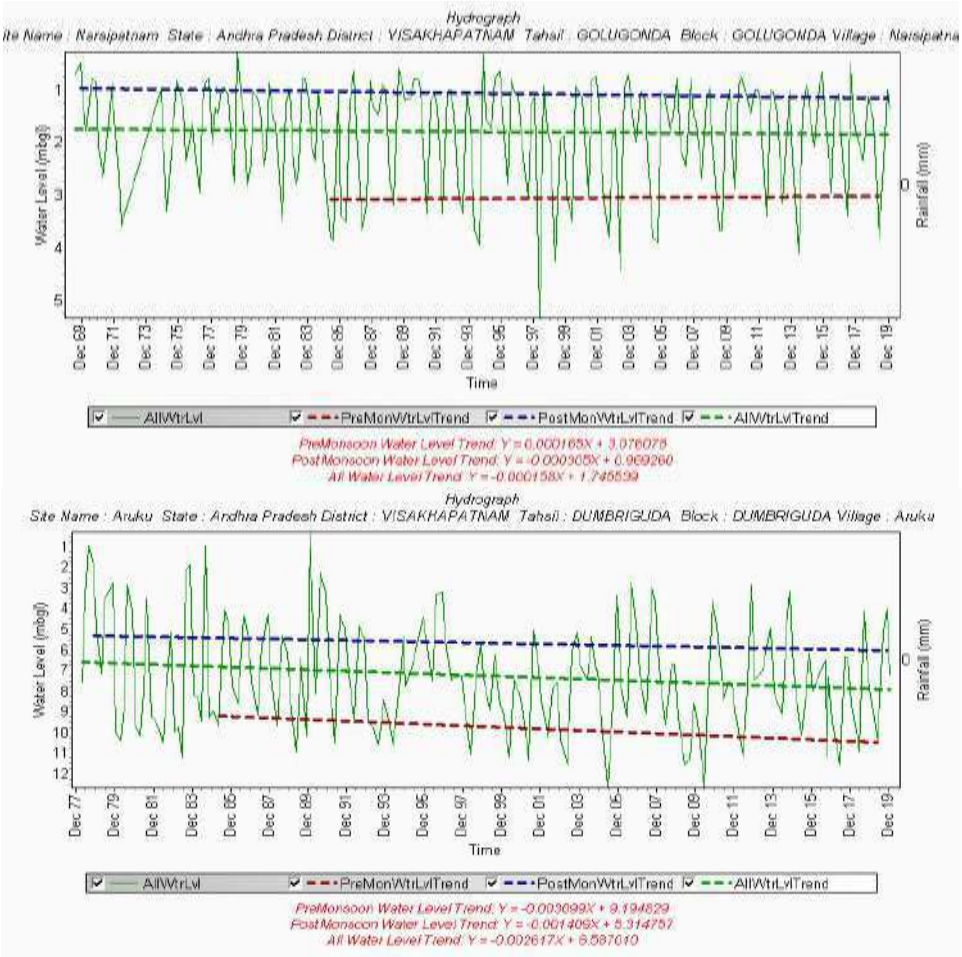


Fig 2.9: Hydrographs of NHS monitoring stations in Visakhapatnam district

2.4 Geophysical Studies:

Vertical Electrical Soundings (VES) were carried out in 35 locations over the entire district of Visakhapatnam district. Attempt on factor analysis of VES data at each location marked probable occurrence of fractured aquifer in compact rocks. Borehole lithology and comparison of aquifer zone depths mapped from exploratory drilling by CGWB are matching more or less similar to the depth zones delineated by Factor analysis as well the shallow and middle level aquifer bearing formation dimensions.

Resistivity is in the range of <28 to 100 ohm (Ω) m for the weathered and fractured granite with an inferred depth of 2 - 70 m, whereas resistivity is in the range of 250 to 4000 Ω m for massive granite with maximum thickness of 50 m to 200 m. The resistivity for the weathered and fractured Khondalite ranges from <2.3 to 90 ohm (Ω) m, while it is in the range of and 106 - 625 Ωm for massive Khondalite with maximum thickness of 90 m to 200 m. Charnockite formations are generally shows high resistivity values more than 500 Ωm. The resistivity of shear zone aquifers is very low 12 to 30 Ωm.

2.5 Hydro-chemical Studies:

To understand chemical nature of groundwater, 342 ground water sample data is utilized from ground water monitoring wells of CGWB and SGWD wells (Pre-monsoon: 197 wells and post-monsoon: 145 wells) during the pre-monsoon and post-monsoon seasons of 2019 respectively. The Parameters were analyzed are pH, EC (in µS/cm at 25° C), TH, Ca, Mg, Na, K, CO_3, HCO_3, Cl, SO_4, NO_3 and F.

2.5.1 Pre-monsoon: (Total 197 samples were analyzed (CGWB: 59, SGWD: 138**)**

Groundwater from the area is mildly alkaline to alkaline in nature with pH in the range of 6.56-9.48 (Avg: 8.40). Electrical conductivity varies from 50-8200 µ Siemens/cm@25°C (avg: 1229 µ Siemens/cm@25°C)**.** In 90% of area EC is within 2000 µ Siemens/cm, in 7% area is 2000-3000 µ Siemens/cm and in 3% area is **>**3000 µ Siemens/cm (**Fig.2.10).** Nitate concentration varies from 0.04-261 mg/L in 14% of samples is beyond permissible limits of 45 mg/L (**Fig.2.11**). Fluoride concentration varies from

0.04-3.4 mg/L (**Fig 2.12**) and 94% of samples are within permissible limits of BIS and rest is beyond permissible limit of 1.5 mg/L. High fluoride concentration is observed mostly in the staitions of Ananthagiri, Narsipatnam, Kotauratla, Anakapalli, Koyyru, Rambilli, Atchutapuram, Sabbavaram, Chodavaram, Pendurthi, Anandapuram, Padmanabham, Devarapalli, Bhimunipatnam, Visakhapatanm urban area of mandals and in the district.

2.5.2 Post-monsoon: (Total 145 samples were analyzed (SGWD: 145)

Groundwater from the area is mildly alkaline to alkaline in nature with pH in the range of 6.65 - 8.97 (Avg: 8.17). Electrical conductivity varies from 98 - 5610 µ Siemens/cm@25°C (avg: 1269 µ Siemens/cm@25°C)**.** In 90% of area EC is within 2000 µ Siemens/cm, in 6% area is 2000-3000 µ Siemens/cm and in 4% area is **>**3000 µ Siemens/cm (**Fig.2.13).** Nitrate concentration varies from 0.03 - 50.50 mg/L in 0.01% of samples (very negligible) is beyond permissible limits of 45 mg/L i.e at location of B.J Palem of Sabbavaram Mandal (**Fig.2.14**). Fluoride concentration varies from 0.04-2.93 mg/L (**Fig 2.15**) and 99% of samples are within permissible limits of BIS and rest is beyond permissible limit of 1.5 mg/L. High fluoride concentration is observed in S. Rayavaram, V. Madugula, Gajuvaka, Nakkapalli, Parawada, Pedagantyada and Narsipatnam mandals of the district.

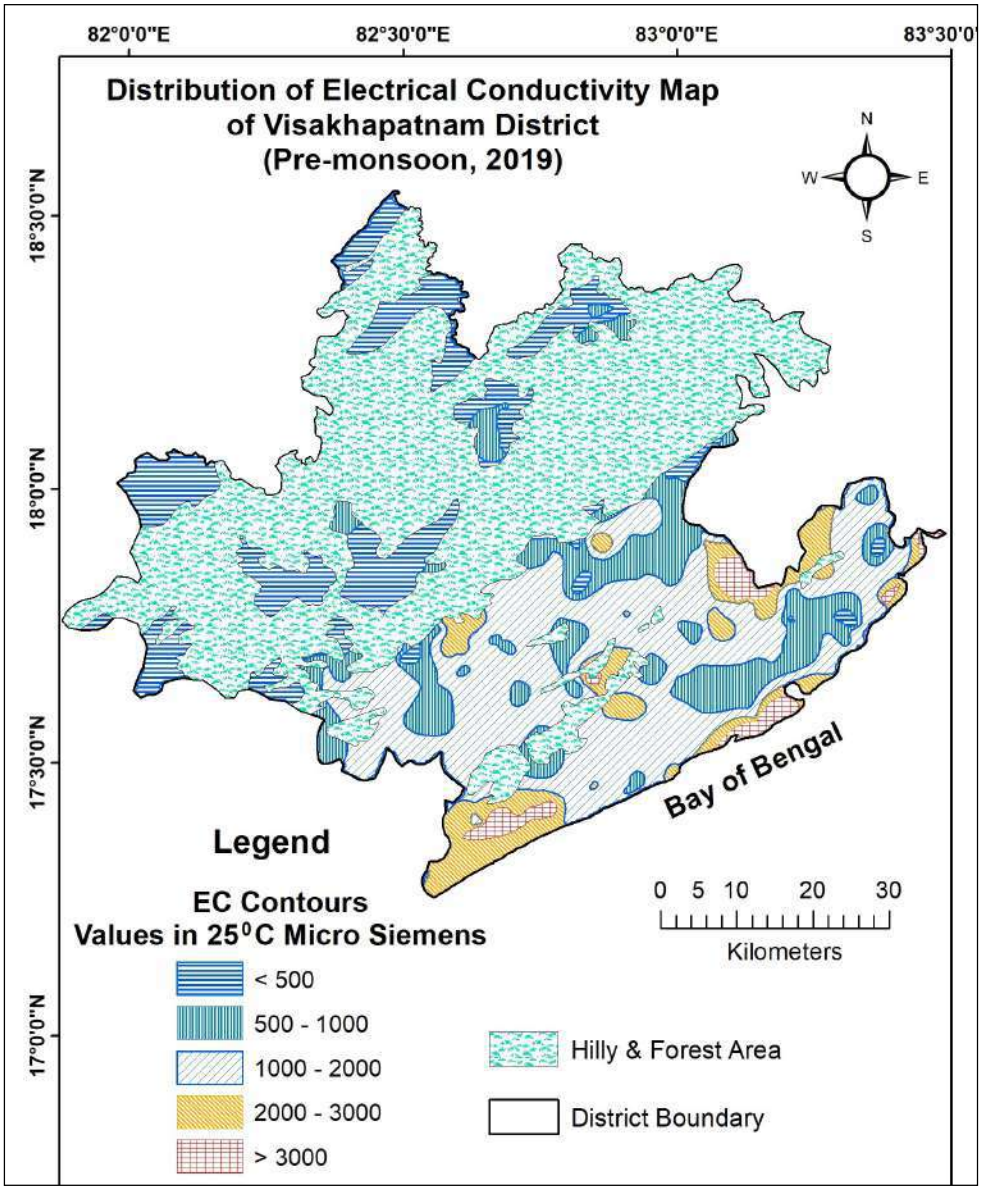


Fig. 2.10: Distribution of Electrical conductivity (Pre-monsoon).

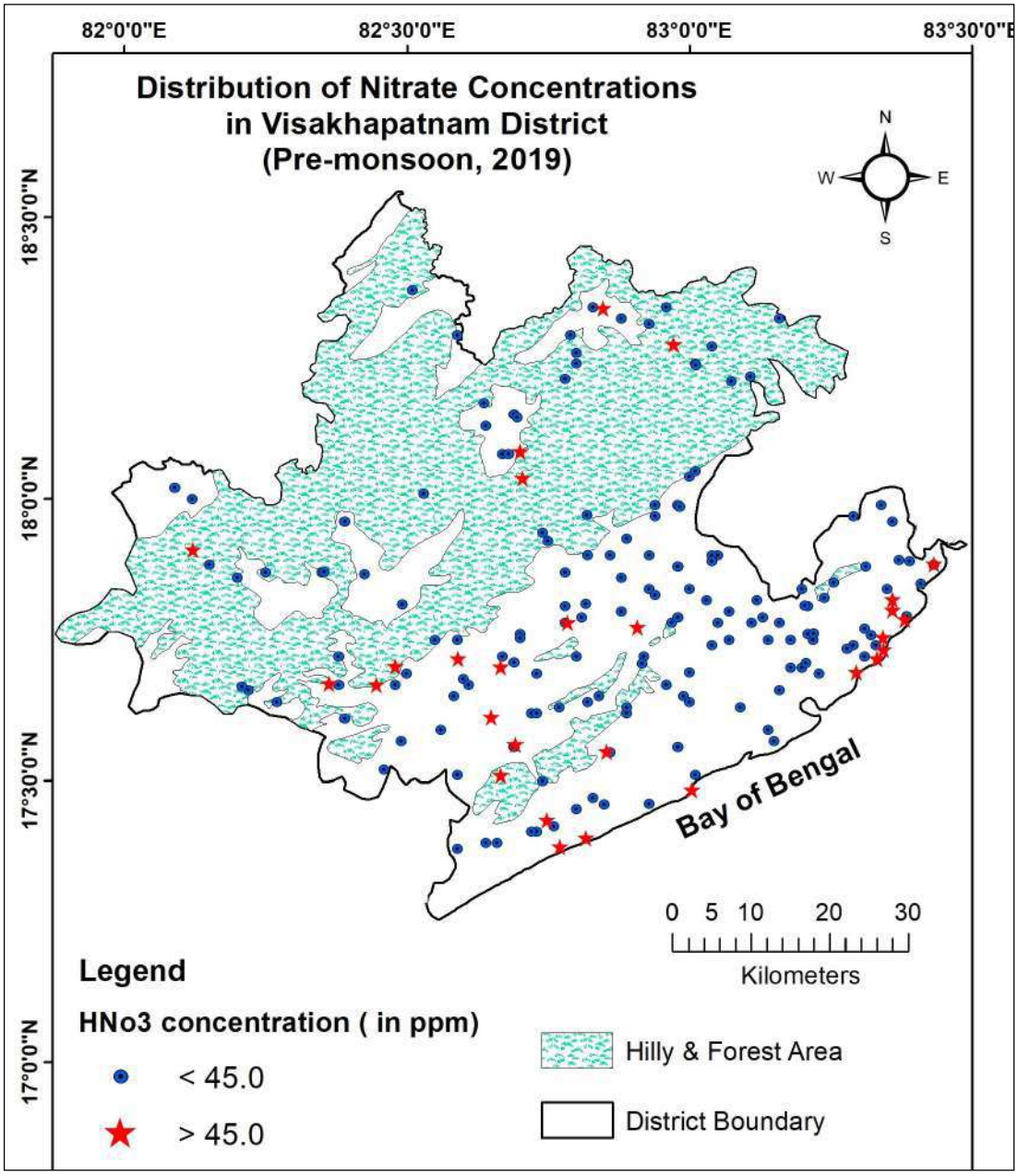


Fig.2.11: Distribution of Nitrate concentrations (Pre-monsoon).

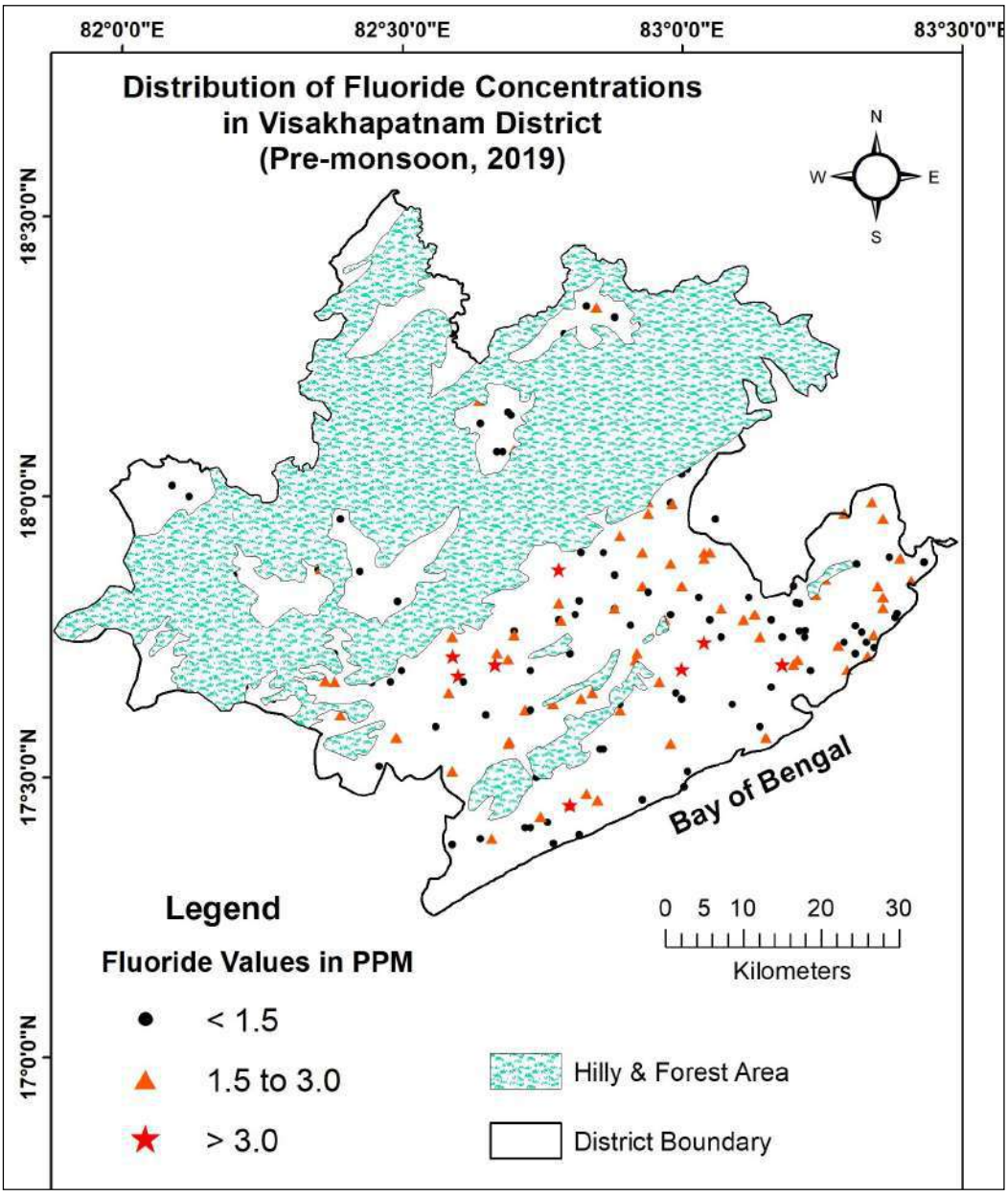


Fig.2.12: Distribution of Fluoride concentrations (Pre-monsoon).

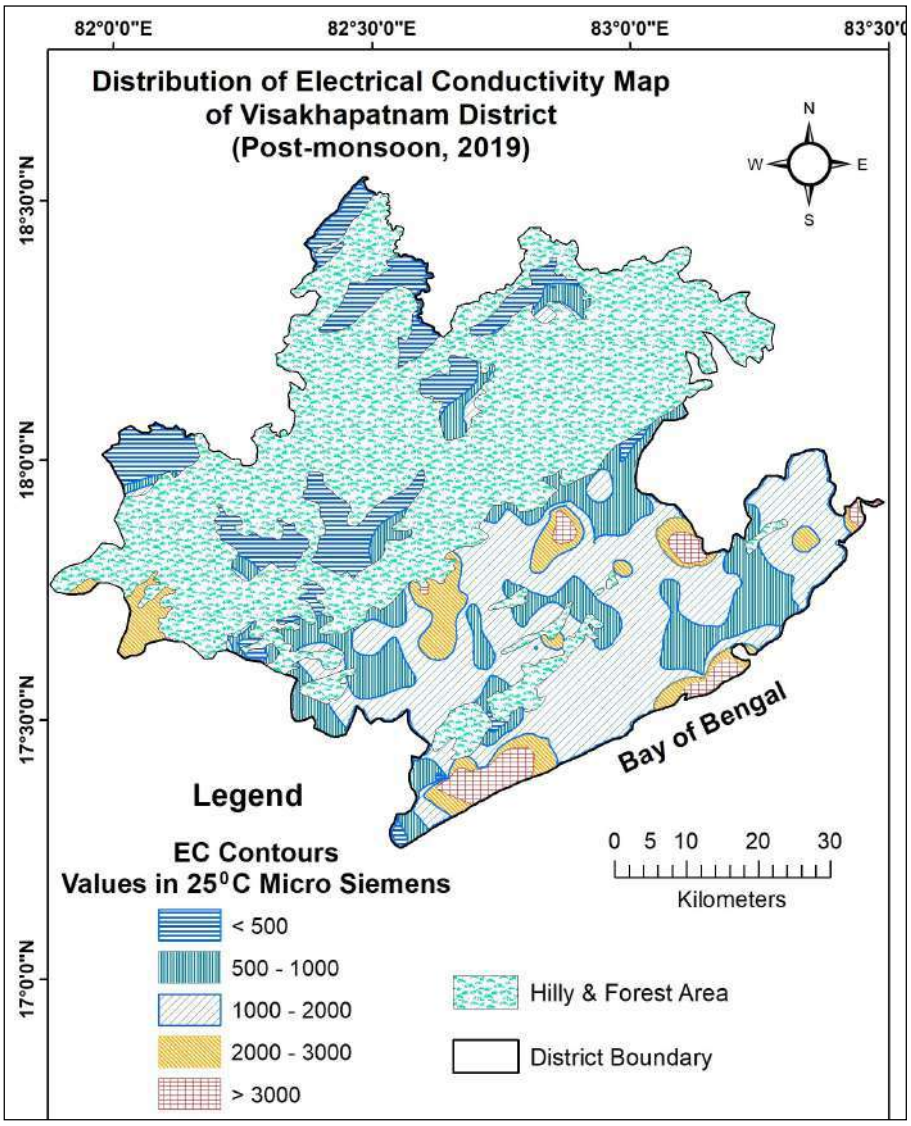


Fig. 2.13: Distribution of Electrical conductivity (Post-monsoon).

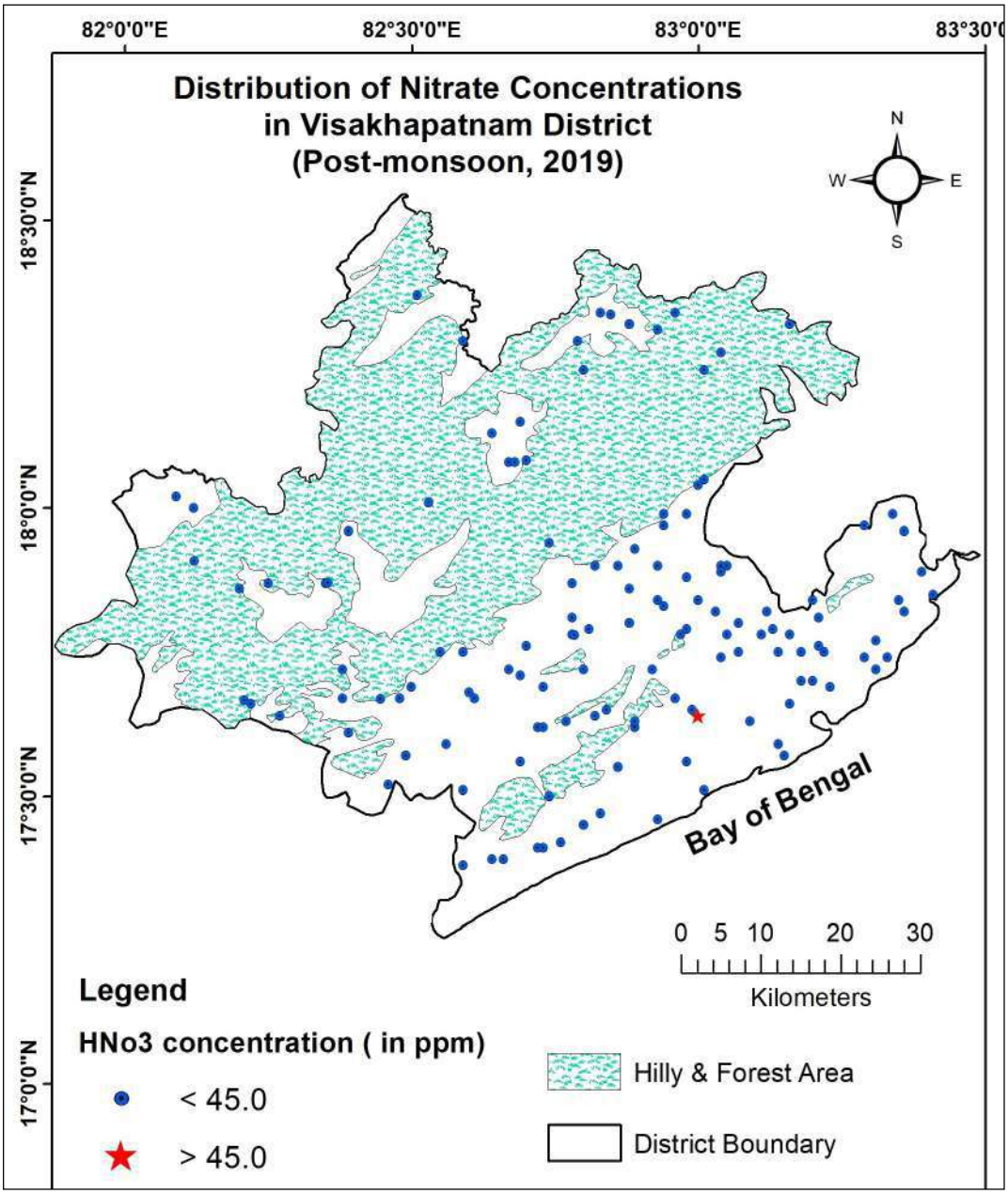


Fig.2.14: Distribution of Nitrate concentrations (Post-monsoon).

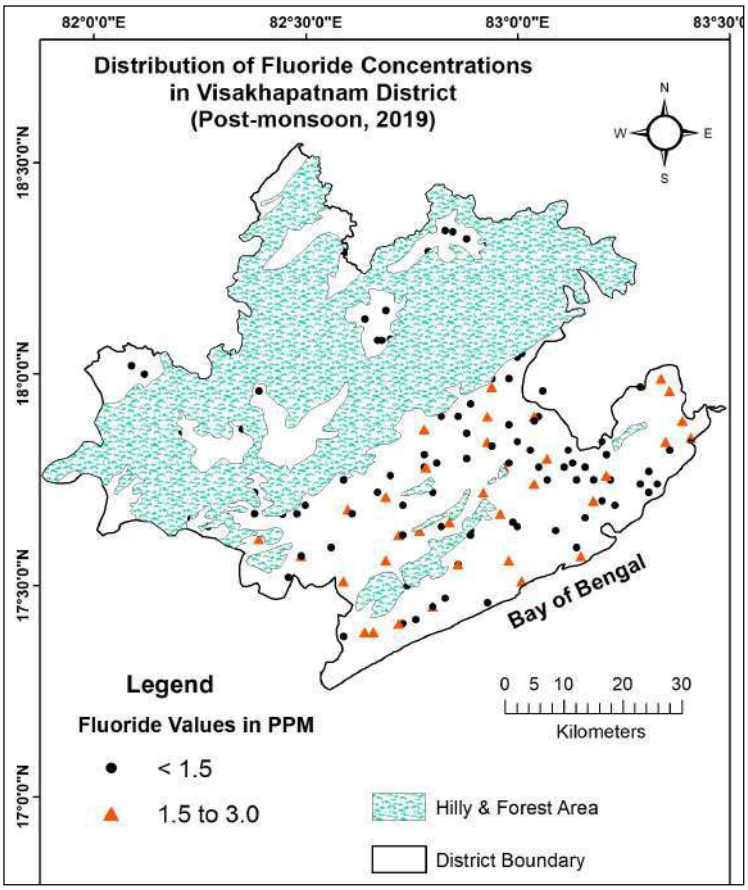


Fig.2.15: Distribution of Fluoride concentrations (Post-monsoon).

3. DATA INTEGRATION, INTERPRETATION AND AQUIFER MAPPING

Conceptualization of 3-D hydrogeological model was generated by interpreting and integration of 143 number of data points (CGWB: 63, SGWD: 45 and VES: 35) for conceptualization of Aquifers disposition. The well data points are calibrated for elevations from SRTM data and finally, the optimised lithological information were used to generate 3-D maps and hydrogeological concepts i.e lithological models, panel/fence diagrams and 2-D cross-sections by using the RockWorks-17 software for Visakhapatnam district **(Fig.3.1 & 3.2)**.

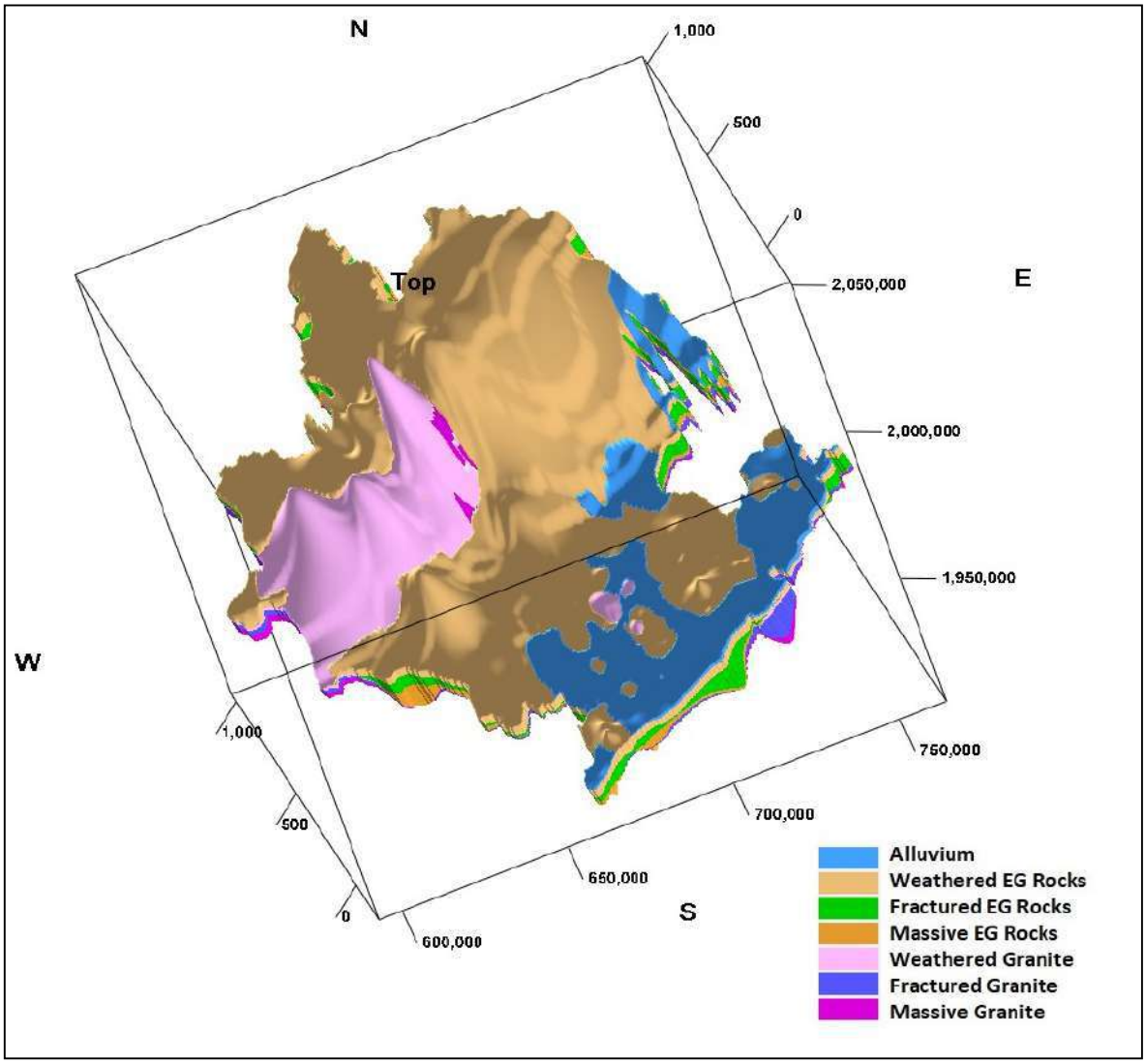


Fig.-3.1: 3-D Stratigraphic models of Visakhapatnam district.

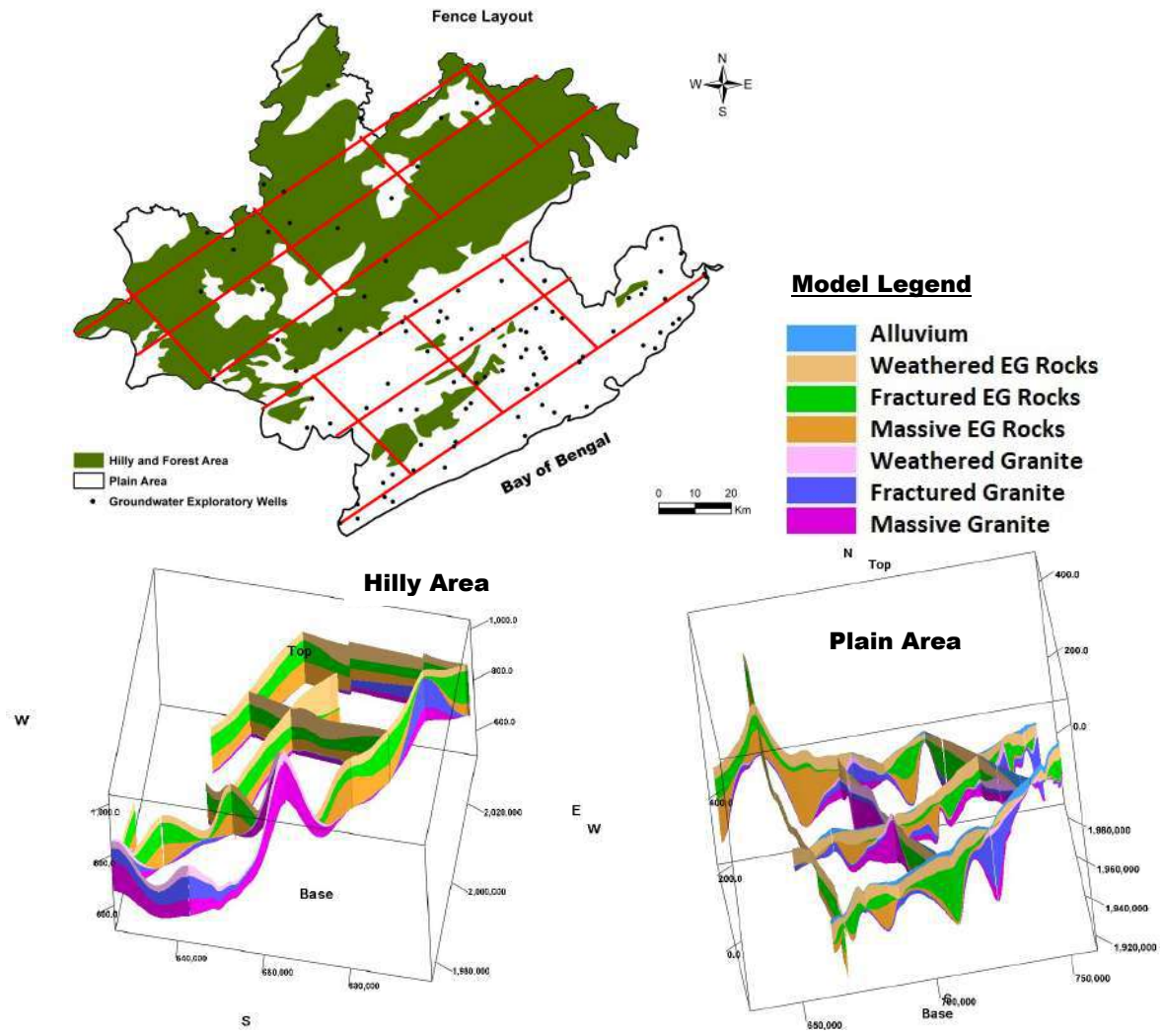


Fig.-3.2: 3-D stratigraphic fence diagrams of Visakhapatnam district.

3.1 Conceptualization of aquifer system in 3D

The rock types of Khondalite, lyptonites, quartzites in lithounits are catergorized in to Eastern group of rocks and which all are underlined by basement Granite gneiss. Weathered zone is considered up to the maximum depth of weathering and first fracture encountered (below weathered depth) generally down to ~27 m average depth and the fractured zone (fractured granite) is considered up to the depth of deepest fracture below weathered zone (~27-200 m).

3.2 Hydrogeological Sections

Hydrogeological sections are prepared in NW-SE, SW-NE and W-E direction (**Fig. 3.3**) for hilly-valley areas and plain areas of Visakhapatanam distict.

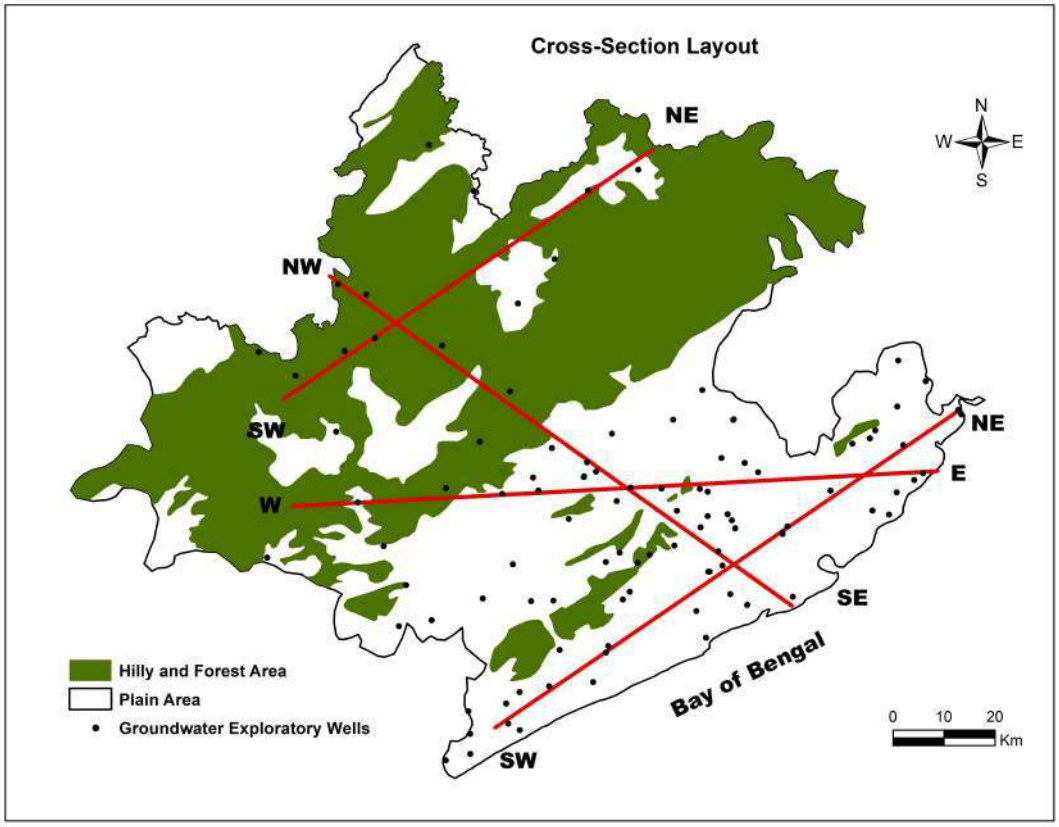
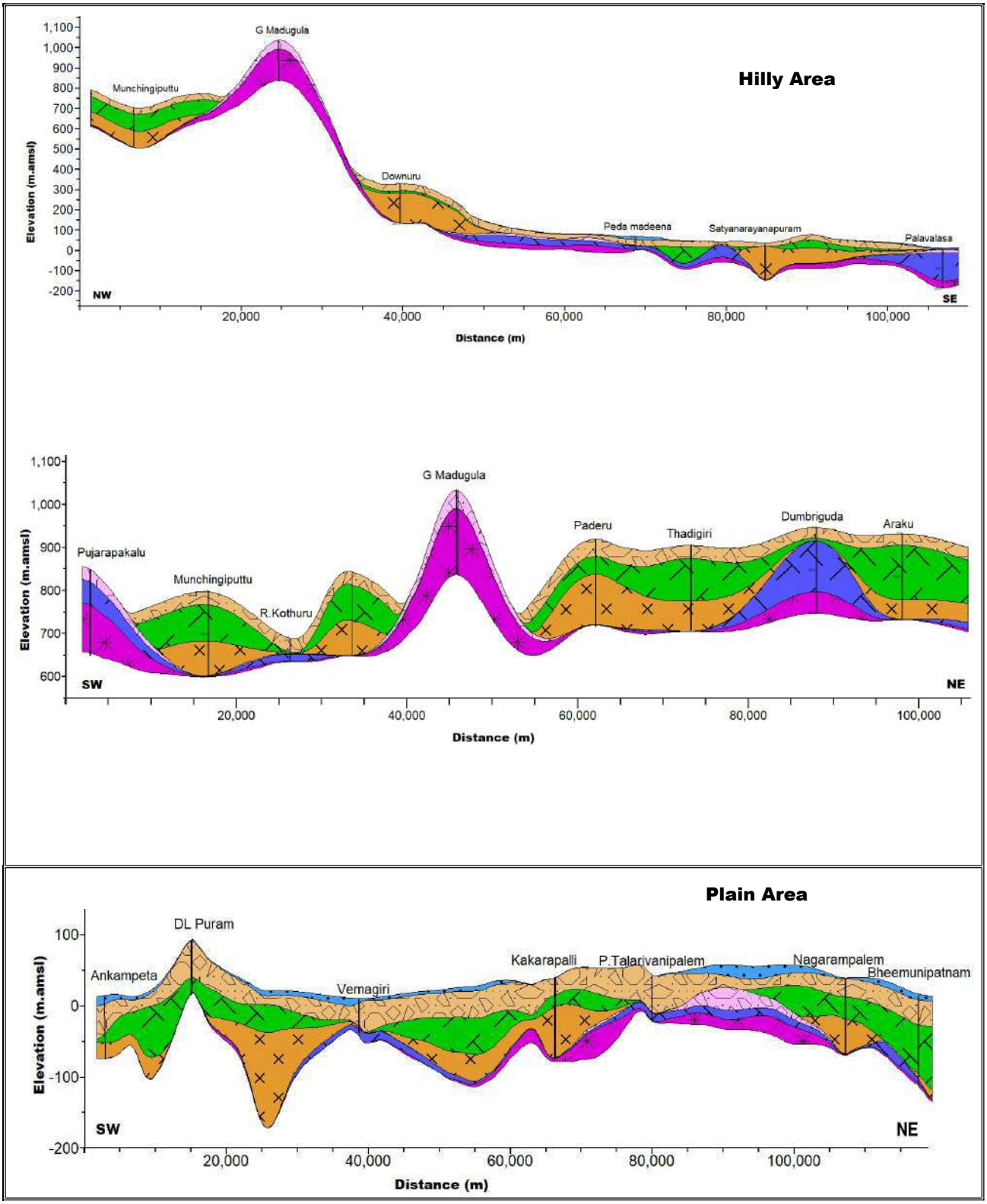


Fig.-3.3: Map showing orientation of hydro geological Sections.

3.2.1 North-West and South-East Section: The section is drawn along the NW-SE direction from hilly to plain area covering distance of ~110 kms (**Fig.3.4a**). It depicts thin weathered zones and fractured zones in south-eastern and north western parts in Eastern Ghat rock types (Khondalite and Charnockite formations) and underlain by Granites which forms the basement. Along this direction, it is observed that Eastern ghat rock types are more dominent rock formations towards south eastern direction and granite gneiss is predominant exposure in NW directions in hilly area. Fractured formations are also observed very limited fractured zones in hilly areas along the direction.

3.2.2 South-West and North-East Section: The section is drawn along the SW-NE parts covering distance of ~105 kms (**Fig.3.4b**). It depicts thin weathered zones and thick fractured zones in south- western and north eastern parts of this direction in Eastern Ghat rock types (Khondalite and Charnockite formations) and and underlain by Granites which forms the basement. Along the direction, it is observed that Eastern ghat rock types are more dominent rock formations towards SW-NE direction and granite gneisses are predominant exposures found in centre part of direction i.e in hilly area. Fractured formations are more dominant extensions in NE direction as compare to SW part in hilly areas. Eastern Ghat rock types are more dominant in plain area as compare to granite gneiss existence in the form of vertical distribution.

3.2.3 West-East Section: The section drawn horizontally along the West-East direction covering distance of ~120 kms (**Fig.3.4c**), depicts alluvium is partially covered in small pockets of beach areas i.e eastern part and also basement exposures also observed in eastern part and western part of direction. Thick weathered zones and thick fracture zones observed in all along the direction.


Hilly Area
G Madugula
Munchingiputtu
Downuru
Peda madeena
Satyanarayanapuram
Palavalasa
Elevation (m.amsl)
NW
SE
Distance (m)
G Madugula
Pujarapakalu
Munchingiputtu
R.Kothuru
Paderu
Thadigiri
Dumbriguda
Araku
Elevation (m.amsl)
SW
NE
Distance (m)
Plain Area
DL Puram
Ankampeta
Vemagiri
Kakarapalli
P.Talarivanipalem
Nagarampalem
Bheemunipatnam
Elevation (m.amsl)
SW
NE
Distance (m)

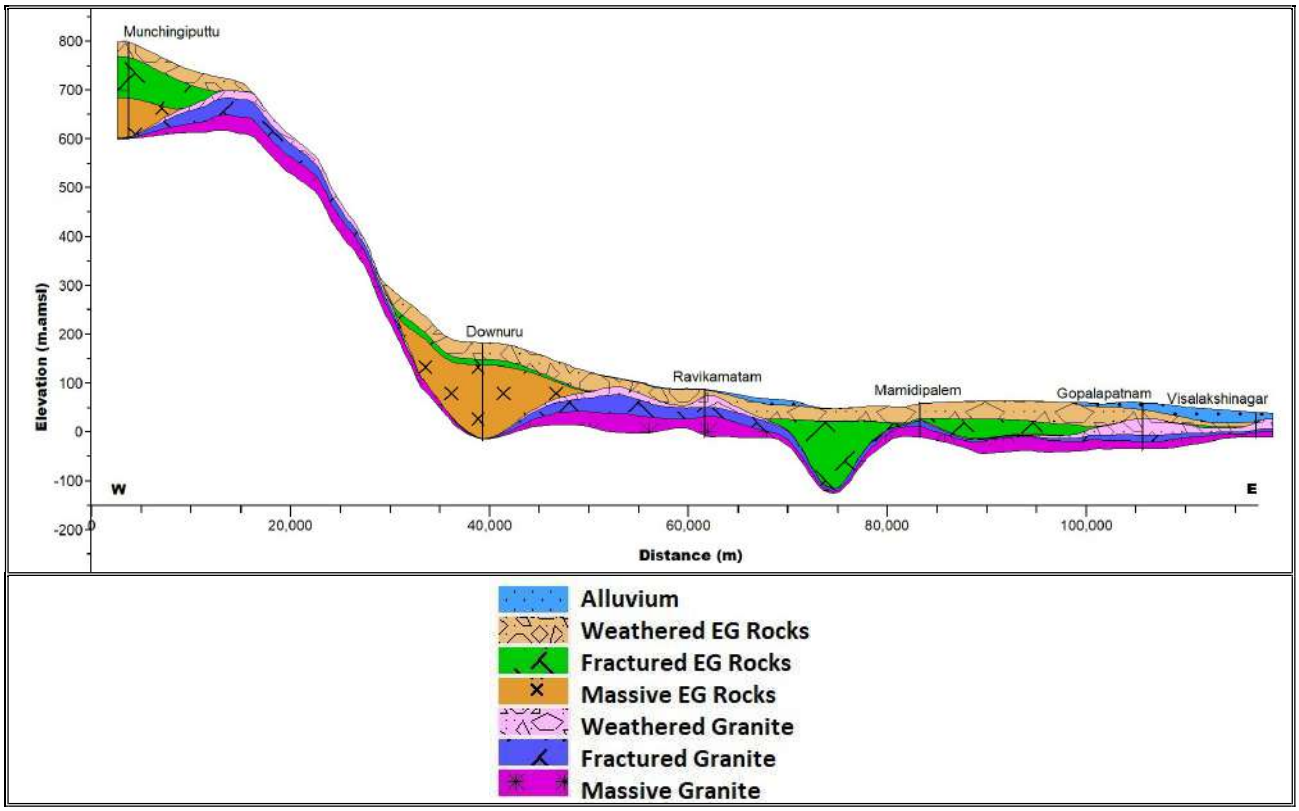


Fig.3.4 (a-c): Hydrogeological profiles in different directions of Visakhapatnam district.

3.3 Aquifer Characterization

3.3.1 Weathered Zone: The average depth of occurrence of weathering is of ~27 m bgl which varies in different formations from meagre to ~25 mbgl in Granitic formations, meagre to 34 m in Charnockite, upto ~60 m in Khondalite. Spatial distribution of weathering depth zone map is given in **Fig.3.5**. Thickness of weathered zone is in the range of 20 - 40 m occurs in most part of area (70%). Shallow weathered zones i.e < 10 m occurs in 3% of the area, 10-20 m in 7% area and deep weathered zone (**>**40 m to max. 60 m depth zone) occurs in rest of the area (20%). The graphical presentation for weathered zones in mappable area is shown in **Fig.3.6**.

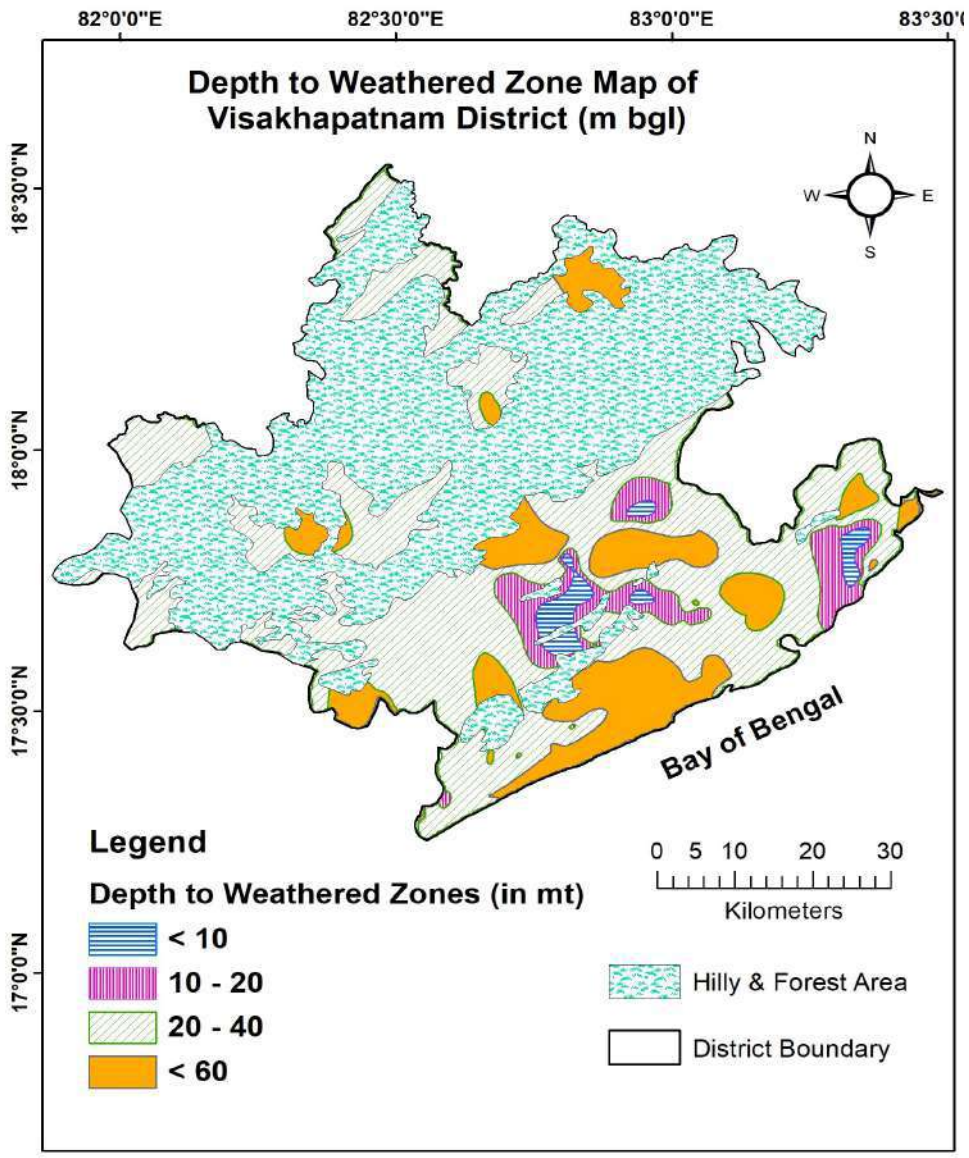


Fig.3.5: Thickness of Weathered zones in Visakhapatnam district.

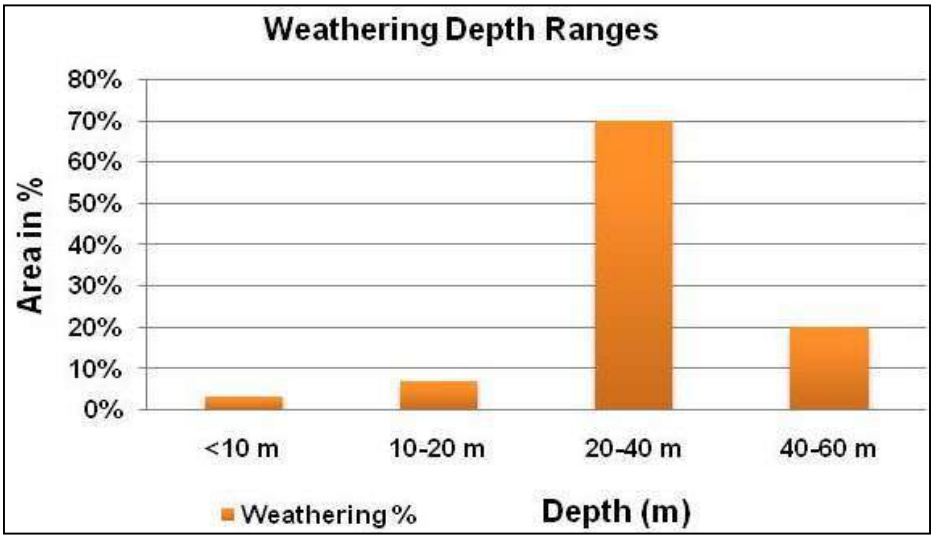


Fig.3.6: Depth wise weathered zone distribution details in Visakhapatnam district.

3.3.2 Fractured zone: Ground water is extracted mainly through bore wells of beyond the depth of ~27 m from each fractured zones of the hard rocks. Based on CGWB, VES data and SGWD drilling data analysis (143 well point data), it is inferred that fractures depth starts from ~27 to 200 m bgl. The fracture zones at the depth range of 150-200 m is more predominant (40% of the area), followed by 100-150 m depth (25% of the area), 50-100 m depth (15% of the area) and rest 20%, the fractures are with in <50 m depth.

Groundwater yield of fractured granites / gneisses varies from 0.01 to >5 lps (avg: 1.4 lps). Wells located in the command area have higher yield (1.4 - 5 lps) and sustains more hours of pumping as compared to non-command area where yields are relatively low and sustains for 2 - 3 hrs. Stotativity of the fracture zones varies from 3.2 x 10^{-6} to 1.92 x 10^{-2}. The graphical presentation for fracture zones in formation wise is explained and shown in **Fig.3.7** and the distribution of depth wise occuurrenece of fractures shown in **Fig.3.8.**

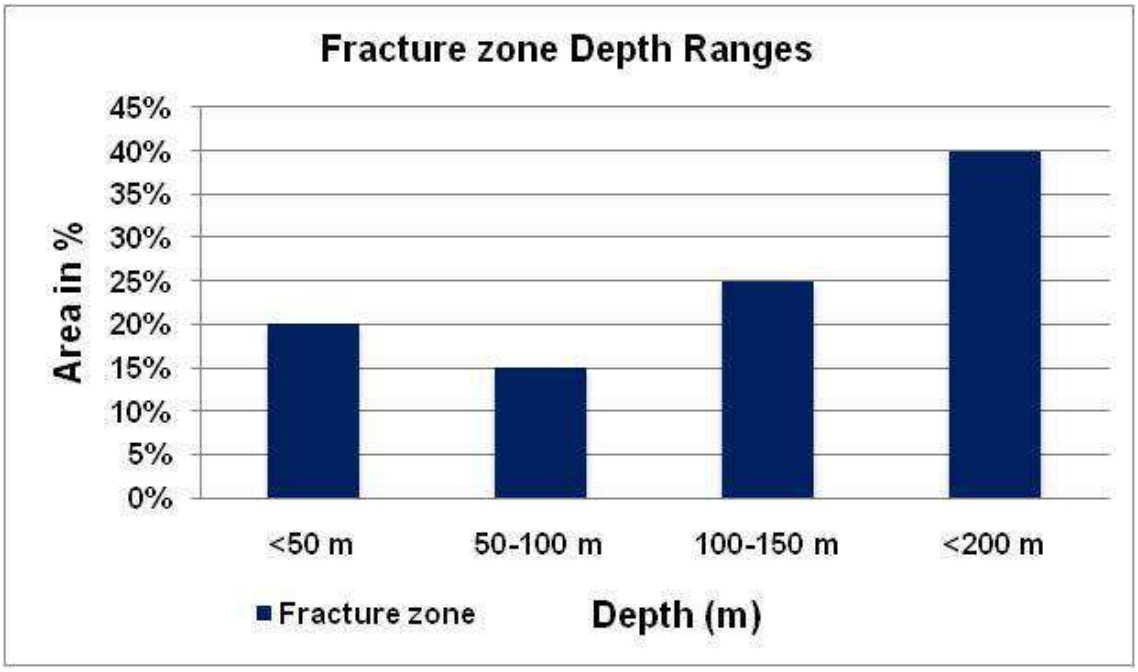


Fig.-3.7: Depth wise fracture zones details in Visakhapatnam district.

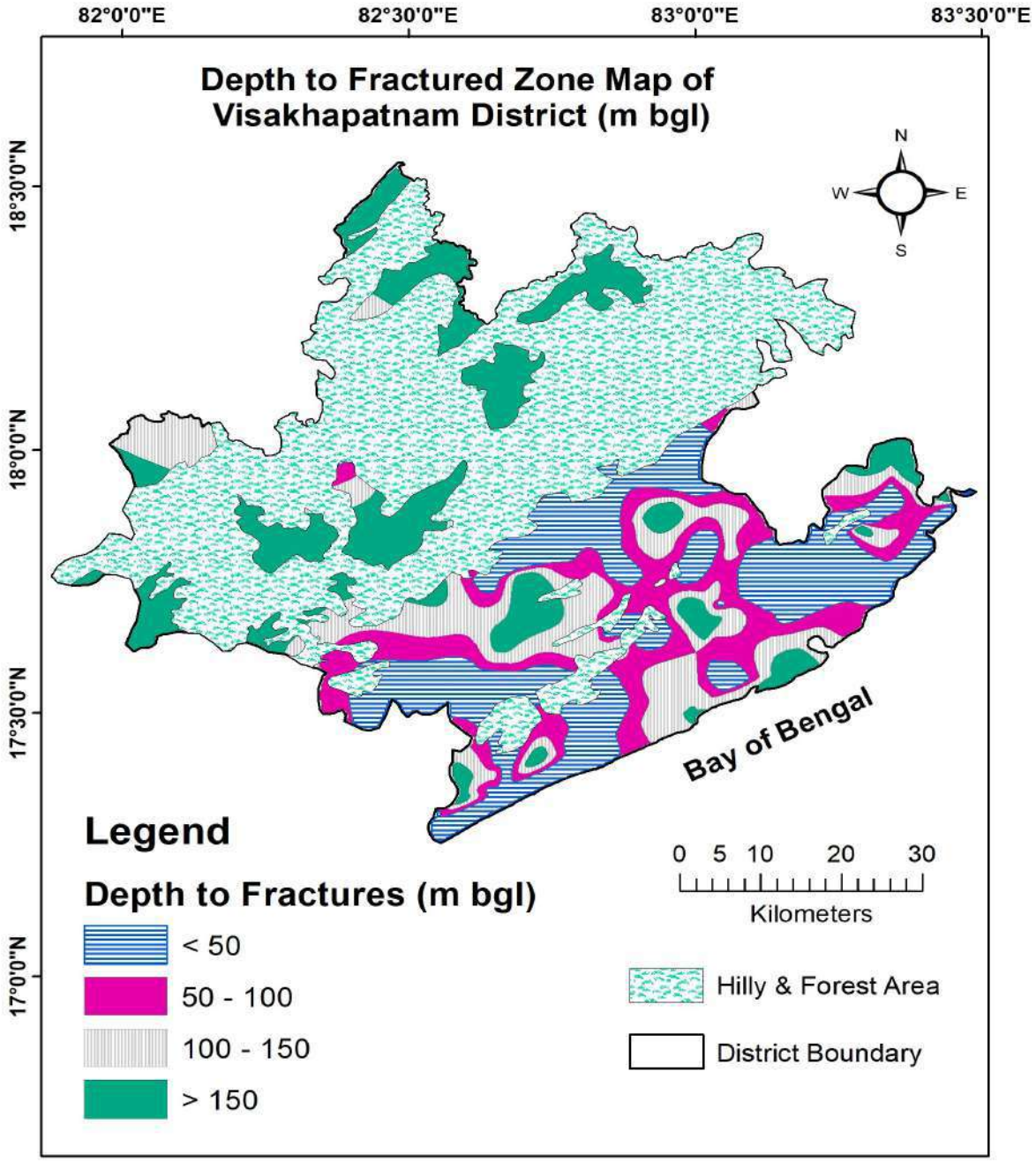


Fig.-3.8: Depth of occurrence of Fractured zones

4. GROUND WATER RESOURCES (2020)

In hard rocks, for practical purpose it is very difficult to compute zone wise (aquifer wise) ground water resources, because the weathered zone (WZ) and fractured zone (FZ) are inter-connected with fractures/joints and fractured zone gets recharged through weathered zone. The resources are estimated considering is as a single aquifer system. The dynamic ground water resources are computed as per the guidelines laid down in GEC methodology.

The Summarized command/ non-command area and mandal wise resources are given in **Table-4.1**. As per GWRA - 2020, the annaual extractable ground water rresources are 939.6 MCM, gross ground water draft for all uses 255.8 MCM, net annual ground water provision for drinking, industrial and irrigation use for the year 2025 is 697.5 MCM. All 43 mandals are categorized as Safe in the district. The Mandal wise stage of ground water development (SOD) varies from 9% (Ananthagiri mandal) to 53% (Munagapaka mandal) with average of SOD is 27% for Visakhapatnam district. The maps showing categorization of manadls and utilizable ground water resource are prepared and shown in **Fig. 4.1 a & b**.

Table-4.1: Computed Dynamic ground water resources in Visakhapatnam district.

Parameters	Total Resources (2017)	Total Resources (2020)
As per GEC 2017 & 2020	MCM	MCM
Dynamic (Net GWR Availability)	**595.61**	**939.61**
• Ground Water recharge from rainfall	687.30	725.57
• Ground Water recharge from Applied Irrigation (Ground water + surface water)	79.68	251.13
• Ground Water recharge from other sources (Canal seepage+water bodies+AR structures)	140.56	
• Environmental Flows	45.38	-
Gross GW Draft	**191.04**	**255.81**
• Irrigation	126.08	91.79
• Domestic and Industrial use	64.96	164.02
Provision for Drinking and Industrial use for the year 2025	79.80	166.56
Net GW availability for future use	515.81	697.45
Stage of GW development (%)	23%	27%

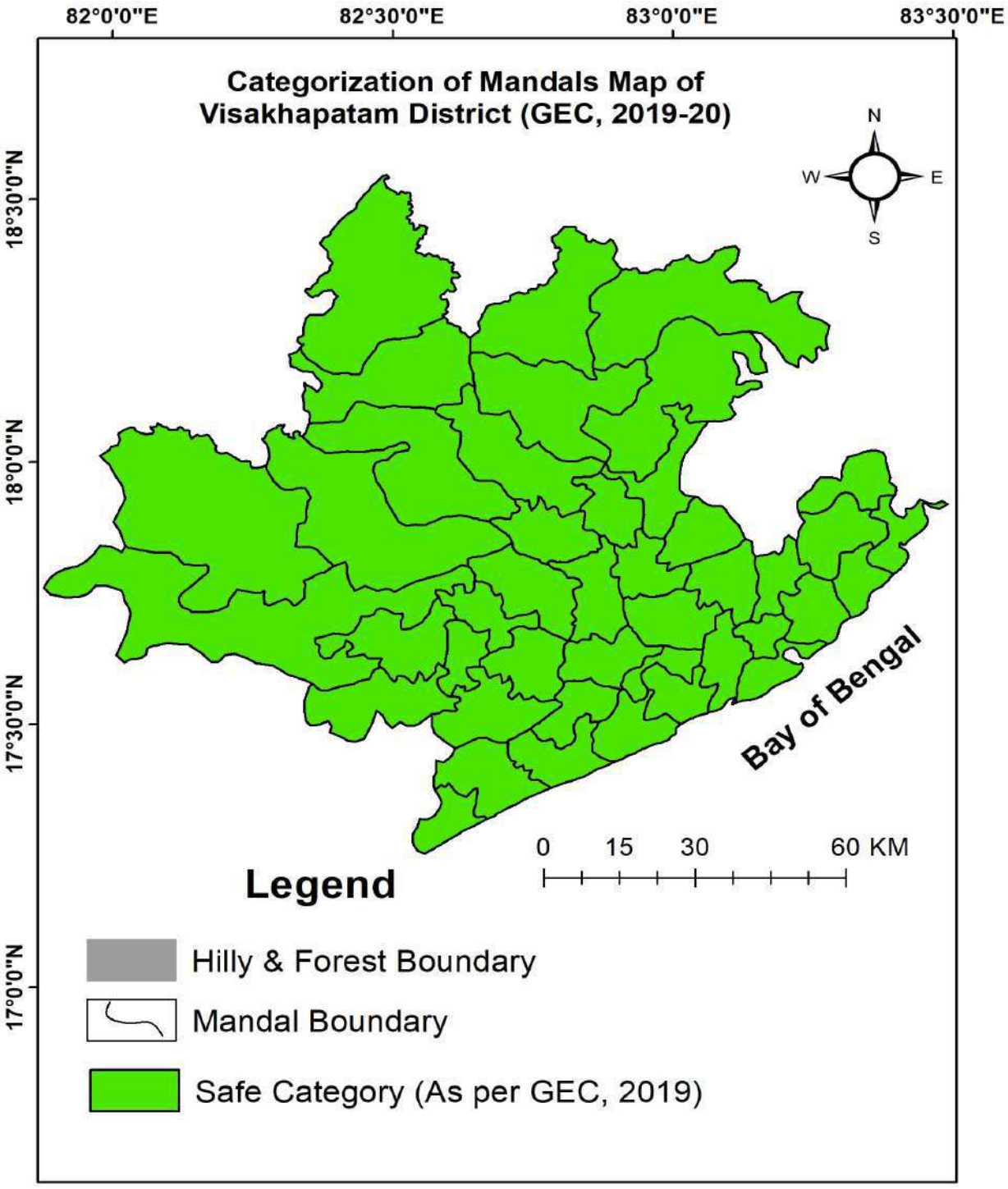


Fig.4.1 a: Categorization of mandals (GEC 2020) in Visakhapatnam district.

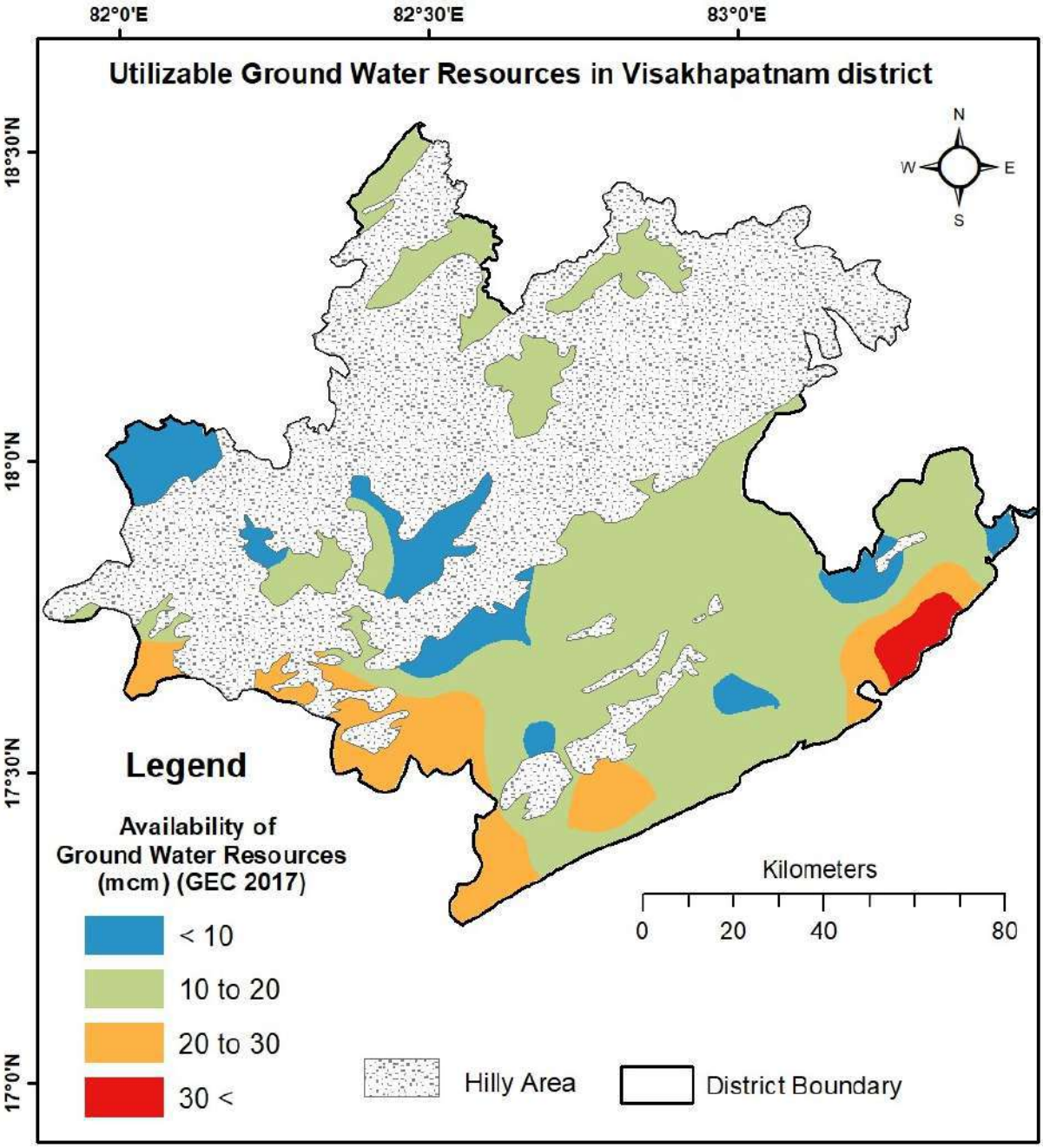


Fig.4.1 b: Utilizable ground water resources in Visakhapatnam district.

5.0 Visakhapatnam Urban Water Supply

The Greater Visakhapatnam Municipal Corporation (GVMC) with an area of 624 Sq km, comprises of Visakhapatnam Municipal Corporation, Gajuwaka Municipality and 32 villages. It forms large residential and industrial base with major industries such as the Visakhapatnam Steel Plant, Bharat Heavy Plate and Vessels and the Hindustan Zinc etc. The GVMC is the responsible body for water supply.

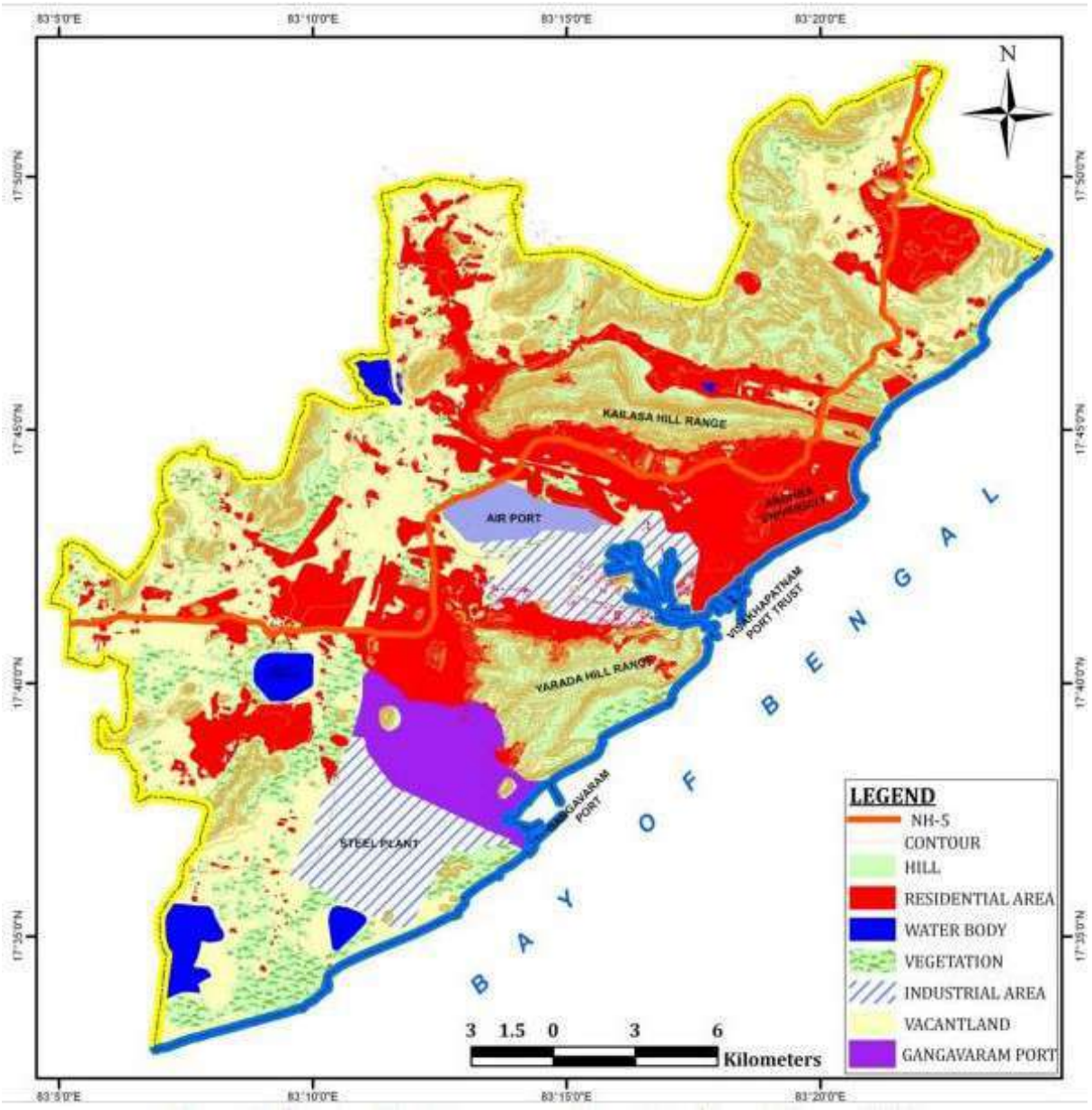


Fig-5.1: Map showing Visakhapatnam Urban Area

5.1 Surface Water Availability:

The GVMC is supplying drinking water to the GVMC area from the followoing reservoirs.

Table 5.1: Sources of Surface Water Supply to GVMC area

S. No.	Name of Reservoir	Distance from GVMC (Km)	Quantity drawn in MLD
1	Godavari/Yeleru reservoir	190	182 to 204
2	Raiwada reservoirs	56	72.5
3	Gosthani river surface	25	20.5
4	Thatipudi reservoir	60	45.0
5	Meghadrigadda reservoir	GVMC	41.0
6	Mudasarlova reservoir	GVMC	4.5
7	Gambheeram reservoir	GVMC	2.7
8	Anakapalli sarada river	GVMC	6.0
9	Bheemili (Samayyavalasa Nagarampalem)	GVMC	5.8
		Total	**380 MLD**

Out of 380 MLD of raw water is available from all sources, GVMC is able to drawn 345.5 MLD due to shortage of water from Raiwada reservoir and Gostani River.

5.2 Ground Water Availability:

As per Dynamic Ground Water Resources estimation (2020), The total ground water resources are estimated as 402 MCM in GVMC and surrounding all zones. The dynamic ground water resources are 56.01 MCM and in-storage water resources estimated as 344.14 MCM. The stage of groundwater development for Greater Visakhapatnam Municipal Corporation is 51% and categorized in Safe mandal. The details are as follows (refer Table 5.2).

Table 5.2: Particulars of ground water resources availability in GVMC Visakhapatnam (GEC, 2020)

Total Area of GVMC & surrounding all zones isakhapatnam (Sq.km)	Methods used	Dynamic GW Resources (GEC, 2020) (M.Cu.m)	In-storage (M.Cu.m)	Total Resources (M.Cu.m)
624.20	RIF and GWF	57.41	344.14	401.55
Aquifer		Particulars		MCM
Unconfined Aquifer* (Hard rock)	:	Dynamic Resources (Annual Extractable Ground Water Resources)		57.41
	:	Ground Water extraction for all uses		29.19
	:	Annual allocation for Domestic and Industrial Uses		38.35
	:	Stage of Ground Water Developement and Category		50.84% (Safe)
Confined Aquifer (Hard rock)	:	In-storage ground water resources		344.14

***SY for Un-Confined Aquifer: 1.5 to 3%**

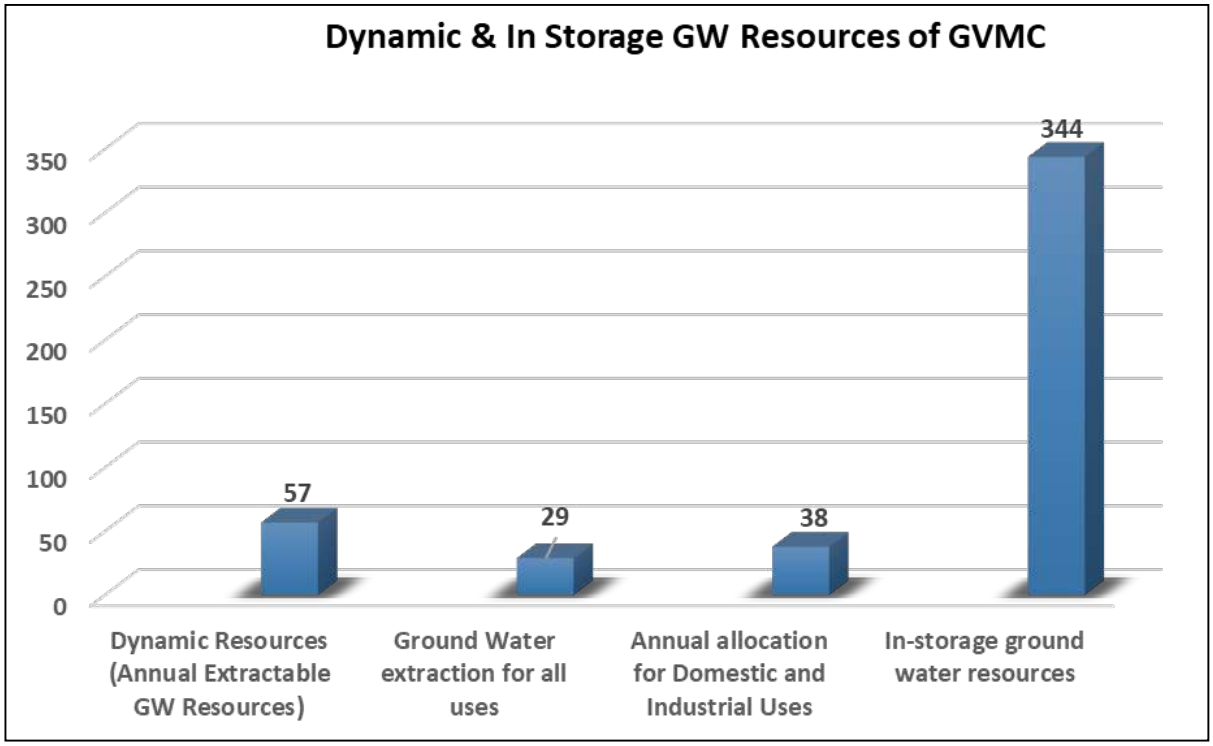


Fig - 5.2 Graphical representation of Ground water Resources of GVMC area

5.3 Total Water Demand for Deficit in GVMC:

The total demand projected by GVMC Visakhapatnam Urban and its surroundings for the Year 2020 is 490 MLD (180 MCM/year), 828 MLD (302 MCM/Year) for the Year 2031 and 1014.02 (393 MCM/Year) for the Year 2041 (Table-5.3 and Fig-5.3).

Table 5.3: Water demand vs supply and deficit in present and future perception for GVMC.

S. No.	Year	Population	Quantity @ 135 LPCD (in MLD)	Bulk demand (MCM)	Losses @15% (MCM)	Clear Water Demand (MLD)	Present Supply (in MLD)	Deficit (in MLD)
1	2020	23,48,655	315	115	20	490	391	99
2	2021	24,00,000	323	173	82	578	391	186
3	2031	36,80,000	496	219	114	828	391	437
4	2041	49,20,000	664	264	150	1078	391	687

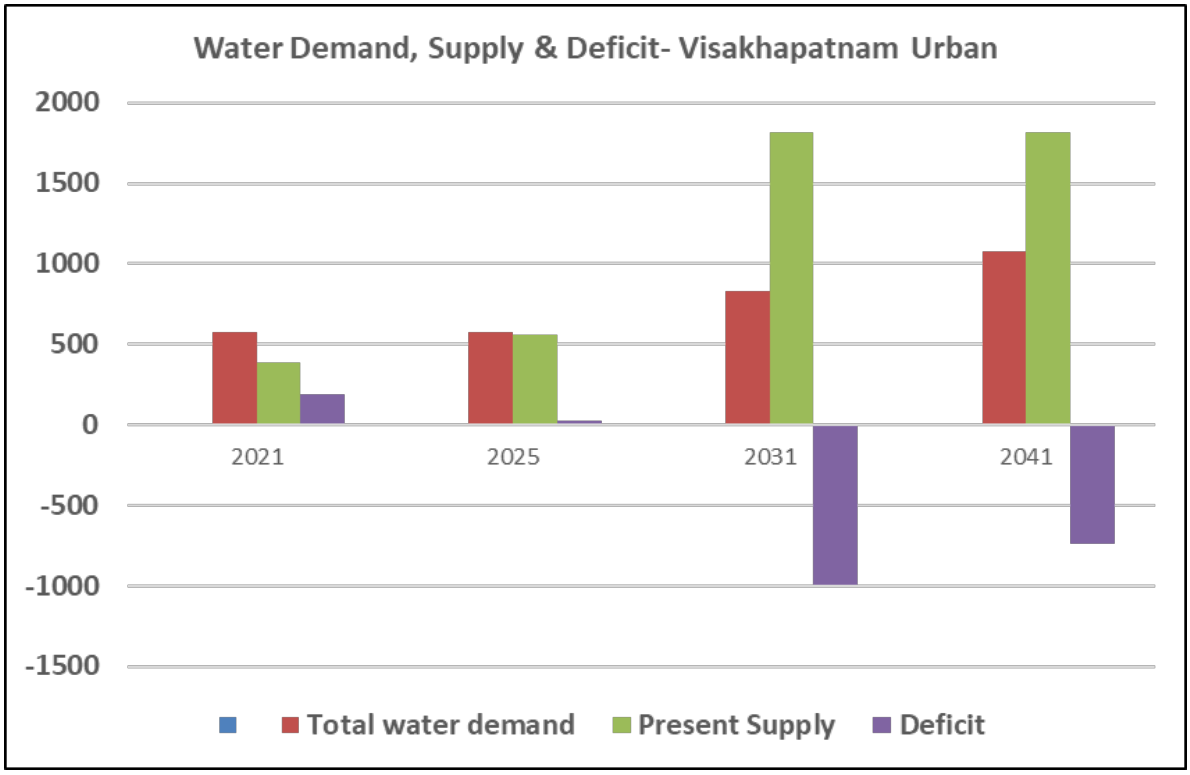


Fig-5.3: Graphical representation of water supply status in GVMC area

5.4 Proposed Plans for Water Supply in GVMC area:

The present and future water demands can't be meted out from ground water in GVMC area. Ground Water can only be supplementing the water supply during lean periods and majority of the water requirements need to be meted out from surface water sources. The GVMC had submitted proposals for improvement of water supply in GVMC area through interconnections to trunk main and lying of distribution pipe lines of about 245 kms and service reservoirs for mitigating the water supply in peripheral areas and hill areas. Also, upon completion of from Polavaram reservoir, the allocated 12 TMC of water supply, the demands of water for both domestic and industrial needs of Visakahpatnam can be meted out.

In addition, for sustainable ground water development and management, there is a need for artificial recharge and roof top rainwater harvesting for ground water recharge in the urban areas.

6. GROUND WATER RELATED ISSUES

Overall, the Visakhapatnam district, the ground water regime scenario is good except a few locations where quantity and quality issues identified. Over the years, there is no significant change in water levels in the district and water levels are showing a significant rising trend. However, at few places meagre decline in water table exists, which need to be managed through suitable artificial recharge and water conservation practices. However, the magnitude of the decline is less. Water logging does not exist in the canal command and irrigated areas of the district.

In terms of ground water quality, geogenic and antropogenic contamination in the district is noticed at few mandals. High concentration of Nitrate, more than permissible limits in the district during pre-mosson can be attributed to excess use of fertilizers, urban sewerage disposal and improper drainage system. The reduction in the nitrate concentration can be attributed to dilution during post monsoon season. High concentration of Fluoride is observed in some places. Though the district has a coast line of 132 km, no sea water intrusion/ ingress is reported and observed. Heavy metal pollution of ground water exists in the Mindi - Chukkavanipalem industrial area due to the industrial effluents.

- Low yield (<1 lps) occurs in ~60 % of area in the district. This is mainly attributed to hard rock aquifers, absence of primary porosity, negligible development of secondary porosity, discrete occuurence of fractures etc.

- Deep water levels in the range of >20 m bgl occupy about 2% of the area falling mostly in parts of Devarapalli mandal.

- Water-logging is observed in and around Bhimunipatnam, Visakhapatnam urban village coastal areas with areas of ~10 to 15 sq.km during postmonsoon seasons.

- High concentration of Flouride 1.54 to 3.40 mg/L during pre-monsoon season is found in groundwater at S. Rayavaram, Rolugunta V. Madugula, Gajuwaka, Anakapalli, Narsipatnam, Bhemili, Visakhapatnam

urban, Kasimkota & Kottakota mandals. Higher concentration of fluoride in ground water is attributed due to source rock i.e Granite Gneiss and Khondalite, rock water interaction where acid-soluble fluoride bearing minerals (fluorite, fluoro-apatite) gets dissolved under alkaline conditions. Higher residence time of ground water in deeper aquifer may also cause.

- High nitrate (**>** 45 mg/L) is observed in 28 locations of 10 mandals i.e Koyyuru, G.K Veedi, Dumbriguda, Paderu, Golugonda, Ravikantam, Rambilli, Kotauratla, Visakhapatnam urban and Bhimilipatnam mandals during pre-monsoon in range of 48 mg/L to 200 mg/L. Higher concentration of Nitrate is mainly attributed to unscientific sewage disposal of untreated effluents in urban and rural areas. High use of fertilizers in rural areas.
- The presence of iron in ground water in agaency area/Paderu diviosn of the district.

- In Visakhapatnam urban surroudnings i.e Parwada and Atchutapuram mandals, high concentration of trace metals found in ground water in a few samples due to industrial contamination.

- The high concentration of EC (**>** 3000 micro-seimens/cm) in 3% area is **>**3000 µ Siemens/cm of the area is observed during pre-monsoon and post-monsoon seasons respectively.

- As per the fresh-saline water interface drawn along and across the coast shows, no saline water interface with the depth ranage of 300 m. There is no saline water intrusion in the district. However, few pockets there is salinity issues owing to marine depostional conditions.

7. MANAGEMENT STRATEGIES

The lacking of assured irrigation facilities in the rural areas, the demand and gap in water supply in urban areas, the dependency of ground water is increasing day by day. The ground water development in hard rock aquifer system may led to a steady fall in water levels, pose sustainability issues which may pose challenges to food and drinking water security in future. The occurrence of fractures in hard rock aquifers are 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 100-150 m depth (40%). Though the general ground water scenario of the district is good, the uneven groundwater availability and its utilization indicates for requirement of integrated water resource management and sustainable practices for maintaining sustainable ground water scenario in the district.

Management plan

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

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

7.1 Supply side measures:

7.1.1 Repair, Renovation and Restoration of existing tanks (Competed): De-silting of 5.3 MCM of silt from existing (minor irrigation tanks and Percolation tanks) tanks are completed under State Govt. sponsored NEERU-CHETTU programme and created additional surface storage in stabilization of ayacut in acres i.e 1925 acres. This will contribute ~0.54 MCM to groundwater (considering 25% of recharge) and with this additional ~780 ha land can be brought under irrigated dry (ID) crops in tank ayacut.

7.1.2 Artificial Recharge structures:

In the district 286 MCM of recharge potential volume is vaialble in the aquifers. This can be utilized for implementing artificial recharge structures. Govt. of AP under IWMP and MNREGS constructed a total of 1091 Check dams and 301 percolation tanks in the district. The details of ARS have been provided in the figure and table.

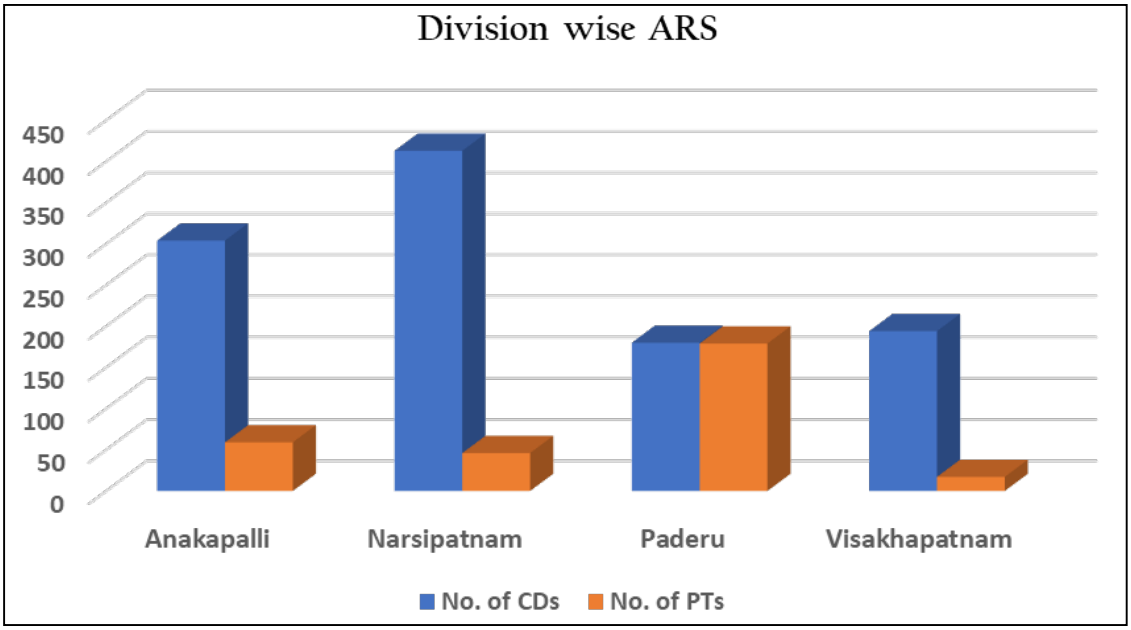


Fig- 7.1 Graphical representation of Existing ARS and WCS

Division	No. of FP	No. of CDs	No. of PTs	Others
Anakapalli	5709	304	59	8202
Narsipatnam	5930	413	46	7624
Paderu	1534	180	179	842
Visakhapatnam	3103	194	17	2874
Total	16276	1091	301	19542

Table-7.1: No. of existing ARS and WCS

It is recommended for desiltation of all existing artificial recharge structures and water conservation structures for effective utilization of existing structures and storage created through these structures. In addition, there is a scope for construction of 2340 artificial recharge structures (1151 CDS and 1189 PTS), which can be taken up as per requirement in the districts (Fig-7.2). With this 82 MCM of ground water can be recharged.

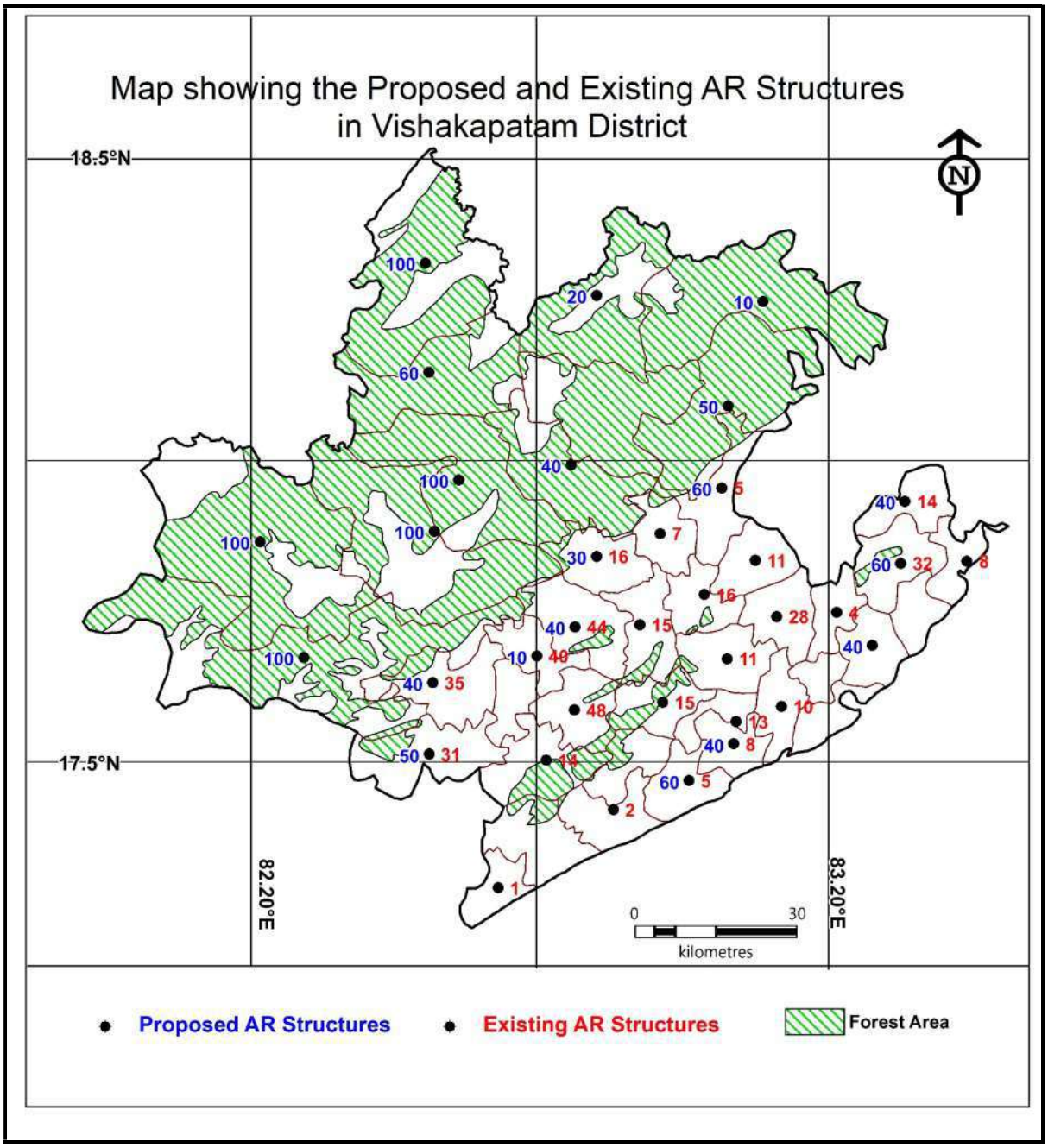


Fig- 7.2 Map showing existing and proposed AR Strctures in Visakhapatnam district

While calculating the requirement of no. of artificial recharge structures in each village, the recharge potential if aquifer is estimated by multiplying the area with specific yield and unsaturated thickness (post-monsoon water levels below 5 m). Potential surface run off is estimated by following standard procedures. 20% run off yield is considered as uncommitted yield for recommending artificial recharge structures.

- Roof top rainwater harvesting structures should be made mandatory for all Government buildings and all Apartments and intrastructes in urban areas (as per norms of CGWA, 2021).

7.1.3 Water Conservation Measures (WCM) (Farm Ponds):

The farm ponds are the ideal water conservation structures, which are constructed in the low-lying areas of the farm. The Govt. of Andhra Pradesh had constructed around 16276 no. of farm ponds in the district. It is recommended for desilting of existing farm ponds. Further, it is recommended to construct 17060 farm ponds (20 in each village in 853 villages).

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

7.2.1Ongoing Works

- In the district till date a total number of 811 no's drip and sprinklers are sanctioned which has irrigated ~1533 ha of land saving ~2.30 MCM of groundwater from the district considering 30% of net savings as compared to traditional practice of flood irrigation. (MI Census data 2013-14).

7.2.2 Proposed Work

- ~42,650 ha of additional land that can be brought under micro-irrigation (@50 ha/village in 853 villages) considering 1 unit/ha @0.6 lakh/ha. With this 85 MCM of ground water can be conserved over the traditional irrigation practices (considering 0.004 MCM/ha for ID crops against 0.006 MCM/ha).

7.3 Other measures

- Change in cropping pattern from water intensive paddy to irrigated dry crops like pulses and oil seeds are recommended, particularly in water stress/ Over-exploited/ Critical areas. If necessary, some regulatory rules may be framed and implemented. Whereas water intensive crops are also recommended in water logged areas.
- As a mandatory measure, every groundwater user should harvest and recharge rainwater through artificial recharge structures in proportionate

to the extraction. This mechanism will be helped in rejuvenating ground water vulnerability zones into fresh water zones.

- 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 into ground water system. GVMC must adopt proper treatment of sewerage water treatment plants by installing STPs in urban area before it reaches to ocean (otherwise which will a creat major damage in ocean bio-diversity).
- Implementation polavaram canal towards drinking water supply for Visakhapatnam urban and rural areas, which will be helped in minimizing ground water abstraction rate in urban areas.

With the above interventions, the likely benefit would be the net recharge/conservation of 167 MCM of ground water in the district.

Existing and Proposed Artificial Recharge Structures in Visakhapatnam District

S.No.	District	Mandal	Existing CDs	Existing PTs	Total	Proposed CDs	Proposed PTs	Total
1	VISAKHAPATNAM	ANAKAPALLE	11	0	11	0	0	0
2	VISAKHAPATNAM	ANANDAPURAM	32	0	32	29	32	61
3	VISAKHAPATNAM	ANANTAGIRI	0	0	0	61	65	126
4	VISAKHAPATNAM	ARAKU VALLEY	0	0	0	5	5	10
5	VISAKHAPATNAM	ACHUTAPURAM	8	0	8	28	23	51
6	VISAKHAPATNAM	BHEEMUNIPATNAM	8	0	8	0	1	1
7	VISAKHAPATNAM	BUCHCHAYYAPETA	15	0	15	0	0	0
8	VISAKHAPATNAM	CHIDIKADA	7	0	7	0	0	0
9	VISAKHAPATNAM	CHINTAPALLE	0	0	0	107	114	221
10	VISAKHAPATNAM	CHODAVARAM	16	0	16	0	0	0
11	VISAKHAPATNAM	DEVARAPALLE	1	4	5	42	28	70
12	VISAKHAPATNAM	DUMBRIGUDA	0	0	0	16	17	33
13	VISAKHAPATNAM	GUDEM KOTHAVEEDI	0	0	0	179	192	371
14	VISAKHAPATNAM	GANGARAJU MADUGULA	0	0	0	96	102	198
15	VISAKHAPATNAM	GAJUVAKA	0	0	0	0	0	0
16	VISAKHAPATNAM	GOLUGONDA	35	0	35	17	17	34
17	VISAKHAPATNAM	HUKUMPET	0	0	0	0	0	0
18	VISAKHAPATNAM	K.KOTAPADU	11	0	11	0	0	0
19	VISAKHAPATNAM	KASIMKOTA	15	0	15	0	0	0
20	VISAKHAPATNAM	KOTAURATLA	13	1	14	0	0	0
21	VISAKHAPATNAM	KOYYURU	0	0	0	188	202	390
22	VISAKHAPATNAM	MADUGULA	16	0	16	21	19	40
23	VISAKHAPATNAM	MAKAVARAPALEM	47	1	48	0	0	0
24	VISAKHAPATNAM	MUNAGAPAKA	13	0	13	1	0	1
25	VISAKHAPATNAM	MUNCHINGIPUTTU	0	0	0	130	140	270
26	VISAKHAPATNAM	NAKKALLI	0	0	0	0	0	0
27	VISAKHAPATNAM	NARSIPATNAM	0	0	0	0	0	0
28	VISAKHAPATNAM	NATAVARAM	31	0	31	50	52	102
29	VISAKHAPATNAM	PADERU	0	0	0	28	30	58
30	VISAKHAPATNAM	PADMANABHAM	14	0	14	28	29	57
31	VISAKHAPATNAM	PARAVADA	10	0	10	0	0	0
32	VISAKHAPATNAM	PAYAKARAOPETA	1	0	1	0	0	0
33	VISAKHAPATNAM	PEDDABAYALU	0	0	0	35	38	73
34	VISAKHAPATNAM	PEDDAGANTYADA	0	0	0	0	0	0
35	VISAKHAPATNAM	PENDURTI	4	0	4	0	0	0
36	VISAKHAPATNAM	RAMBILLI	4	1	5	34	25	59
37	VISAKHAPATNAM	RAVIKAMATAM	41	3	44	17	18	35
38	VISAKHAPATNAM	ROLUGUNTA	40	0	40	14	13	27
39	VISAKHAPATNAM	S.RAYAVARAM	2	0	2	0	0	0
40	VISAKHAPATNAM	SABBAVARAM	28	0	28	0	0	0
41	VISAKHAPATNAM	VISAKHAPATNAM(R)	0	0	0	0	0	0
42	VISAKHAPATNAM	VISAKHAPATNAM(U)	0	0	0	25	27	52
		Total	**423**	**10**	**433**	**1151**	**1189**	**2340**