केन्द्रीय भूमि जल बोर्ड
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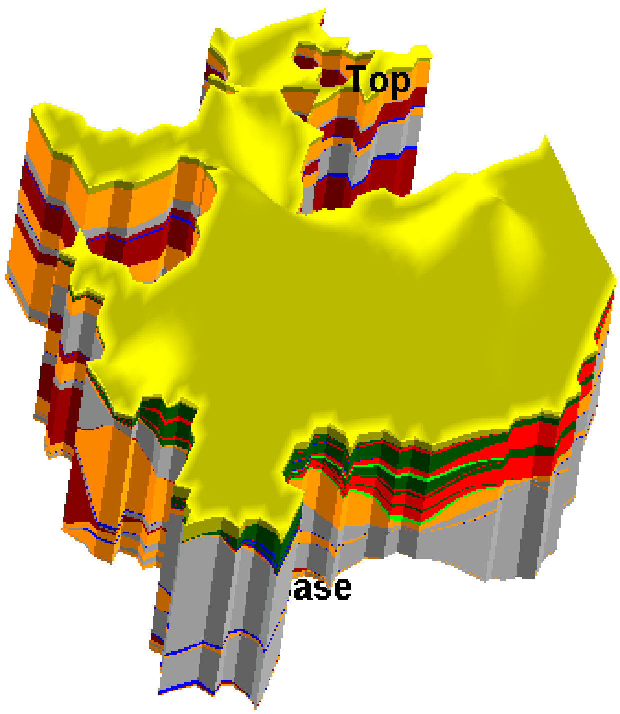
विभाग, जल शक्ति मंत्रालय
भारत सरकार
Central Ground Water Board
Department of Water Resources, River
Development and Ganga Rejuvenation,
Ministry of Jal Shakti
Government of India

AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES

NEEMUCH DISTRICT
MADHYA PRADESH

उत्तर मध्य क्षेत्र, भोपाल
North Central Region, Bhopal

AQUIFER MAPPING AND GROUND WATER MANAGEMENT PLAN OF NEEMUCH DISTRICT, MADHYA PRADESH



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भारत सरकार
जल शक्ति मंत्रालय
जल संसाधन, नदी विकास और गंगा संरक्षण विभाग
केन्द्रीय भूमि जल बोर्ड, उत्तर मध्य क्षेत्र

Government of India
Ministry of Jal Shakti
Department of Water Resources, R D & G R
Central Ground Water Board, North Central Region

PREFACE

Aquifer mapping can be defined as a scientific process, where in a combination of geologic, geophysical, hydrologic and chemical field and laboratory analyses are applied to characterize the quantity, quality and sustainability of ground water in aquifers. Systematic aquifer mapping is expected to improve our understanding of the geologic framework of aquifers, their hydrologic characteristics, water levels in the aquifers and how they change over time, and the occurrence of natural and anthropogenic contaminants that affect the portability of ground water. Results of these studies will contribute significantly to resource management tools such as long-term aquifer monitoring networks and conceptual and quantitative regional ground-water-flow models used planners, policy makers and other stakeholders.

Under the project on National Aquifer Mapping (NAQUIM), Central Ground Water Board (CGWB) North Central Region, Bhopal has taken up Neemuch district to prepare the Aquifer Maps for the entire district as well as block wise and formulate Block-wise Aquifer Management Plan. Neemuch district occupies an area of 4200 sq km, out of which the ground water recharge worthy area is 3757 sq. km. and the rest is covered by hilly and forest area. Almost entire district is falling under Chambal sub-basins area of the Ganga Basin. The major rivers flowing in the district is Chambal River. The district is mainly occupied by Deccan Trap basalt, rock formations of Vindhyan Super Group. Both in shallow and deep aquifers the water levels between 10 to 20 mbgl in the pre-monsoon and between 2 to 5 mbg in post-monsoon are observed in major parts of the district. As per the Dynamic Ground Water Resource Assessment Report (2020), the annual Ground Water Extractable Resource in the district is 383 mcm and the total ground water extraction for all uses is 354 mcm, resulting the stage of ground water extraction to be 92.40 % as a whole for district. After successful implementation of supply side and demand side management plan the stage of extraction in Neemuch district is expected to improve. The interventions suggested in the report will not only have a positive impact on the ground water regime but would also play a key role in augmenting the net cropping area and would ultimately enhance the agricultural productivity and economy of the district.

I would like to place on record my appreciation of the untiring efforts of **Shri Chitta Ranjan Biswal, Scientist-B** for preparing the Aquifer maps and Management plan and compiling this informative report. I fondly hope that this report will serve as a valuable guide for sustainable development of Ground Water in the Neemuch District, Madhya Pradesh.

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(Regional Director)

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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 (Deccan Trap Basalt and Vindhyan Formations) 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 AND SCOPE OF STUDY

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.

The main scope of study is summarised below.

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

2. Periodic long term monitoring of 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.

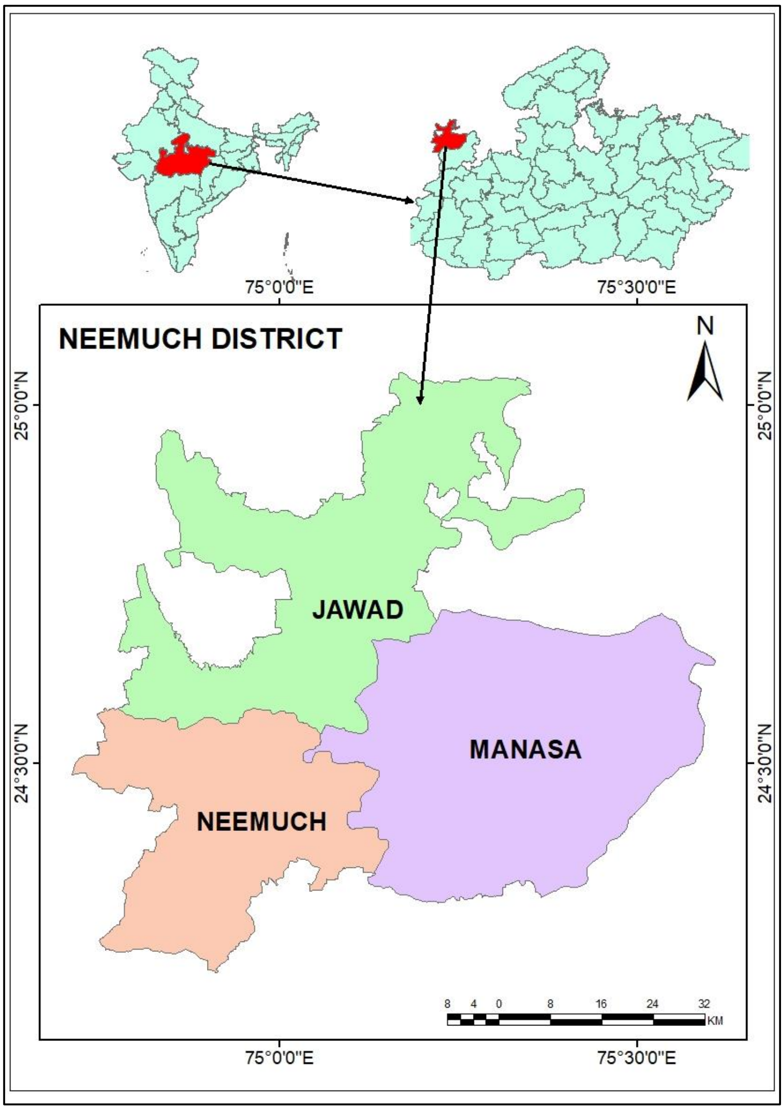

Fig.1.1:Location Map

1.2 STUDY AREA

The Neemuch district having geographical area of 4200.44 km^2, lies between north latitude 24°12´-25°02´ and east longitude 74°42´-75°36´ located in the north-western part of Madhya Pradesh falling in Survey of India part of toposheet No. 45L/ 13, 14, 15 and 45P/ 1, 2, 3, 6 &

7. The district is bounded on southeast by Mandsaur district and on the north, northeast and western side by Rajasthan State. As of 2011 India census, Neemuch district had a population of 826,067. Males constitute 51.16 % of the population and females 48.84 %. According to 2011 census nearly 70.31% Population of Neemuch District is in rural area while 29.69% in urban area. Neemuch has a literacy rate of 70.80%.

1.3 CLIMATE AND RAINFALL

The climate of Neemuch district is generally dry except the southwest monsoon season. The year can be divided in to four seasons. The winter commences from middle of November and lasts till the end of February. The period from March to about first week of June is the summer season. May is the hottest month of the year. The southwest monsoon starts from middle of June and lasts till end of September. October and middle of November constitute the post monsoon or retreating monsoon season.

District received maximum rainfall during south west monsoon period i.e. June to September. About 90.5 % of the annual rainfall received during monsoon season. Only 9.5 % of the annual rainfall takes place between October to May period. Thus surplus water for ground water recharge is available only during the southwest monsoon period.

10-year annual rainfall (2010 to 2019) for the three blocks Neemuch, Jawad and Manasa are compiled and presented in the **Table.1.1.** From 2010-2019, district receives higher rainfall in the year 2019. Based on the three rain gauge of Water Resource Department we prepared a Normal Isohyets map and presented in the **Fig.1.2**.

Table.1.1: Year wise Annual Rainfall of three blocks

	Year wise Annul Rainfall in Milimeter									
Block	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Neemuch	756	1162	935	1151	947	804	1185	802	1387	1851
Manasa	855	1033	1082	1221	983	662	1006	692	818	2057
Jawad	770	1128	731	963	803	833	1127	572	1473	1456

The normal maximum temperature received during the month of May is 39.8° C and minimum during the month of January is 9.8° C. The normal daily mean monthly maximum temperature is 31.6° C and daily mean minimum temperature is 19.0° C. The summer season is the driest period of the year. The relative humidity generally exceeds 87% in the month of August. The average normal annual wind velocity of the district is 9.2 km./ hr.

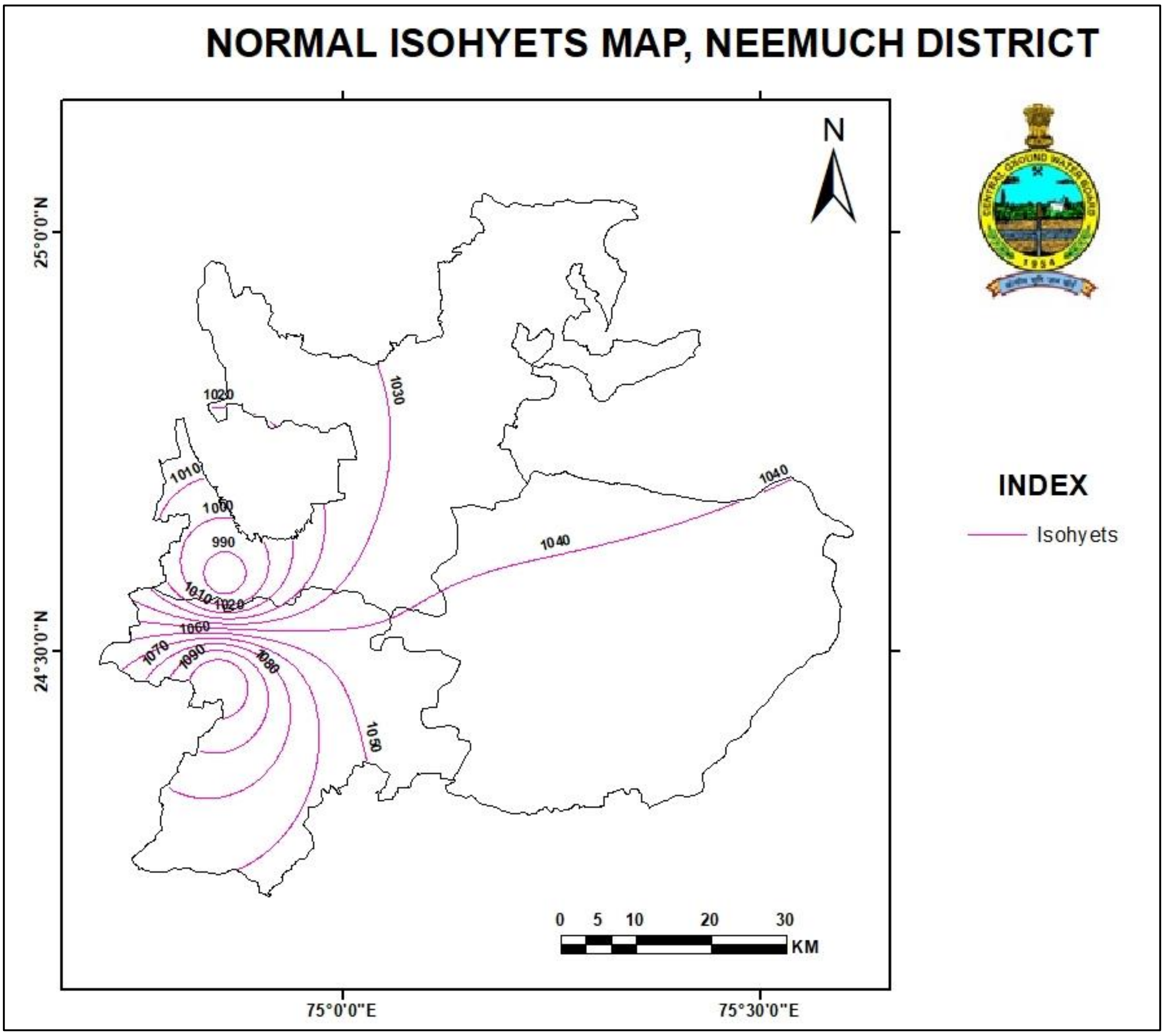

Fig.1.2:Normal Isohyets Map, Neemuch District

1.4 GEOMORPHOLOGICAL SET UP

Neemuch district forms the part of Malwa plateau. It can broadly be divided into two physical divisions; northern plateau consists of Vindhyan rocks and southern Malwa plateau. Major part of the district is occupied by pediment pediplains complex, present mostly in the southern side and partly in the northern side. The central part of the district is occupied by moderately dissected plateau. Low dissected plateau is present sparcely in the northern side. Dissected hills and valleys, flood plain and alluvial plain landforms are occupied very small part of the district. Pediment Pediplain complex is the major landform covering about 2468 km^2 (57%) area. The other major landform observed is dissected plateau covering about 1503 km^2 (35%). The geomorphological map is presented in the **Fig.1.3**.

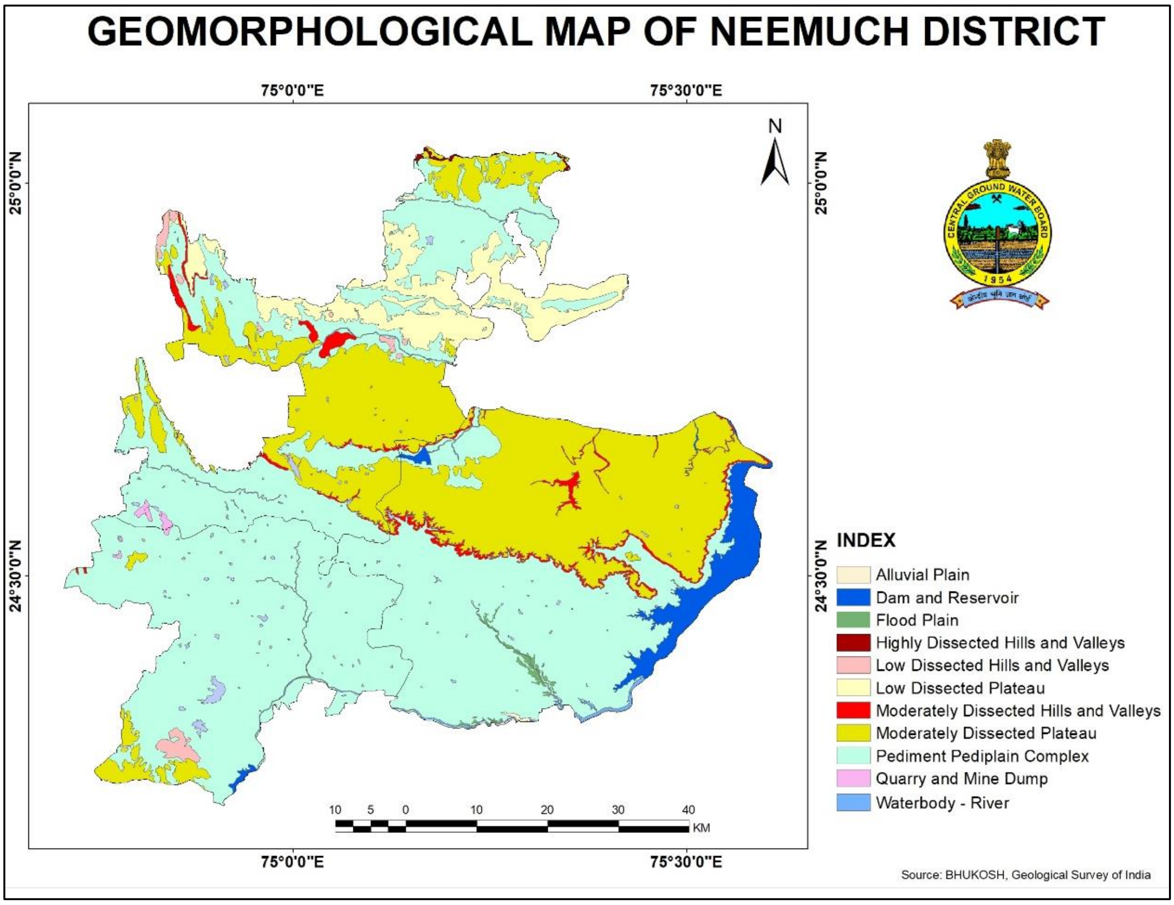

Fig.1.3: Geomorphology map

All the geomorphology feature types of the district are represented in a pie and shown in the **Fig.1.4.**

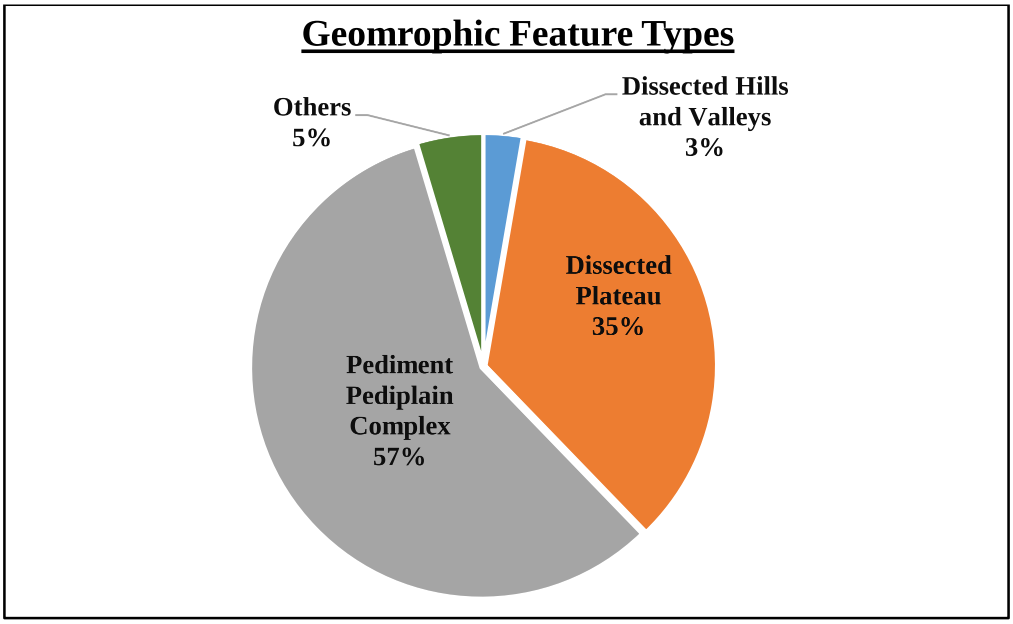

Fig.1.4: Geomorphic feature types Pie Chart

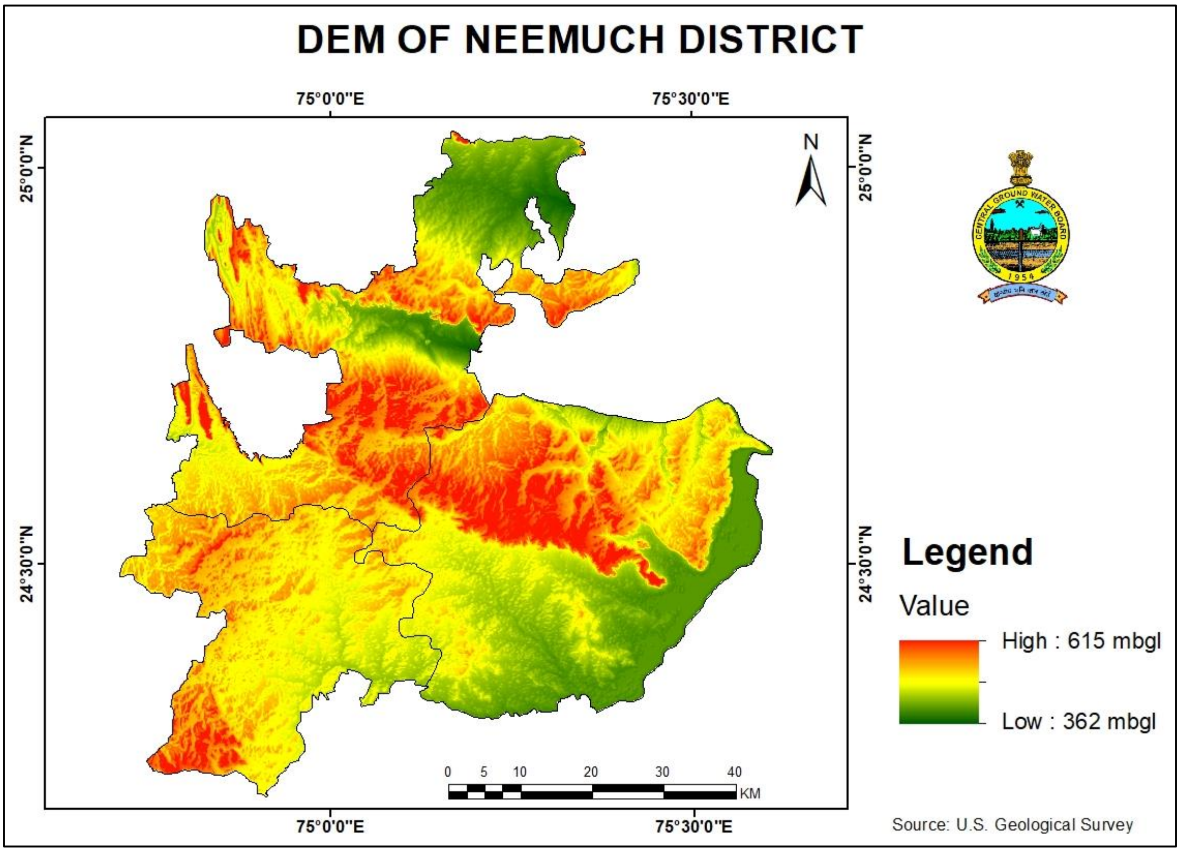

Fig.1.5:DEM

1.5 PHYSIOGRAPHY

The district exhibits rolling topography with high and deep fronted hill ranges, valleys and plains. The elevation is generally high at the central part of the district. The highest elevation of the district is 615 m amsl. The elevation is decreases towards the northern and south eastern side. The lowest elevation of the district is 362 m amsl. The DEM of the district is made and presented in the **Fig.1.5**.

1.6 SOIL STATUS

The district is mainly covered with two type of rocks, sedimentary and basaltic. Soil depending upon Lithology of the area has been classified in two groups

(A) Soils of Sedimentary rocks

(B) Soils of Basaltic rocks

Soils of sedimentary rocks are occupying major northern and central part of the district, where as soils of basaltic rocks are occurring at southern and central part of the district. Soils of these types have been further classified as per classification of National Bureau of Soil Survey and Land Use Planning, Nagpur and they are described in **Table.1.2**, Soil Map of the district is given in **Fig.1.6**.

Table.1.2: Types of Soil in Neemuch District

Soil Type	Description	Soil Taxonomy
(A) Soils of Sedimentary rocks	**1. Soils of Hills with Escarpment :** Very shallow somewhat excessively drained, loamy soil on gently sloping, undulating plateau.	Loamy, Kaolinitic, Hyperthermic, lithic ustorthents.
	2. Soils of Hills with Escarpment: Moderately deep, moderately well drained, calcareous, clayey soils on gently sloping plateau with moderate erosion and moderately stony	Fine mixed(Calcareous), Hydperthermic typic ustocherpts.
	3. Soils of Plateau: Deep, moderately well drained, Calcareous, clayey soil on gently sloping plateau with moderate erosion	Fine mixed heperthermic typic ustocherpts.
	4. Soils of Undulating Plateau: Shallow somewhat excessively drained clayey soils on moderately slopping undulating plateau with severe erosion and strongly stony	Loamy, Skeletal, Kaolinitic, Hyperthermic, lithic ustorthents.
(B) Soils of Basaltic rocks	**1. Soils of Undulating Plateau:** Moderately deep, well drained calcareous clayey soils on very gently sloping undulating plains with mounds with moderate erosion	Fine montmorilonitic (Calcareous) Hyperthermic vertic ustocherpts.
	2. Soils of Undulating Plains: Deep moderately well drained , calcareous, clayey soil on gently sloping undulating plain with mounds with moderate erosion and slightly stony.	Fine montmorilonitic (Calcareous) Hyperthermic typic haplusterts.

The soils in the district are also classified in to four types viz., Medium Deep Black cotton soil, Red loamy soil, Laterite soil and Alluvial soil. Black cotton soil is derived from weathering and disintegration of basaltic lava flow. Major parts of the district are covered by medium deep black soils. Red loamy soils consist of sandy loam to clayey loam and brick in colour. This soil is derived from Vindhyan sandstone and shale and occurring in valley portion on the plateau and adjacent to hill composed of Vindhyan sandstone. This type of soil covers a Northern part of the district. Laterite soil dark brown to pink coloured lateritic soil is found as capping over hillocks of basaltic terrain. Alluvial soils are greyish yellow to brownish yellow in colour and occupy along the major rivers.

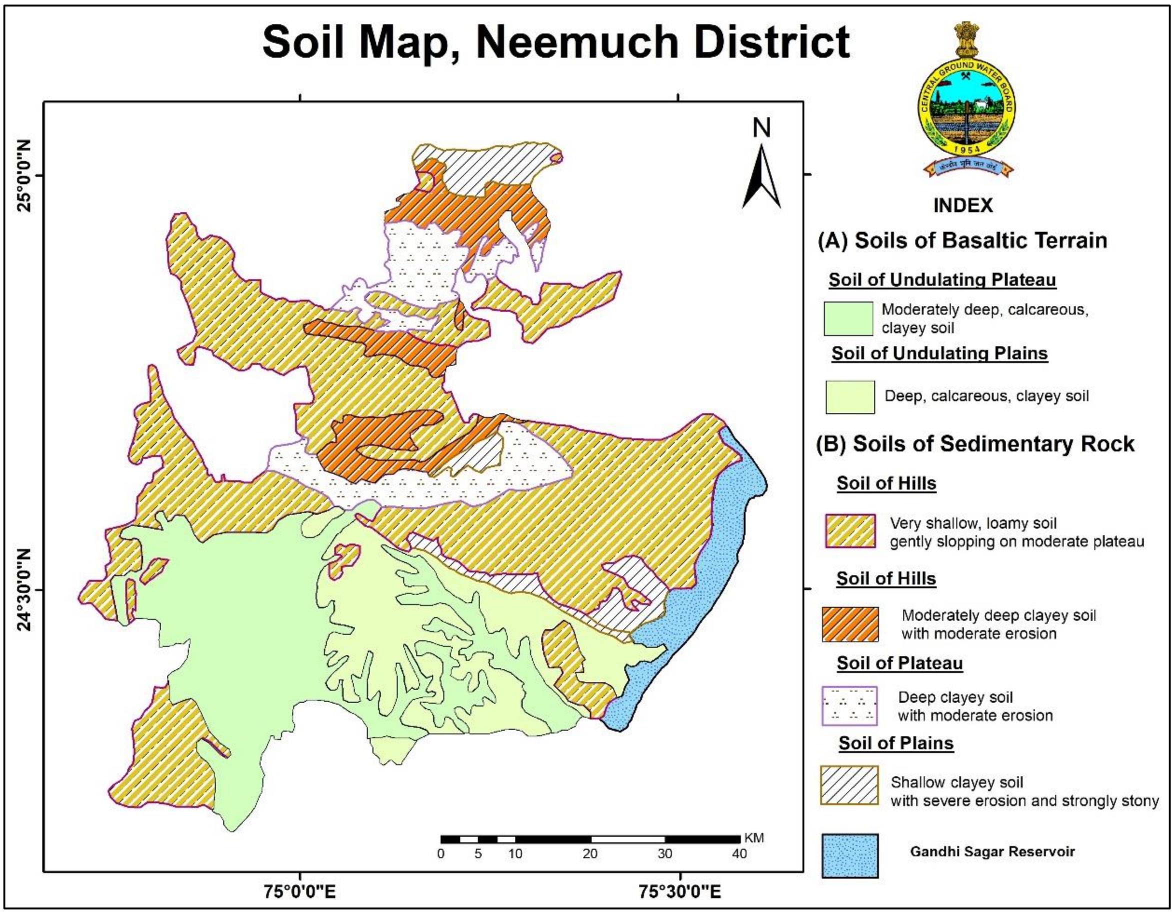

Fig.1.6: Soil Map

1.7 DRAINAGE AND BASIN

Almost entire district is falling under Chambal sub-basins area of the Ganga Basin. The river Chambal is flowing in eastern part of the district in northeast direction. The Retam, Idar, Erda, Rupa, Bamni, Gangali & Rajori are main tributaries of the Chambal River and are ephemeral in nature, except Idar river which is flowing in south-east direction all other tributaries of Chambal river are flowing either east or northeast direction. Gambhir River flowing north of Jawad town in northwest part of the district is only westerly flowing river. Retam River is forming boundary in southern part of the district and it rises near Pratapgarh in Rajasthan and flows to the northeast direction, it joins the Chambal near Sundi. Idar nala a tributary which rises from Malkeera hill (550m) drains the southern scarp of Rampura Pathar and flows to the southeast direction. The Ganjali River rises from the hills near Jat and flows from west to east below the central scarp of the northern plateau; the Ganjali joins the Chambal near Motipura. The Bamni rises near Begun flows to the east past Singoli, it joins Chambal at Bhainsrograh. Map depicting drainage is presented in **Fig.1.7.**

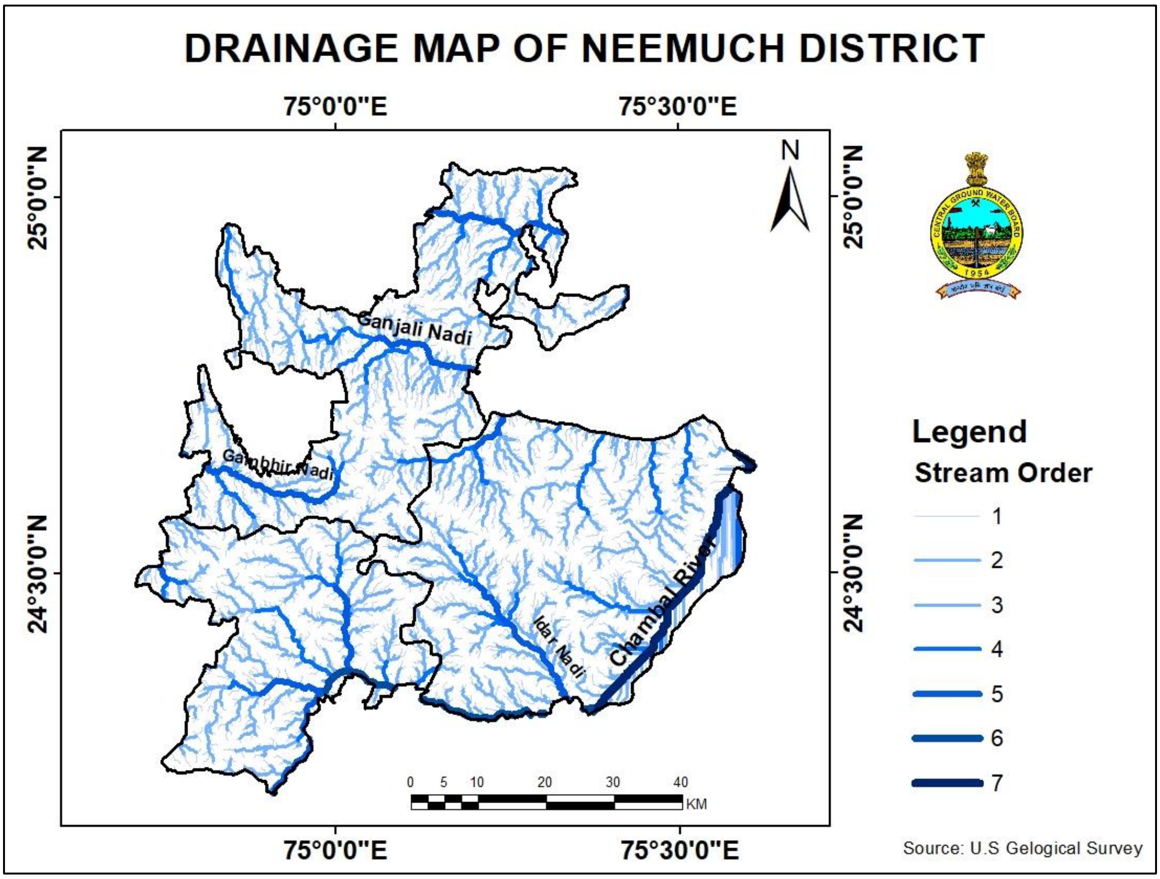

Fig.1.7:Drainage map

1.8 LAND USE, AGRICULTURE, IRRIGATION AND CROPPING PATTERN

Agriculture and forest are the prominent land use aspects in Neemuch district and forms 56 % and 31 % of total area respectively followed by the shrub land and water bodies. The spatial distribution of land use is presented in **Fig. 1.8** (as per Land Use Land cover data, NASA, USA). The land use land cover types are prepared in a pie diagram and shown in the **Fig.1.9.**

The total arable land of Neemuch district is 181150 ha, out of which, the irrigated area is about 68%. The much sources of irrigation are Tube well, Dugwells and Ponds. The irrigated area under Tube wells, dug wells, and Ponds, mainly depended on rains.

The district has good potential for irrigation through different sources, though there are no major or medium irrigation scheme in the district, however, minor lift irrigation schemes, dug well, water harvesting structures, seasonal rivers and other sources provides water for irrigation. Main crops grown are oil seeds 134380 ha (75%) followed by Cereals 29157 ha (16%), Pulses 3383 ha (2%), Fruits in 5331 ha (2%) and vegetables in 3112 ha (2%) during khariff and Cereals 54667 ha (34%), Spice crops 48912.5 ha (31%), oil seeds 18907 ha (12%), pulses 11080 ha (7%), vegetables 4412 ha (3%) during rabi season respectively. Season wise cropping pattern is given in **Fig.1.10.**

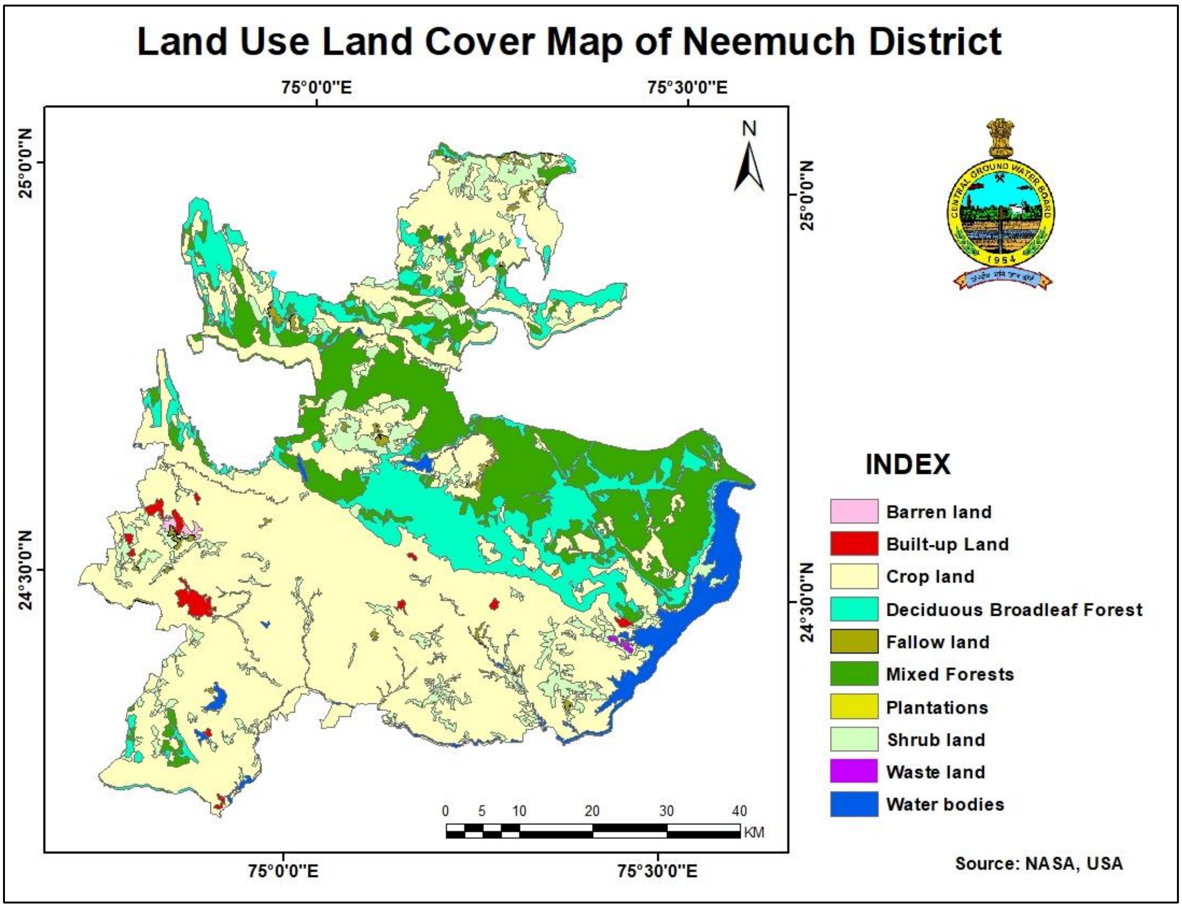

Fig.1.8:Land use land cover Map

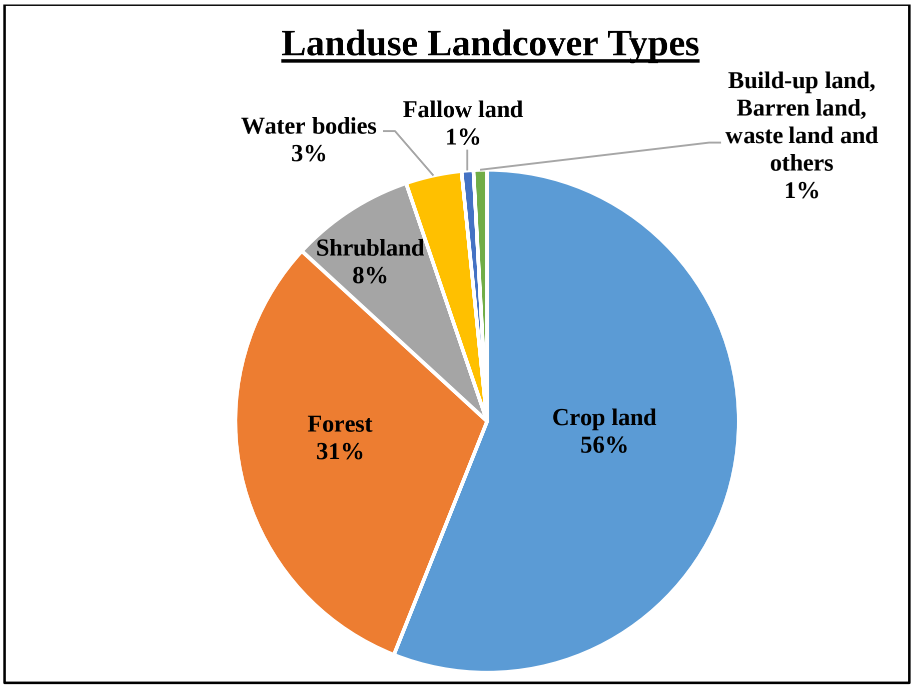

Fig.1.9:Land use Land Cover Pie

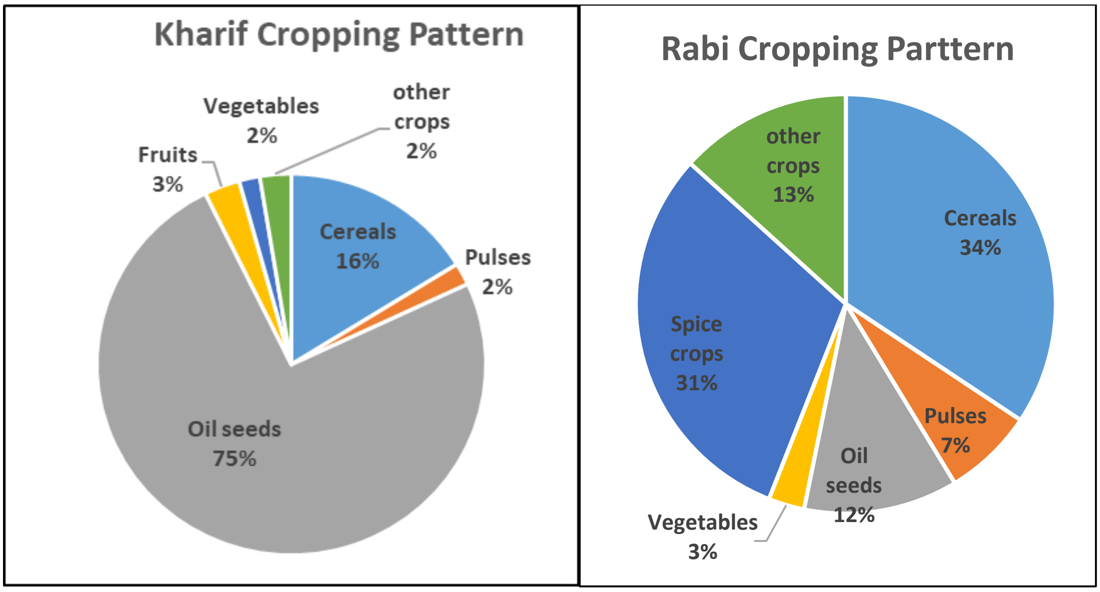

Fig.1.10: Season wise Cropping pattern (Source: DIP, PMKSY)

1.9 GEOLOGY

The district is mainly occupied by Deccan Trap basalt, rock formations of Vindhyan Super Group. Northern part of the district is mainly occupied by sedimentary rocks of Vindhyan Super Group and southern part of the district mainly by Deccan Basalt. The Generalised succession of the district is prepared and represented in the **Table.1.4**.

1.9.1 Lower Vindhyan

Semri Group: The Lower Vindhyan rocks mainly the Nimbahera limestones are exposed over a limited area around Jawad towards west of the district. These limestones are interbedded with shales. Semri group of rocks are also present in the south west corner in the Neemuch block in the eastern part near Gandhi Sagar Dam.

Table.1.3: General Geological Succession

Age	Stratigraphic Unit	Lithology
Quaternary to Recent	**Laterite**	**Ferruginous limonite**
Upper Cretaceous to Lower Eocecne	Deccan Trap	Basaltic lava flows
Unconformity		
Proterozoic	Upper Vindhyans	Bhander Group : Shales, limestone & sandstone
		Rewa Group : Sand stone & shale
		Kaimur Group : Sand stone & shale
	Unconformity	
	Lower Vindhyans	Semri Group : Nimbahera Limestone and Shale

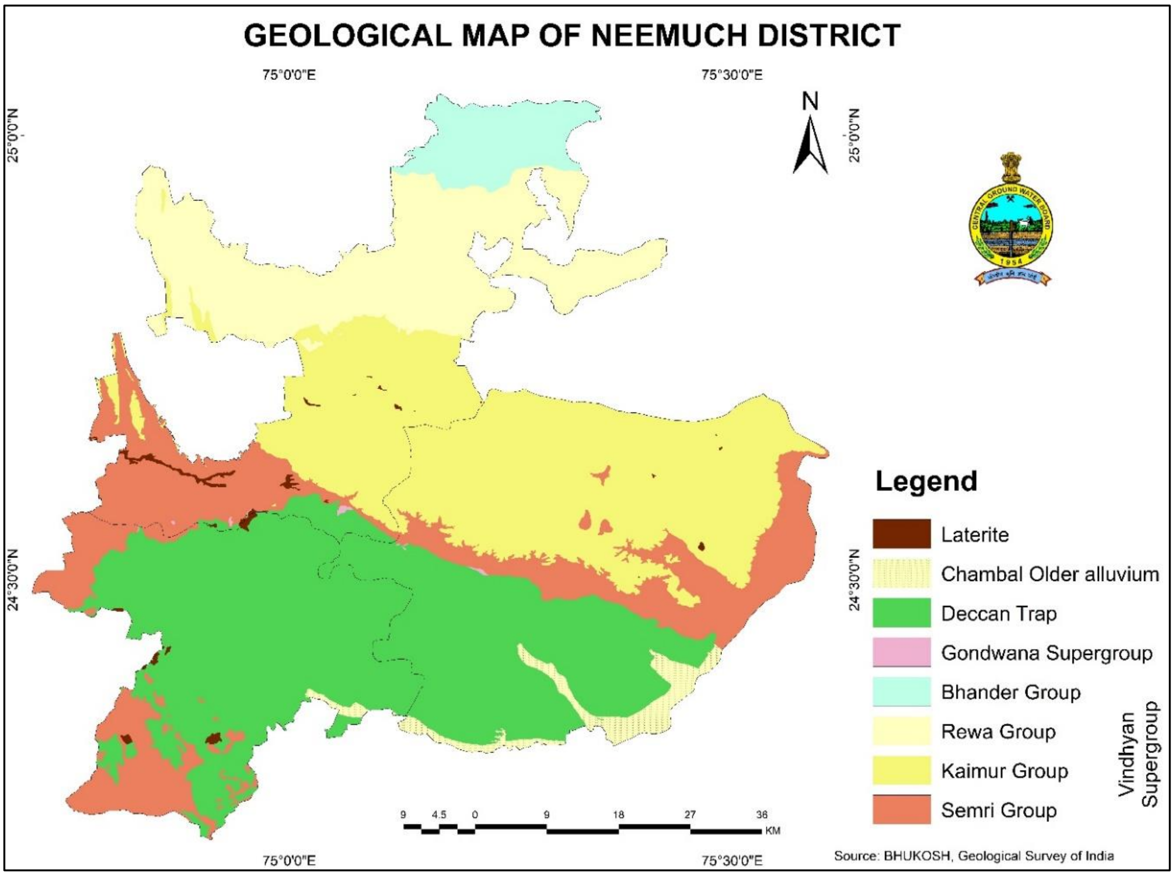

Fig.1.11: Geological Map

1.9.2 Upper Vindhyan

The Vindhyan Groups of rock formations exposed in the district are mainly Upper Vindhyans – the Kaimur, Rewa and Bhander comprising sandstone, shale and limestone.

Kaimur Group: Kaimur sandstone and shale are exposed over a large area, particularly towards east of the district, around Jawad town up to Gandhi Sagar reservoir. All these sandstones and shales are highly compact and groundwater occurs in the weathered zone and in the fractured zones and along joint planes which also act as conduits for groundwater movement.

Rewa Group: Rewa Sand stone & shales occur in between the Bhander and Kaimur outcrops of Jawad block near Rattangarh.

Bhander Group: Consists of Shales, Limestone and Sandstone, exposed in extreme northern end of the district.

1.9.3 Deccan Trap basalt

A major southern part of the district is occupied by near horizontal Deccan Trap basalt flows capping the Vindhyans ranging in age fron upper Cretaceous to lower Eocene. Each basalt flow comprises massive basalt at the bottom overlain by vesicular basalt.

1.9.3 Laterite

Laterite present near north of Neemuch town capping on Deccan traps. Laterites are occurring in patches at different part of the district. These are brownish red rocks consisting essentially limonite minerals. Laterites are residual deposits formed under typical climatic conditions in tropical regions.

2. DATA COLLECTION AND GENERATION

2.1 DATA COLLECTION AND COMPILATION

The data collection and compilation for various components was carried out as given below.

Hydrogeological Data: Current and historical water levels along with water level trend data of 24 Dug wells representing Shallow aquifer (Aquifer-I) and 14 piezometers representing Deep aquifer (Aquifer-II) of Central Ground Water Board. The water levels of 28 exploratory wells and 3 observation wells representing Aquifer-II were also collected and compiled.

Hydrochemical Data: Ground water quality data of 24 monitoring wells of Central Ground Water Board representing shallow aquifer.

Exploratory Drilling: Ground water exploration data of 28 exploratory wells of CGWB.

Geophysical Data: The soil and weathered zone thickness of the district from the 95 vertical electrical sounding conducted by Central Ground Water Board.

Hydrometeorological Data: Block wise 10 years (2010-19) rainfall data from Water Resource Department, Govt of Madhya Pradesh and the Normal annual rainfall data from Indian Meteorological Department, Govt of India were collected.

Water Conservation Structures: Numbers, type of water conservation structures prevailing in the district from MGNREGA.

Agricultural Data: Data on prevailing cropping pattern, Irrigation details collected from District Irrigation Plan prepared for PMKSY.

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.

S. No.	Activity	Sub-activity	Task
		Identification of Data Gap	Data gap in thematic layers, sub-surface information and aquifer parameters, information on 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.
		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.
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.

3. DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING

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

3.1 HYDROGEOLOGY

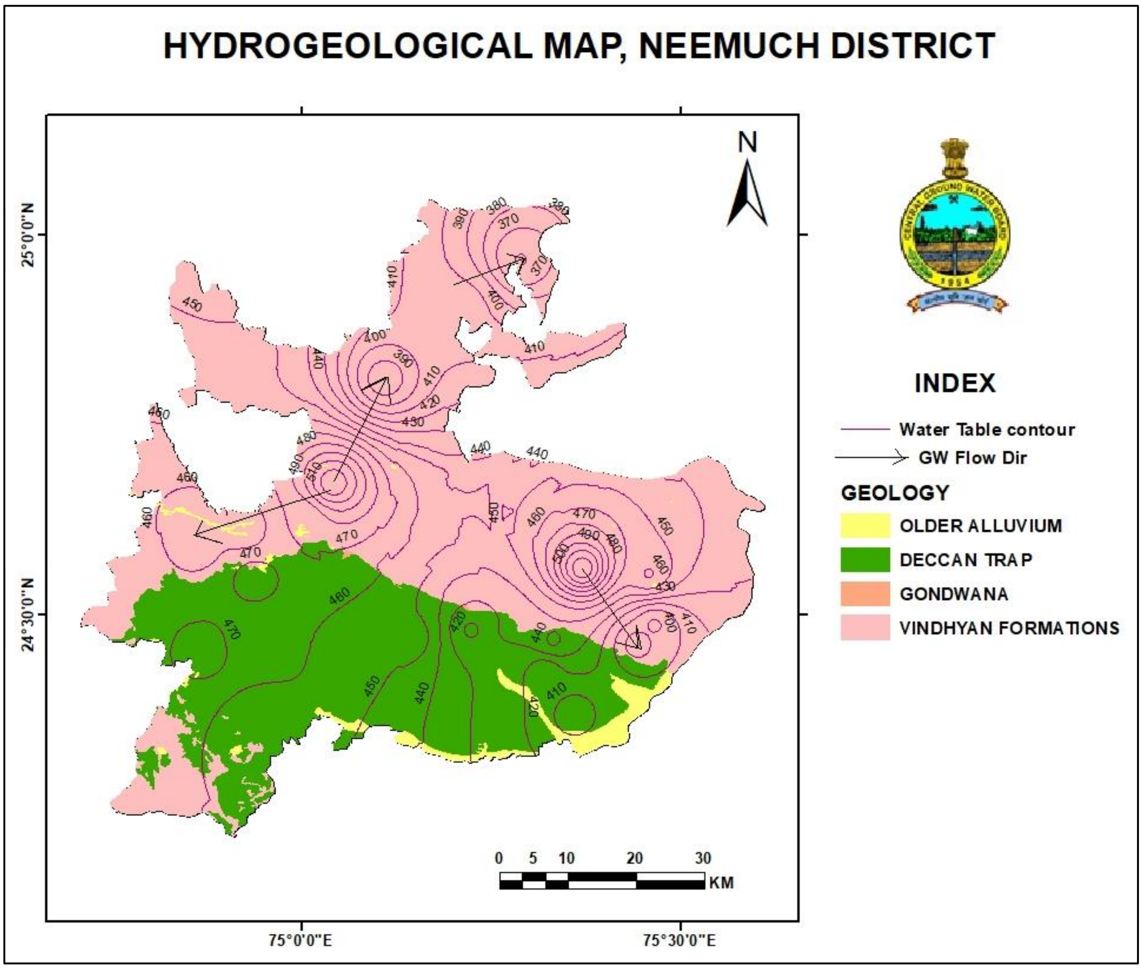

Fig.3.1:Hydrogeological Map.

Hydrogeology is concerned primarily with mode of occurrence, distribution, movement and chemistry of 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. Neemuch district is underlain by various geological formations, forming different types of the aquifer in the area. Main geological units of the area are Deccan traps and Vindhyan formations. The principal aquifers in the area are Basalt, Sandstone and Limestone where the occurrence and movement of ground water primarily depends on the degree of interconnection of secondary pores/voids developed by fracturing and weathering. The hydrogeological map of area is prepared and presented in **Fig.3.1**.

The water table elevation map was also prepared (**Fig.2.1**) to understand the ground water flow directions. The groundwater movement in the northern part is towards the north-eastern side, In the eastern part towards the Chambal River and in the western part of the district the movement is towards both side, one towards the northern side i.e. towards Ganjali River and the other towards southern side i.e towards Gambhir River.

3.1.1 Deccan Trap

The Deccan trap basalts occur in the district as lava flow infillings in the valleys of pre-existing Vindhyan topography. Ground water occurs under unconfined and semi-confined/confined conditions 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. Shallow groundwater occurs in the weathered, vesicular, jointed and fractured basalt under unconfined conditions. In areas where the weathered basalt layer is extensive a continuous phreatic aquifer can be traced to some distance. However, due to low permeability of weathered basalts the aquifer sustains limited groundwater withdrawal, mainly through open wells. On higher ground the weathered basalts may be thin or even absent. In such condition groundwater occurrence is restricted to the joints and fractures. The groundwater in Deccan traps at deeper levels occurs under semi-confined to confine conditioned, at different lava flow contacts, at Deccan trap and underlying Vindhyan contact or in the deeper jointed/fractured and vesicular amygdular basaltic horizons. The red bole horizons (clay) generally act as semi confining or confining layers for the deeper aquifers. The yields in the area is reported low to moderate (1-3 lps).

3.1.2 Vindhyan Formation

Vindhyan formations are consists of mainly sandstone, shale and limestone which are poor repository of groundwater. The joints and fractures control the occurrence of groundwater in areas located in topographical depression and adjacent to surface water bodies. The soil and weathered profile developed on the Vindhyan is generally thin and as a result groundwater occurs at shallow depth under unconfined conditions in the areas where the rock is jointed, fractured and weathered. The yields in the area is reported as low (1-2 lps)

3.2 EXPLORATORY DRILLING

Central Ground Water Board drilled 28 exploratory wells and 4 observation wells to delineate the aquifers vertically as well as laterally and to determine the aquifer parameters. The wells were plotted the **Fig.3.2**

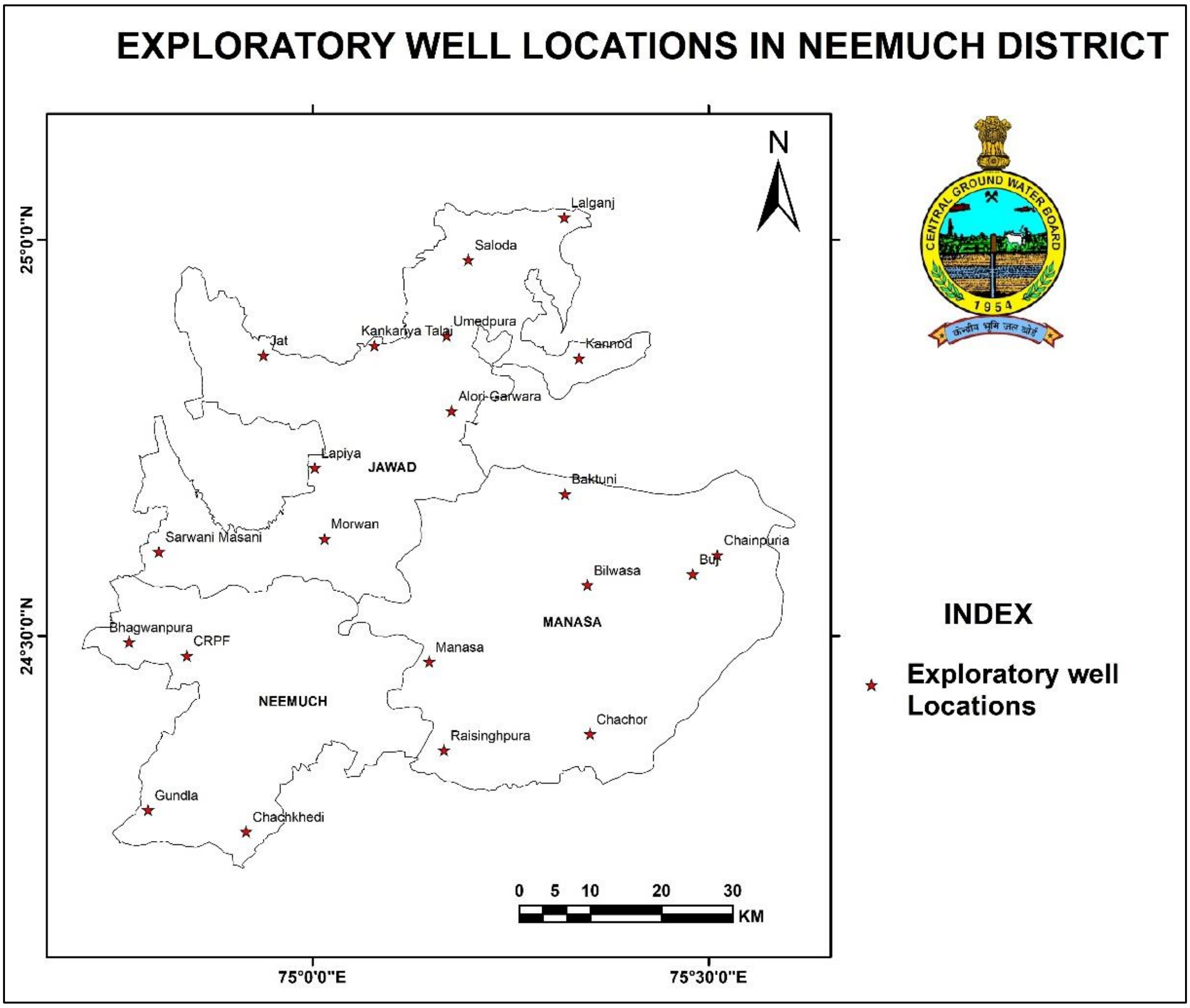

Fig.3.2: Exploratory well locations

3.3 WATER LEVEL SCENARIO

Central Ground Water Board monitored the water level of 24 dug wells and 14 piezometers four times (January, May, August and November) in every year. The monitored dug wells and piezometer locations are plotted in the **Fig.3.3**. The present depth to water level scenario of both shallow and deeper aquifers were generated by utilizing water level data of 24 monitoring wells representing shallow aquifer and 14 piezometers representing deeper aquifer.

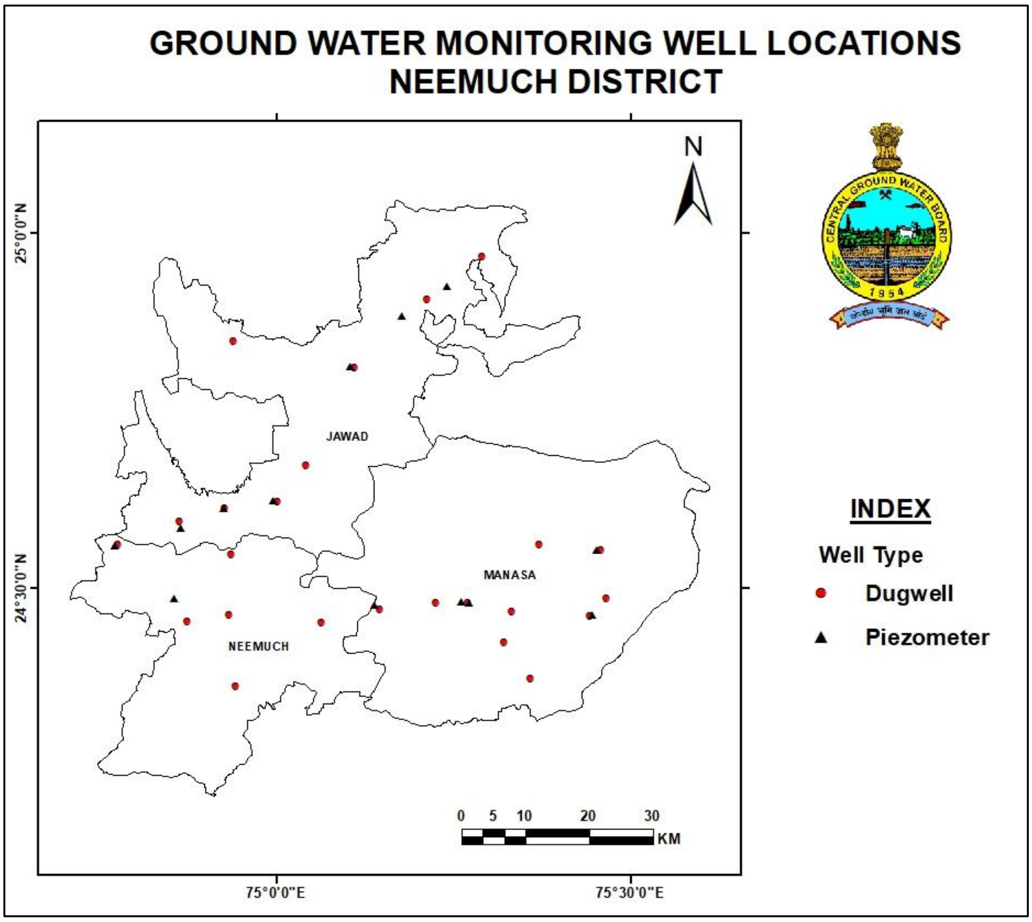

Fig.3.3:Ground water Monitoring well locations

3.3.1 SHALLOW AQUIFER

3.3.1.1 Pre-Monsoon (May 2019)

The pre-monsoon depth to water levels during May 2019 ranged between 3.5 (Nayagaon, Neemuch block) to 26.1 mbgl (Lalpura, Jawad block). The water levels between 10 to 20 mbgl are observed in major part of the district and the water levels between 5 to 10 mbgl are observed in patches in the district. The depth to water level map is given in **Fig.3.4.** Out of total 24 observation wells in the district, in 11 wells the water level observed is more the 10 mbgl.

3.3.1.2 Post-Monsoon (November, 2019)

The post-monsoon depth to water levels during November 2019 ranged between 0.5 (Nayagaon, Neemuch block) to 8.54 mbgl (Singoli, Jawad block). The water levels between 2 to 5 mbgl are observed in major parts of the district. The water level between 0 to 2 mbgl is observed mostly in the Neemuch block and the water level between 5 to 10 mbgl is observed in northern and central part of Jawad block. The depth to water level map is given in **Fig.3.5.**

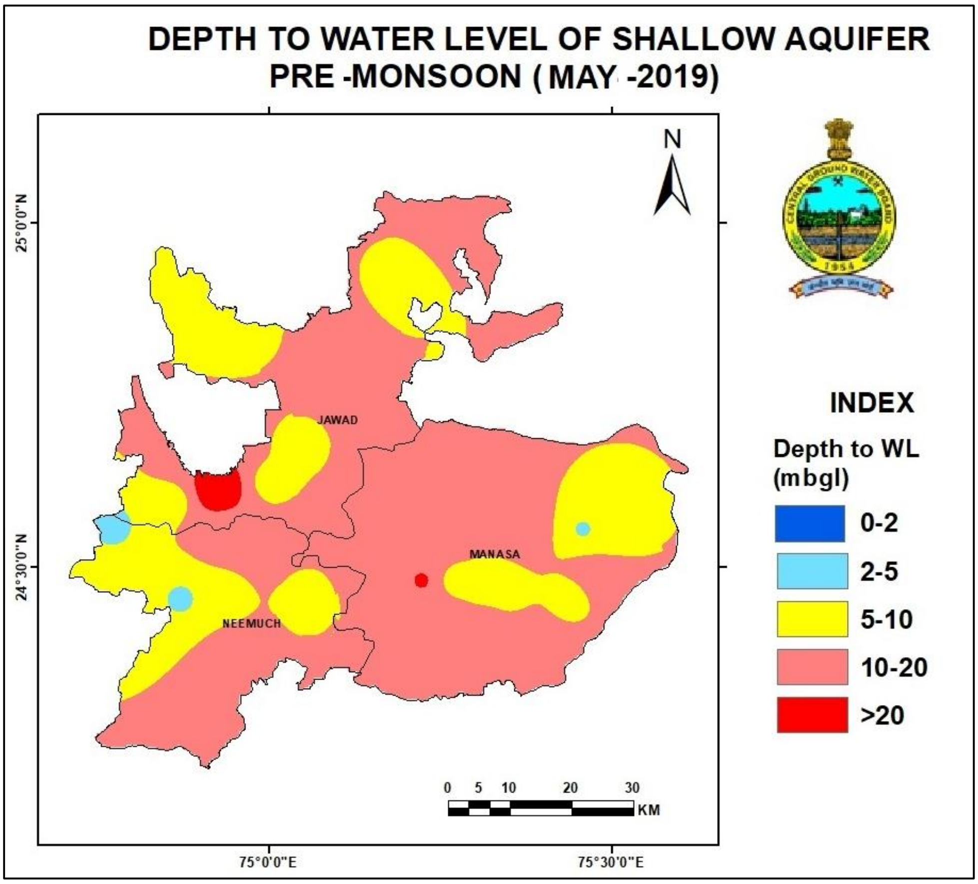

Fig.3.4:Pre-monsoon (May 2019) Depth to Water Level of Shallow Aquifer

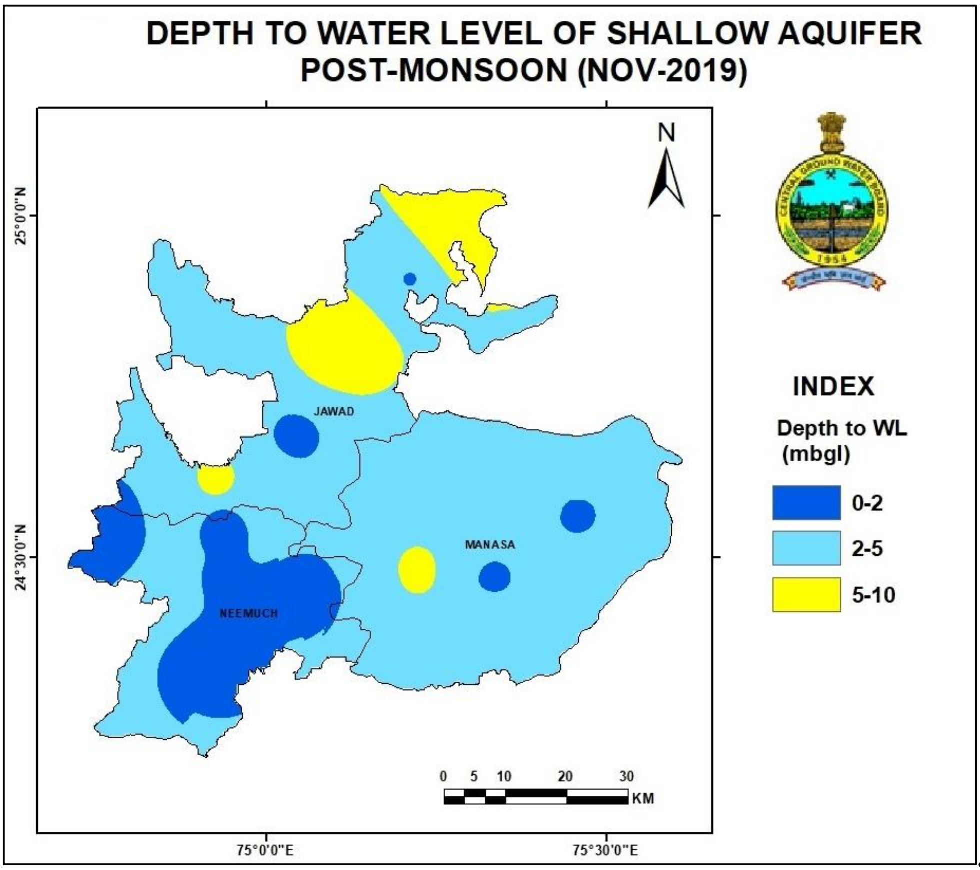

Fig.3.5:Post-monsoon (Nov 2019) Depth to Water Level of Shallow Aquifer

3.3.1.3 Seasonal Water level Fluctuation

The water level measured during pre-monsoon (May 2019) and post monsoon (Nov 2019) period was used to compute the seasonal fluctuation. The analysis of water level fluctuation data indicated that minimum water level fluctuation was observed at Neemuch (1.3 m) while maximum water level fluctuation was observed at Lalpura (30.2 m). The water level fluctuations were grouped under three categories i.e., less, moderate and high and the % of wells in each category was analysed. The analysis is described in **Table.3.1**.

Table.3.1: Analysis of Water Level Fluctuation.

S. No.	Category	Fluctuation Range	% of Wells
1.	Less water level fluctuation	0 to 2 m	4%
2.	Moderate water level fluctuation	2 to 5 m	33%
3.	High water level fluctuation	>5 m	63%

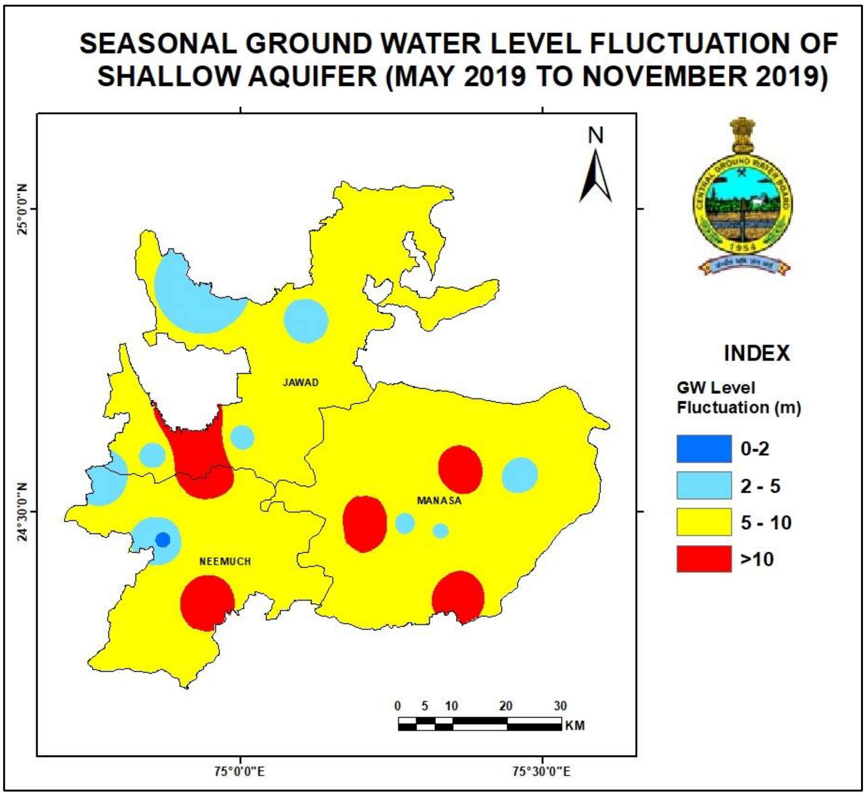

Fig.3.6: Seasonal Fluctuation of Water Level, Shallow Aquifer

The analysis indicates that of 63% the wells are falling in high fluctuation indicating aquifer storage is not good, whereas moderate water level fluctuation is observed in 33 % wells and low water level fluctuation were observed in 4 % wells. The seasonal fluctuation map is presented as **Fig.3.6** the perusal of map indicates that fluctuation between 5 to 10 meter is observed in major part of the district.

The pre-monsoon, post monsoon water level and seasonal fluctuation for the year 2019 of shallow aquifer is shown in the **Annexure.1**.

3.3.1.4 Long Water Level Trend (2012-21)

In order to study long term behavior of the water levels and also the effect of various developmental activities with time, the data for the period 2012-21 have been computed and analyzed.

The decadal pre-monsoon water level trend is presented in the **Fig.3.7,** which indicates that during pre-monsoon period, more than 90 % of the area showing declining trend. Maximum falling trend is ranged between 0 to 0.2 m/yr. Only the western part of Manasa block, Northern part of Neemuch block and the southern part of Jawad block is showing rising trend.

Similarly, the decadal post-monsoon water level trend is presented in the **Fig.3.8,** which indicates that about 95% of the area showing declining trend. Maximum falling trend is ranged between 0 to 0.2 m/yr. Only a small western part of the district showing rise in water levels.

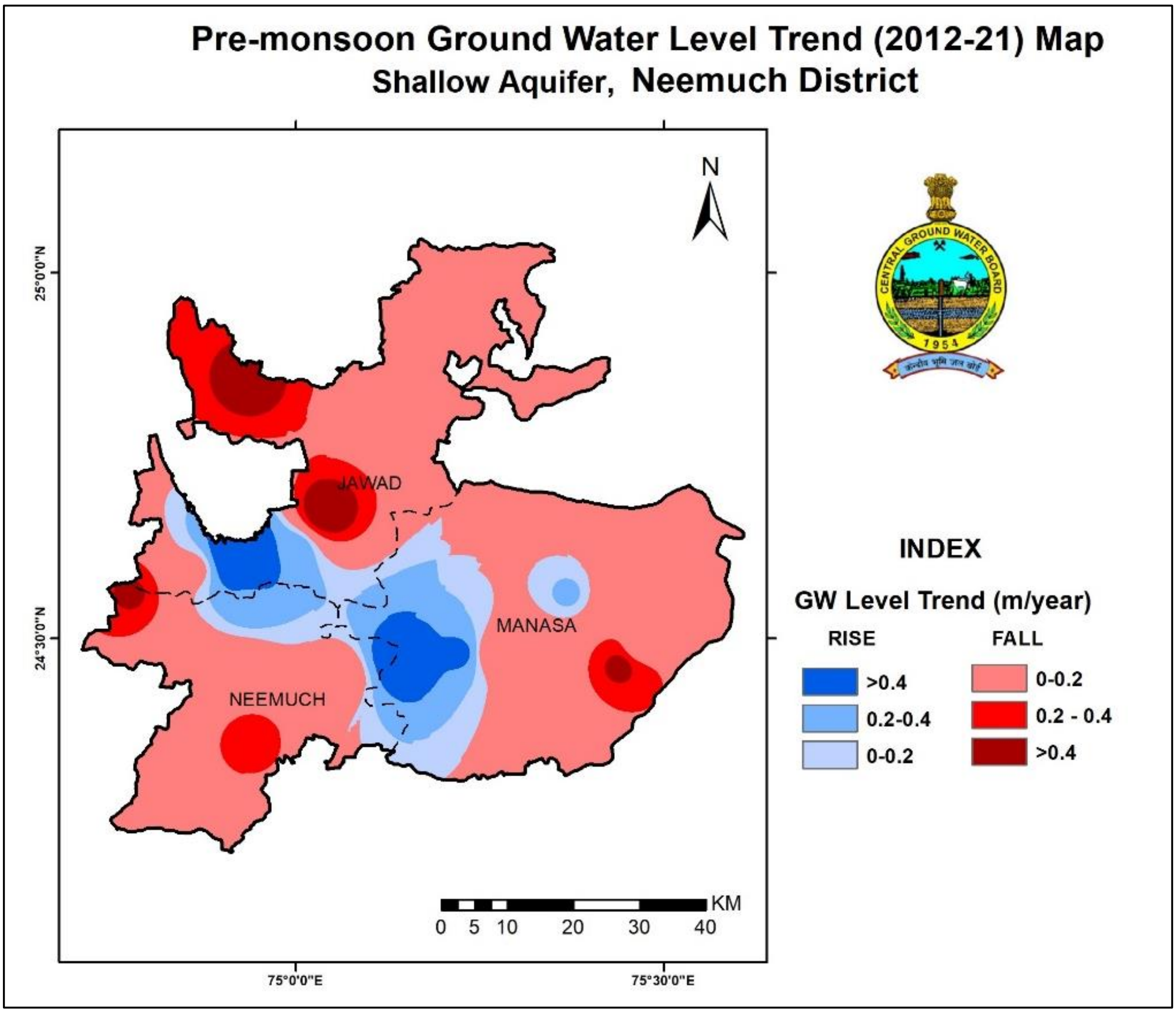

Fig.3.7:Pre-monsoon Water Level Trend (May 2012-21) of Shallow Aquifer

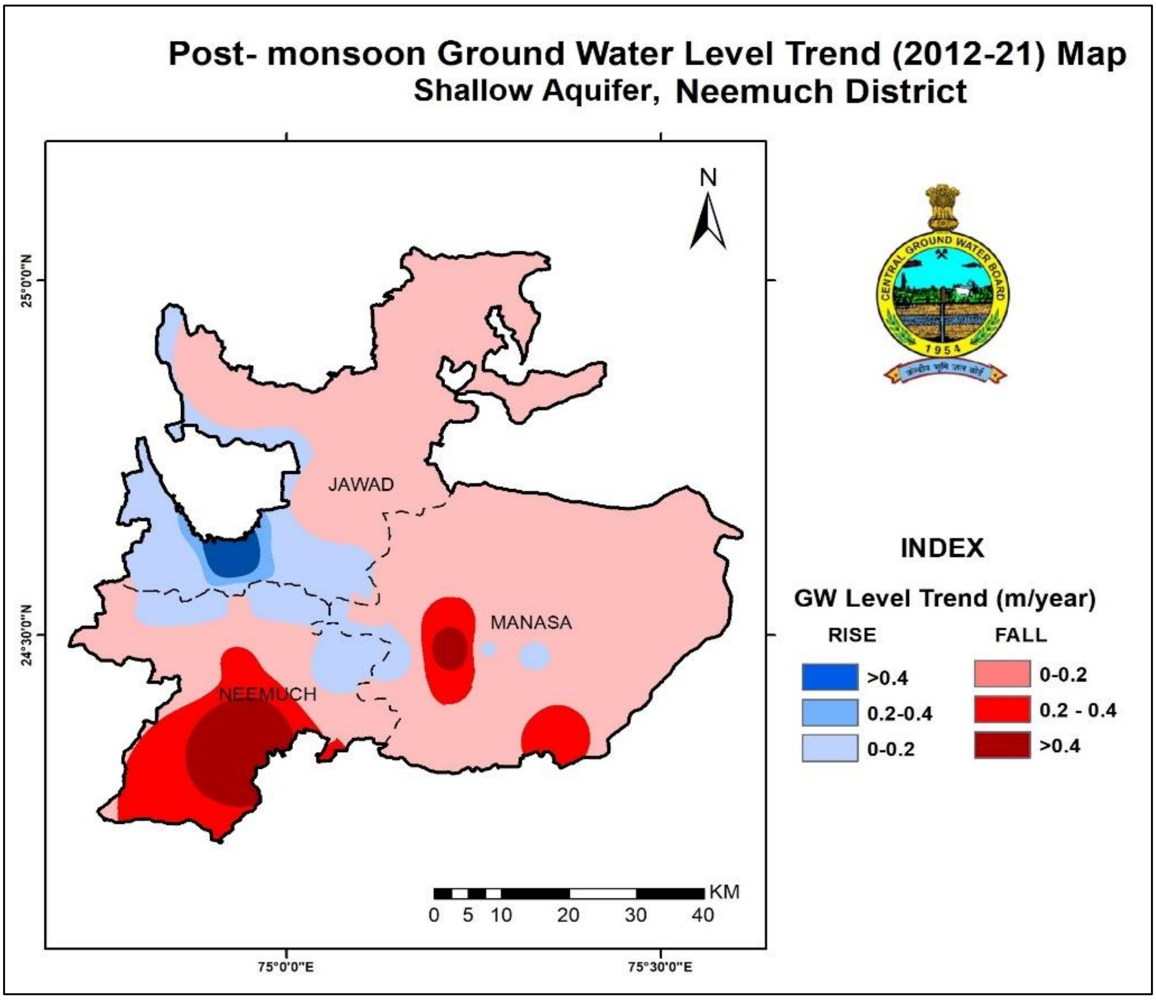

Fig.3.8: Post-monsoon Water Level Trend (Nov 2012-21) of Shallow Aquifer

3.3.2 DEEP AQUIFER

3.3.2.1 Pre-Monsoon (May 2019)

The pre-monsoon depth to water levels during May 2019 ranged between 4.9 (Manasa) to 26.1 mbgl (Athwakheda, Jawad block). The water levels between 10 to 20 mbgl are observed in major part of the district and the water levels between 5 to 10 mbgl are observed in patches the eastern part of the district around Chambal River in the central part around Neemuch and Manasa block border and in the western part in neemuch block. The depth to water level map is given in **Fig.3.9.** Out of total 13 observation wells in the district, in 8 wells the water level observed is more the 10 mbgl.

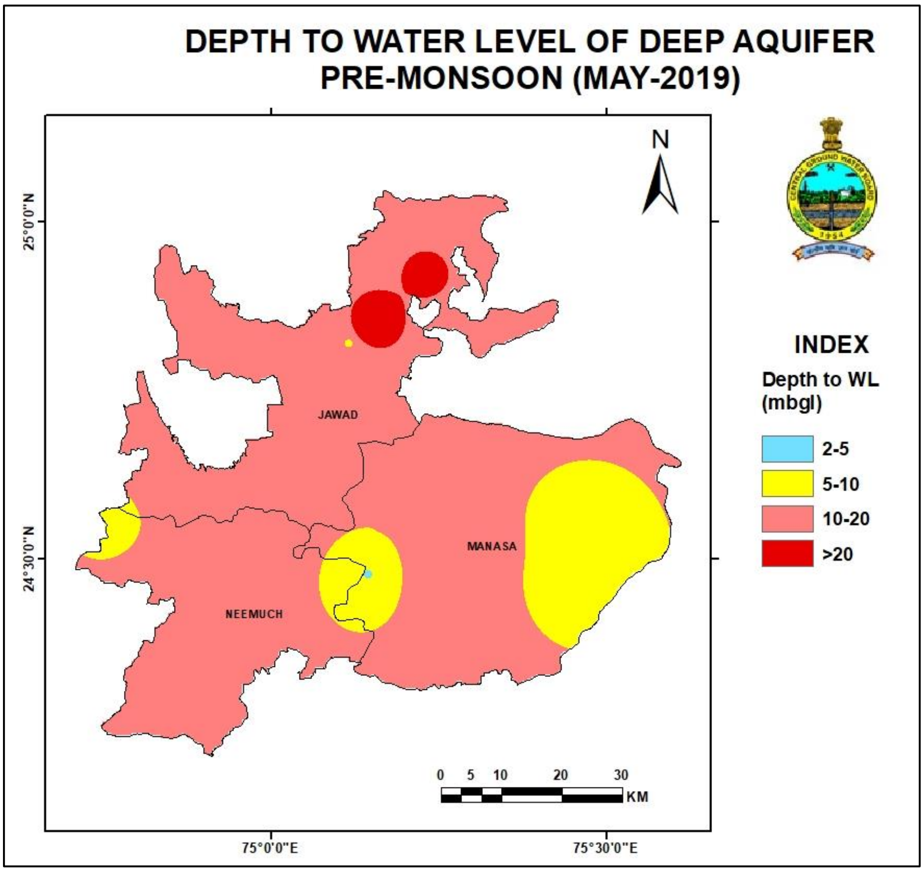

Fig.3.9:Pre-monsoon (May 2019) Depth to Water Level of Deep Aquifer

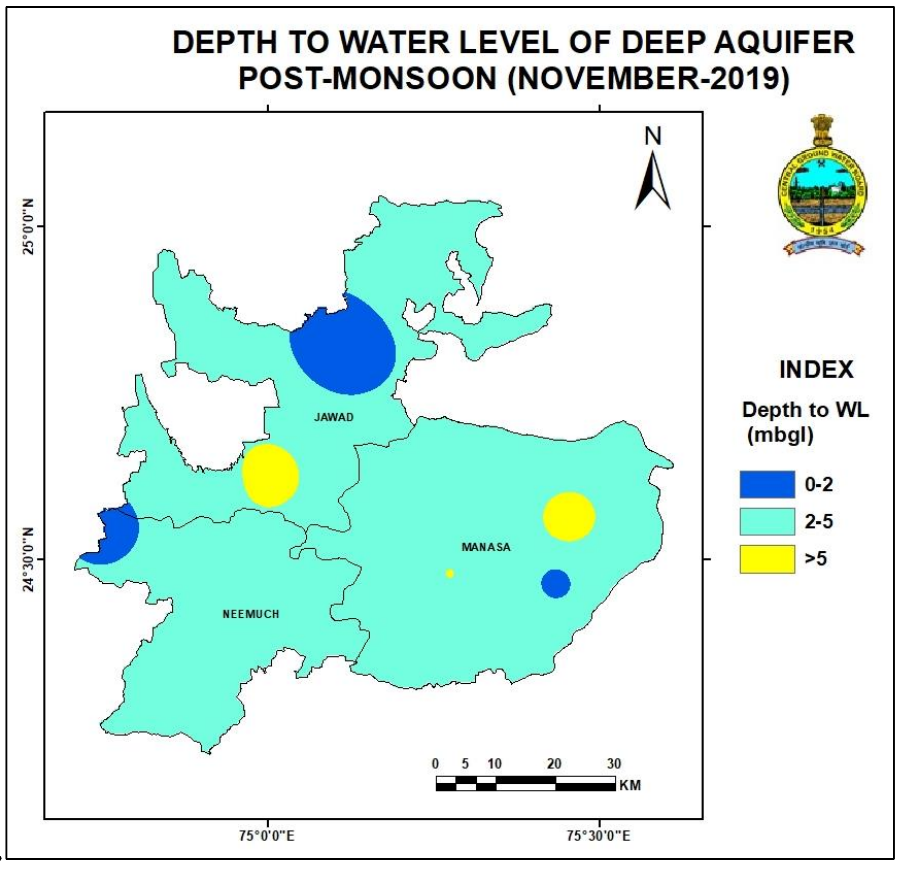

Fig.3.10: Post-monsoon (Nov 2019) Depth to Water Level of Deep Aquifer

3.3.1.2 Post-Monsoon (November, 2019)

The post-monsoon depth to water levels during November 2019 ranged between 0.5 (Ratangarh, Jawad block) to 6.21 mbgl (Morwan, Jawad block). The water levels between 2 to 5 mbgl are observed in major parts of the district. The water level between 0 to 2 mbgl and more than 5 mbgl are observed only in patches. The depth to water level map is given in **Fig.3.10**

3.3.1.3 Seasonal Water level Fluctuation

The water level measured during pre-monsoon (May 2019) and post monsson (Nov 2019) period was used to compute the seasonal fluctuation. The analysis of water level fluctuation data indicated that minimum water level fluctuation was observed at Besla, Manasablock (1.6 m) while maximum water level fluctuation was observed at Athwakheda, Jawad block (24.6 m). The water level fluctuations were grouped under three categories i.e., less, moderate and high and the % of wells in each category was analysed. The analysis is described in **Table.3.2**.

Table.3.2: Analysis of Water Level Fluctuation, Deep Aquifer

S. No.	Category	Fluctuation Range	% of Wells
4.	Less water level fluctuation	0 to 2 m	8%
5.	Moderate water level fluctuation	2 to 5 m	15%
6.	High water level fluctuation	>5 m	77%

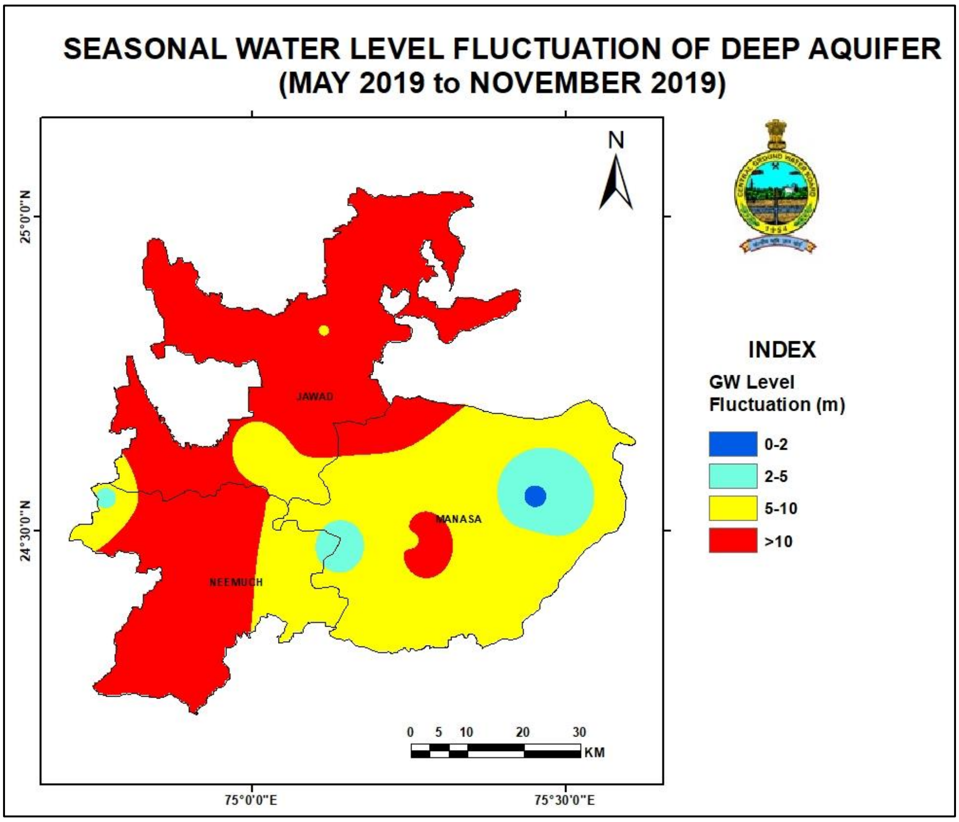

Fig.3.11: Seasonal Fluctuation of Water Level, Deep Aquifer

The analysis indicates that of 77% the wells are falling in high fluctuation indicating aquifer storage is not good, whereas moderate water level fluctuation is observed in 15 % wells and low water level fluctuation were observed in only 8 % wells. The seasonal fluctuation map is presented as **Fig.3.11** the perusal of map indicates that fluctuation between 5 to 10 meter and more than 10 meter is observed in major part of the district. 5 to 10-meter fluctuation is observed mostly in Manasa block while more than 10 meter is observed mostly in Neemuch and Jawad block.

The pre-monsoon, post monsoon water level and seasonal fluctuation for the year 2019 of deep aquifer is shown in the **Annexure.2**.

3.3.1.4 Long Water Level Trend (2012-21)

In order to study long term behavior of the water levels and also the effect of various developmental activities with time, the data for the period 2012-21 have been computed and analyzed.

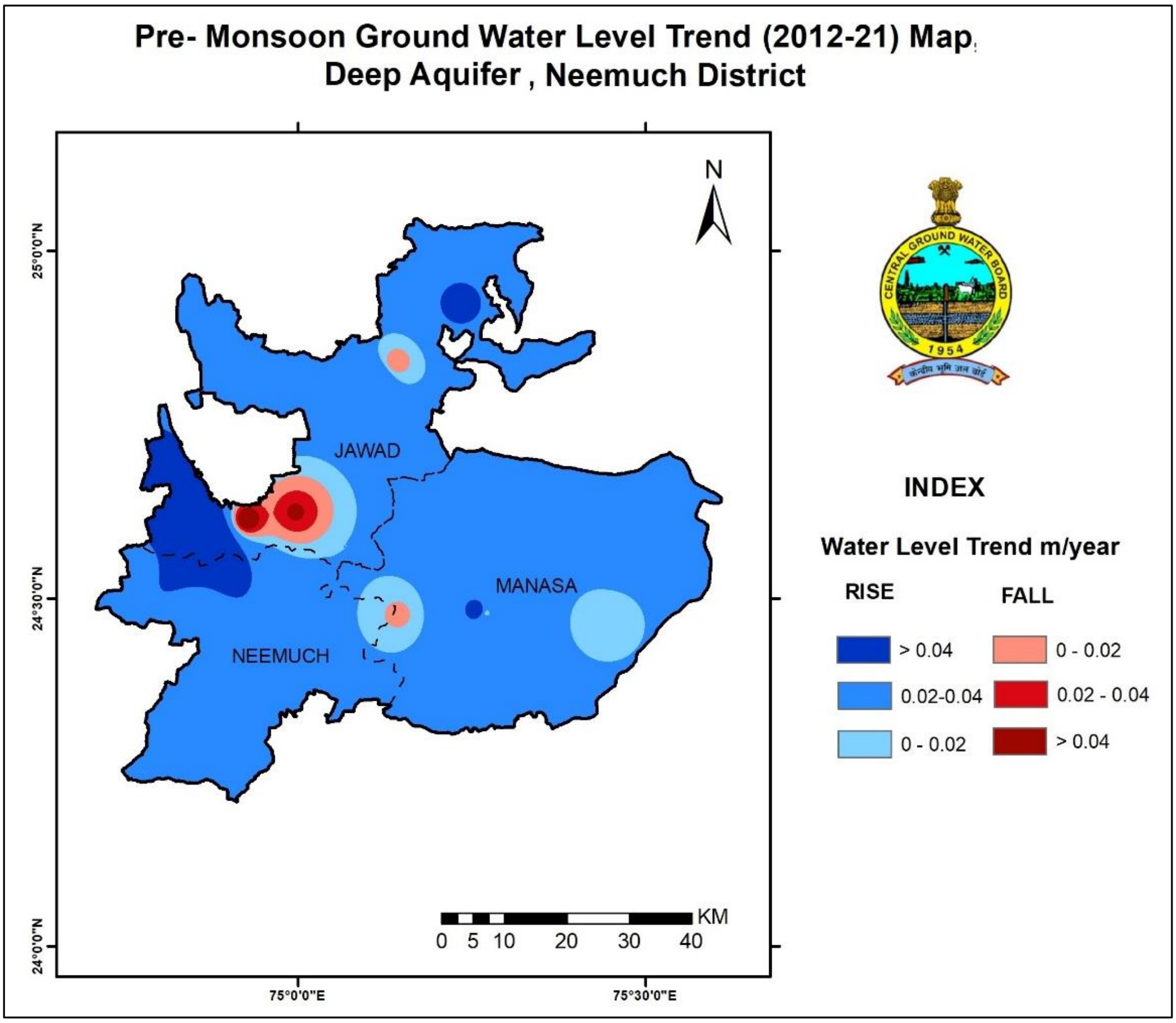

Fig.3.12: Pre-monsoon Water Level Trend (May 2012-21) of Deep Aquifer

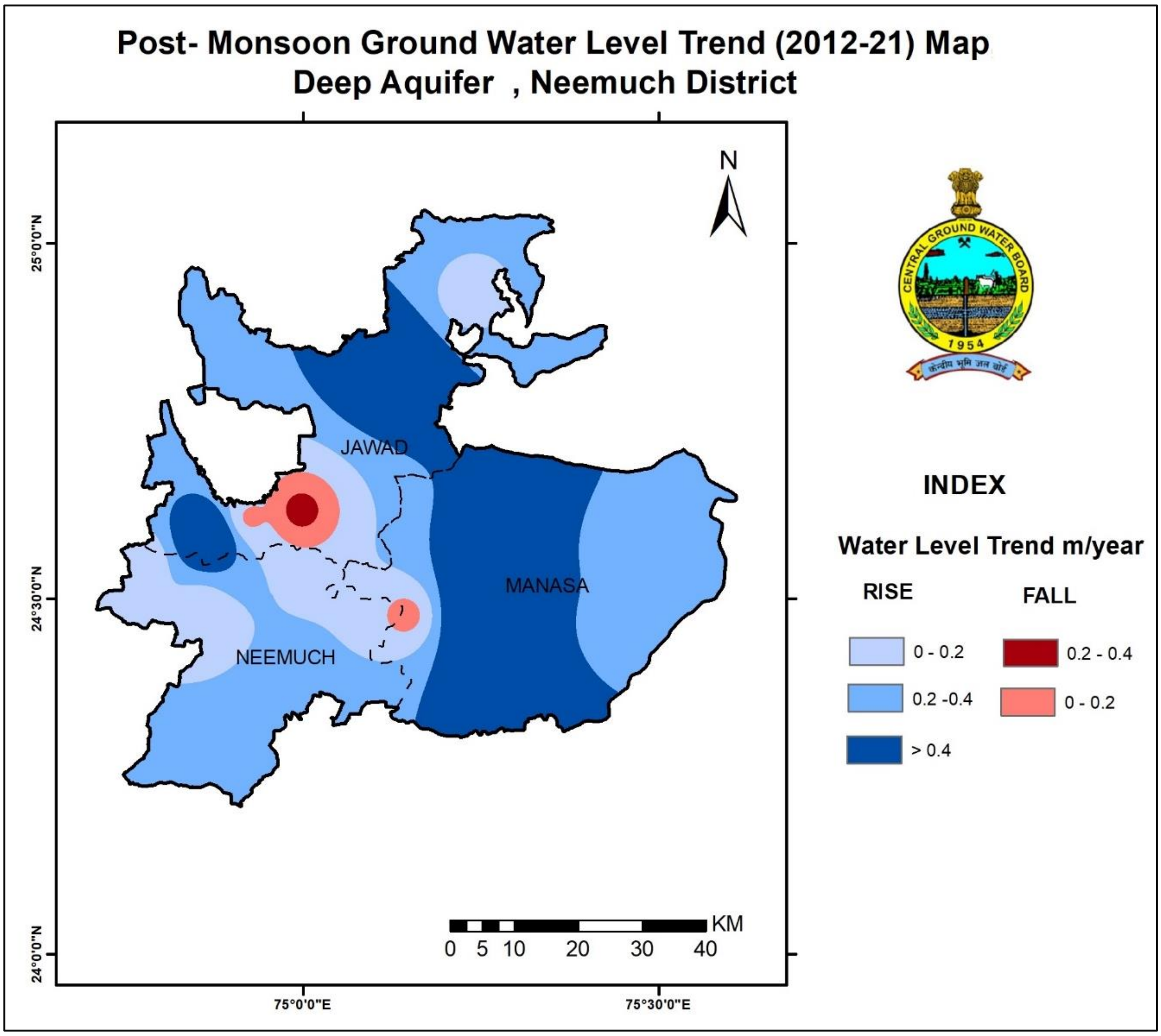

Fig.3.13: Post-monsoon Water Level Trend (Nov 2012-21) of Deep Aquifer

The decadal pre-monsoon water level trend is presented in the **Fig.3.12,** which indicates that during pre-monsoon period, more than 90 % of the area showing rising trend. Maximum rising trend is ranged between 0.02 to 0.04 m/yr. Only the western part of Manasa block, and the southern part of Jawad block is showing declining trend.

Similarly, the decadal post-monsoon water level is presented in the **Fig.3.13,** which indicates that about 95% of the area showing rising trend. Maximum rising trend is ranged between 02 to 0.4 m/yr. Only a small western part of the district showing declining trend in water levels.

3.4 GEOPHYSICAL STUDIES

Total 95 Vertical electrical sounding is conducted in Neemuch district. The conducted VES locations are plotted in **Fig.3.14.** From the interpreted VES data, it reveals that resistivity less than 120 ohm (**Ω**) m for the weathered formations (Weathered Basalt, weathered sandstone, weathered limestone) (1-30 mbgl), 3-150 **Ω** m for underlying fractured formations and greater than 350 **Ω** m for massive formations.

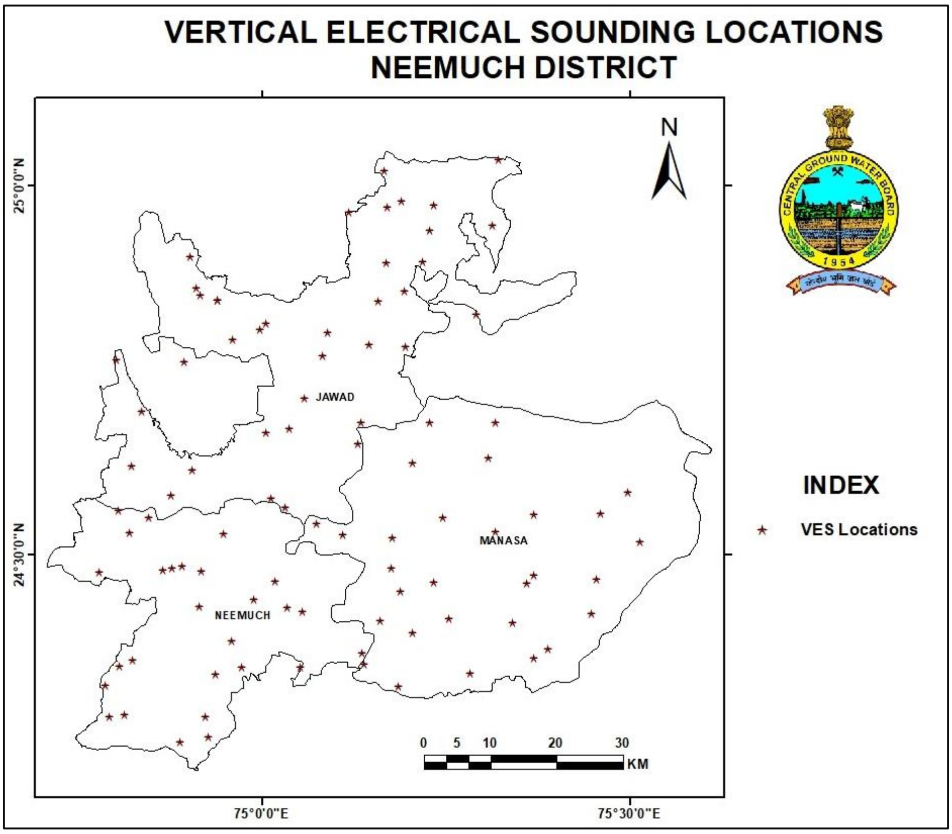

Fig.3.14: VES locations

Based on the interpretation of these data the thickness of weathered zone and soil layer maps are prepared and shown in the **Fig.3.15** and **Fig.3.16** respectively**.**

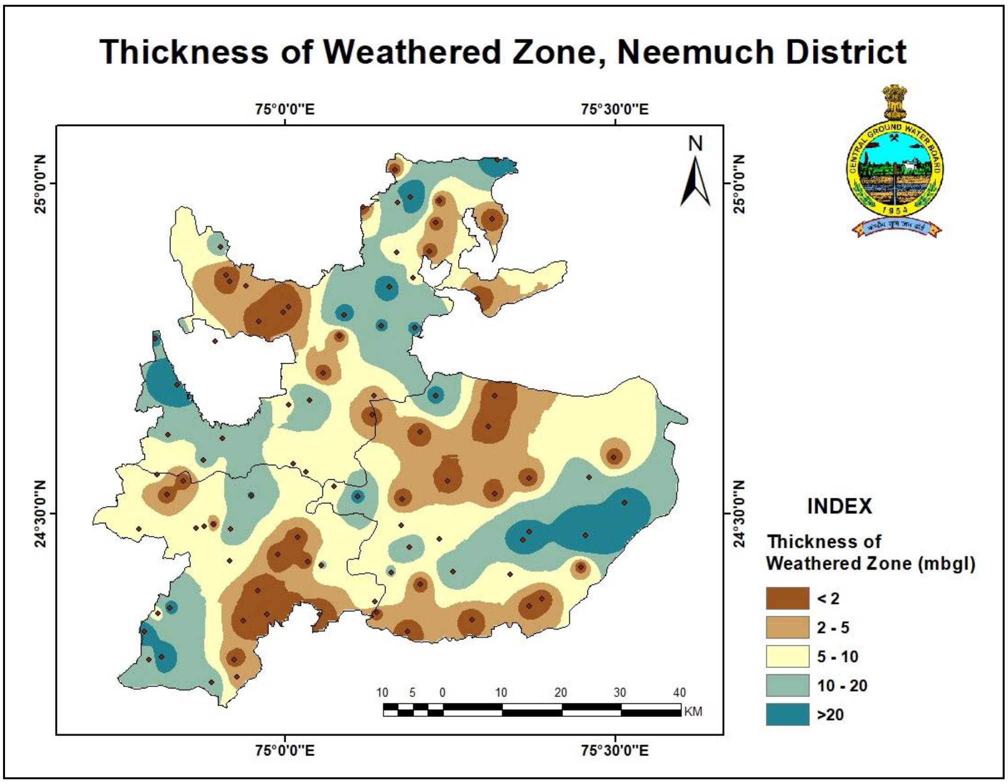

Fig.3.15: Weathered Zone thickness map

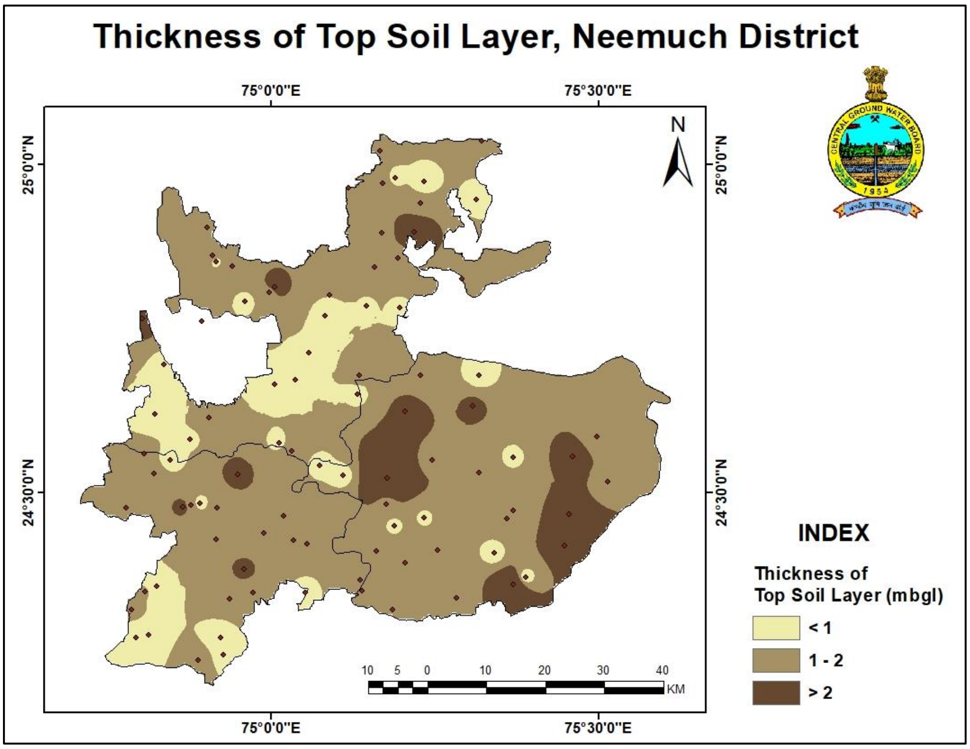

Fig.3.16: Top soil Layer thickness map

3.5 HYDRO CHEMICAL STUDIES

Water samples were collected from 24 Ground Water Monitoring Wells during May 2020 and monitored for chemical quality of ground water (phreatic aquifer) and their location is given in **Figure.3.3**. Detailed analysis of the chemical samples was carried out parameters namely: pH, Electrical Conductivity (EC), Carbonate, Bi-carbonate, Chloride, Fluoride, Nitrate, Sulphate, Phosphate, Total hardness, Calcium, Magnesium, Sodium and Potassium. The results of chemical data observed are given in **Annexure 4**.

3.5.1 Quality of Ground Water for Drinking Purpose

The ground samples that are collected are analysed, compared with Beureau of Indian Standard set for drinking water quality and ranges of different chemical constituents present in ground water are given in **Table 3.3**.

Table.3.3: Ranges of chemical constituents in Shallow aquifer

Constituents	Acceptable Limit	Permissible limit in the absence of alternate source	Aquifer – I (Shallow aquifer)		
			Min.	Max.	No. of samples above Permissible limit
pH	6.5	8.5	7.42	8.4	Nil
EC	-	-	770	3350	1
TH	200	600	165	1380	3
Calcium	75	200	16	226	1
Magnesium	30	100	24	198	3
Potassium	-	-	1.1	120	-

Constituents	Acceptable Limit	Permissible limit in the absence of alternate source	Aquifer – I (Shallow aquifer)		
			Min.	**Max.**	**No. of samples above Permissible limit**
Sodium	-	-	30	321	-
Carbonate	-	-	0	18	-
Bi-carbonate	200	600	67	653	1
Chloride	250	1000	35	592	Nil
Nitrate	-	45	7	315	12
Fluoride	1	1.5	0.24	1.68	2

The ground water samples from Neemuch district have varied range of pH from 7.42 to 8.40. As per BIS (IS 10500: 2012) recommendation, all the water samples have pH recorded within the permissible limits of 6.5 to 8.5, the maximum pH recorded in the water sample of Bhadana (8.40). The pH of ground water can be assessed as slightly to moderately alkaline in nature.

The electrical conductivity of ground water in Neemuch district ranged between 770 to 3350 µS/cm at 25°C and the maximum EC value at Kundaliya (3350 µS/cm at 25°C) villages. The electrical conductivity shows that the ground water is good to moderately saline in nature and at some locations. i.e. at Semali Chandrawat (2125 µS/cm at 25°C), Manasa (2670 µS/cm at 25°C) and Kundaliya (3350 µS/cm at 25°C) villages moderately saline. The EC contour map is shown in the **Fig.3.17**.

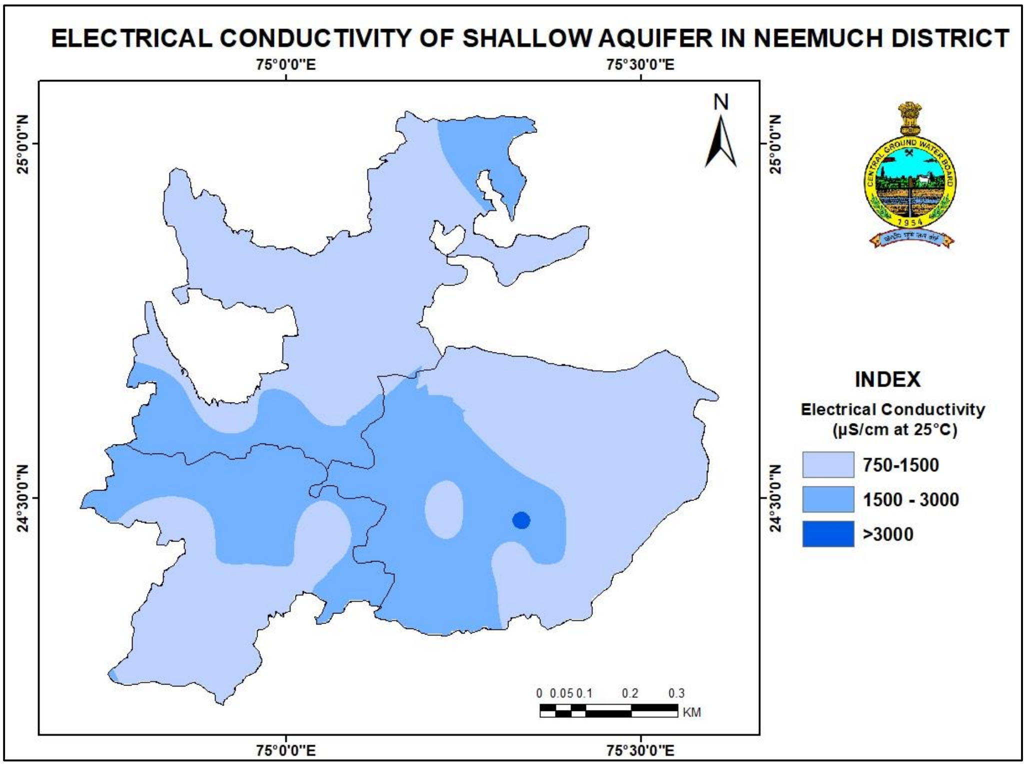

Fig.3.17: Electrical Conductivity in Shallow aquifer

The fluoride concentration was ranged in between 0.24 to 1.68 mg/l. In the district, fluoride concentration has been observed within the permissible limit of BIS recommendation i.e. 1.5 mg/l except Lalpura (1.56 mg/l) and Barlai (1.68 mg/l) villages. The distribution of fluoride concentration is shown in the **Fig.3.18**.

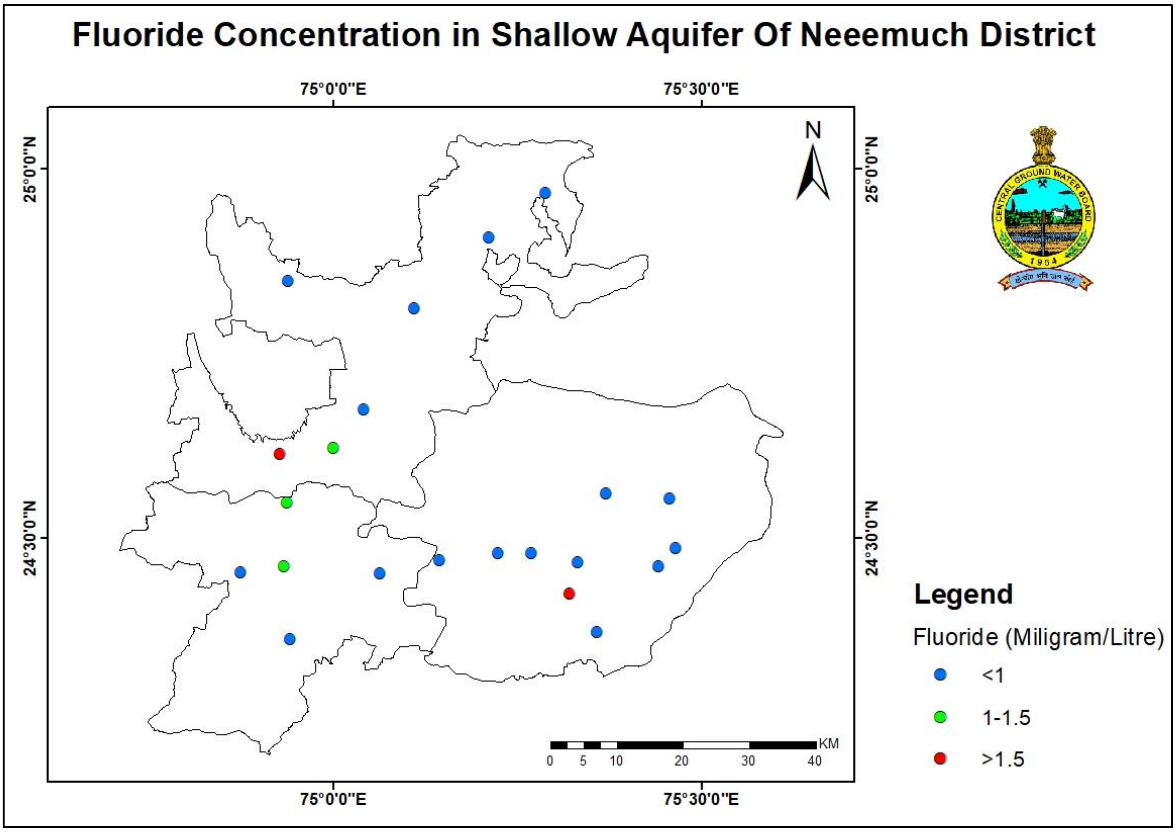

Fig.3.18: Distribution of Fluoride Concentration in Shallow aquifer

In the district, nitrate concentration in ground water ranged in between 7 to 315 mg/l. About 45.5% ground water samples recorded nitrate concentration within the acceptable limit of 45 mg/l and 54.5% water samples recorded more than 45 mg/l as per BIS recommendation. The high nitrate concentration has been recorded in ground water of Besla (52 mg/l), Kukreshwar (60 mg/l), Kacholi (75 mg/l), Jamalpura (87 mg/l), Morban1 (95 mg/l), Singoli (95 mg/l), Kundaliya (105 mg/l), Ratangarh (120 mg/l), Gota Pipliya (129 mg/l), Bhadana (130 mg/l), Girdola (175 mg/l) and Manasa (315 mg/l) villages. The distribution of nitrate concentratin is shown in the **Fig.3.19**.

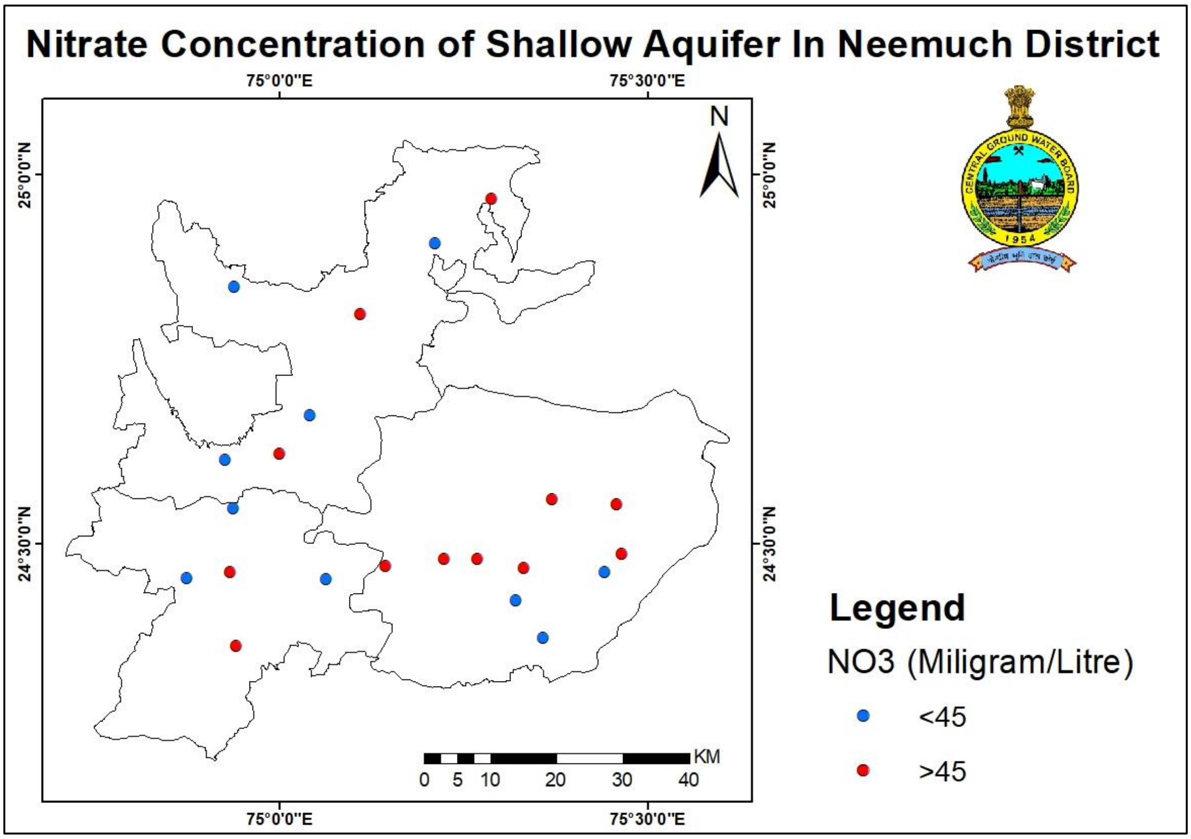

Fig.3.19: Distribution of Nitrate Concentration in Shallow aquifer

Total hardness of ground water in the study area ranged in between 165 to 1380 mg/l. The high concentration has been observed in the dug well of Girdola (870 mg/l) Manasa (900 mg/l) and Kundaliya (1380 mg/l) villages.

Piper diagram has three parts: a Cation triangle, an Anion triangle, and a Central diamond-shaped field. In Cation triangle, the relative percentages of the major cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}) are plotted. In Anion triangle the major anions (HCO_3^{-}+CO_3^{2-}, SO_4^{2-}, Cl^{-}) are plotted. These points are then projected to the central diamond shaped field. In the district, the piper diagram shows the ground water are Calcium chloride (4 nos.) i.e. permanent hardness types of water; Calcium-Bicarbonate (8 nos.) i.e. temporary hardness type of water; Mixed type (7 nos.); Sodium Chloride (2 nos.) i.e. saline type of water and Sodium-Bicarbonate (1 no.) i.e. alkali carbonate type of water.

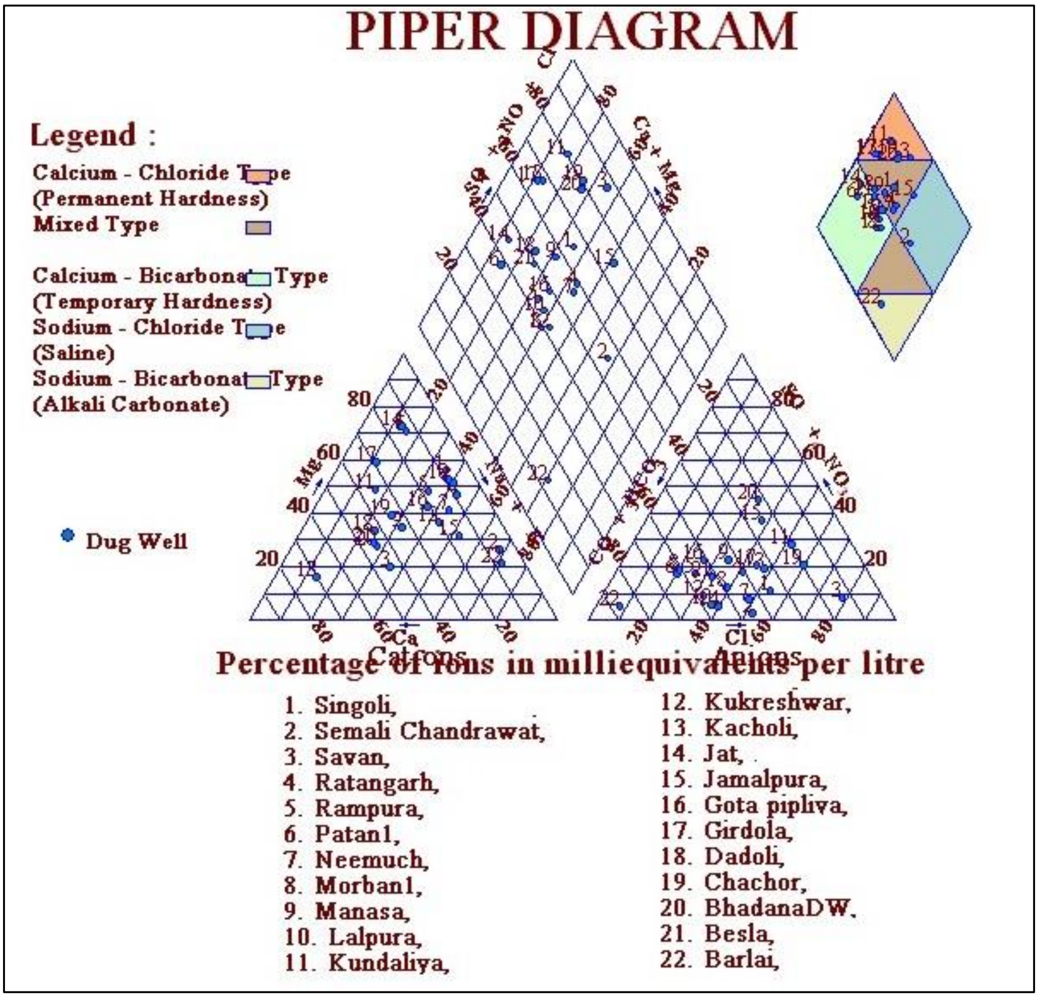

Fig.3.20: Hill Piper Diagram representing classification of water samples

3.5.2 Quality of Ground Water for Irrigation Purpose

In classification of water for irrigation purpose, it is assumed that the water will be used for irrigation purpose based upon its soil texture, infiltration rate, drainage and climate. Suitability of ground water for irrigation can be assesses using the indices for salinity, chlorinity and sodicity. Various indices such as SAR (**Sodium Absorption Ratio**), SSP (**Soluble Sodium Percentage**) %Na, KI (**Kelly's Index**), PI (**Permeability Index**), RSC (**Residual Sodium Carbonate**) are used for quality criteria for irrigation water. The ground samples that are collected are analysed, compared with the standard values of different indices and ranges of indices and its suitability for irrigation are given in **Table 3.4**. The formula for different indices and calculation of all the indices are given in **Annexure-5.**

The chemical data of all the water samples from Neemuch district is plotted on U.S. Salinity Laboratory diagram. In the district USSL diagram shows that 82% wells of study area are observed under C_3-S_1 Class (High Salinity & Low Sodium) which means that these waters can be used for irrigation purpose for most of the crops, 9% of total ground water samples fall under

C_3-S_2 class (High Salinity & Medium Sodium) whereas 9% of total ground water samples fall under C4-S1 class (Very High Salinity & Low Sodium). The water from C3-S2 and C4-S1 classes may be used for irrigation purpose under proper soil management

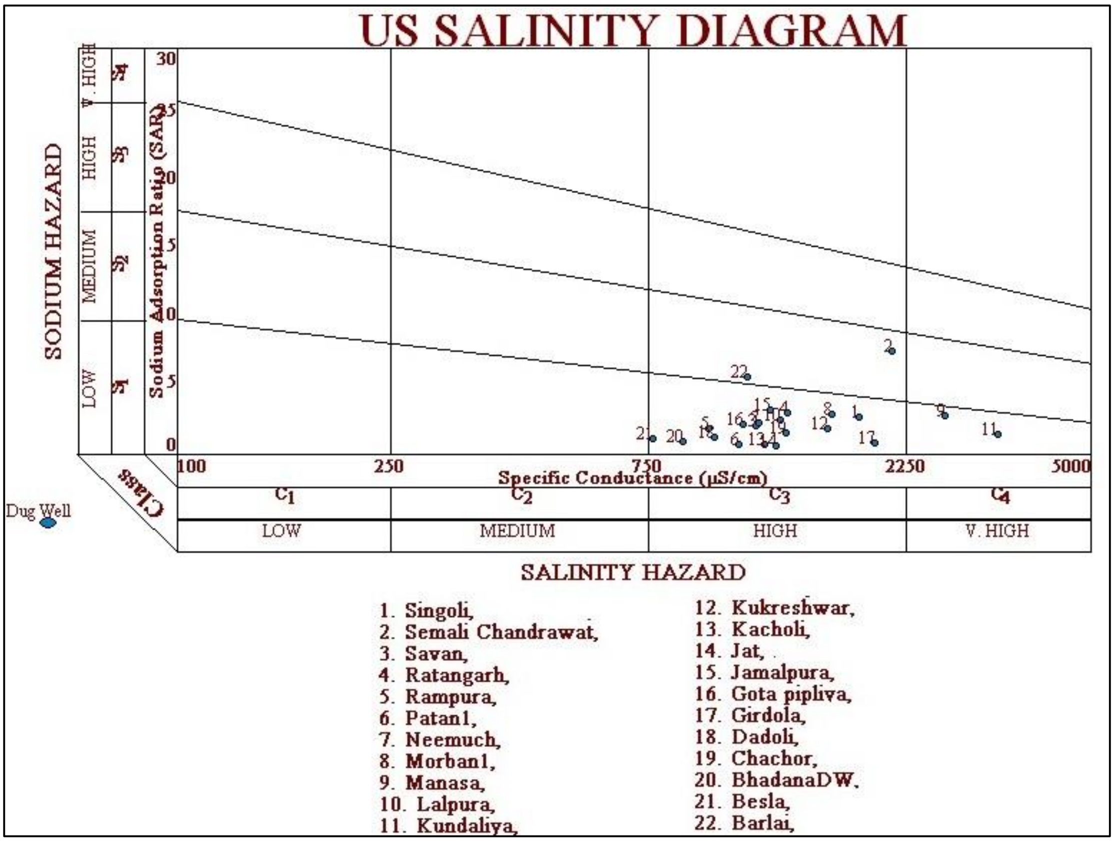

Fig.3.21: US Salinity Diagram

Table.3.4: Ranges of Indices and Suitability of Ground Water for irrigation

	Standards for Irrigation	Aquifer – I (Shallow aquifer)		
		Min.	Max.	No. of samples above MPL
Salinity (EC)	3000	770	3350	1
Soluble Sodium Percentage	50	10.45	69.08	3
Sodium Absorption Ratio	10	0.55	7.57	Nil
%Na	40-60	11.85	71.43	2
Residual Sodium Carbonate	1.25-2.50	-21.59	6.53	1
Kelly's Index	1	0.12	2.23	3
Mg2+ Ratio	50	18.68	87.27	18
Permeability Index	75	23.87	98.70	2

3.5.2 Quality of Ground Water for Industrial Purpose

Ground water quality needs to be assessed with reference to its usefulness for industrial purposes as majority of the industries consume huge quantities of water in various processes, water with in specific quality is a must to protect the necessary machinery from scaling or corrosion effects. The Corrosivity ratio (CR) is calculated for all the samples collected during pre-monsoon. The CR value of water with less than or equal to 1 is considered good whereas more than 1 indicates corrosive nature and is not fit for transportation through metal pipes (Ryner 1944; Raman 1985) and it is not suitable for industrial or domestic purposes. The CR values for all the samples is calculated and values are less than 1, so the Ground water of shallow aquifer in Neemuch district is suitable for industrial purpose. The calculation of Corrosivity ratio (CR) are given in **Annexure-6.**

3.6 3-D AND 2-D AQUIFER DISPOSITION

The data generated from ground water monitoring wells, exploratory and observation wells, various thematic layers was utilized to decipher the aquifer disposition of the area. This particularly includes the information on geometry of aquifers and hydrogeological information of these aquifers. In the area the two aquifer systems have been deciphered as listed below:

a. **Aquifer –I (Shallow Aquifer)**
b. **Aquifer – II (Deeper Aquifer)**

3.6.1 Fence Diagram and 3D model

As the district is covered with hard rocks, the thickness of the aquifers is limited. The weathered formations generally form the shallow aquifer, which are extends maximum up to the depth of 30m. The fractured /jointed Deccan trap basalt, Vindhyan Sandstone, Shale, Limestne form the deeper aquifer. The fence diagram and 3-D representation indicating the disposition of various aquifers is presented in **Fig.3.22** and in **Fig. 3.23** respectively**.** The disposition of Aquifer-I and Aquifer-II and other geological units can be observed in the Fence and 3D diagram.

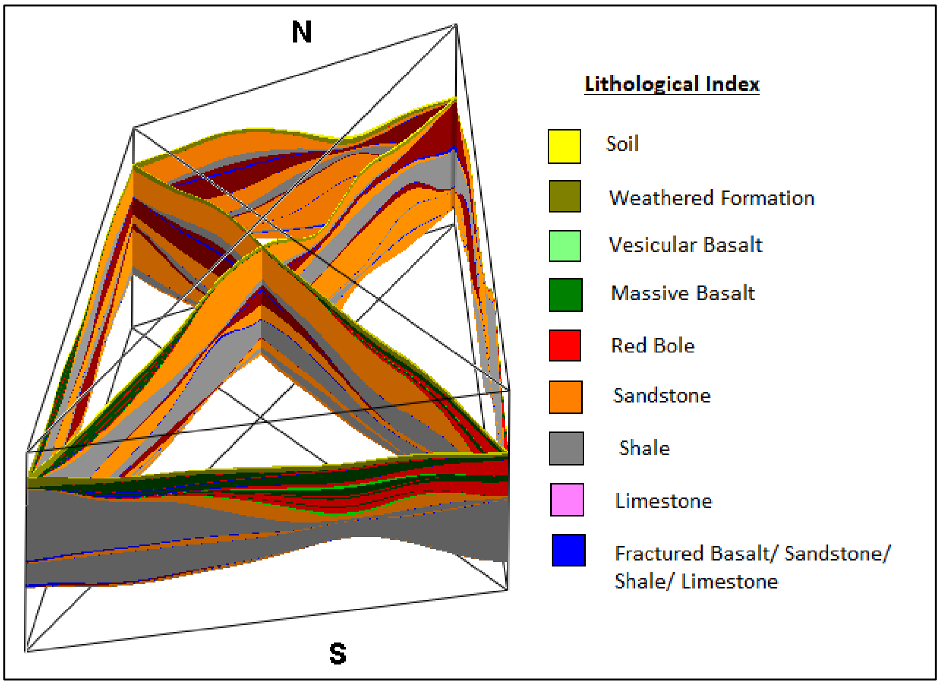

Fig.3.22: Fence Diagram, Neemuch District

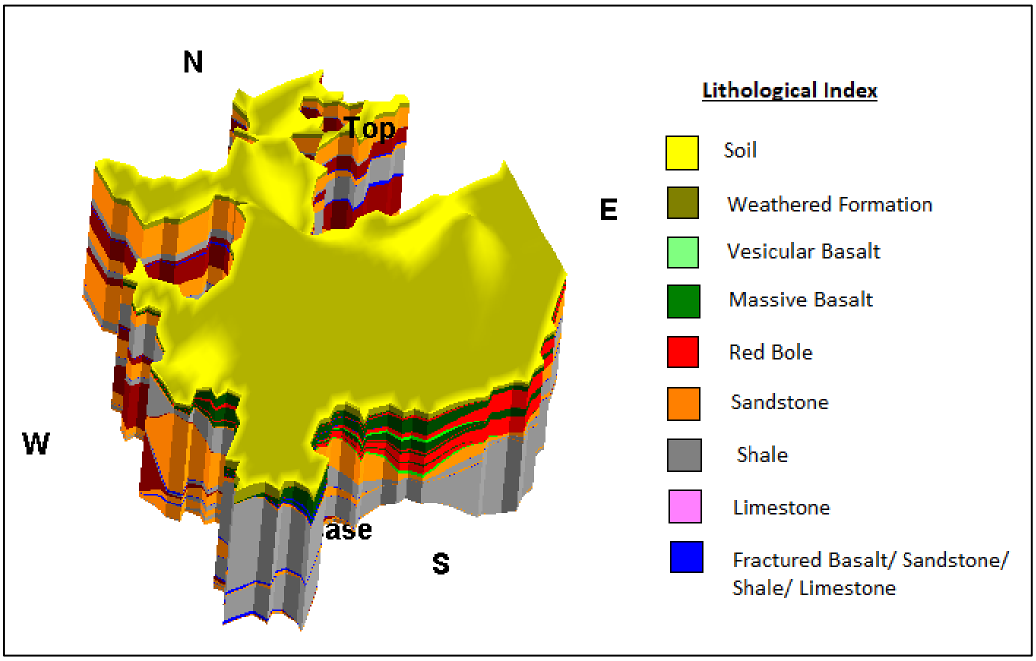

Fig.3.23: 3D Representation of Aquifers, Neemuch District

3.7 AQUIFER CHARACTERISTICS

Deccan trap Basalt present in the district comprises two distinct units viz, upper vesicular unit and lower massive unit. The massive basalt is hard, compact and does not have primary porosity and is impermeable. Weathering, jointing and fracturing induces secondary porosity in massive unit of basalt. In vesicular basalt, when vesicles are interconnected constitutes good primary porosity and when the vesicles are filled/ partly filled the porosity is limited. Ground water occurs under phreatic/ unconfined to semi-confined conditions in basalts.

Vindhyan Sandstone, Shale and Limestone also don't have primary porosity and is impermeable. So the aquifers formed when the rock is weathered, fractured and jointed. Based on the ground water exploration and monitoring carried out in the Neemuch district, the following two types of aquifers can be demarcated and the details are given below in **Table 3.5**.

Table.3.5: Aquifer Details of Shallow and deep Aquifer

Major Aquifer	**Basalt / Sandstone /Limestone/Shale**	
Type of Aquifer	Aquifer-I	Aquifer-II
Formation	Weathered Basalt/Sandstone/Limestone	Jointed / Fractured Basalt/Sandstone/Limestone
Depth of Occurrence (mbgl)	1 to 30	30 to 200
SWL (mbgl)	2.3 to 18	3 to 32
Weathered / Fractured rocks thickness (m)	2 to 14	0.5 to 17
Fractures encountered (mbgl)	Upto 30	Upto 200
Yield	-	Up to 3.28 lps
Transmissivity		Up to 45 m^2/day
Suitability for drinking/ irrigation	Suitable for both drinking and agriculture, except high Nitrate at places	Suitable for both drinking and agriculture, except high Nitrate and Fluoride at places

4. GROUND WATER RESOURCES

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. 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.

4.1 DYNAMIC GROUND WATER RESOURCES

The ground water resource assessment has been carried out for Neemuch district and the salient features of the resources are described below**.**

As per the Dynamic Ground Water Resource 2020, the overall contribution of rainfall (both monsoon & non-monsoon) recharge to District's total annual ground water recharge is 70.22 % and the share of recharge from 'Other sources' viz. canal seepage, return flow from irrigation, recharge from tanks, ponds and water conservation structures taken together is 29.78. (**Fig.4.1**).

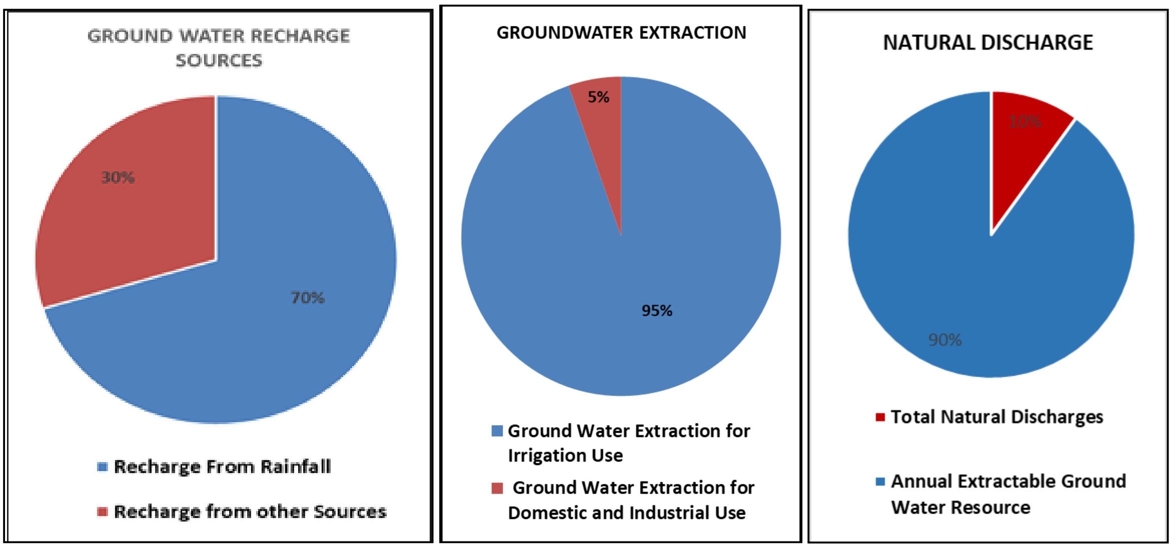

Fig.4.1: Ground Water Resource and Extraction Scenario

Total annual recharge from all sources in the district is of the order of 425.56 mcm. Total unaccounted natural discharge in the district is of the order of 42.56 mcm. The total natural discharge is about 10% of the total annual Groundwater recharge. The Annual Extractable Ground Water Resource is 383 mcm, which is 90% of the total annual Groundwater recharge (**Fig 4.1**)

Table.4.1: Groundwater Recharge

Block	Recharge from Rainfall-Monsoon Season (mcm)	Recharge from Other Sources-Monsoon Season (mcm)	Recharge from Rainfall-Non Monsoon Season (mcm)	Recharge from Other Sources-Non Monsoon Season (mcm)	Total Annual Ground Water Recharge (mcm)	Total Natural Discharges (mcm)	Annual Extractable Ground Water Resource (mcm)
Jawad	93.69	5.60	0.00	22.39	121.69	12.17	109.52
Manasa	92.50	29.43	0.00	33.16	155.09	15.51	139.58
Neemuch	112.62	7.80	0.00	28.36	148.78	14.88	133.90
District Total	**298.81**	**42.83**	**0.00**	**83.92**	**425.56**	**42.56**	**383.00**

Total extraction of ground water for all uses in district is calculated as 353.90 mcm. From the **Table.4.2**, it is seen that extraction for irrigation accounts for more than 95% of total ground water extraction, whereas extraction for domestic & industrial supply accounts for meager 5% of the total ground water extraction in the district (**Fig 4.1**).

Table.4.2: Total Groundwater extraction

Block	Ground Water Extraction for Irrigation Use (mcm)	Ground Water Extraction for Domestic Use (mcm)	Total Extraction (mcm)	Stage of Ground Water Extraction (%)	Categorization
Jawad	104.38	5.47	109.85	100.30	**Over_exploited**
Manasa	101.76	5.37	107.13	76.75	**Semi_critical**
Neemuch	128.84	8.09	136.92	102.25	**Over_exploited**
District Total	**334.97**	**18.93**	**353.90**	**92.40**	

The overall stage of groundwater extraction in the district is 92.40 %. The blockwise stage of groundwater extraction is given in the **Table.4.2**. The Jawad and Neemuch block are categorised as 'Over_exploited' and Manasa block as 'Semi_critical'.

5. GROUND WATER RELATED ISSUES

In the district there are some Groundwater issues both in quantity and quality wise. All the issues are described as follows.

5.0 OVER-EXPLOITATION

For the assessment year the 2020 the stage of extraction of Neemuch district is 92.4 % and in 2017 is was 87.44%. The stage of extraction of the district are increasing in every year. The increasing stage of Ground water extraction of the district is presented as histogram in the **Fig.5.1** respectively.

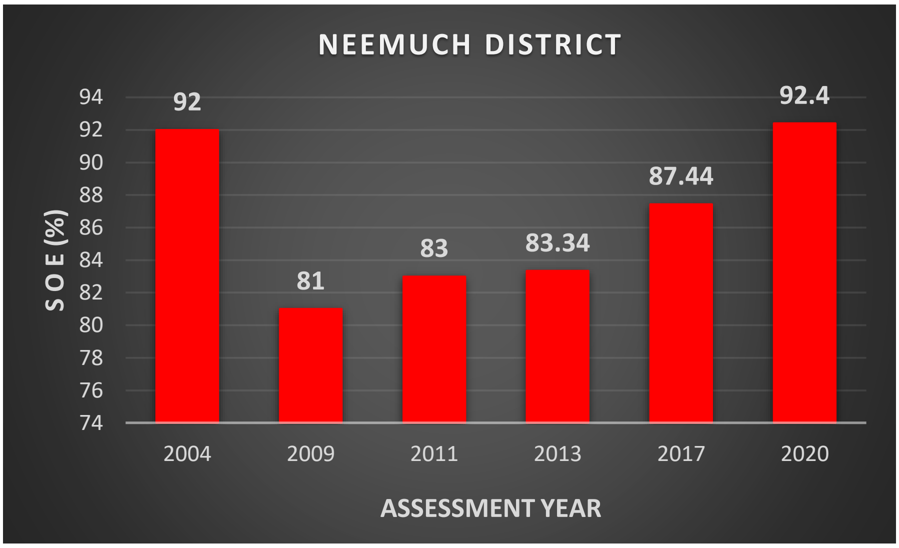

Fig.5.1: Assessment year wise Stage of Ground Water Extraction

5.2 DECLINING WATER LEVEL

The decline in the water level both in pre and post monsoon is observed in major part of the district. The pre and post monsoon declining trend of one hydrograph presented in the **Fig.5.2**.

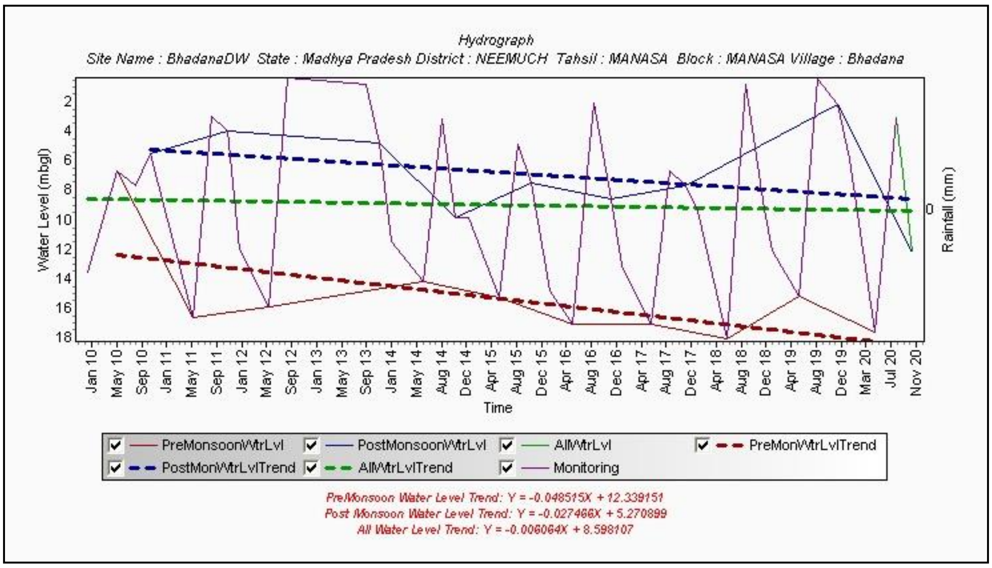

Fig.5.2:Hydrograph, Village-Bhadana, Block-Manasa

5.2 LOW GROUND WATER POTENTIAL / LIMITED AQUIFER THICKNESS / SUSTAINABILITY

The district is covered mostly with hard rock i.e. Deccan trap basalt and Vindhyan formations. These hard rocks don't have primary porosity and are impermeable. So they can form aquifers only when they are weathered, fractured and jointed. In the district the depth of weathering in shallow aquifer and aquifer thickness in deeper aquifers are limited. Sustainability of both the aquifers is very low.

5.3 INFERIOR GROUND WATER QUALITY AT SOME PLACES

In some parts of the district there is higher concentration nitrate, fluoride and total hardness are reported. The details about groundwater quality of shallow aquifer have been already discussed in **Chapter-3** and the block wise quality related issues will be described in the **part-II**.

6. MANAGEMENT STRATEGIES

As discussed in previous chapter, there are many groundwater related issues owing to many socio-economic and hydrogeological reasons. The groundwater management plan for Neemuch district has been made keeping in view the area specific details and includes the strategies like enhancing the ground water resources through the construction of artificial recharge structures such as percolation tanks, check dams/nala bunds, recharge shafts, etc. and ensuring water use efficiency through maintenance/renovation of existing water bodies/water conservation structures. Also, adoption of micro irrigation technique such as sprinkler irrigation has been proposed, that would not only conserve ground water resources by reducing the draft, but would also increase the net cropping area thereby augmenting the agricultural economy of the district. The uneven distribution of groundwater availability and its utilization indicates that a single management strategy cannot be adopted and requires integrated hydrogeological aspects along with socio-economic conditions to develop appropriate management strategy.

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

1. Supply side measures
2. Demand side measures

6.1 SUPPLY SIDE MEASURES

The thickness of available unsaturated zone (below 3 m bgl) of above categories is estimated by considering the different ranges of water level. The total volume of unsaturated zone is calculated. This volume was then multiplied by average specific yield on area specific basis to arrive at the subsurface storage potential i.e, 200.44 mcm. After assessing the volume of water required for saturating the unsaturated zone (subsurface storage potential), the actual requirement of source water is estimated based on the experience gained in the field experiments. An average recharge efficiency of 75% of the individual structure is only possible. Therefore, to arrive at the total volume of actual source water required at the surface, the volume of water required for artificial recharge is calculated by multiplying the estimated storage potential with 1.33 (i.e. reciprocal of 0.75) which is 266.58 mcm. (**Table.6.1)**

Table.6.1: Supply Side management plan, Neemuch district

Block	Area (Sq.KM)	Normal Annual Rainfall (mm)	Average Post-monsoon Water Level (m bgl)	Suitable Area for AR (sq.km)	Un-Saturated Zone (m)	Specific Yield	Sub-surface storage (mcm) Col6x7x8	Sub-Surface water required (mcm) Col 9x1.33	Runoff /sq.km	Runoff (mcm)	Non Commuted Runoff (mcm)	Available water required/ Non Commuted Runoff (mcm)
Jawad	1619.44	854.85	3.91	1569.44	0.91	0.02	28.51	37.92	0.16	262.3	78.70	37.92
Manasa	1496	854.85	5.58	1153.00	2.58	0.02	59.52	79.16	0.16	242.4	72.71	72.71
Neemuch	1085	854.85	8.43	1035.00	5.43	0.02	112.41	149.51	0.16	175.8	52.73	52.73
District Total	4200.44						**200.44**	**266.58**		**680.47**	**204.14**	**163.35**

Table.6.2: Total Cost estimate, Neemuch district

Block	No of percolation tanks Proposed	No of Check Dams Proposed	No of nala bunds/cement plugs Proposed	no of village ponds/ Farm Ponds Proposed	cost of percolation tanks in crores @0.20 crores/ PT	cost of Check Dams in @0.06 crores/ CD	Cost of Recharge shaft in each RS @ 0.01crores per RS	cost of nala bund/cement plugs in @0.01 crores per NB	cost of village pond in @0.025 crores per VP
Jawad	57	498	567	259	11.40	29.88	4.98	5.67	6.48
Manasa	62	1048	1089	222	12.40	62.88	10.48	10.89	5.55
Neemuch	91	694	779	189	18.20	41.64	6.94	7.79	4.73
District Total	**210**	**2240**	**2435**	**670**	**42**	**134.4**	**22.4**	**24.35**	**16.75**

The availability of non-committed source water is one of the main requirements for any artificial recharge scheme. The rainfall received during southwest monsoon between June and September is the principal source of water in Neemuch district. The surplus non-committed monsoon runoff can be utilized as source water for artificial recharge schemes. The surface water resources have been calculated block wise by considering Strange's Table showing depth of runoff as percentage of total monsoon rainfall and yield of run off per square kilometer in mcm for average catchment.

The total water requirement to recharge unsaturated zone is 266.58 mcm. Total available non-committed runoff is 204.14 mcm. In some of the blocks the non-committed runoff is more than the water requirement, whereas, in other blocks it is less than requirement. Considering the water requirement and availability, 163.35mcm water is proposed to be utilised for artificial recharge.

The district is covered mainly with hard rocks and in hard rock areas the surface spreading techniques consisting of percolation tanks and Check dams /cement plugs/nala bunds along with recharge shafts are most appropriate. Other structures like contour trenches and gabion structure etc. may also be taken up side-by-side, which would be more appropriate for soil and moisture conservation. The underground Bhandaras or sub surface dykes are ground water conservation structures and hence may be taken up at site specific location to conserve the ground water at technically suitable locations.

The storage capacity of recharge structure was worked out based on the findings of various artificial recharge studies under taken in Madhya Pradesh. Depending upon the rainfall pattern during the monsoon season, 3 to 4 fillings of the structures are considered to arrive at the storage capacity of the structure:

- A percolation tank of 0.066 mcm capacity (single filling) will actually store more than 300% due to multiple fillings during monsoon. This will have gross storage capacity of 0.2 mcm.
- A check dam with recharge shaft, of 0.01 mcm capacity (single filling) will actually store more than 300% due to multiple filling in monsoon. This will provide gross storage of 0.030 mcm. The recharge shaft will facilitate additional recharge to the ground water regime.
- A nala bund, cement plug will store more than 300% due to multiple filling in monsoon and it will provide gross storage of 0.01 mcm.
- A Village pond will store more than 300% due to multiple filling in monsoon. This will provide gross storage of 0.01 mcm in multiple fillings.

The number of recharge structures as mentioned above, required to store and recharge the ground water reservoir has been worked out as follows:

No. of structures = $\frac{\textbf{Total surface water considered}}{\textbf{Average gross capacity of PT/CP/CD/NB}}$
(Considering multiple fillings)

The amount of surface water considered for planning the artificial recharge is 163.35 mcm (**Table.6.1**). Based on the field situation it has been considered that 35% storage would be through percolation tank, 45% by check dams, 15% by nala bunds and cement plug, and remaining 5% by Renovation of village ponds/form pond. Accordingly, 35% of it i.e. 57.17 mcm will be stored in percolation tanks, 45% of it i.e., 73.51 mcm to be stored in check dams and Recharge Shaft, 15% of it i.e., 24.40 mcm to be stored in nala bunds and Cement plugs, remaining 5% i.e., 8.17 mcm to be stored in Village ponds.

The Existing structure constructed by MGNREGA has been subtracted to arrive at the number of structures proposed for Artificial Recharge. 210 percolation tanks, 2240 check dams, 2435 nala bunds and 670 Village ponds (in each village) are proposed in the identified areas of Neemuch district (**Table.6.2**).

One recharge shaft in each check dam has been proposed for effective recharge through these structures. Therefore, 2240 recharge shafts are proposed. The percolation tanks should be constructed on second and third order drainage, on favorable hydrogeological and physiographical locations. The nala bunds/cement plugs can be constructed on first or second order of drainage in hard rock areas.

Based on the experiences gained from central sector scheme, "Study of artificial recharge to Ground Water", it is observed that the cost of recharge schemes depends upon the site-specific conditions. The average cost of construction of a percolation tank is considered around Rs. 20 lakhs. The cost of masonry check dam considered is Rs. 6 lakhs. The average cost of one recharge shaft considered is Rs. 1 lakh. The average cost of nala bund considered is Rs 1 lakhs and average cost of renovation/ new village pond/farm pond is 2.5 lakhs. However, the costs may vary from area to area depending upon site-specific conditions. The total cost of these structures will be **239.9** Crores (**Table.6.2**).

6.1 DEMAND SIDE MEASURES

However, considering the low storage potential of hard rock aquifer in the area the above ground water development plan should also be coupled with ground water augmentation plan, so that there is no stress on ground water regime of the area. Micro irrigation technologies such as drip and sprinkler systems are being increasingly promoted as technological solutions for achieving water conservation. Micro irrigation comprises two technologies—drip and sprinkler irrigation. Both saves conveyance losses and improve water application efficiency by applying water near the root-zone of the plant some benefits of the micro-irrigation have been listed below:

- The increase in yield for different crops ranges from 27 per cent to 88 per cent and water saving ranges from 36 per cent to 68 per cent vis-à-vis conventional flow irrigation systems (Phansalker and Verma, 2005).
- It enables farmers to grow crops which would not be possible under conventional systems since it can irrigate adequately with lower water quantities.
- It saves costs of hired labour and other inputs like fertilizer.
- It reduces the energy needs for pumping, thus reducing energy per ha of irrigation because of its reduced water needs. However, overall energy needs of the agriculture sector may not get reduced because most farmers use the increased water efficiency to bring more area under irrigation.

Adoption of Sprinkler irrigation techniques would save 30% of gross ground water extraction for irrigation. Also, the 60% of additional recharge created by construction of artificial recharge structures can be utilized to increase the total cropping area, thereby enhancing the productivity and economy of the district. A summarized table for the demand side management is given in the **Table.6.3**.

Table.6.3: Demand Side management plan, Neemuch district

Annual Extractable GW Resource (mcm)	**MCM**	**383.00**
Total Extraction for all uses		**353.90**
Stage of GW Extraction	**%**	**92.40**
Saving by Sprinkler	**MCM**	**100.49**
Additional recharge created by AR		**163.35**
After intervention of AR Structure Net GW AvL.		**546.35**
After intervention of AR Structure & utilisation of 60% of additional GW created.		**98.01**
Extraction after sprinkler & additional area created for agriculture		**351.42**
Stage of GW Extraction W/O GW use for additional Area Irrigation	**%**	**64.32**

After successful implementation of supply side and demand side management plan the stage of extraction is expected to improve by nearly 28% i.e. from **92.40 %** to **64.32 %.**

The block wise demand side and supply side management plan is described in detail in **Part-II**

7. BLOCKWISE AQUIFER MAPS AND MANAGEMENT PLAN

7.1 JAWAD BLOCK

7.1.1 SALIENT INFORMATION

<table>
<tr><td colspan="3">Area</td><td>Sq Km</td><td>1619.44</td></tr>
<tr><td colspan="3">Normal Rainfall</td><td>millimetre</td><td>854.9</td></tr>
<tr><td colspan="2" rowspan="7">Land use and Agriculture</td><td>Principal crops</td><td colspan="2">Soyabean, Groundnut, Til, Ramtil, Linseeds, Mustard, Rice, Wheat, Jowar, Maize,</td></tr>
<tr><td>Gross cropped area</td><td rowspan="3">Sq Km</td><td>565.68</td></tr>
<tr><td>Net sown area</td><td>496.16</td></tr>
<tr><td>Area sown more than once</td><td>69.51</td></tr>
<tr><td>Cropping intensity</td><td>%</td><td>114%</td></tr>
<tr><td>Area under forest</td><td rowspan="2">Sq Km</td><td>431.04</td></tr>
<tr><td>Area under Waste land</td><td>216.48</td></tr>
<tr><td colspan="2" rowspan="2">Data Utilised</td><td>Monitoring Wells for Water Level</td><td></td><td>Dugwell -8 , Piezometer-6</td></tr>
<tr><td>Monitoring Wells for Quality</td><td></td><td>Dugwell -8</td></tr>
<tr><td rowspan="4">Water level Behaviour</td><td rowspan="2">Shallow</td><td>Pre-monsoon WL _2019</td><td rowspan="4">mbgl</td><td>Min-6.1, Max-37</td></tr>
<tr><td>Post-monsoon WL _2019</td><td>Min-0.9, Max-8.54</td></tr>
<tr><td rowspan="2">Deep</td><td>Pre-monsoon WL _2019</td><td>Min-9.35, Max-26.4</td></tr>
<tr><td>Post-monsoon WL _2019</td><td>Min-0.64, Max-6.21</td></tr>
</table>

7.1.2 AQUIFER DISPOSITION

Major Aquifer	Basalt/ Sandstone/Limestone/Shale	
Type of Aquifer	Aquifer-I	Aquifer-II
Formation	Weathered Basalt/Sandstone/Limestone/Shale	fractured/ Jointed Sandstone/Limestone/Shale
Depth of Occurrence (mbgl)	1 to 30	30 to 200
Weathered / Fractured rocks thickness (m)	0.5 to 15	0.5 to 3
Fractures encountered (mbgl)	Upto 30	Upto 200
Yield	-	Up to 2 lps

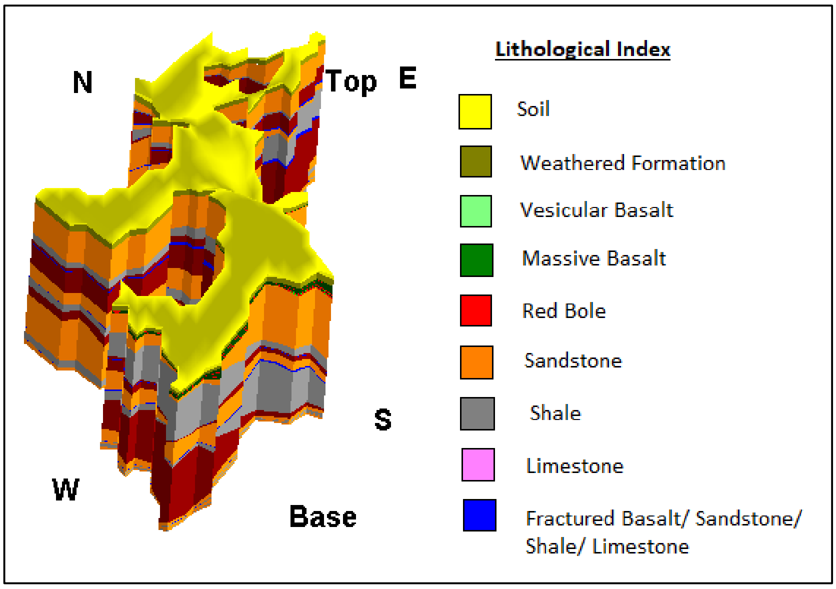

Fig.7.1:3-D Lithological Model, Jawad Block

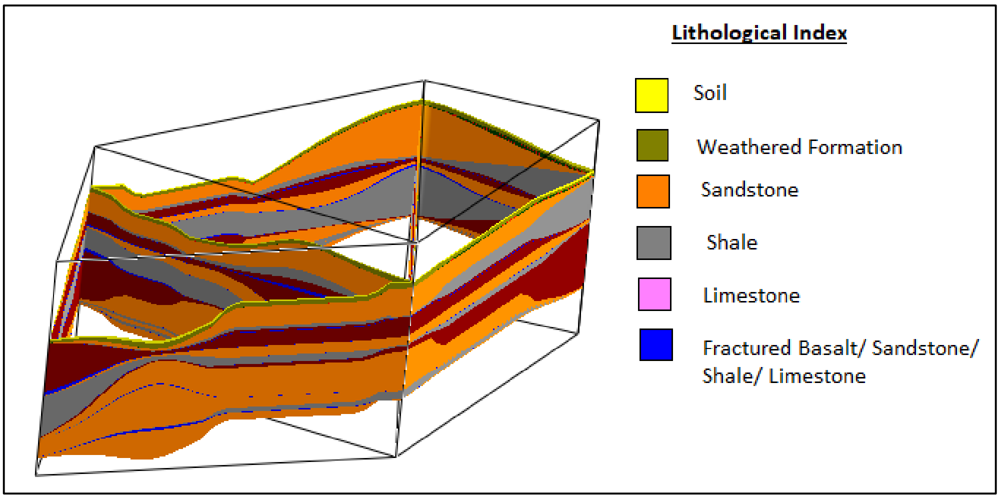

Fig.7.2:Fence Diagram, Jawad Block

7.1.3 GROUND WATER RESOURCE

DYNAMIC GROUNDWATER RESOURCES 2020	Recharge worthy area	**Sq Km**	1561
	Annual Extractable Groundwater Resource	**mcm**	109.52
	Total Ground Water Extraction		109.85
	Stage of Ground Water Extraction	**%**	100.30%
	Category		**Over Exploited**

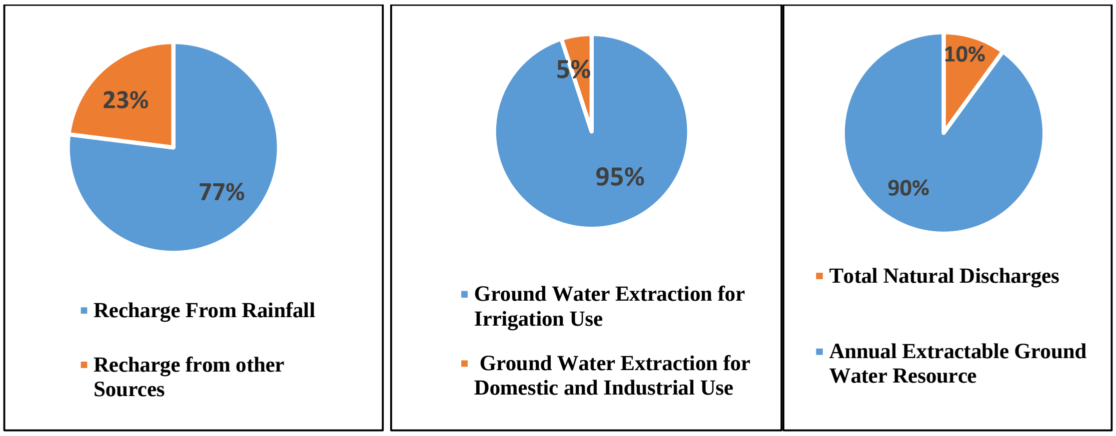

Fig.7.3: Groundwater Resource, Extraction, Jawad Block

7.1.4 GROUND WATER RELATED ISSUES

Stage of Extraction	Increasing Stage Of Extraction (**Fig.7.4**)
Water Level	Declining water level observed both in pre and post-monsoon in major part of the block (**Fig.7.5**)
Low Ground Water Potential / Limited Aquifer Thickness /Low Sustainability and High runoff	As the block is covered with hard Vindhan Formations there is restricted depth of weathering (**Fig.**) in Aquifer-I and limited aquifer thickness in Aquifer-II. Sustainability of both the aquifers are limited.
Ground Water Quality	High nitrate concentration at Morban & Singoli (95 mg/l) and Ratangarh (120 mg/l) villages. High fluoride concentration Lalpura (1.56 mg/l)

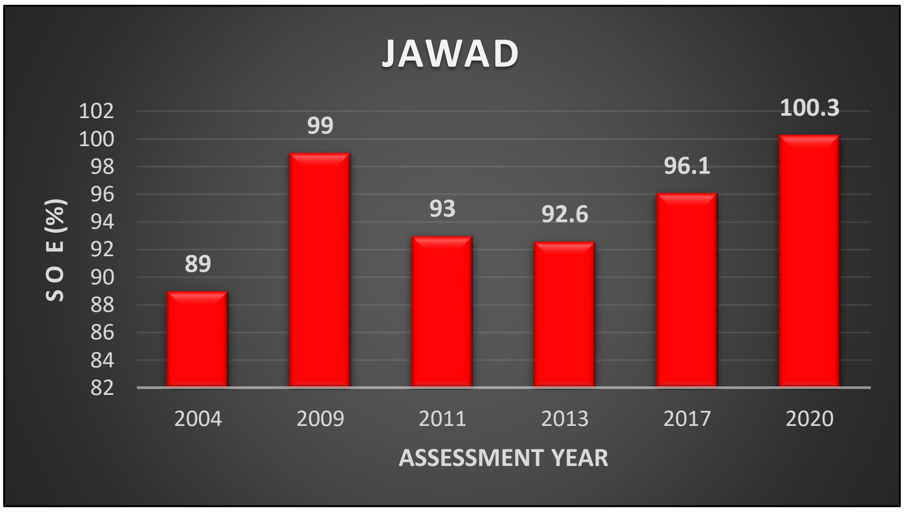

Fig.7.4: Assessment year wise Stage of Ground Water Extraction, Jawad block

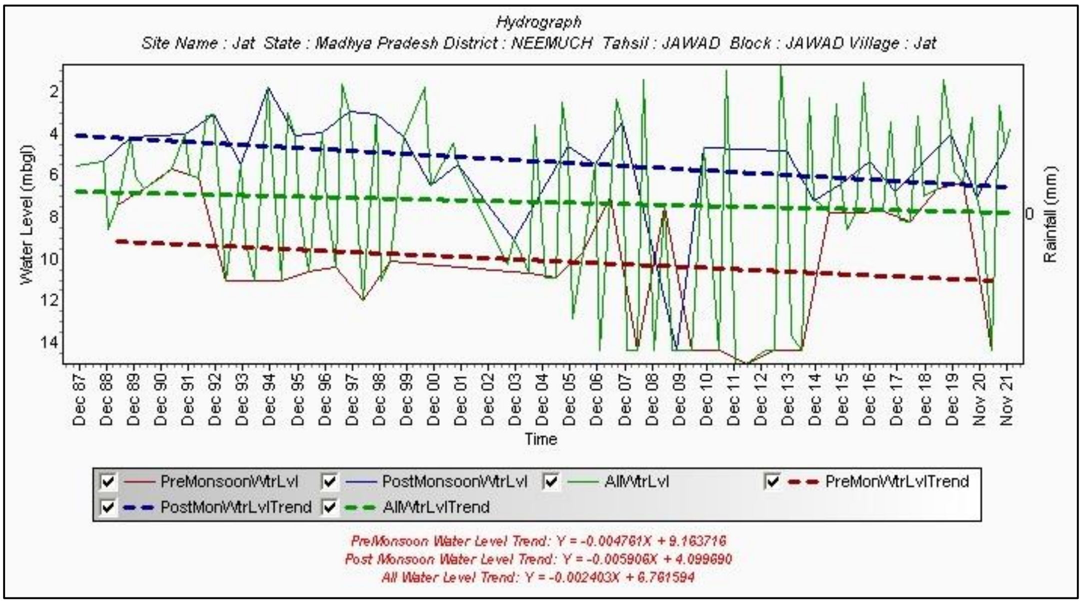

Fig.7.5: Hydrograph of village- Jat, Block-Jawad

7.1.5 SUPPLY SIDE MANAGEMENT PLAN

Type of Structures	Number	Cost (in Crores)
Percolation Tanks	57	11.4
Check Dam	498	29.88
Recharge Check Dam Shaft in	498	4.98
Nala Bund/ Cement Plugs	567	5.67
Village Ponds/ Farm Ponds	259	6.48
Total Cost		**58.41**

7.1.6 DEMAND SIDE MANAGEMENT PLAN

Annual Extractable Ground Water Resource	mcm	109.52
Total Extraction		109.85
Stage of Ground Water Extraction	%	100.3
Saving by Sprinkler	mcm	31.31
Additional recharge created by Artificial Recharge Structure		37.92
After intervention of Artificial Recharge Structure Net Ground Water Available		147.43
After intervention of Artificial Recharge Structure & utilisation of 60% of additional Ground Water created		22.75
Extraction after sprinkler & additional Ground Water created for agriculture		101.28
Stage of Extraction With effect of Ground Water use for additional Area Irrigation	%	68.7
Additional area irrigated by Ground Water after intervention	Hactare	5687.3

7.2 MANASA BLOCK

7.2.1 SALIENT INFORMATION

Area			Sq Km	1496
Normal Rainfall(2005-14)			millimeter	854.9
Land use and Agriculture		Principal crops		Soyabean, Groundnut, Til, Ramtil, Linseeds, Mustard, Rice, Wheat, Jowar, Maize,
		Gross cropped area	Sq Km	592.75
		Net sown area		407.96
		Area sown more than once		184.79
		Cropping intensity	%	145%
		Area under forest	Sq Km	18.42
		Area under Waste land		30.5
Data Utilised		Monitoring Wells for Water Level		Dw-10 , Pz-5
		Monitoring Wells for Quality		Dw-10
Water level behaviour	**Shallow**	Pre-monsoon WL (2019)	mbgl	Min-4.5, Max-21.15
		Post-monsoon WL (2019)		Min-0.95, Max-6.7
	Deep	Pre-monsoon WL (2019)		Min-4.9, Max-18.48
		Post-monsoon WL ()2019		Min-2, Max-5.78

7.2.2 AQUIFER DISPOSITION

Major Aquifer	Basalt/ Sandstone/Limestone/Shale	
Type of Aquifer	Aquifer-I	Aquifer-II
Formation	Weathered Basalt/Sandstone/Limestone/Shale	fractured/ Jointed Sandstone/Limestone/Shale
Depth of Occurrence (mbgl)	1 to 30	30 to 200
Weathered / Fractured rocks thickness (m)	0.5 to 28	0.5 to 3
Fractures encountered (mbgl)	Upto 30	Upto 200
Yield	-	Up to 2.38 lps

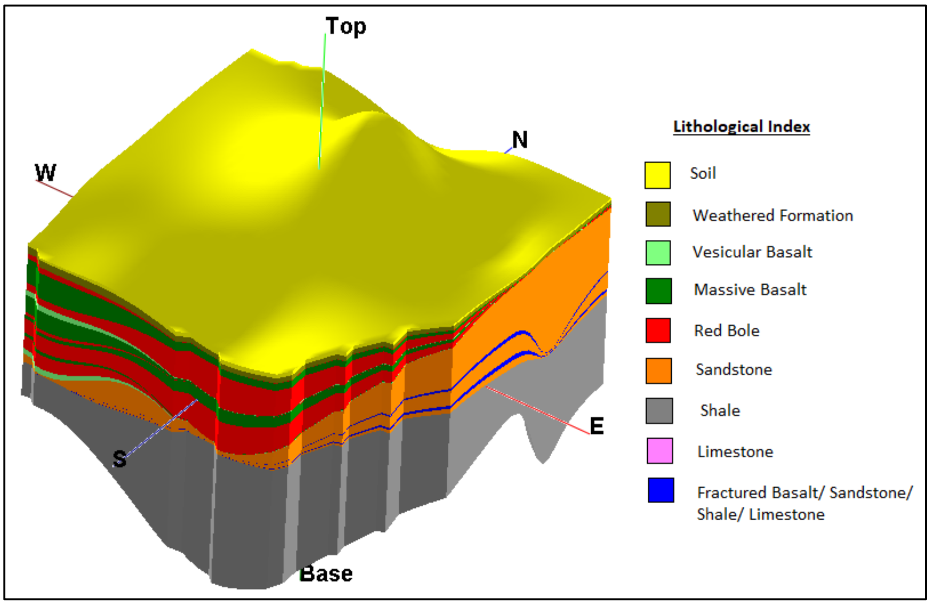

Fig.7.6:3-D Lithological Model, Manasa Block

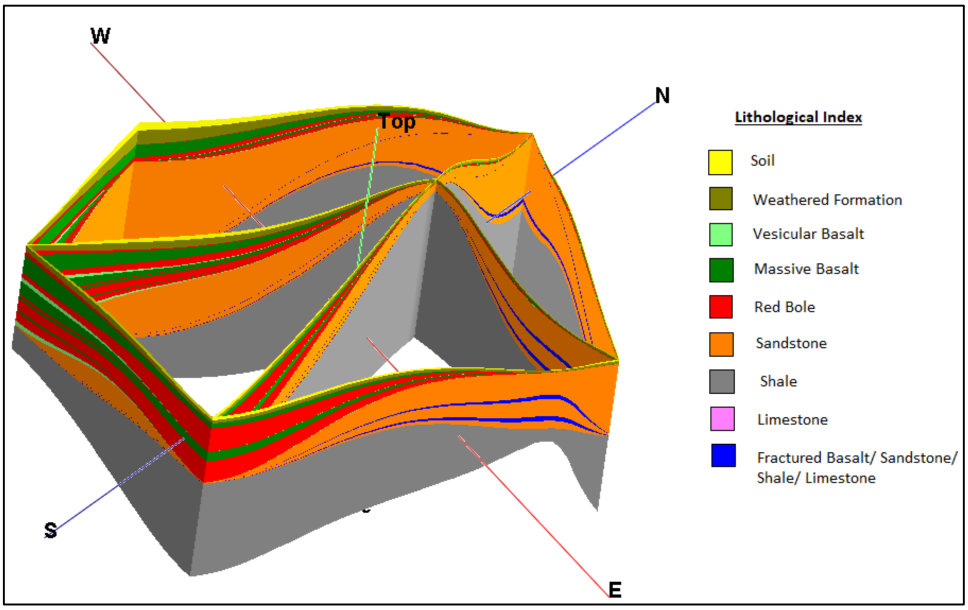

Fig.7.7:Fence Diagram, Manasa block

7.2.3 GROUND WATER RESOURCE

DYNAMIC GROUNDWATER RESOURCES 2020	Recharge worthy area	**Sq Km**	1153
	Annual Extractable Groundwater Resource	**mcm**	139.58
	Total Ground Water Extraction		107.13
	Stage of Ground Water Extraction	**%**	76.75%
	Category		**Semi-Critical**

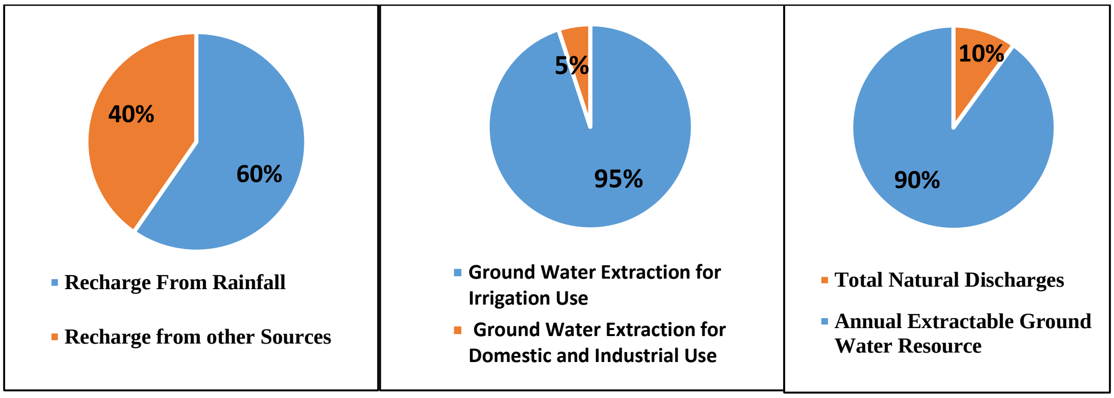

Fig.7.8: Groundwater Resource, Extraction, Manasa Block

7.2.4 GROUND WATER RELATED ISSUES

Stage of Extraction	Increasing Stage Of Extraction (**Fig.7.8**)
Water Level	Declining water level observed both in pre and post-monsoon in major part of the block (**Fig.**)
Low Ground Water Potential / Limited Aquifer Thickness /Low Sustainability and High runoff	As the block is covered with hard Vindhan Formations there is restricted depth of weathering (**Fig.**) in Aquifer-I and limited aquifer thickness in Aquifer-II. Sustainability of both the aquifers are limited.
Ground Water Quality	High Electrical conductivity has been observed in Kundaliya (3350 µS/cm at 25°C) and Manasa (2670 µS/cm at 25°C)
	High nitrate concentration Jamalpura (87 mg/l), Kundaliya (105 mg/l), Gota Pipliya (129 mg/l), Bhadana (130 mg/l) and Manasa (315 mg/l) villages.
	High concentration of Fluoride Barlai (1.68 mg/l)
	High concentration of Total Hardness Kundaliya (1380 mg/l) and Manasa (900 mg/l).

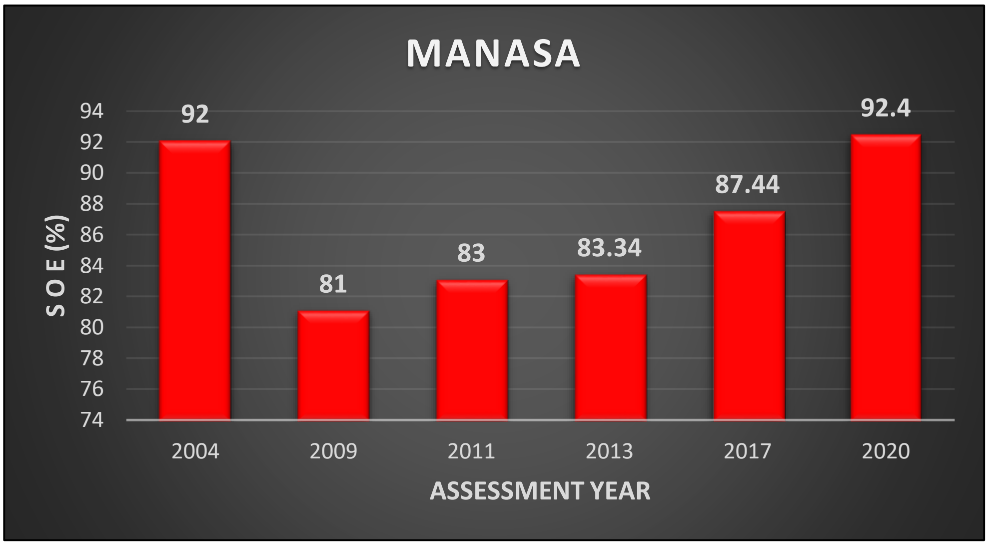

Fig.7.9: Assessment year wise Stage of Ground Water Extraction, Manasa block

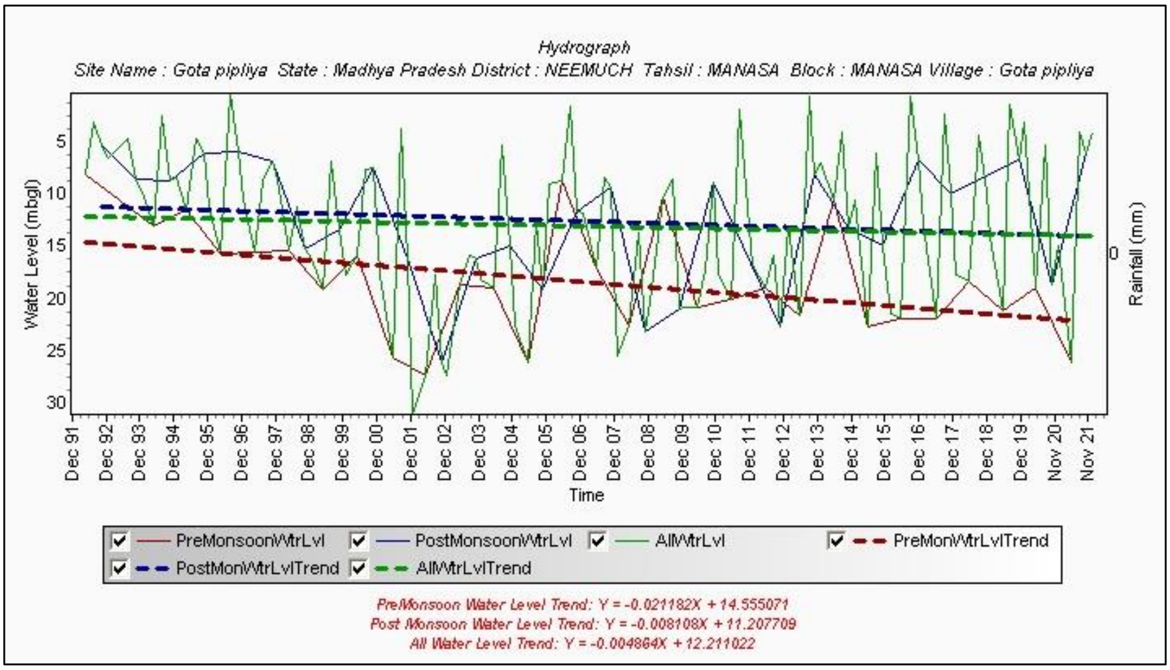

Fig.7.10: Hydrograph, Village-Gota Pipliya, Manasa

7.2.5 SUPPLY SIDE MANAGEMENT PLAN

Type of Structures	Number	Cost (in Crores)
Percolation Tanks	62	12.4
Check Dam	1048	62.88
Recharge Check Dam Shaft in	1048	10.48
Nala Bund/ Cement Plugs	1089	10.89
Village Ponds/ Farm Ponds	222	5.55
Total Cost		**102.2**

7.2.6 DEMAND SIDE MANAGEMENT PLAN

Annual Extractable Ground Water Resource	mcm	139.58
Total Extraction		107.13
Stage of Ground Water Extraction	%	76.75
Saving by Sprinkler	mcm	30.53
Additional recharge created by Artificial Recharge Structure		72.71
After intervention of Artificial Recharge Structure Net Ground Water Available		212.29
After intervention of Artificial Recharge Structure & utilisation of 60% of additional Ground Water created		43.62
Extraction after sprinkler & additional Ground Water created for agriculture		120.23
Stage of Extraction With effect of Ground Water use for additional Area Irrigation	%	56.63
Additional area irrigated by Ground Water after intervention	Hactare	10905.84

7.3 NEEMUCH BLOCK

7.3.1 SALIENT INFORMATION

Area			Sq Km	1085
Normal Rainfall(2005-14)			millimeter	854.9
Land use and Agriculture		Principal crops		Soyabean, Groundnut, Til, Ramtil, Linseeds, Mustard, Rice, Wheat, Jowar, Maize
		Gross cropped area	Sq Km	1043.79
		Net sown area		566.03
		Area sown more than once		477.76
		Cropping intensity	%	185%
		Area under forest	Sq Km	3.61
		Area under Waste land		31.51
Data Utilised		Monitoring Wells for Water Level		Dw-6 , Pz-2
		Monitoring Wells for Quality		Dw-6 ,
Water level behaviour	**Shallow**	Pre-monsoon WL (2019)	mbgl	Min-3.5, Max-13.2
		Post-monsoon WL (2019)		Min-0.5, Max-2.42
	Deep	Pre-monsoon WL (2019)		Min-5.3, Max-19.1
		Post-monsoon WL (2019)		Min-0.9, Max-2.6

7.3.2 AQUIFER DISPOSITION

Major Aquifer	Basalt/ Sandstone/Limestone/Shale	
Type of Aquifer	Aquifer-I	Aquifer-II
Formation	Weathered Basalt/Sandstone/Limestone/Shale	fractured/ Jointed Sandstone/Limestone/Shale
Depth of Occurrence (mbgl)	1 to 30	30 to 200
Weathered / Fractured rocks thickness (m)	0.5 to 28	0.5 to 3
Fractures encountered (mbgl)	Upto 30	Upto 200
Yield	-	Up to 2.38 lps

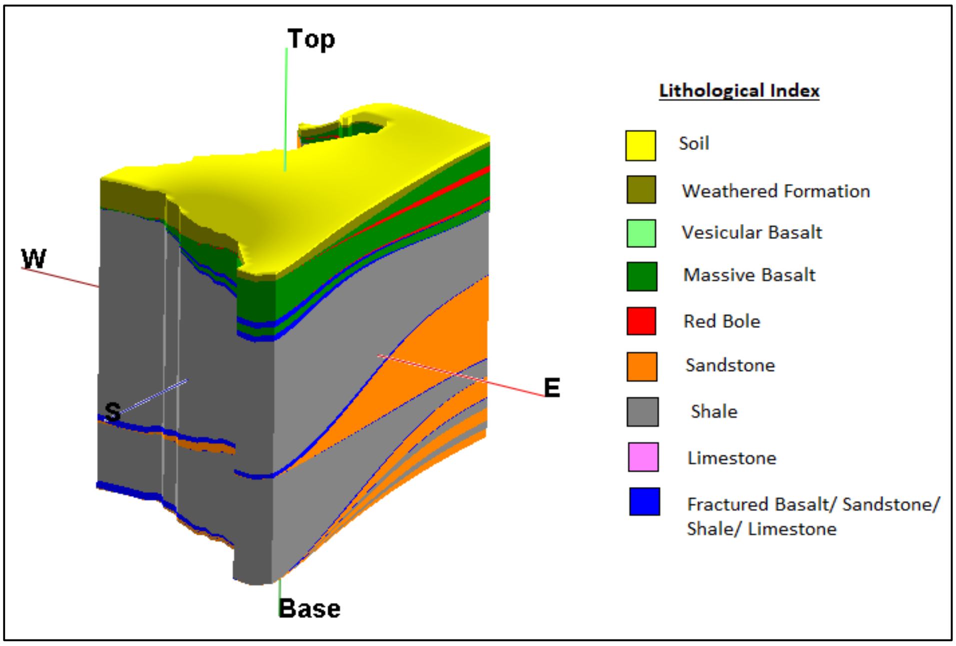

Fig.7.11: 3-D Lithological Model, Neemuch block

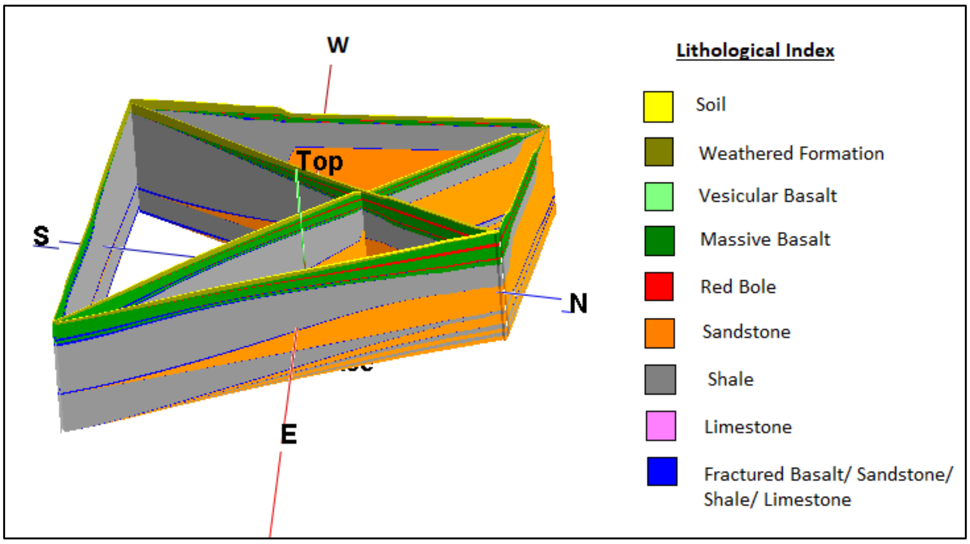

Fig.7.12: Fence Diagram, Neemuch block

7.3.3 GROUND WATER RESOURCE

DYNAMIC GROUNDWATER RESOURCES 2020	Recharge worthy area	**Sq Km**	1035
	Annual Extractable Groundwater Resource	**mcm**	113.9
	Total Ground Water Extraction		136.92
	Stage of Ground Water Extraction	**%**	102.25%
	Category		**Over Exploited**

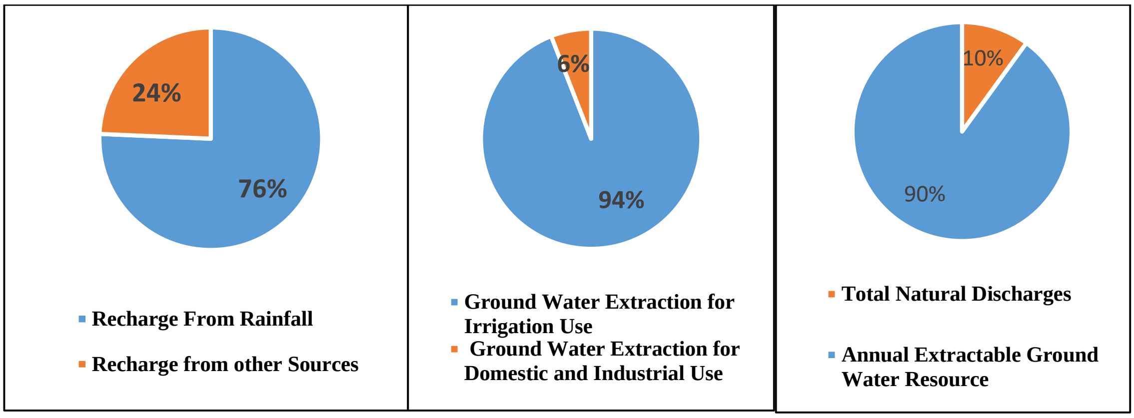

Fig.7.13: Groundwater Resource, Extraction, Neemuch Block

7.3.4 GROUND WATER RELATED ISSUES

Stage of Extraction	Increasing Stage Of Extraction (Fig.)
Water Level	Declining water level observed both in pre and post-monsoon in major part of the block (**Fig.1.3**)
Low Ground Water Potential / Limited Aquifer Thickness /Low Sustainability and High runoff	As the block is covered with hard Vindhan Formations there is restricted depth of weathering (**Fig.**) in Aquifer-I and limited aquifer thickness in Aquifer-II. Sustainability of both the aquifers are limited.
Ground Water Quality	High nitrate concentration Kacholi (75 mg/l) and Girdola (175 mg/l) villages.
	High concentration of Total Hardness Girdola (870 mg/l) village

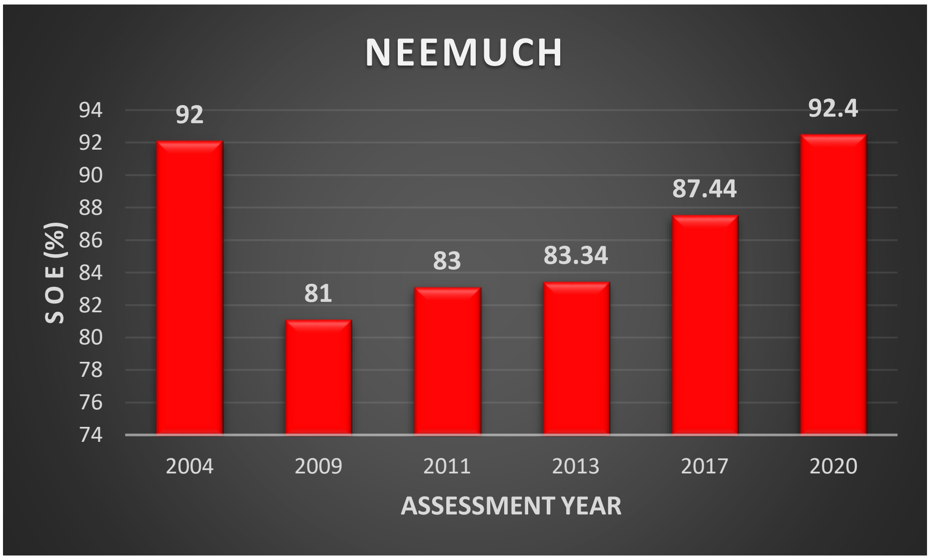

Fig.7.14: Assessment year wise Stage of Ground Water Extraction, Neemuch block

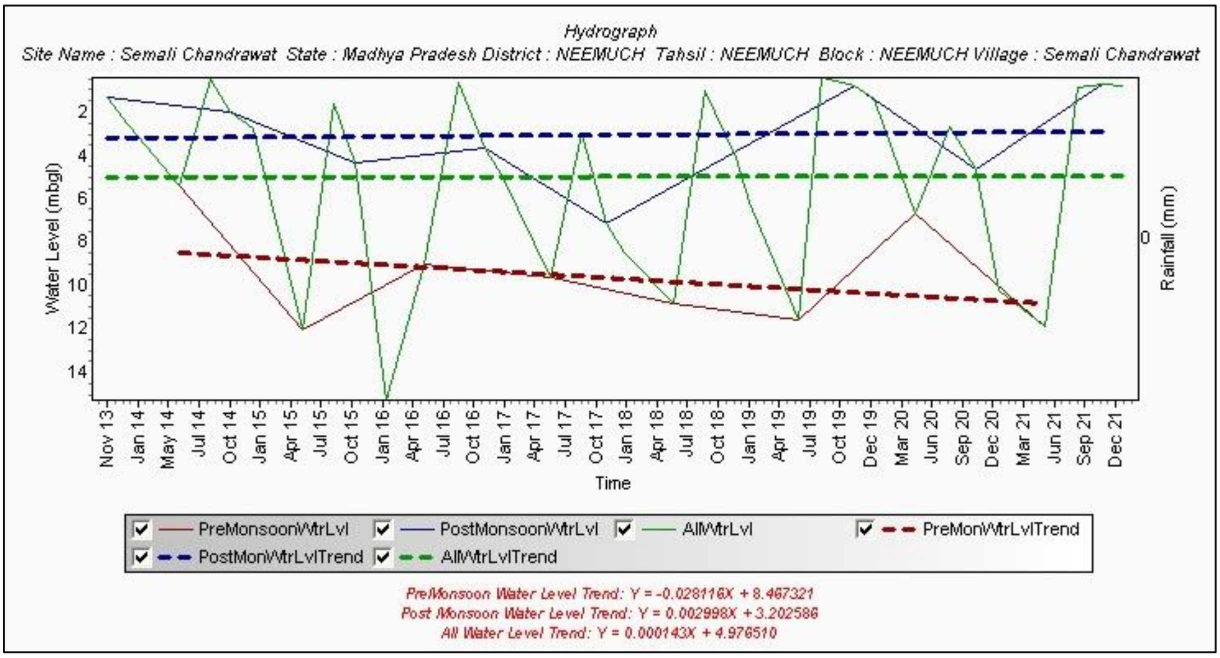

Fig.7.15: Hydrograph, Village-Semali Chandrawat, Block- Neemuch

7.3.5 SUPPLY SIDE MANAGEMENT PLAN

Type of Structures	Number	Cost (in Crores)
Percolation Tanks	91	18.2
Check Dam	694	41.64
Recharge Check Dam Shaft in	694	6.94
Nala Bund/ Cement Plugs	779	7.79
Village Ponds/ Farm Ponds	189	4.73
Total Cost		**79.3**

7.3.6 DEMAND SIDE MANAGEMENT PLAN

Annual Extractable Ground Water Resource	mcm	133.9
Total Extraction		136.92
Stage of Ground Water Extraction	%	102.25
Saving by Sprinkler	mcm	38.65
Additional recharge created by Artificial Recharge Structure		52.73
After intervention of Artificial Recharge Structure Net Ground Water Available		186.63
After intervention of Artificial Recharge Structure & utilisation of 60% of additional Ground Water created		31.64
Extraction after sprinkler & additional Ground Water created for agriculture		129.91
Stage of Extraction With effect of Ground Water use for additional Area Irrigation	%	69.61
Additional area irrigated by Ground Water after intervention	Hactare	7909.65

8. SUM UP & RECOMMENDATIONS

- A thorough study was carried out based on data gap analysis, data generated in-house; data acquired from State Govt. departments and GIS maps prepared for various themes. All the available data was brought on GIS platform and an integrated approach was adopted for preparation of aquifer maps and aquifer management plans of Neemuch district.
- The study area is spanning over 4200 sq.km, out of which 443 sq.km is hilly area and area suitable for recharge is 3757 sq.km.
- Almost entire district is falling under Chambal sub-basins area of the Ganga Basin. The major rivers flowing in the district is Chambal River. The Retam, Idar, Erda, Rupa, Bamni, Gangali & Rajori are main tributaries of the Chambal River and are ephemeral in nature.
- The district is mainly occupied by Deccan Trap basalt, rock formations of Vindhyan Super Group.
- In the shallow aquifer water levels between 10 to 20 mbgl in pre-monsoon and between 2 to 5 mbgl in the post-monsoon are observed in major parts of the district. The decadal pre-monsoon water level trend analysis indicates that during pre-monsoon period, more than 90 % of the area showing declining trend. Maximum falling trend is ranged between 0 to 0.2 m/yr Similarly, the decadal post-monsoon water level trend analysis indicates that about 95% of the area showing declining trend. Maximum falling trend is ranged between 0 to 0.2 m/yr.
- In the deep aquifer water levels between 10 to 20 mbgl in pre-monsoon and between 2 to 5 mbgl in the post-monsoon are observed in major parts of the district.
- For Shallow aquifers the electrical conductivity of ground water in Neemuch district ranged between 770 to 3350 µS/cm at 25°C and the maximum EC value., pH ranged in between 7.42 to 8.40, fluoride concentration was ranged in between 0.24 to 1.68 mg/l, nitrate concentration ranged in between 7 to 315 mg/l. Total hardness ranged in between 165 to 1380mg/l.
- During annual recharge from rainfall contributes maximum component (299 mcm) and recharge from other sources is 127 mcm. The Annual Extractable Ground Water Resource is 383 mcm, which is 90% of the total annual Groundwater recharge. Total extraction of ground water for all uses in district is calculated as 354 mcm. The overall stage of groundwater extraction in the district is 92.40 %.

- The Jawad (100.30 %) and Neemuch (102.25 %) block are categorised as 'Over_exploited' and Manasa (76.75 %) block as 'Semi_critical'.
- In Neemuch district, the main ground water issues are Decline in the water level, Limited Ground Water Potential / Limited Aquifer Thickness / Sustainability, Deeper Water Levels particularly in deeper aquifers, Inferior Ground Water Quality both in shallow and deep aquifers and Increasing Stage of ground water extraction
- On the basis of the exploratory bore wells drilled by CGWB, NCR under its NAQUIM program, it has been observed that the yield varies from meagre to 4 lps and the sustainability of the aquifers are very low.
- As per the Management plan prepared under NAQUIM of all the Block of Neemuch District, a total number of 210 Percolation Tanks, 2240 check dams/Recharge Shafts and 2435 Nala Bunds/Cement Plugs have been proposed and financial expenditure is expected to be Rs.240 Crores in Neemuch District for sustainable development and management of ground water resources.
- After successful implementation of supply side and demand side management plan the stage of extraction in Neemuch district is expected to improve by nearly 28% i.e. from 92.40 % to 64.32 %.
- The number of artificial recharge structure and financial estimation has been proposed based on the Central Ground Water Board Master plan 2020. It may be differ from the field condition as well as changes in dynamic Ground water resources.

Annexure-1: Depth to Ground Water level of Shallow Aquifer 2019, Neemuch District

Block	Village	Latitude	Longitude	Pre-monsoon (mbgl)	Post-monsoon (mbgl)	Seasonal Fluctuation
Jawad	Singoli	24.9678	75.2881	13.77	8.54	5.23
Jawad	Ratangarh	24.8106	75.1089	12.3	8	4.3
Jawad	Patan1	24.9072	75.2111	7	1.9	5.1
Jawad	Dadoli	24.6739	75.0411	8.25	0.9	7.35
Jawad	Jat	24.8481	74.9381	6.65	4.05	2.6
Jawad	Morban1	24.6222	75.0000	6.6	3.85	2.75
Jawad	Lalpura	24.6136	74.9264	37	6.8	30.2
Jawad	Jawad	24.5942	74.8622	6.1	3.4	2.7
Manasa	Barlai	24.4242	75.3200	11.9	3.95	7.95
Manasa	Besla	24.5542	75.4567	4.5	1.6	2.9
Manasa	Chachor	24.3722	75.3572	14.8	2.2	12.6
Manasa	Gota pipliya	24.4800	75.2233	21.15	6.7	14.45
Manasa	Kukreshwar	24.4800	75.2681	7.8	4.5	3.3
Manasa	Kundaliya	24.4667	75.3308	5.3	0.95	4.35
Manasa	Manasa	24.4706	75.1439	12	2.15	9.85
Manasa	Rampura	24.4619	75.4411	8.08	2.18	5.9
Manasa	BhadanaDW	24.5611	75.3694	15.2	2.2	13
Manasa	Jamalpura	24.4867	75.4642	13.58	4.28	9.3
Neemuch	Savan	24.4522	75.0631	7.75	0.85	6.9
Neemuch	Neemuch	24.4536	74.8739	3.72	2.42	1.3
Neemuch	Kacholi	24.3625	74.9414	13.2	1.3	11.9
Neemuch	Girdola	24.4622	74.9322	8.8	1.7	7.1
Neemuch	Semali Chandrawat	24.5481	74.9361	11.6	0.8	10.8
Neemuch	Nayagaon2	24.5611	74.7764	3.5	0.5	3
			Minimun	**3.5**	**0.5**	**1.3**
			Maximun	**37**	**8.54**	**30.2**
			Average	**10.86**	**3.16**	**7.70**

Annexure-2: Depth to Groundwater level of Deep aquifer 2019, Neemuch District

BLOCK	Vilage	Latitude	Longitude	Pre-Monsoon (mbgl)	Post-Monsoon (mbgl)	Fluctuation
Jawad	Ratangarh Npz	24.82	75.1167	9.35	0.4	8.95
Jawad	Pipalikheda Npz	24.9206	75.2306	20.4	4.3	16.1
Jawad	Lalpura Npz	24.6133	74.9264	19	4.1	14.9
Jawad	Athwakheda Npz	24.8383	75.14	26.4	1.8	24.6
Jawad	Morban(D)	24.6239	74.9964	14.11	6.21	7.9
Jawad	Javad(D)	24.5847	74.8672	17.16	4.46	12.7
Manasa	Besla Npz	24.5533	75.45	7.3	5.7	1.6
Manasa	Kukreshwar Npz	24.4817	75.2617	10.8	2	8.8
Manasa	Manasa Npz	24.4767	75.145	4.9	2.1	2.8
Manasa	Rampura Npz	24.4667	75.4333	7.4	1.7	5.7
Manasa	Kukreswar(D)	24.4792	75.2708	18.48	5.78	12.7
Neemuch	Nayagaon Npz	24.5517	74.77	5.3	0.9	4.4
Neemuch	Kanawati Npz	24.4867	74.8567	19.1	2.6	16.5
			Minimun	**4.9**	**0.4**	**1.6**
			Maximum	**26.4**	**6.21**	**24.6**
			Average	**13.82**	**3.23**	**10.59**

Annexure-3: Aquifer Details in Neemuch District

Block	Village	Latitude	Longitude	Weathering Zone Thickness (Aquifer-I)	Aquifer-I	Major Aquifer-II zones	Aquifer-II	Discharge (lpm)
Jawad	Alori garwara	24.7843	75.1757	5.5	Sandstone	44.7-47.7	Sandstone	84
Jawad	Jat	24.8544	74.9381	11.1	Sandstone	56.9-59.9	Sandstone	Meagre
Jawad	Kankariyla Talai	24.8668	75.0784	11.1	Sandstone	53.8-56.9	Sandstone	Meagre
Jawad	Kanod	24.8506	75.3366	5.5	Sandstone			
Jawad	Lalganj	25.0283	75.318	5	Limestone			
Jawad	Lapiya	24.7125	75.0029	6.1	Sandstone	92.5-98.5	Limestone	18
Jawad	Morwan	24.6231	75.0154	8.1	Sandstone			
Jawad	Sarwnia Masani	24.6069	74.8063	8.1	Shale	135.53-141.26	Limestone	108
Jawad	Saloda	24.9751	75.1969	14.1	Sandstone	53.8-54.9, 139.2-142.3	Sandstone	74.4
Jawad	Umedpura	24.879	75.1696	5	Sandstone			
Manasa	Baktuni	24.6796	75.3189	2	Sandstone	83.3-86.4	Sandstone	30
Manasa	Basantpura	24.4263	75.3704	7.1	Basalt			
Manasa	Bilwasa	24.5646	75.3472	10.1	Sandstone			
Manasa	Buj EW1	24.3442	75.2849		Sandstone	21.6-24.3, 30-35.6	Sandstone	792
Manasa	Buj EW2	24.3442	75.2849		Sandstone	22-26.3, 52.1-57.8	Sandstone	1200
Manasa	Chachor	24.3763	75.351	7.2	Basalt	68.1-71.1	Basalt, Shale	12
Manasa	Chainpuriya	24.6027	75.5112		Sandstone	92-93	Sandstone	Meagre
Manasa	Manasa	24.4679	75.1474	4	Basalt	41.2-44.6	Limestone	6
Manasa	Palasiya	24.6401	75.1491	28.4	Basalt			
Manasa	Raisinghpura EW1	24.3563	75.3563	7.1	Basalt			

Block	Village	Latitude	Longitude	Weathering Zone Thickness (Aquifer-I)	Aquifer-I	Major Aquifer-II zones	Aquifer-II	Discharge (lpm)
Manasa	Raisinghpura EW2	24.3563	75.3563	7.1	Basalt			
Neemuch	CRPF Camp	24.4755	74.8415	5	Basalt			
Neemuch	Amlikheda	24.441	75.101	11	Basalt			
Neemuch	Bagwanpura EW	24.481	74.779	5	Sandstone	51-52, 129-130, 140-141	Sandstone, Shale	1108.8
Neemuch	Bagwanpura OW	24.481	74.779	11	Sandstone	67-68, 134-135, 150-151	Sandstone, Shale	1108.8
Neemuch	Barukheda	24.49	74.863	29	Basalt	60-61, 91-92	Shale	4.5
Neemuch	Chackhedi EW	24.245	74.925	5	Basalt	31-32, 129-130	Basalt, Shale	270
Neemuch	Chackhedi OW	24.245	74.925	5	Basalt	29-30, 129-130	Basalt, Shale	25.8
Neemuch	Gudla	24.28	74.79	19	Basalt	82-83, 154-155, 199-200	Shale	491.4
Neemuch	Gudla	24.28	74.79	17	Basalt	199-200	Shale	1444.8
Neemuch	Kasbi	23.32	74.79	5	Shale			

Annexure-4: Groundwater Quality of Shallow Aquifer

Block	Location	pH	EC	CO_3	HCO_3	Cl	SO_4	NO_3	F	PO_4	SiO_2	TH	Ca	Mg	Na	K	TDS
			µS/cm at 25°C	mg/l													
Jawad	Dadoli	7.63	1000	0	281	136	54	7	0.74	BDL	28	375	84	40	54	2.5	650
Jawad	Jat	8.37	1300	12	397	181	25	13	0.24	BDL	33	560	36	114	30	18	845
Jawad	Lalpura	7.5	1320	0	458	180	25	20	1.56	BDL	32	425	24	89	120	1.5	858
Jawad	Morban1	7.79	1650	0	592	120	75	95	1.12	BDL	40	490	26	103	150	6	1073
Jawad	Patan	7.51	1110	0	378	75	65	26	0.38	BDL	25	460	30	94	35	7.3	722
Jawad	Ratangarh	7.5	1360	0	329	200	25	120	0.77	BDL	33	380	24	78	135	5	884
Jawad	Singoli	7.42	1850	0	378	352	22	95	0.57	BDL	23	590	30	125	150	4.5	1203
Manasa	Barlai	8.12	1150	0	598	35	18	13	1.68	BDL	27	165	16	30	168	34	748
Manasa	Besla	7.88	770	0	232	89	20	52	0.59	BDL	22	280	68	27	45	2	501
Manasa	Bhadanadw	8.4	875	18	67	96	75	130	0.41	0.02	33	315	78	29	37	32	569
Manasa	Chachor	7.58	1355	0	153	287	100	43	0.92	0.02	30	495	92	64	76	12	881
Manasa	Gota Pipliya	7.47	1130	0	342	106	22	129	1	BDL	31	355	46	58	94	1.1	735
Manasa	Jamalpura	8.29	1270	12	110	124	95	87	0.87	BDL	25	225	30	36	110	5	826
Manasa	Kukreshwar	7.51	1620	0	561	191	25	60	0.76	0.01	49	460	64	73	90	120	1053
Manasa	Kundaliya	7.58	3350	0	366	592	350	105	0.39	BDL	34	1380	226	198	125	3.4	2178
Manasa	Manasa	7.85	2670	0	653	317	36	315	0.81	BDL	35	900	174	113	195	1.2	1736
Manasa	Rampura	7.52	974	0	329	90	72	14	0.93	BDL	34	320	34	57	75	1.3	633
Neemuch	Girdola	7.62	1985	0	397	309	60	175	1.02	BDL	23	870	114	142	52	3	1290
Neemuch	Kacholi	7.61	1240	0	232	205	55	75	0.43	BDL	42	530	172	24	38	1.2	806
Neemuch	Neemuch	8.39	1210	18	268	202	30	20	0.75	BDL	32	335	34	61	98	43	787
Neemuch	Savan	7.8	1190	0	85	320	25	29	0.78	BDL	31	380	104	29	95	4	774
Neemuch	Semali Chandrawat	8.25	2125	18	519	387	18	16	1.47	BDL	46	340	24	68	321	12.3	1381
	Minimum	**7.42**	**770**	**0**	**67**	**35**	**18**	**7**	**0.24**	**0.01**	**22**	**165**	**16**	**24**	**30**	**1.1**	**501**
	Maximum	**8.4**	**3350**	**18**	**653**	**592**	**350**	**315**	**1.68**	**0.02**	**49**	**1380**	**226**	**198**	**321**	**120**	**2178**

Annexure-5: Groundwater Quality Calculation for Irrigation

Block	Location	S S P%	SAR	%Na	RSC	K I	Mg2+ Ratio	P I
Jawad	**Dadoli**	23.86	1.21	24.35	-2.89	0.31	43.94	45.67
Jawad	**Jat**	10.45	0.55	13.63	-4.27	0.12	83.90	30.88
Jawad	**Lalpura**	37.97	2.53	38.14	-1.02	0.61	85.92	57.91
Jawad	**Morban1**	40.02	2.95	40.58	-0.07	0.67	86.70	59.13
Jawad	**Patan1**	14.15	0.71	15.61	-3.04	0.16	83.76	37.29
Jawad	**Ratangarh**	43.52	3.01	44.05	-2.23	0.77	84.25	60.73
Jawad	**Singoli**	35.62	2.69	36.02	-5.59	0.55	87.27	49.22
Manasa	**Barlai**	69.08	5.71	71.43	6.53	2.23	75.53	98.70
Manasa	**Besla**	25.82	1.17	26.31	-1.82	0.35	39.52	51.55
Manasa	**Bhadana**	20.38	0.91	27.85	-4.59	0.26	37.96	33.65
Manasa	**Chachor**	25.09	1.49	26.79	-7.36	0.33	53.38	37.11
Manasa	**Gota Pipliya**	36.62	2.17	36.78	-1.47	0.58	67.48	57.84
Manasa	**Jamalpura**	51.73	3.20	52.39	-2.26	1.07	66.39	66.26
Manasa	**Kukreshwar**	29.82	1.82	43.13	-0.01	0.42	65.24	52.94
Manasa	**Kundaliya**	16.45	1.46	16.67	-21.59	0.20	59.05	23.87
Manasa	**Manasa**	32.02	2.83	32.10	-7.29	0.47	51.66	44.38
Manasa	**Rampura**	33.79	1.82	34.01	-1.00	0.51	73.40	57.85
Neemuch	**Girdola**	11.51	0.77	11.85	-10.88	0.13	67.21	24.49
Neemuch	**Kacholi**	13.51	0.72	13.73	-6.77	0.16	18.68	29.46
Neemuch	**Neemuch**	38.80	2.32	44.37	-1.73	0.63	74.70	57.89
Neemuch	**Savan**	35.25	2.12	35.81	-6.19	0.54	31.46	45.33
Neemuch	**Semali Chandrawat**	67.25	7.57	67.74	2.31	2.05	82.34	81.31
	MIN	**10.45**	**0.55**	**11.85**	**-21.59**	**0.12**	**18.68**	**23.87**
	MAX	**69.08**	**7.57**	**71.43**	**6.53**	**2.23**	**87.27**	**98.70**

Formulae: -

Soluble Sodium Percentage (S S P%)= Na*100/ Ca+Mg+Na
Sodium Absorption Ratio (SAR)= Na / √ (Ca+Mg) / 2
%Na=((Na+K) / (Ca+Mg+Na+K)) *100
Residual Sodium Carbonate (RSC) = (HCO3 + CO3) – (Ca + Mg)
Kelley's Index (K I) = Na/Ca+Mg\
Mg2+ Ratio =(Mg) / (Ca+Mg)*100
Permeability Index (P I) =((Na+ (√HCO3) / (Ca+Mg+Na))*100

Annexure-5 Groundwater Quality Calculation for Industrial use

Location	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}	Cl/35.50	$2(SO_4/96)$	$((Cl/35.50+2(SO_4/96))$	$2(HCO_3+CO_3/100)$	$((Cl/35.50+2(SO_4/96))/2(HCO_3+CO_3/100)$
Dadoli	0	281	136	54	3.83	1.13	4.96	562	0.00881848
Jat	12	397	181	25	5.10	0.52	5.62	794.24	0.007075223
Lalpura	0	458	180	25	5.07	0.52	5.59	916	0.006103991
Morban	0	592	120	75	3.38	1.56	4.94	1184	0.004174647
Patan	0	378	75	65	2.11	1.35	3.47	756	0.004585771
Ratangarh	0	329	200	25	5.63	0.52	6.15	658	0.00935355
Singoli	0	378	352	22	9.92	0.46	10.37	756	0.013721992
Barlai	0	598	35	18	0.99	0.38	1.36	1196	0.001137889
Besla	0	232	89	20	2.51	0.42	2.92	464	0.006301097
Bhadanadw	18	67	96	75	2.70	1.56	4.27	134.36	0.03175592
Chachor	0	153	287	100	8.08	2.08	10.17	306	0.033228237
Gota Pipliya	0	342	106	22	2.99	0.46	3.44	684	0.005035452
Jamalpura	12	110	124	95	3.49	1.98	5.47	220.24	0.024846188
Kukreshwar	0	561	191	25	5.38	0.52	5.90	1122	0.005259461
Kundaliya	0	366	592	350	16.68	7.29	23.97	732	0.032742791
Manasa	0	653	317	36	8.93	0.75	9.68	1306	0.007411621
Rampura	0	329	90	72	2.54	1.50	4.04	658	0.00613254
Girdola	0	397	309	60	8.70	1.25	9.95	794	0.012536808
Kacholi	0	232	205	55	5.77	1.15	6.92	464	0.01491483
Neemuch	18	268	202	30	5.69	0.63	6.32	536.36	0.011774071

Location	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}	Cl/35.50	$2(SO_4/96)$	$((Cl/35.50+2(SO_4/96))$	$2(HCO_3+CO_3/100)$	$((Cl/35.50+2(SO_4/96))/2(HCO_3+CO_3/100)$
Savan	0	85	320	25	9.01	0.52	9.53	170	0.056087752
Semali Chandrawat	18	519	387	18	10.90	0.38	11.28	1038.36	0.010859826

Formulae: -
Corrosivity Ratio (CR) = $((Cl/35.50 + 2(SO_4/96)) / 2(HCO_3 + CO_3/100)$

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