केंद्रीय भूमि जल बोर्ड

जल संसाधन, नदी विकास और गंगा संरक्षण मंत्रालय

भारत सरकार

Central Ground Water Board

Ministry of Water Resources, River Development and Ganga Rejuvenation

Government of India

Report

on

AQUIFER MAPPING AND GROUND WATER MANAGEMENT

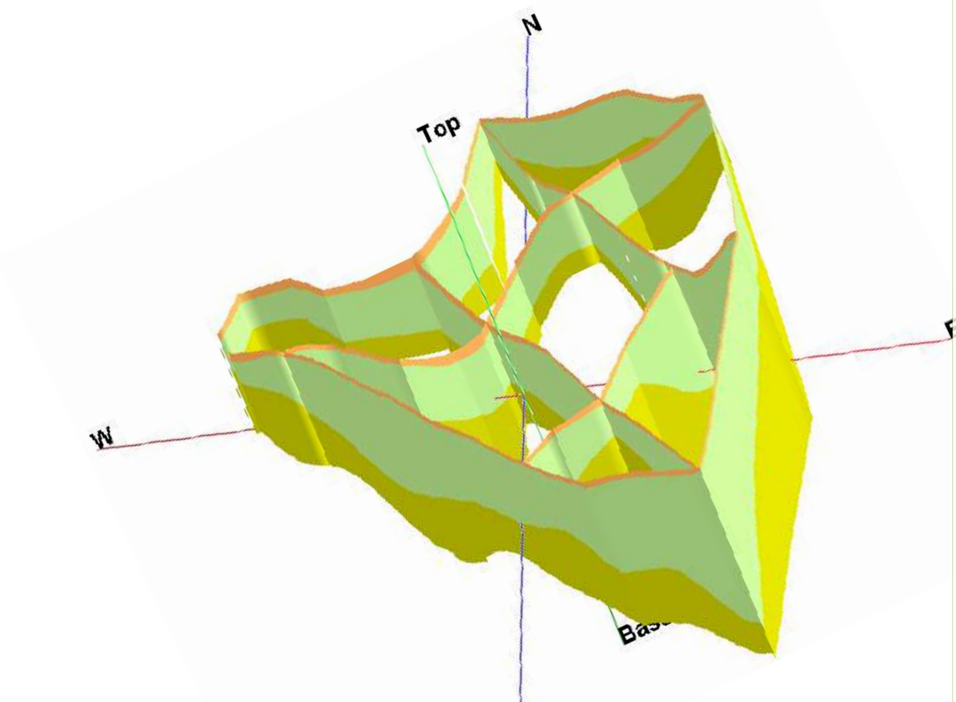
Bhavani River Basin, Tamil Nadu

दक्षिण पूर्वी तटीय क्षेत्र, चेन्नई

South Eastern Coastal Region, Chennai

सरकारीउपयोगकेलिए

REPORT ON AQUIFER MAPPING AND GROUNDWATER MANAGEMENT PLAN FOR BHAVANI RIVER BASIN AQUIFER SYSTEM, TAMIL NADU



Government of India
Ministry of Water Resources, River Development & Ganga Rejuvenation
Central Ground Water Board, South Eastern Coastal Region
Chennai

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Foreword

Groundwater is the major source of freshwater that caters the demand of ever growing domestic, agricultural and industrial sectors of the country. This renewable resource has been indiscriminately exploited in some parts of the country by several users as it is easily available and reliable. Intensive and unregulated groundwater pumping in many areas has caused rapid and widespread groundwater decline. Out of 6607 ground water assessment units (Blocks/ mandals / taluks etc.), 1071 units are over-exploited and 914 units are critical. These units have withdrawal of ground water is more than the recharge (over exploited) and more 90% 7 less than 100% of recharge (Critical).

Central Ground Water Board (CGWB) has taken up largest Aquifer mapping endeavour in the world, targeting total mapable area of country ~ 23.25 lakh sq. km with a vertical extent of 300 m in soft rock area and 200 m in hard rock area. The extent of aquifer, their potential, resource availability, chemical quality, its sustainable management options will be addressed by National Aquifer Mapping (NAQUIM). The NAQUIM programme will also facilitate participatory management of ground water to provide long term sustenance for the benefit of farmers. Currently, focus is on ground water stressed areas of eight states comprising 5.25 lakh sq.km viz. Tamil Nadu, Haryana, Punjab, Rajasthan, Gujarat, Andhra Pradesh, Telangana, Karnataka and Bundelkhand region.

South Eastern Coastal Region, Central Ground Water Board, Chennai under NAQUIM has been envisaged with the Mapping of an area of 70,102 sq.km during 2012-17 (XII five year plan) in Tamil Nadu and UT of Puducherry. This report deals with the Aquifer mapping studies carried out in water stressed Bhavani basin covering an area of 10391 sq .km with a hilly area of 1198 sq.km and the total mappable area is 9193 sq.km. The basin comprises of seven districts of parts of Coimbatore, Erode, Namakkal, Nilgiris Karur, Salem and Tiruppur with 97 firkas (56 Over Exploited & Critical), and is mainly dependent on groundwater (85%) for its agricultural needs. The major issues in the basin include declining groundwater levels, sustainability of wells, heavy metal contamination due to industrial clusters and high Fluoride concentration in patches leading to risk of dental and skeletal fluorosis. Two aquifer units were deciphered with aquifer Unit - I being the weathered, occurs from ground level to 38 m bgl and Aquifer Unit –II is the fractured/Jointed zone existing from 10 to 200 m bgl (3-4 fractures are encountered). In order to arrest the declining groundwater levels and to increase the sustainability of wells groundwater management plans for supply and demand side interventions have been formulated firka wise.

I hope this report will be useful for the district administrators, water managers, stakeholders including farmers in knowing the aquifer and managing it resources effectively in the Upper Ponnaiyar aquifer system.

A.Subburaj
Head of Office

EXECUTIVE SUMMARY

Aquifer mapping studies were carried out in the Bhavani aquifer system covering a mappable area of 9193 sq. km. covering districts of parts of Coimbatore, Erode, Namakkal, Nilgiris Karur, Salem and Tiruppur districts of Tamilnadu. The data pertinent to geology, geophysics, hydrology, hydrochemistry was collected, synthesised and analysed to bring out this report. This report mainly comprises the Aquifer geometry and Aquifer properties of the study area which are considered to be measuring scales for groundwater availability and potentiality. Keeping these parameters in view a sustainable management plan has been suggested through which the groundwater needs can be fulfilled in a rational way.

Area experiences semi-arid climate with 750 mm average annual normal rainfall (100 years). The Nilgiris district experiences high rainfall of above 2000mm. About 58% of the geographical area is under agricultural activity in the basin. The main crops irrigated are paddy, sugarcane, groundnut, maize, cotton, ragi and other minor crops are turmeric, vegetables and flowers.

Integrated study helped in deciphering main aquifer units, weathered zone at the top followed by a discrete anisotropic fractured/fissured zone at the bottom. Groundwater occurs under unconfined condition in the weathered zone and unconfined to semi-confined conditions in the fractured/fissured zone and flows downward from the weathered zone into the fracture zone. The predominant water levels are in the range of 1.19 -22.63 m bgl during pre-monsoon season and 1.13 – 21.32 mbgl during post-monsoon season (2015). The net annual ground water availability is 1369.9 MCM and the gross ground water draft is 1400.3 MCM and the average stage of groundwater development is of 103%.

The major issues in the basin include declining groundwater levels, sustainability of wells, heavy metal contamination due to industrial clusters and high Fluoride concentration in patches leading to risk of dental and skeletal fluorosis. The fluoride levels in the ground waters of the basin exceed the permissible limit of 1.5ppm in Karur and isolated patches in Namakkal and Erode districts due to geogenic contamination. This problem is addressed through alternate drinking water supply to the affected villages from Bhavani sagar reservoir.

Aquifer systems from the area can be conceptualized as weathered zone down to ~38m and fractured zone between ~10-200 m bgl with possibility of occurrence 3 to 4 fractures. The weathered zone is disintegrated from the bed rock (upper part–saprolite zone) and partially/semi weathered in the lower part (sap rock zone) with yield ranging from 15-25 m^3/hr and can sustain for 1 to 2 hrs of pumping during summer period (April to June). The fractured zone is fractured Gneiss or Charnockite which occur in limited extent, associated sometime with quartz vein. The average yield ranges from 2 - 15 m^3/hr and can sustain for 2 to 3 hrs of pumping during summer period.

Fast growing urban agglomeration shares the groundwater which otherwise is being used for irrigation purpose resulting in either shortage for irrigation needs or creates excessive draft to meet the both demands in groundwater potential areas. The study formulates management strategies for supply side as well as demand side. The supply side measures include construction of artificial recharge structures of 81 Check dams, 412 Nala Band, 1266 recharge shafts in addition to the 480 ponds earmarked for rejuvenation with recharge shafts in all the 56 OE & Critical firkas of the basin. The estimated cost for construction of these structures is to be Rs. 183.17 Crores. The estimated recharge to groundwater system through these structures will be in the order of 80 MCM. In addition water conservation plan is proposed through low pressure water distribution system in 1590 sq.km irrigation area and digging of 6370 recharge ponds which support storage as well as recharge. Demand side management is also recommended by change in irrigation pattern from flooding method to Ridge & furrow for paddy and flooding to drip for sugarcane and banana crops. This intervention would save 262 mcm of water annually. By carrying out both supply and demand side interventions the stage of groundwater development would be lowered from 103 to 77%.

The existing regulatory measures may be modified suitably for optimal utilization of groundwater as well as for sustainable development of rural agricultural based economy. To achieve this goal opinion pool has to be obtained from more user groups and valid suggestions may be incorporated in the regulatory acts for the Bhavani River basin aquifer system.

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AQUIFER MAPS AND GROUND WATER MANAGEMENT PLANS, BHAVANI BASIN AQUIFER SYSTEMS, TAMIL NADU

1 INTRODUCTION

Central Ground Water Board, Ministry of Water Resources, River Development and Ganga Rejuvenation, New Delhi had been assigned to carry out National Aquifer Mapping (NAQUIM) in country wide under XII five-year plan on 1: 50,000 scale. National Aquifer Mapping (NAQUIM) involves in deciphering the aquifers in terms of configuration, quantity, quality, rejuvenation and sustainability. Aquifer mapping is prepared by integrating hydrogeological information such as geology, geophysics, hydrology and hydro-chemistry and analysed to characterise the quantity, quality and sustainability of ground water in aquifers.

The unplanned ground water development due to intensive agriculture practices and unorganised urban acclamation, erratic rainfall had changed the groundwater scenario into stress conditions. The groundwater in stressed aquifer is required planned and proper management in respect of demand and supply side intervention. The groundwater occurs in very complex conditions particularly in hard crystalline formation wherein high varied and diverse hydrogeological settings exist. The groundwater movement and occurs in weathered and fractured hard rock formation. It is essential to understand the complex geometry of the aquifer systems of the area to prepare implementable ground water management plans. Hence, aquifer mapping is required to have groundwater management plan. The proposed management plans will provide the “Road Map” for ensuring sustainable management and equitable distribution of ground water resources, thereby primarily improving drinking water security and irrigation coverage. The aquifer mapping and management plan will be shared by the groundwater user agency and stock holder. The user agency is mainly of the State Government and Agriculturist. The application of aquifer mapping is felt only when it reaches to effective implementation of the management plan. This can be achieved only through community participation.

1.1 Objective and Scope

Aquifer mapping itself is an improved form of groundwater management – recharge, conservation, harvesting and protocols of managing groundwater. These protocols will be the real derivatives of the aquifer mapping exercise and will find a place in the output i.e, the aquifer map and management plan. The activities under NAQUIM are aimed at:

- Identifying the aquifer geometry,
- aquifer characteristics and their yield potential
- quality of water occurring at various depths,
- aquifer wise assessment of ground water resources
- preparation of aquifer maps and
- Formulate ground water management plan.

This clear demarcation of aquifers and their potential will help the agencies involved in water supply in ascertaining, how much volume of water is under their control.

1.2 Approach and Methodology

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

Considering the objectives of the NAQUIM, the data on various components was segregated, collected and brought on GIS platform by geo-referencing the available information for its utilisation for preparation of various thematic maps.

The approach and methodology followed for Aquifer mapping is as given below:

Compilation of existing data
(Central & State Govt.)

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Identification of Primary Aquifer

↓

Identification of data gaps

↓

Data generation
(water level, exploration, geophysical, hydro-chemical, hydrogeological etc.)

↓

Data integration and Aquifer Maps with 2D & 3D disposition

↓

Generation of different thematic layers

↓

Firka wise Aquifer Management Plan

1.3 Study area

Central Ground Water Board, South Eastern Coastal Region, Chennai has taken up NAQUIM in Bhavani River basin aquifer system to prepare aquifer map and management plan. The Bhavani River basin is located in the western part of Tamil Nadu, bounded by Upper Cauvery River basin aquifer system in north, Amaravathy River basin aquifer system in south, Lower Cauvery River aquifer system in east and Karnataka state in west. The total geographical area of the study area is 10,391 sq.km in which hilly area is covered by 1198 sq km. The mappable area in the study area is 9,193 sq.km. The study area is comprising of 7 nos of districts and 95 Firka (a small division of Revenue division and groundwater assessment unit). There are about 55 nos firka categorised as over exploited and critical. The study area is shown in location map figure 1.1. and the details of the study area is shown in table 1.1.

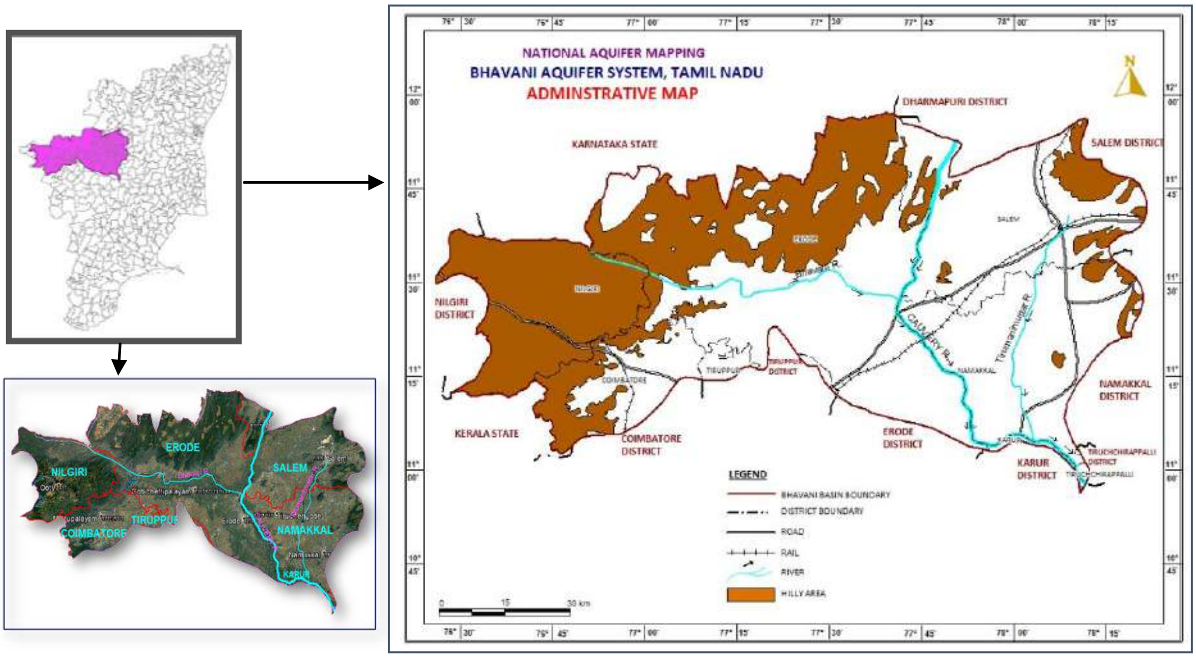


Fig.1.1: Location Map of the area

Table -1.1 The details of the study area

Sl. No	District	Area	No. of Firka	No. of OE and Critical Firka
1	Coimbatore	767	5	3
2	Erode	3187	31	15
3	Karur	49	0	0
4	Namakkal	2272	22	15
5	Nilagiri	1972	11	0
6	Salem	1962	25	19
7	Tiruppur	182	1	0
	Total	10391	95	52

1.4 Data Adequacy and Data Gap Analysis:

The available data such as Exploratory wells, Vertical Electrical Sounding (VES), ground water monitoring stations and ground water quality stations of Central Ground Water Board South Eastern Coastal Region, Tamil Nadu Water Supply and Drainage Board (TWARD), State Surface and Ground Water Data Centre of Public Works Department, Government of Tamil Nadu were compiled and analysed as per the nomenclature for adequacy of the data. The summarised detail on Data Adequacy and Data Gap Analysis is presented in the table 1.2.

Table – 1.2: Data Adequacy and Data Gap Analysis

Sl.no	Data	Required	Available	Gap
1	Exploratory well	57	146	0
2	Geophysical survey	310	279	31
3	Groundwater Monitoring well	57	321	0
4	Groundwater Quality Monitoring well	57	311	0

1.5 Rainfall

The average annual rainfall of the Bhavani basin is 811.47 mm and the computed annual rainfall of the basin ranges from 544.70 mm at Annur of Coimbatore district and 2251.00 mm in Gudalore of Nilgiri district. The rainfall distribution is shown in Fig-1.2 and the details of station given in table -1.3

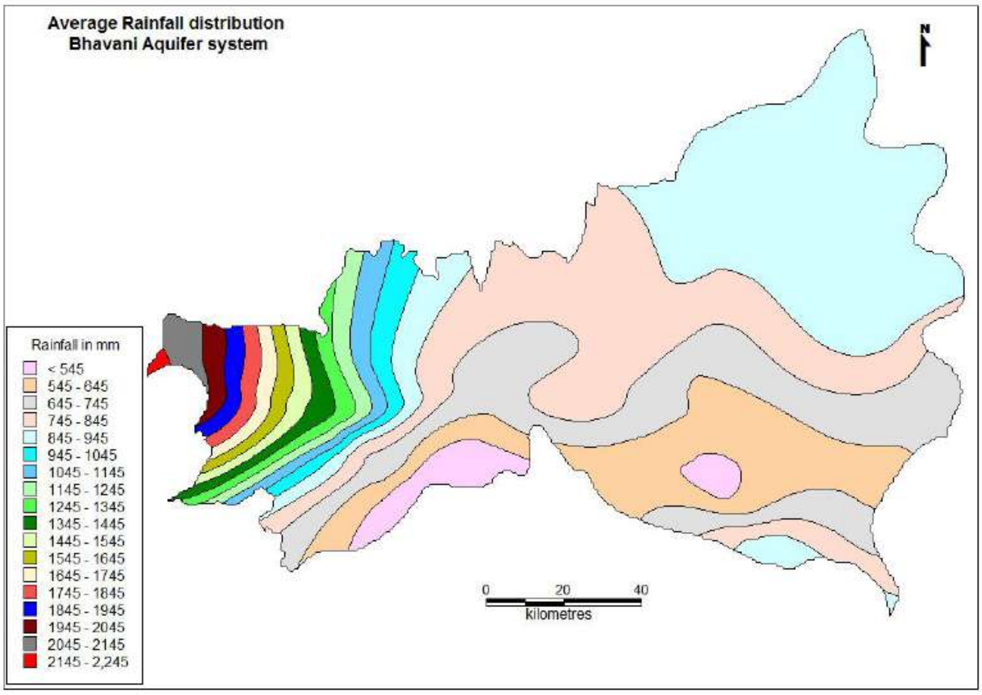


Fig.1.2: Rainfall distribution of the area

Table – 1.3: details of Rain Gauge station

Sl.no	Station Name	lat	long	Rainfall (mm)
1	Mettur	11.81	77.80	976.94
2	Salem City	11.67	78.16	1005.45
3	Sankagiri	11.47	78.87	782.89
4	Namakkal	11.22	78.17	734.34
5	Komarapalayam	11.46	77.72	729.47
6	Ammapettai	11.62	77.74	848.06
7	Bhavani Sagar	11.45	77.68	778.76
8	Gobichettipalayam	11.45	77.43	885.99
9	Sathiyamangalam	11.50	77.25	809.27
10	Modakurichi	11.23	77.78	628.60
11	Erode	11.08	77.89	998.44
12	Mettupalayam	11.30	76.97	826.21
13	Annur	11.23	77.11	544.70
14	Kothagiri	11.41	76.85	1475.20
15	Gudalore	11.51	76.47	2251.00

1.6 Physiography

Based on the SRTM DEM (Cauvery Basin-2014), the study area is divided into eight zones from 200 -300m to 2000-3000mt zones. The study area is having hilly region falling in the western part formed by Western Ghats Hill ranges trending NE-SW direction. The hilly region is occupied in Nilagiri, Erode and Coimbatore districts and covering 1198sq.km area. The plain terrain is found in the eastern parts of the study area falling in Namakkal, parts of Coimbatore, Erode, and Salem districts. The general slope of the study area is NW-SE direction. The lower elevation is found in all along the River valley of Cauvery River (Fig-1.2). In western part of the study area, the elevation is formed by the Nilagiri hill, part of Western Ghat with maximum elevation of 2637 maml and highest point is called Doddabetta. In northern part of the study area, hills are formed by Bhavani and Sathyamangalam hill ranges.

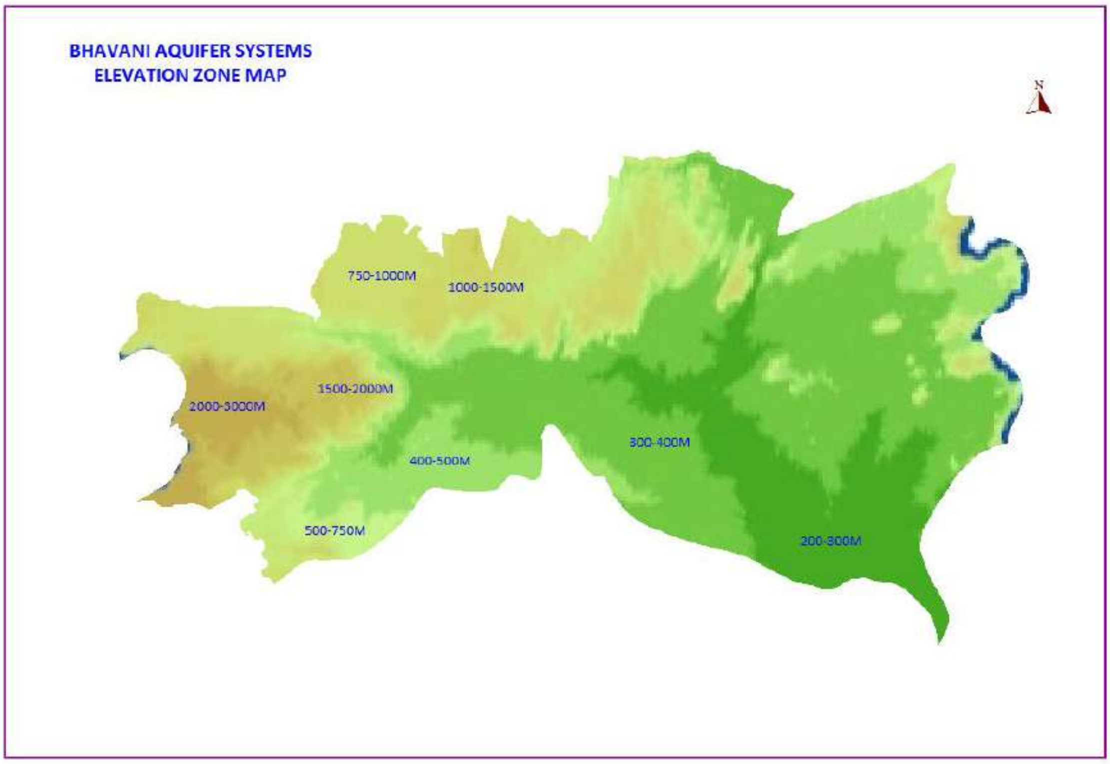


Fig.1.3: Elevation Map of the area

1.7 Hydrology and Drainage

Bhavani, Moyar, Cauvery and Thirumanimuthar Rivers are major rivers flows in the study area. The Bhavani is a perennial river, rising in Attappadi valley in Kerala. It enters Tamilnadu near Mannar and traverses from West to East for 234 kms. and joins the Cauvery near Bhavani TownMoyar River is tributary of Bhavani river and confluence with Bhavani at Bhavanisagar Dam. The Cauvery River is biggest river in south India. It rises at Talakaveri on the Brahmagiri range in the Western Ghats in Karnataka at an elevation of about 1341 m above mean sea level and flows for about 800 km, before its outfall into the Bay of Bengal. The Cauvery river system consists of 21 principal tributaries each with catchment area around 250 sq. km. In the study area, Cuavery River flows from Dharmapuri district and confluence with Bhavani River. All the Rivers receives runoff from the South-West monsoon and occasional floods during North-East Monsoon. Thirumanimuthar River originates in Salem district and confluence with Cauvery River, Namakkal district. The study area is having dendritic to sub-dendritic drainage pattern. The high density is found in the hilly region falling western parts of the study area (Fig-1.3).

In the study area, a medium irrigation projects namely, Lower Bhavani Dam is used for irrigation purposes. This dam is the longest in the basin with a maximum length of 8.79 km and is located on the river Bhavani. The catchment area of this reservoir is 4200 sq. km. The gross and live storage of the reservoir is 929 MCM and 908 MCM respectively.

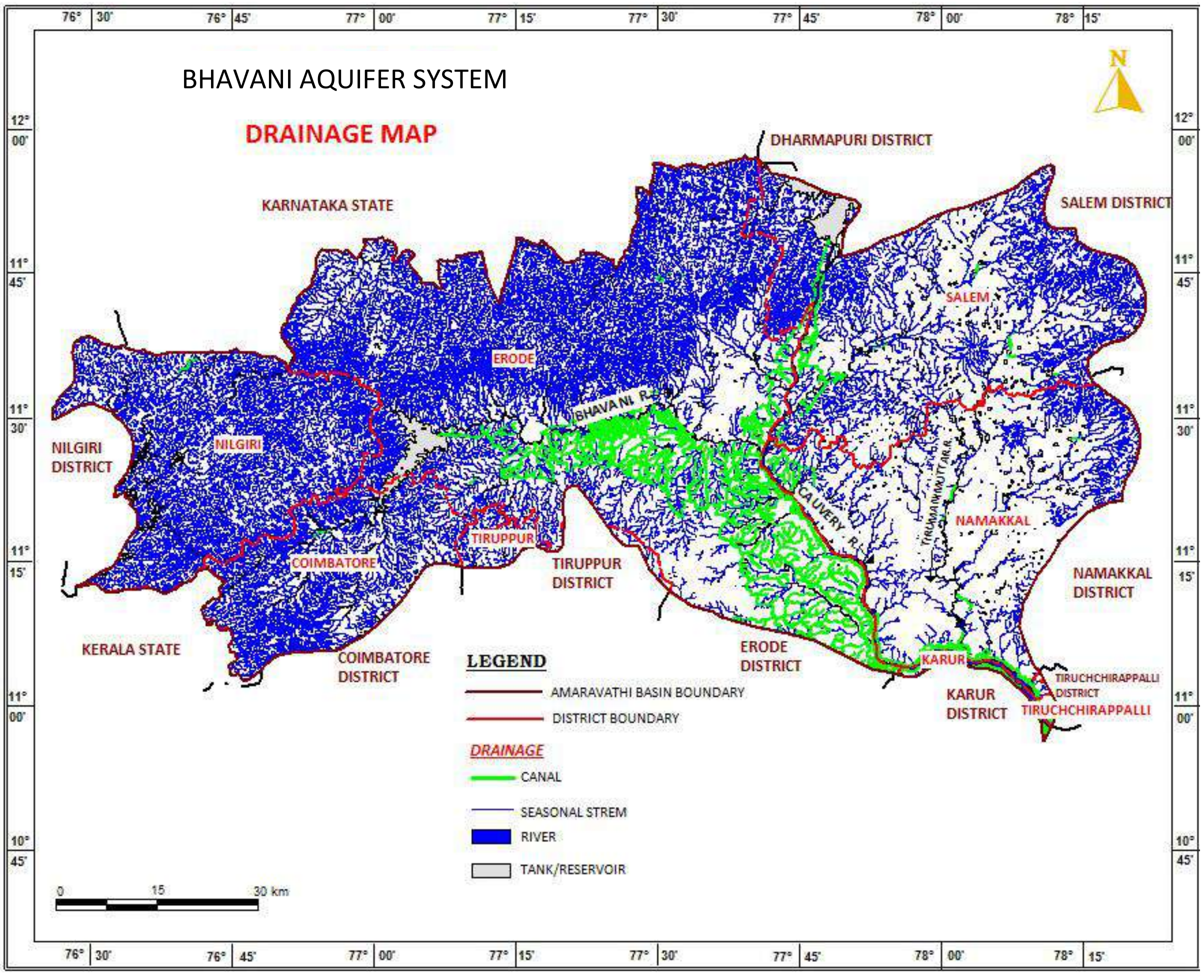
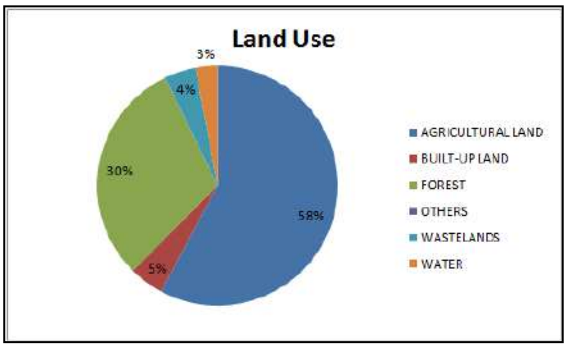
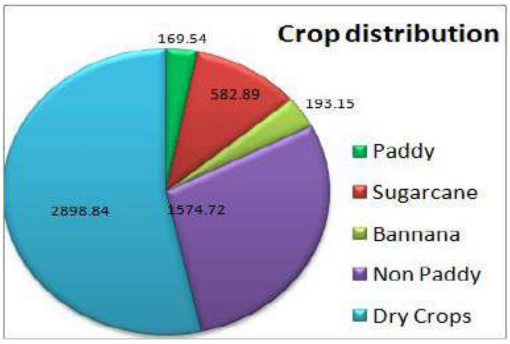


Fig.1.4: Drainage Map of the area

1.8 Agriculture, Irrigation and Cropping Pattern

In the study area, the agriculture and forest are main tow landuse and land cover. the agriculture land is covering about 52 % of the total geographical area of the basin and forest is occupied 30 % of the area. The wasteland, Settlement and water bodies are covering less than 5% of the total geographical area of the basin.





The agriculture land is covering 5419.14 sq.km of the total mappable area and represented by 58 % of the total geographical area of the basin. The total 5419.14 sq.km area of the agriculture land are used for crops such as paddy, sugar cane, banana, non-paddy and dry crops. the dry crops are taken from 2898.84 sq.km area having 53.49 % of the total crops land. The water intensive crops such as paddy, sugar cane and banana are taken from 169.54 sq.km, 582.89 sq.km and 193.89 sq.km respectively. The non-paddy crops are taken from 1574.72 sq.km area having 29.06 % of the crops land. The groundwater is being used to irrigate 2520 sq.km area in the basin but the effective groundwater utilisation is only about 17% of the cropped land.

In the study area, Left Bhavani Major Irrigation project (Bhavanisagar Dam) is having command area 83769 hec of land (Fig-1.4) with full storage capacity of 2272 m cm. It covers Erode and Trichy districts in Tamil Nadu.

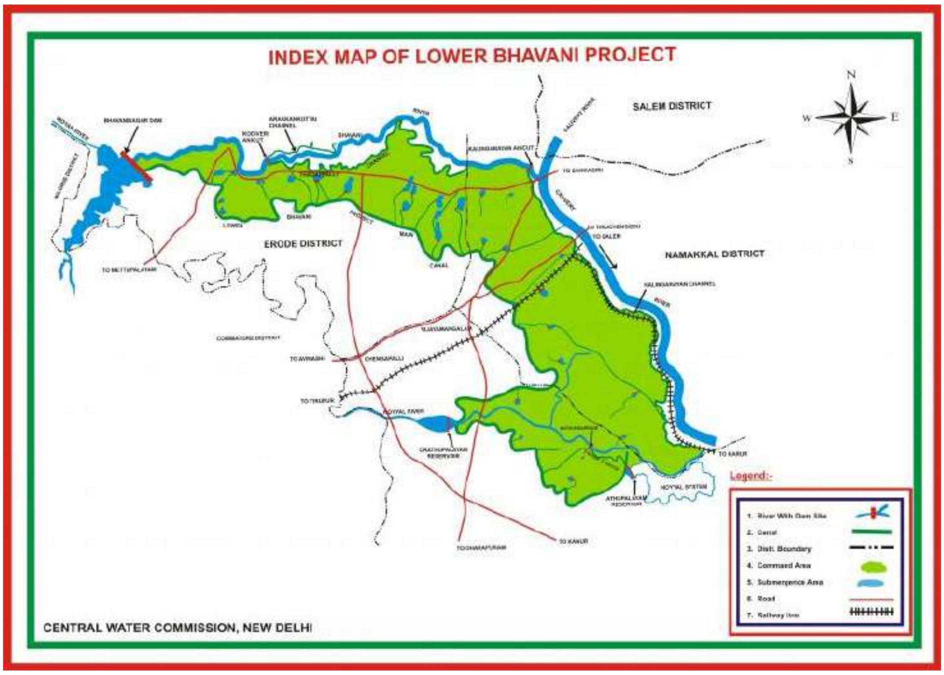


Fig-1.5. Canal command area of LBP

2 DATA COLLECTION AND GENERATION

Hydrogeological data includes quality and quality from existing data were collected and analysed in GIS platform to validate and avoid discrepancy while preparing the aquifer mapping in the basin. The date collected from allied department such as TWADB, SSGWDC of PWD, Agriculture departments and administrative department were also included in the data collection and analysis.

2.1 Groundwater exploration

The groundwater exploration was carried out CGWB, SECR down to depth of 200mts and state departments drilled for drinking water purposes well down to depth of maximum 150mts were collected and compiled for demarcating the aquifer system of the basin. In the study area, 146 nos exploratory well drilled before the NAQUIM and 56 nos of well were drilled in the area where data gap is found during aquifer mapping. The details of the exploratory well are presented in table-2.1 and the location of the exploratory well are shown in Fig-2.1

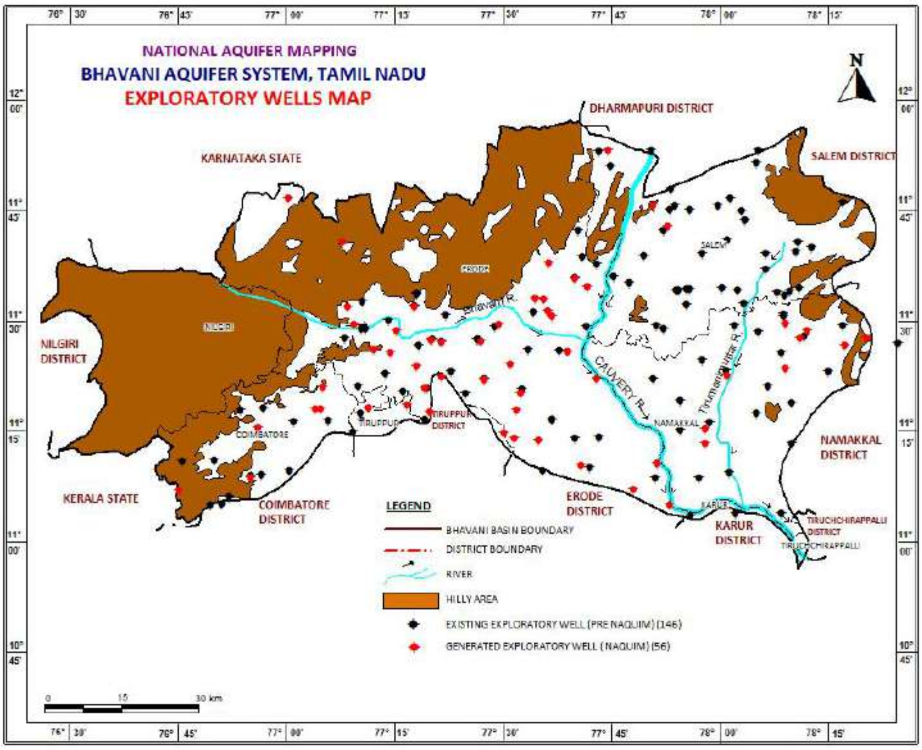


Fig-2.1. Exploratory well location map

2.2 Geophysical Survey

Geophysical survey mainly of Vertical Electrical Sounding (VES) is carried out to know the sub-surface geology of the area. In CGWB, SECR. the VES conducted for 200mts depth of investigation using Schlemberger Electrode array. The sites were located in between the Exploratory bore well to full fill data gap situation to prepare the aquifer mapping. In the study area, 279nos VES was conducted for 200mts depth of investigation and studied the sub-surface geology. The information on sub-surface geology were incorporated with exploratory well data to make the sub-surface geology more accurate to prepare aquifer mapping. The location of VES conducted in the area is shown in Fig-2.2

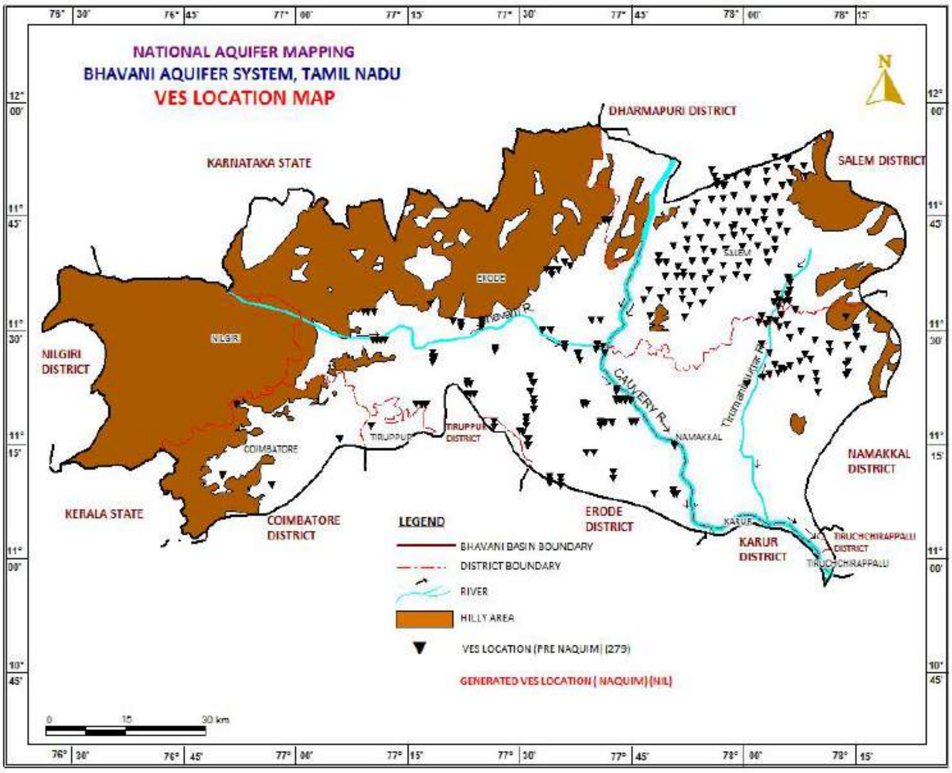


Fig-2.2. VES location map

2.3 Groundwater Level Monitoring Well

Central Ground Water Board, SECR was established key wells to monitor the groundwater level four times in a year in shallow aquifer which will give clear picture about the groundwater recharge in aquifer system. SSGWDC of PWD and TWADB are also monitoring the groundwater level in month wise in each district of water table aquifer mainly of dug well. The fractured aquifer of deeper aquifer is also monitored using the bore well called piezometer. All the water level data are incorporated for analysing the recharge to groundwater in the study area. In the study area, 292nos of well were monitored for water table aquifer and 29nos of piezometer were monitored for fractured well. The groundwater level monitoring well locations are shown in Fig-2.3.

2.4 Groundwater Quality Monitoring Well

Central Ground Water Board, SECR was established wells to monitor the groundwater quality one time in a year of shallow aquifer. SSGWDC of PWD and TWADB are also monitoring the groundwater quality in each district of water table aquifer mainly of dug well. All the groundwater quality data are incorporated for analysing the groundwater quality issues. In the study area, 311nos of well were monitored for groundwater quality. The groundwater quality monitoring well is shown in Fig-2.4.

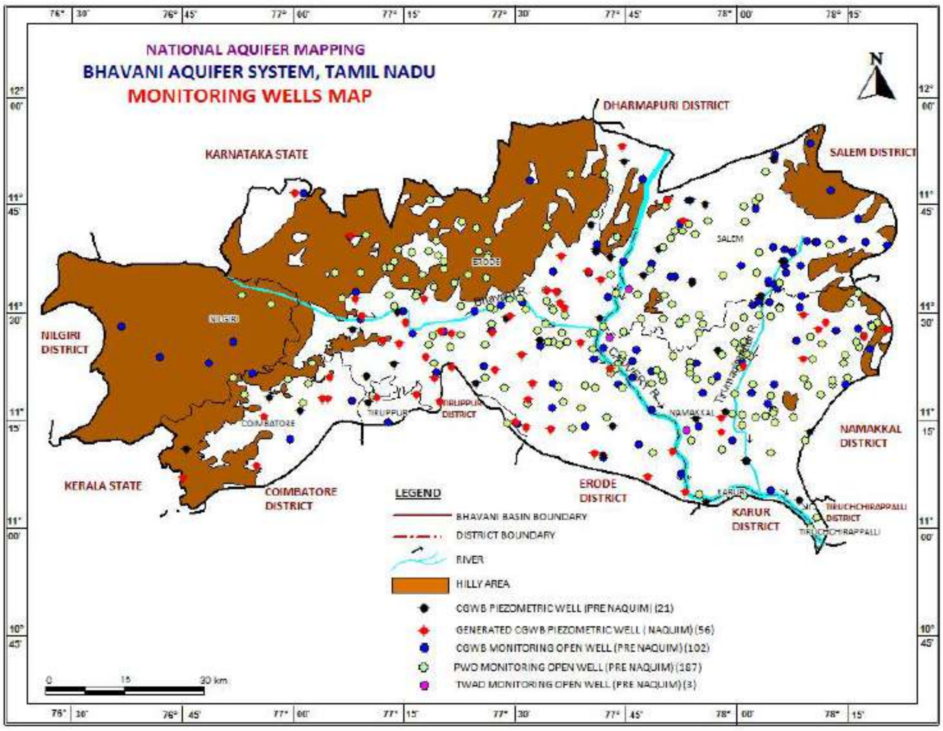


Fig-2.3. Groundwater Level Monitoring well location map

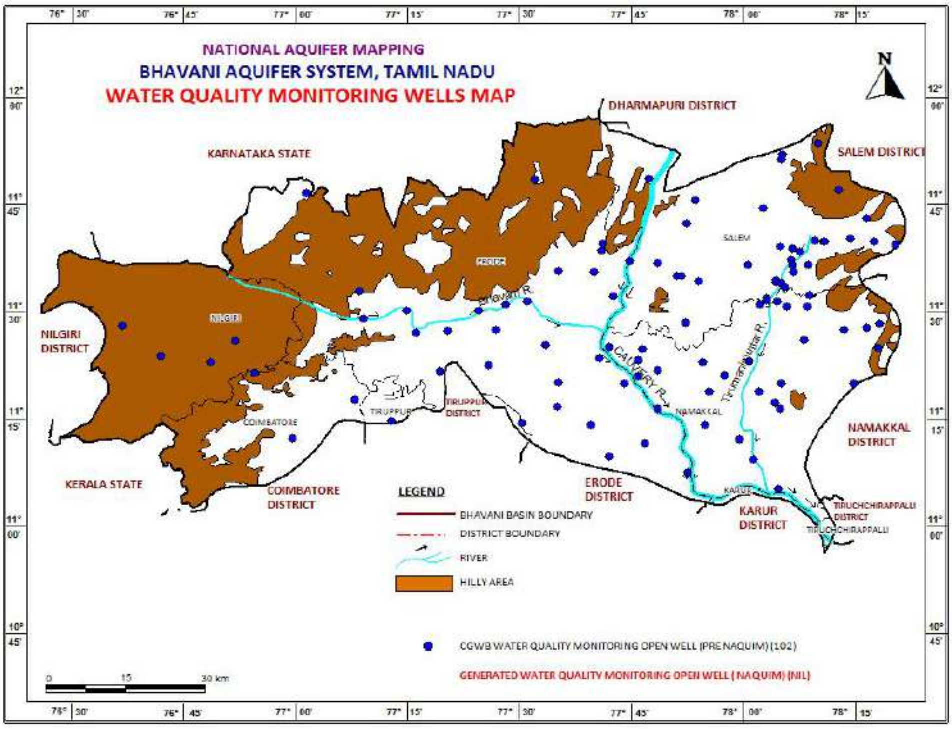


Fig-2.4. Groundwater Quality Monitoring well location map

2.5 Data Generation

Based on the data collected and existing data available with CGWB, data adequacy was worked out to decide the scope and extent of further data generation. The data requirement was optimised and decided that the existing hydrogeological data is sufficient to generate the desired outputs of aquifer maps and management plan. However, about 56 nos of bore well drilled and generated data for aquifer mapping in the area. The groundwater management plan, includes supply side and demand side intervention is prepared based on the spatial information such as geology, geomorphology, drainage, surface water body and landuse/ landcover. All spatial information is generated using remote sensing data and digitally recorded in GIS environ. The same has been used to generate management plan.

2.5.1 Geology

Geologically the area is underlain by the hard crystalline formation of Archean age. Gneiss and charnockites are major rocks types occupied predominantly in the study area (Fig-2.5). The granitic / acidic rock occupied in the eastern parts of the study area is also prominent in the study area. The charnockites and granitic/ acidic rocks are emplaced in the gneissic formation. The charnockite is exposed in the western and northern parts of the study area trending NE-SW direction. Other rocks formations are occupied in small area of the basin aquifer system. Aquifer systems of the area is mainly formed by the gneiss and charnockites of the basin.

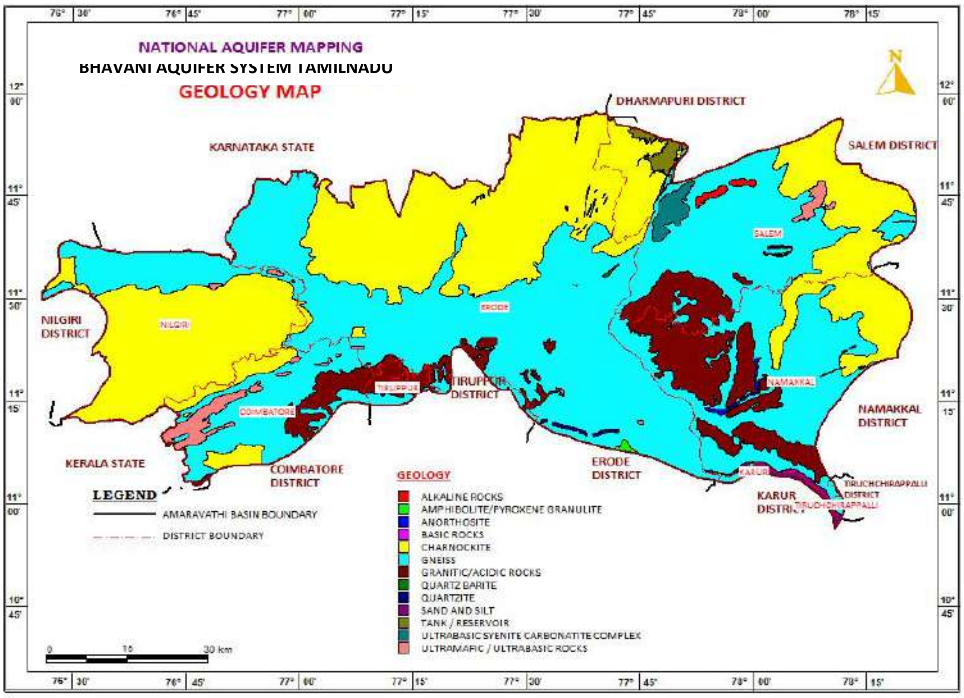


Fig-2.5. Geology map

2.5.2 Geomorphology

The different landforms discernable on the imagery have been broadly classified into Denudational hill, dissected hill and fluvial landforms. The landforms delineated are Hills and plateau, Pediment, pediplain and valley fills (Fig-2.6).

Hills and plateau: Hills and plateau is highly elevated hills prone for dissection and denudation. It devoid or wear very thin soil development. The landforms are un-dissected / less dissected, intermontane valley, structural hill, deflection slope, moderately dissected, highly dissected, denudational / residual hill, structural hill, linear /curvilinear ridge.

Pediment: Pediment is gently undulating rock surface and wears a thin cover of weathered materials. It has been carved over gneissic formation. Pediment zones permit poor infiltration and act as run-off zones, however the fractures, which traverse these zones, could act as good recharge zones. The landforms are bajada, pediment Inselberg complex and dissected / un-dissected plateaus.

Pediplain: This landform is formed by disintegration of county rock. The landforms are pediplain shallow, pediplain moderate and pediplain deep. It is classified on basis of the thickness of the soil development. The pediplain shallow is having thickness of soil ranging from 1-5mts and the pediplain moderate thickness is ranging from 5-10mts. The pediplain deep thickness is more than 10mts. These landforms are formed in the southern parts of the study are.

Valley fill: Valley fill has been developed mainly in the valley portions over charnockite due to deposition of unconsolidated materials by fluvial agencies. The materials are silt, fine sand and at places pebbly. The thickness of fill and weathered zones are ranging from 1 to 15 m and it act as good recharge zone.

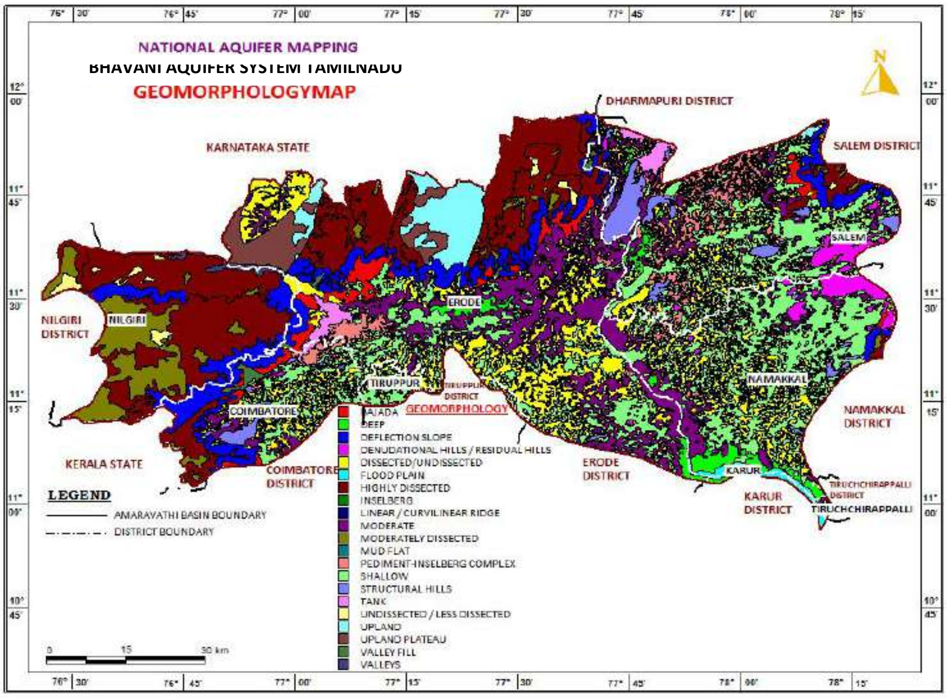


Fig-2.6. Geolomorpholgy map

2.5.3 Landuse /landcover

Landuse / Landcover map was generated using satellite data for the study area. Agriculture land, forest land, waste land, settlement and waterbody are the main landuse/landcover in the area (Fig-2.7). The agriculture land is occurring in the eastern parts of the study area. The forest classes are occurring in the western part of the area.

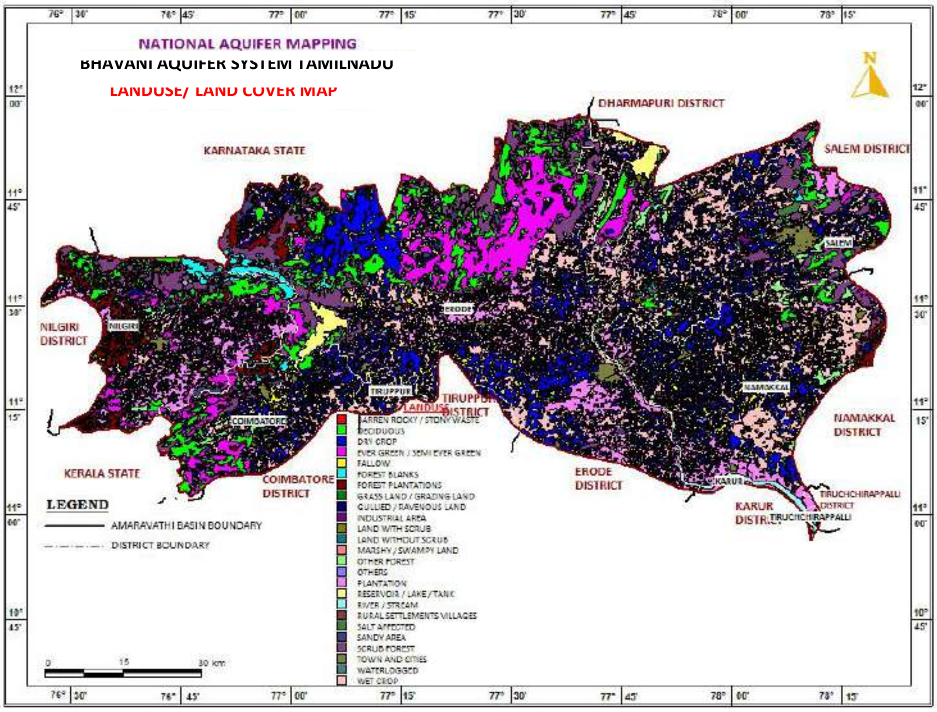


Fig-2.7 Landuse / Landcover map

2.5.4 Soil

Alfisol, Vertisol, Entisol, Inceptisol and Miscellaneous order are soil type mapped in the area (Fig-2.8). Alfisols soils results from weathering process that leach clay minerals and other constituents out of surface layer and in to the sub-soil.

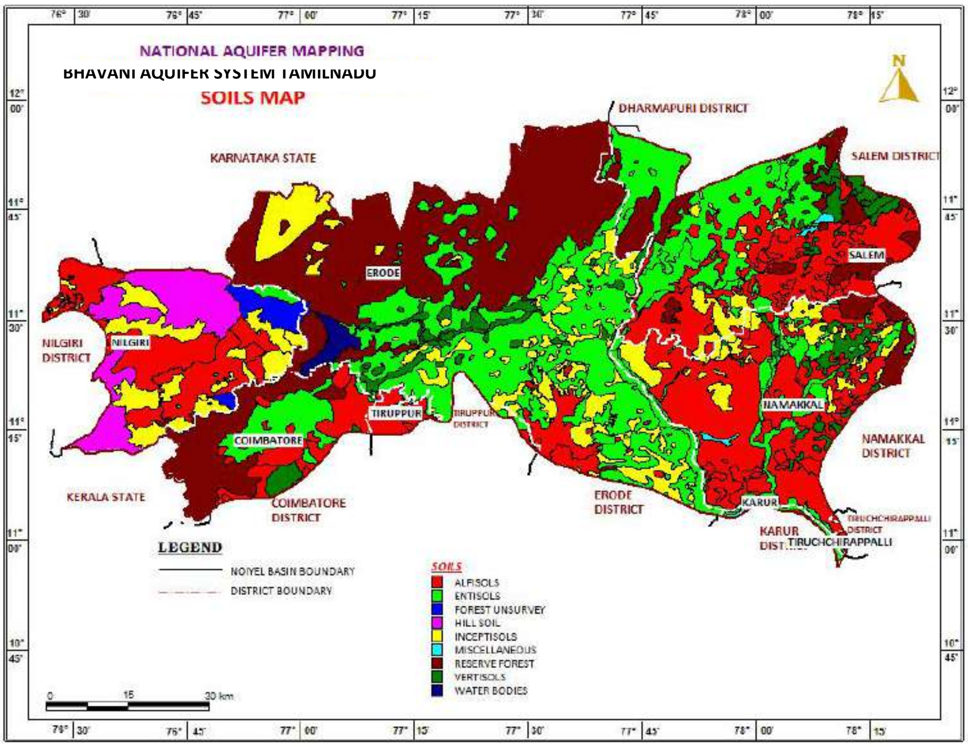


Fig-2.8 Soil map

They formed primarily under forest or mixed vegetative cover and are productive for most crops. In the study area, it is occupying in the eastern parts of the area. Vertisols are soils of semi-arid humid environment that generally exhibit only moderate degree of soil weathering and development. In the study area, it is covering in very small area. Entisols type occurs in the area of recently deposited parent materials or in area where erosion or deposition rates are faster than the rate of soil development such as dunes, steep slopes and flood plains. They occur in many environments. In the study area, it is found central parts of the area. Inceptosols are soils of semi-arid humid environment that generally exhibit only moderate degree of soil weathering and development. In the study area, it is occupying western and eastern parts of the area. Hill soil found in the western parts of the area.

3 DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING

3.1 Hydrogeology

In hard crystalline formation, the groundwater mainly occurs in weathered and fractured rocks. In the study, Gneiss, Charnockites and Granite / acidic rocks are predominant and forms the aquifer systems (Fig-3.1). Recent alluvium occurring along the river course is contributing to groundwater aquifer systems sporadically. The other rock formations are occupying less area and contribute less to groundwater aquifer systems. The Basic rocks are act as barrier for the groundwater movement and generally trending NE-SW direction. The groundwater occurrences in basic rocks are considered to be good in western and northern parts of the basic rocks. The groundwater movement is generally flowing the general slope of the area particularly in the hilly region and plain terrain the groundwater flow towards the major river drain in the area. It indicates that the rivers drains in the area are highly influenced by the groundwater systems.

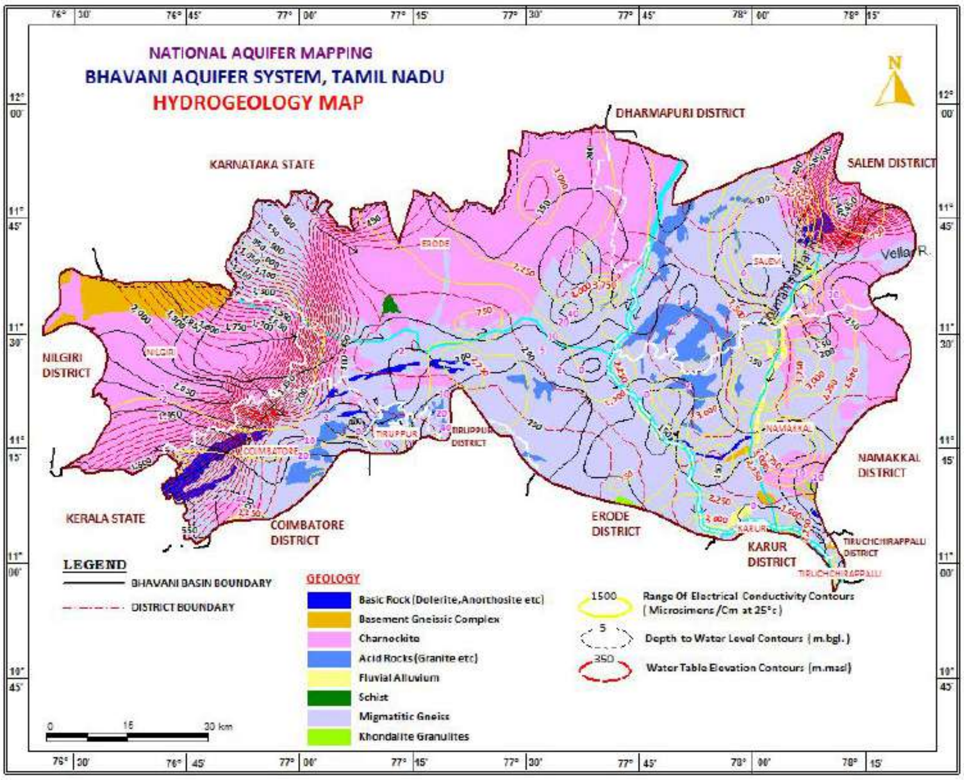


Fig-3.1 Hydrogeology map

3.2 Occurrence of Groundwater in Gneiss

In the study area, gneissic formation is occupying more than 50% of the area and forms main aquifer system in the area. The gneissic formation is occurring in the central and eastern parts of the area. The groundwater generally is occurring in the weathered and fractured rocks. Two types of groundwater abstraction structures such as dug well and bore well are mainly used in this formation. The depth of the dug well is upto 30m bgl and the depth of dug well varies due to surface water sources. The depth of bore well is generally below 200m bgl and the fracture are encountered up to the depth of 200mts.

3.3 Occurrence of Groundwater in Charnockites

In the study area, charnockite formation is occupying 40% of the area and forms the aquifer system in the area. It is occurring in the western and eastern parts of the area. It forms hill region in the area, trending NE-SW direction. The groundwater generally is occurring in the weathered and fractured rocks. The groundwater is mainly occurring in the weathered formation and scanty in fractured medium. The groundwater is mainly abstracted by the dug well in the region. The depth of the dug well is upto 20m bgl and it is recharged during the monsoon. Charnockite of this region plays vital role in groundwater recharge as it is covered with thick vegetation cover and receives good to moderate rainfall. It acts as good recharge zone for the aquifer systems and also contribute to surface water sources due to base flow during non-monsoon time.

3.4 Occurrence of Groundwater in Granitc /acidic

In the study area, Granite / acidic rock formation occupies in a very small area and forms aquifer systems. It is found mainly in the eastern parts of the study area and contribute less to groundwater systems. The groundwater is mainly occurring in the weathered and fracture formation. Dug well and bore well are groundwater abstraction structure. The depth of dug well is up to 25 m bgl and the depth of the bore well is up to 200m bgl.

3.5 Water level scenario

Monitoring groundwater level of the aquifer systems implies the groundwater recharge to aquifer system and rate of groundwater abstraction in an area. In the study area, groundwater level carried out four times in a year which covers the pre-monsoon and post-monsoon period. The water level data collected from dug well and piezometer representing two aquifer systems are analysed for pre-monsoon and post monsoon period. The water level data of May is considered for pre-monsoon and January is considered for post-monsoon water level data. The long term water level data have been used to describe water level scenario of the aquifer system.

3.5.1 Pre-monsoon water level Aquifer-I

Water level data collected from May-2006 to 2015 was analysed for pre-monsoon. The water level data is varies from 0.7 to 29.0 m bgl. The water level data is analysed into five zones such as 0-2, 2-5, 5-10, 10-20 and 20-40 m bgl. Water level of the basin is falling in two zones 5 to 10 10 to 20 mts representing 42% and 43% respectively of total well of 129 nos. The deepest water level is 20-40 mts and 4nos of well is showing deepest water level in the area. The details of water level zone of pre and post monsoon are given in table-3.1.

Table: 3.1 Water level zone of Pre and post monsoon data of Aquifer-I

Monsoon	**Number & percentage of wells showing depth to water level (m)**										**Total No of wells analysed.**
	0-2		**2-5**		**5-10**		**10-20**		**20-40**		
	No	**%**	**No**	**%**	**No**	**%**	**No**	**%**	**No**	**%**	**No**
May (2006-15)	**4**	**3**	**12**	**9**	**54**	**43**	**52**	**42**	**4**	**3**	**129**
Jan-16 (2007-16)	**7**	**5**	**26**	**20**	**70**	**54**	**26**	**20**	**2**	**1**	**131**

Based on the water level data, spatial water level map has been generated in GIS environ showing five zones of 0-2, 2-5, 5-10, 10-20 and 20-40 m bgl. The maximum area is covered by 5-10 m and 10-20 m bgl. Both the zones are occurring in the gneissic formation. The 10-20 m bgl water level zone is occurring in the uplands of gneissic formation. The deepest zone is occurring in small pockets. The 2-5 m water level zone is found along the Cauvery River mainly in Erode and Namakkal districts (Fig-3.2).

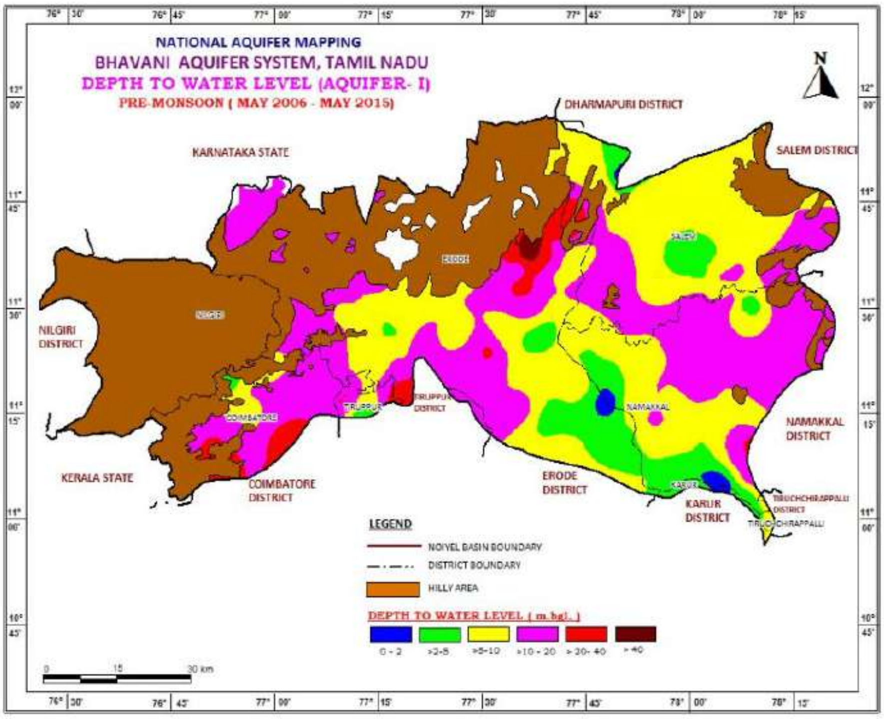


Fig-3.2 Depth to water level zone map (May2006-15) of aquifer -I

3.5.2 Post-Monsoon water level Aquifer-I

Water level data collected from January-2007 to 2016 was analysed for post-monsoon. The water level data is varies from 0.3 to 21.0 m bgl. The water level data is analysed into five zones such as 0-2, 2-5, 5-10, 10-20 and 20-40 m bgl. Water level of the basin is falling in three zones, 2-5,5-10 and 10-20m bgl representing 20%, 54% and 20% respectively of total well of 131 nos. The number of wells falling in 2-5 and 5-10 m bgl zone is increased considerably and decreased in 10-20m bgl water level zone. The deepest water level is 20-40 mts and 2nos of well is showing deepest water level zone in the area. The details of water level zone of pre and post monsoon are given in table-3.1.

Based on the water level data, spatial water level map has been generated in GIS environ showing five zones of 0-2, 2-5, 5-10, 10-20 and 20-40 m bgl. The maximum area is covered by 2-5 and 5-10 m and 10-20 m bgl. All three zones are occurring in the gneissic formation. In post monsoon, the 2-5m bgl water level is occurring in all along Cauvery River Course and area is increased considerably. Followed by 5-10 m bgl water level zone is increased than pre-monsoon. The 10-20 m bgl water level zone occurring in the uplands of gneissic formation is reduced than pre-monsoon. The deepest zone is occurring in small pockets and no change is occurring from pre-monsoon to post mon-soon spatially. The 2-5 m water level zone is found along the Cauvery River mainly in Erode, Salem and Namakkal districts (Fig-3.3).

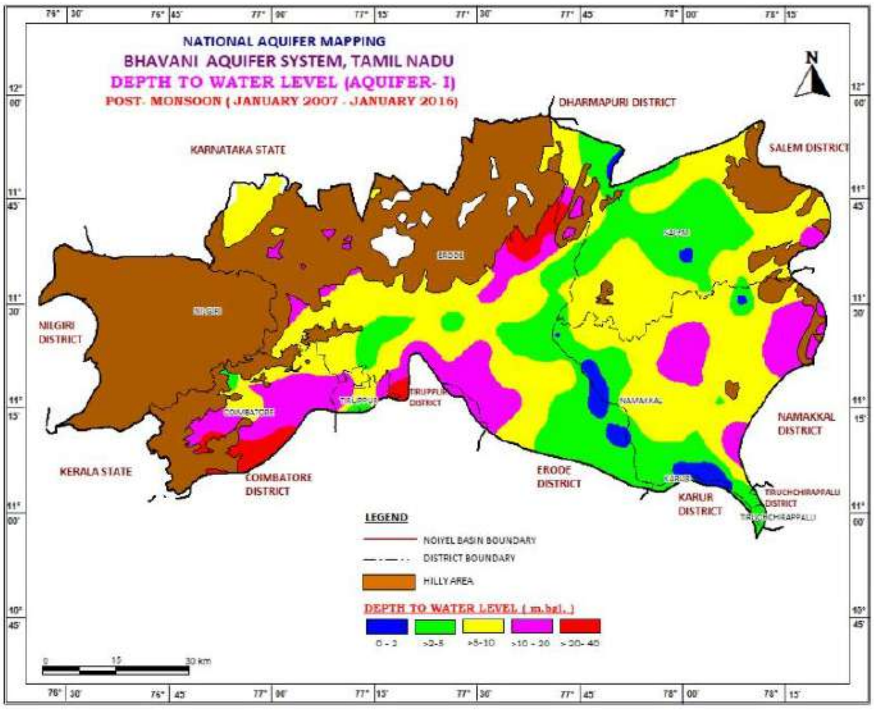


Fig-3.3 Depth to water level zone map (January 2007-16) of Aquifer-I

3.5.3 Pre-monsoon water level aquifer-II

Based on the water level data collected from piezometer for the period between May 2006-15 was analysed and used to describe the water scenario of aquifer-II. The water level of aquifer-II is ranging from 3.2 to 44.0 m bgl. The water level data is analysed into five zones such as 2-5, 5-10, 10-20, 20-40 and > 40 m bgl. Water level of the basin is falling in four zones 5-10, 10-20, 20-40 and >40 m bgl representing 26%, 33%, 15% and 15% respectively of total well of 27 nos. The deepest water level is >40 mts and 4nos of well is showing deepest water level zone in the area. The water level zone of 10-20m bgl is very prominent having 9 nos well representing 33% of the bore well followed by 5-10 m bgl water level zone having 26% of bore well. The water level zones of The details of water level zone of pre and post monsoon are given in table-3.2.

Table: 3.2 Water level zone of Pre and post monsoon data of aquifer-II

Monsoon	**Number & percentage of wells showing depth to Piezometric head (mbgl)**												**Total No of wells analysed.**
	0-2		**2-5**		**5-10**		**10-20**		**20-40**		**>40**		
	No	**%**	**No**	**%**	**No**	**%**	**No**	**%**	**No**	**%**	**No**	**%**	**No**
May (2006-15)	0	0	3	11	7	26	**9**	**33**	**4**	**15**	**4**	**15**	**27**

Jan (2007-16)	2	7	3	10	**13**	**43**	**7**	**23**	**2**	**7**	**3**	**10**	**30**

Based on the water level data, spatial water level map has been generated in GIS environ showing five zones of 2-5, 5-10, 10-20, 20-40 and >40 m bgl. The deepest water level zone of >40m bgl is occupying in two pockets found in northeast and southwest of the area surrounded by the water zone of 40-20 m bgl zone. This is mainly occurring in the uplands of the gneissic terrain. The zone of 5-10m bgl is occurring along the river course found in the southern and south-eastern part of the area (Fig-3.4).

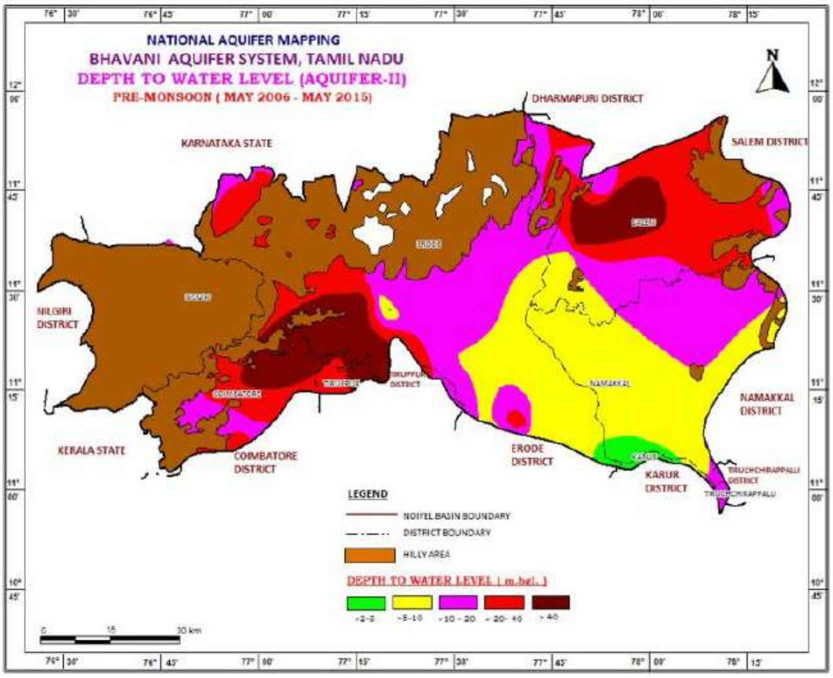


Fig-3.4 Depth to water level zone map (May2006-15) of Aquifer -II

3.5.4 Post-monsoon water level aquifer-II

Based on the water level data collected from piezometer for the period between January 2007-16 was analysed and used to describe the water scenario of aquifer-II. The water level of aquifer-II is ranging from 1.5 to 41.0 m bgl. The water level data is analysed into six zones such as 0-2, 2-5, 5-10, 10-20, 20-40 and > 40 m bgl. Water level of the basin is falling in four zones 5-10, 10-20, 20-40 and >40 m bgl representing 43%, 23%, 7% and 10% respectively of total well of 30nos. The deepest water level is >40 mts and 3nos of well are showing deepest water level zone in the area. The water level zone of 10-20m bgl is very prominent having 9 nos well representing 33% of the bore well followed by 5-10 m bgl water level zone having 26% of bore well. The water level zones of The details of water level zone of pre and post monsoon are given in table-3.2.

Based on the water level data, spatial water level map has been generated in GIS environ showing six zones of 0-2, 2-5, 5-10, 10-20, 20-40 and >40 m bgl. The deepest water level zone of >40m bgl is occupying in two pockets found in northeast and southwest of the area surrounded by the water zone of 40-20 m bgl zone. This is mainly occurring in the uplands of the gneissic terrain. The zone of 2-5m bgl is occurring along the river course found in the southern and south-eastern part of the area and the area of 5-10m bgl is increased than pre monsoon water level zone (Fig-3.5). 0-2 water level zone is occurring in southern tip of the area indicating the waterlogging conditions. The area which is falling in 5-10 water level of pre monsoon is occupied by 2-5 water level zone of post monsoon. It indicates that the groundwater recharge in the shallow fracture is faster than deeper fracture.

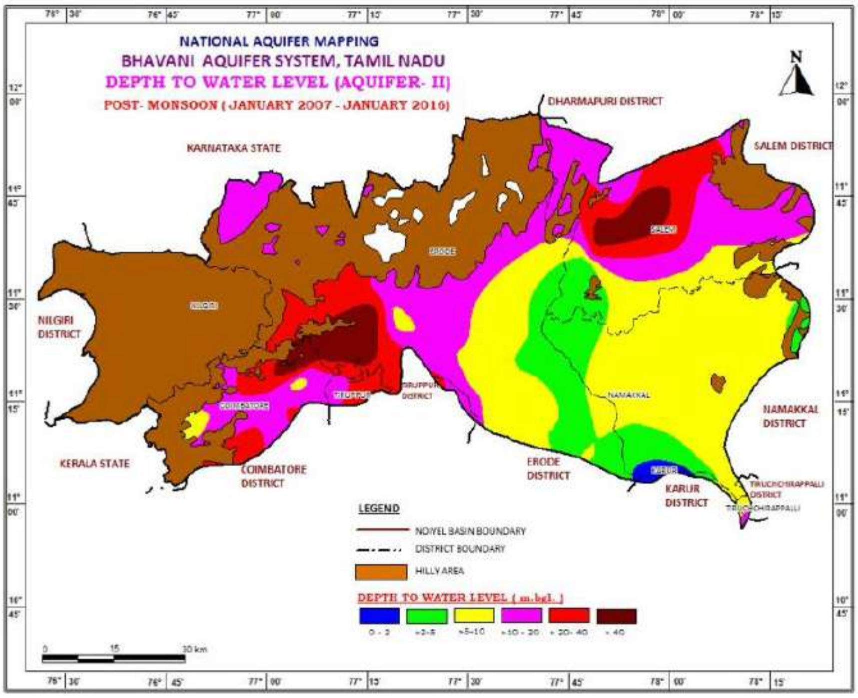


Fig-3.5 Depth to water level zone map (January 2007-16) of aquifer-II

3.6 Groundwater quality

The groundwater samples were collected from 311 dug wells and analysed pH, EC, anion, cation and Fluoride concentrations. In the study area, the EC of groundwater is discussed in the report. Electrical Conductivity of the groundwater is ranging from 150 to 7180 µS/cm at 25 °C. 42% of the sample is showing EC between 750-2250 µS/cm at 25 °C which is considered as moderately fresh water. More than 50% of the sample is falling EC of 2250 - >3000 µS/cm at 25 °C which is showing the groundwater is high concentration mineralisation. Only less than 10% of sample is showing the EC less than 750 µS/cm at 25 °C and this groundwater is considered as fresh (Table-3.3).

The EC data is represented spatially in Fig-3.6 and it shows EC into four zones such as 0-750, 750-2250, 2250-3000 and >3000 µS/cm at 25 °C. The maximum area is falling EC between 750-2250 µS/cm at 25 °C and the less than 750 µS/cm at 25 °C is occurring in the western parts of the area. The EC between 2250 - >3000 µS/cm at 25 °C is falling in the eastern parts of the area where upland of the gneiss and granite formation. The high mineralisation is found in the eastern parts of the area and indicates that high concentration of chemical constituents.

Table-3.3 EC of groundwater

EC (µS/cm at 25º C)	**Water Class**	**Percentage of Samples**
0-750	Fresh	**10%**
750 – 2250	Moderately Fresh	**42%**
2250 – 3000	Slightly mineralized	**25%**
>3000	Highly mineralized	**23%**

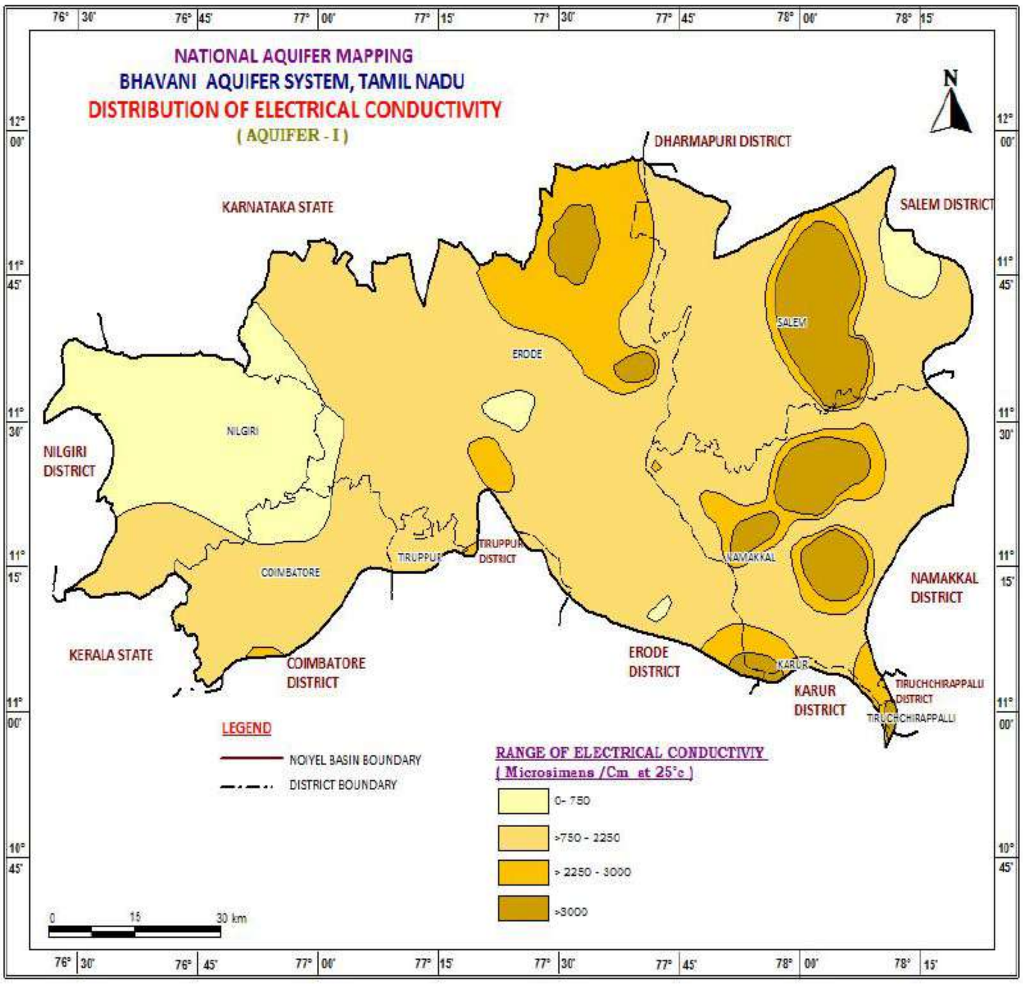


Fig-3.6 Spatial distribution of EC in groundwater

3.7 Aquifer Disposition

The aquifer disposition of the area is demarcated based on the groundwater exploration data which depicts the lateral and vertical configuration of the aquifers using Rockworks software. In the study area, two aquifer systems have been demarcated based on the groundwater water occurrence and movement. The first aquifer (Aquifer-I) is weathered layer of all three lithology such as gneiss, granite and charnockite formation. The second aquifer (Aquifer-II) is fractured layers of all three lithology such as gneiss, granite and charnockite formation. The third layer is massive formation of all three lithology. The bottom of the aquifer-II is demarcated using the lower most fractured depth encountered in the bore well. The aquifer demarcation of the area is depicted in 2D and 3D view.

3.8 2D Aquifer disposition (Hydrogeological cross section)

In the study area, hydrogeological cross sections were prepared across and along basin to know the vertical and lateral extension of the basin aquifer system. Four hydrogeological cross sections were prepared across the basin aquifer systems. Three hydrogeological section along the aquifer basin were prepared for the study area.

3.8.1 Hydrogeological cross section Across aquifer basin

The hydrogeological cross section across the aquifer basin is shown in Fig- 3.7 to 3.10. It indicates that the thickness of fractured aquifer is more in northern part of the study area where the charnockite is occurring and uniform thickness in gneiss formation. The fractured aquifer is almost following the general topography of the terrain.

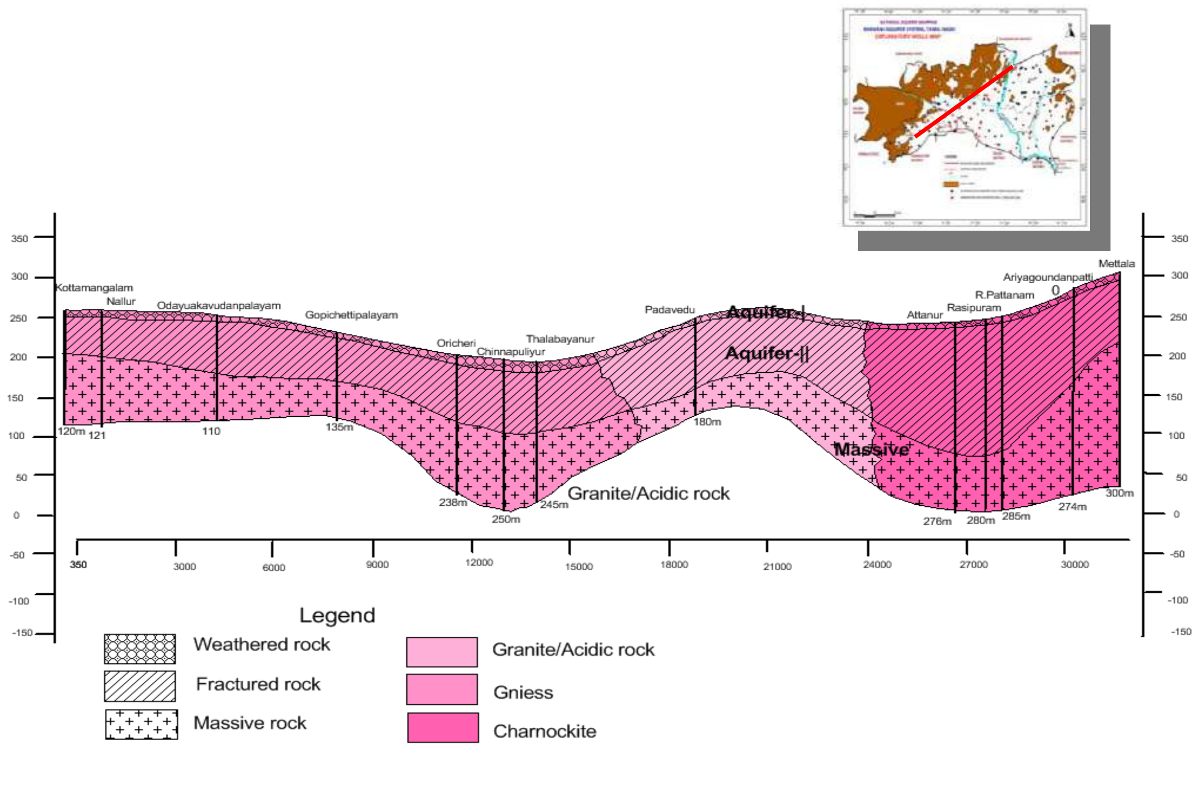


Fig-3.7 Hydrogeological cross section

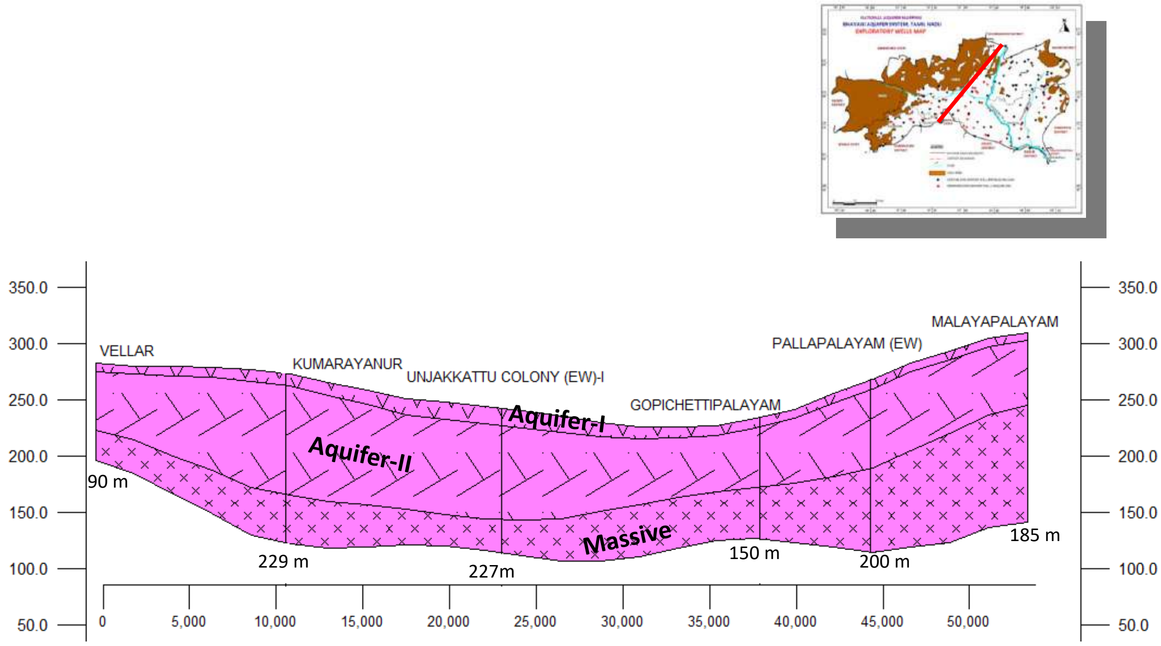


Fig-3.8 Hydrogeological cross section

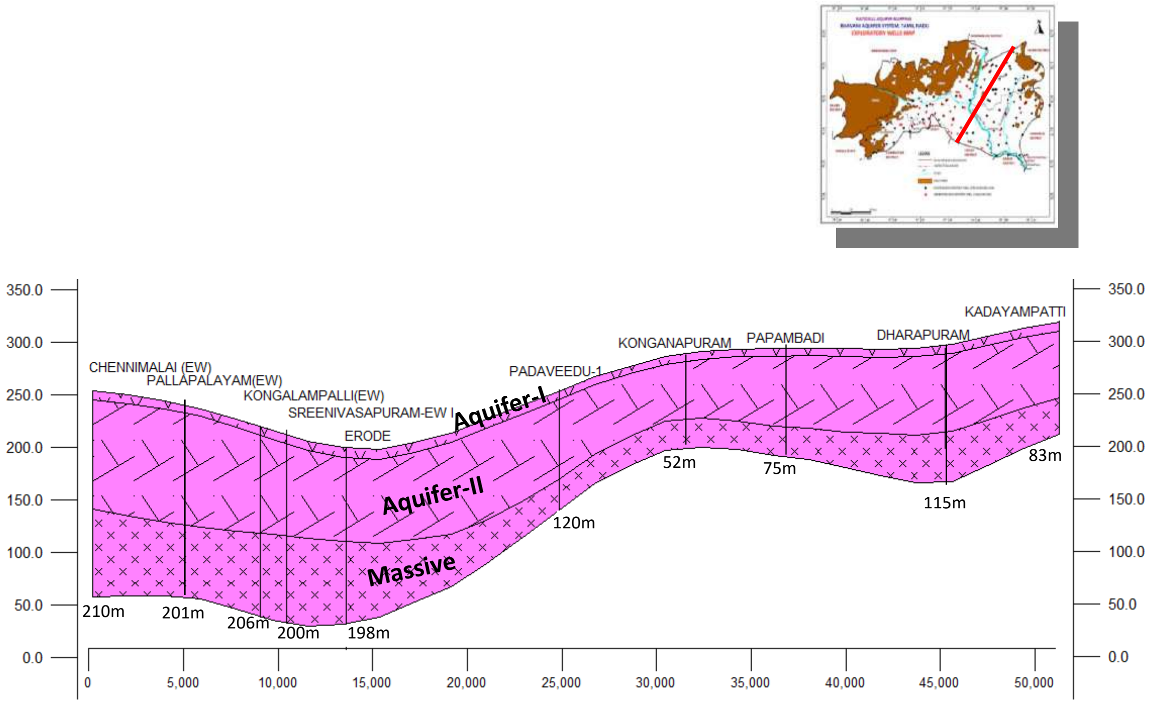


Fig-3.9 Hydrogeological cross section

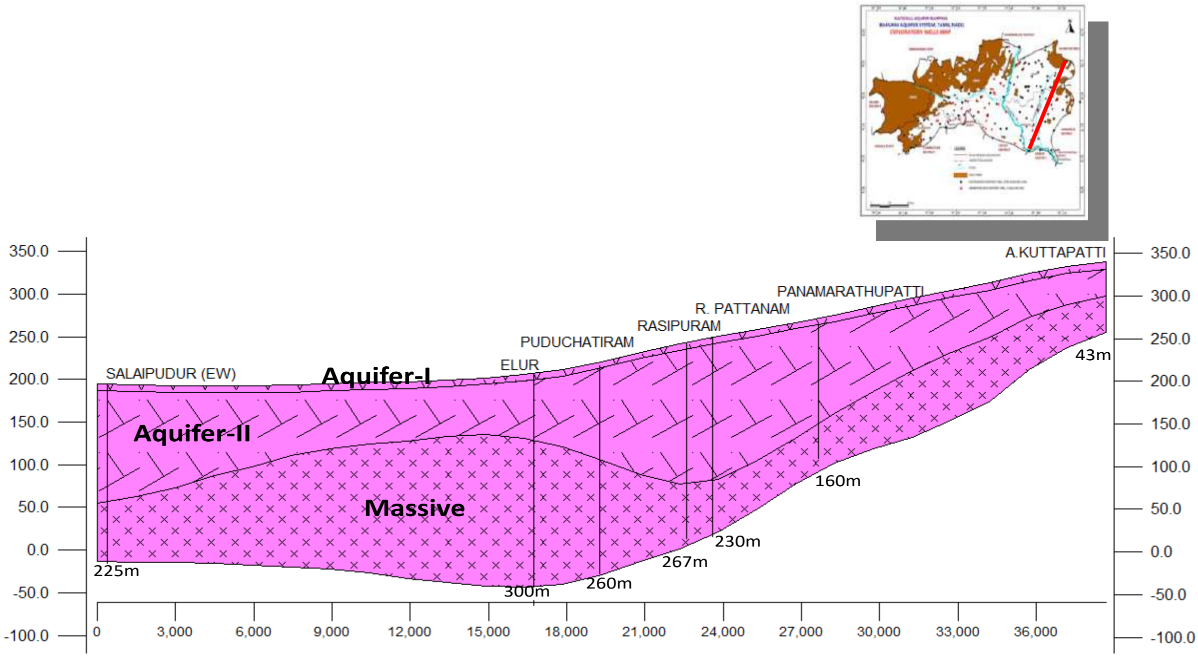


Fig-3.10 Hydrogeological cross section

3.8.2 Hydrogeological cross section along aquifer basin

The hydrogeological cross section along the aquifer basin is shown in Fig- 3.11 to 3.13. It indicates that the thickness of fractured aquifer is more in eastern part of the study area and uniform in other areas. The fractured aquifer is almost following the general topography of the terrain.

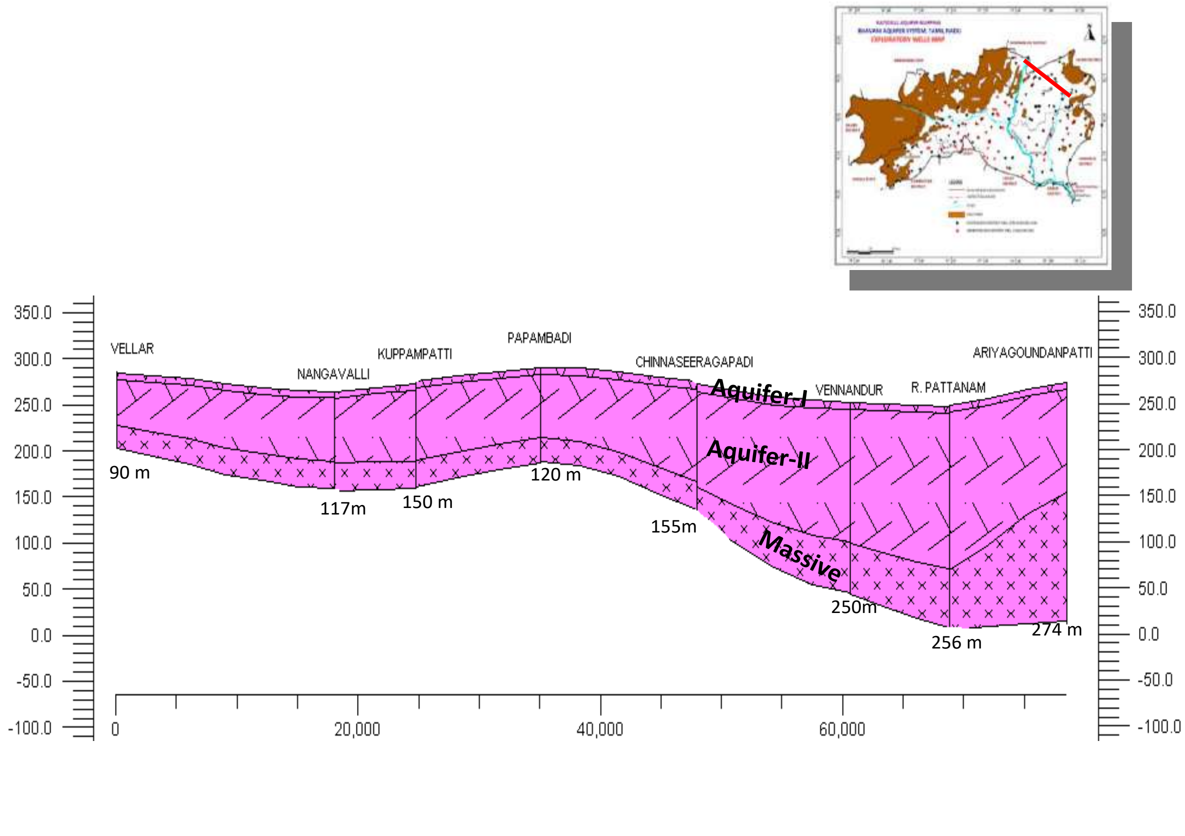


Fig-3.11 Hydrogeological cross section

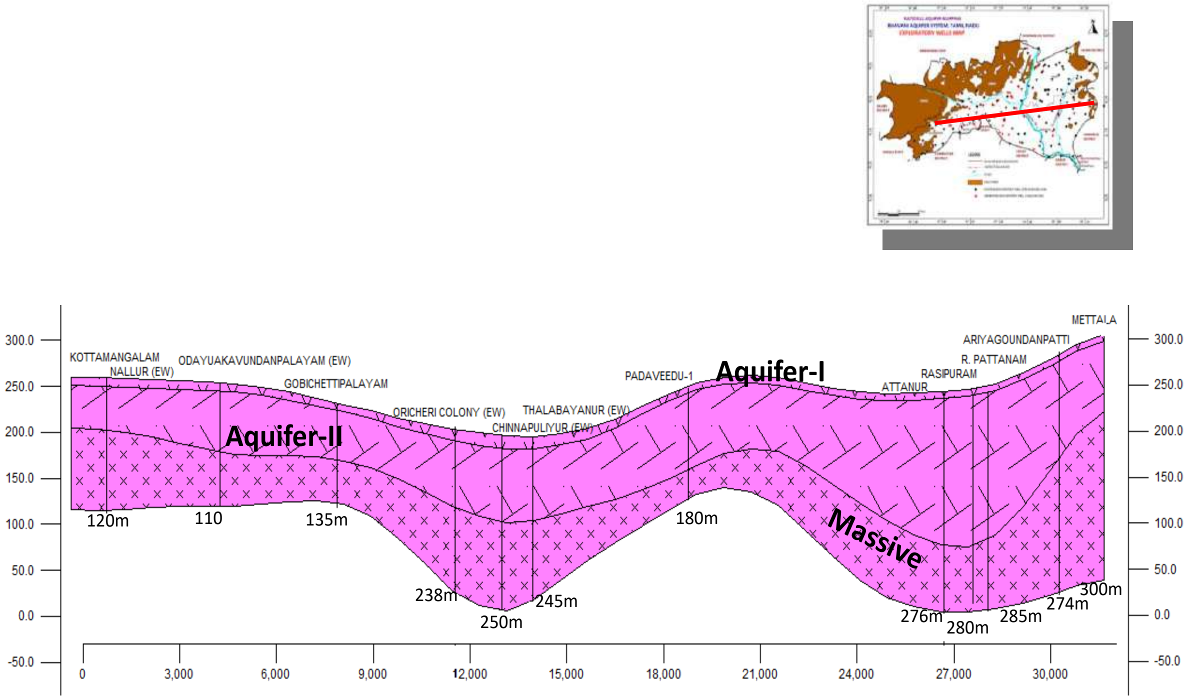


Fig-3.12 Hydrogeological cross section

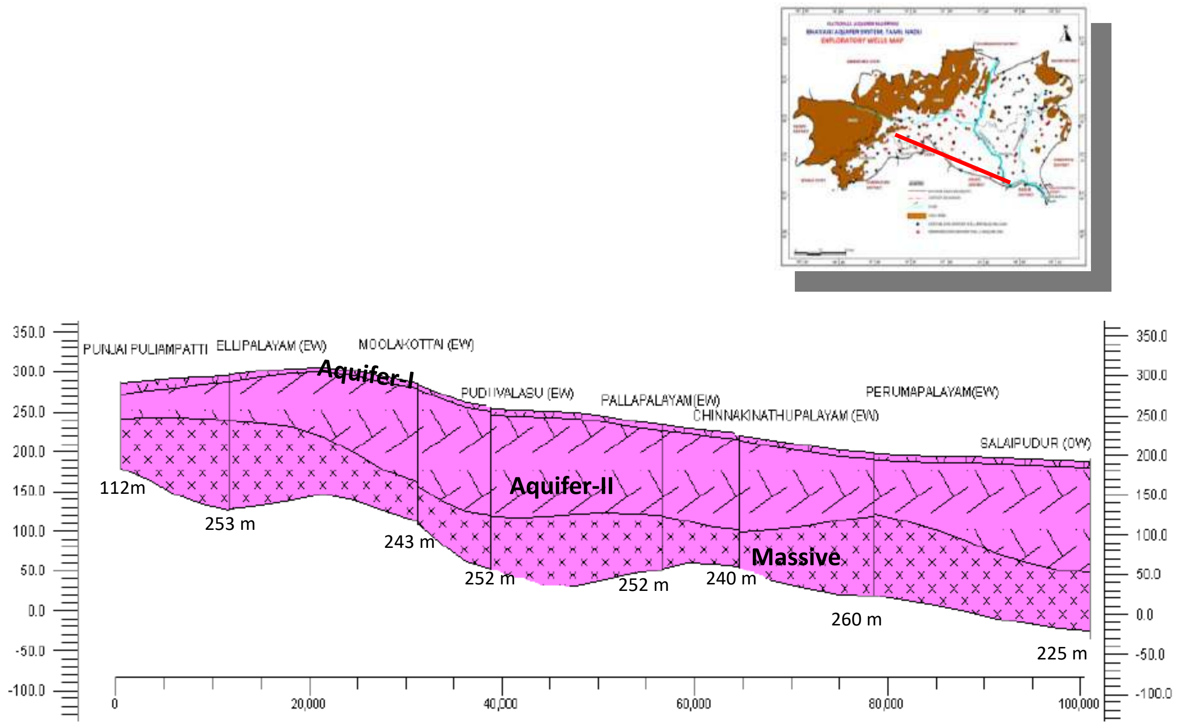


Fig-3.13 Hydrogeological cross section

3.9 3D Aquifer disposition

Fence diagram of the aquifer system of the basin was prepared and shown in Fig-3.14. The thickness of the Aquifer-I is almost same in the aquifer basin. The thickness of the aquifer-II is not uniform in thickness. The thickness of the Aquifer-II is occurring in the NW and SE parts of the aquifer basin.

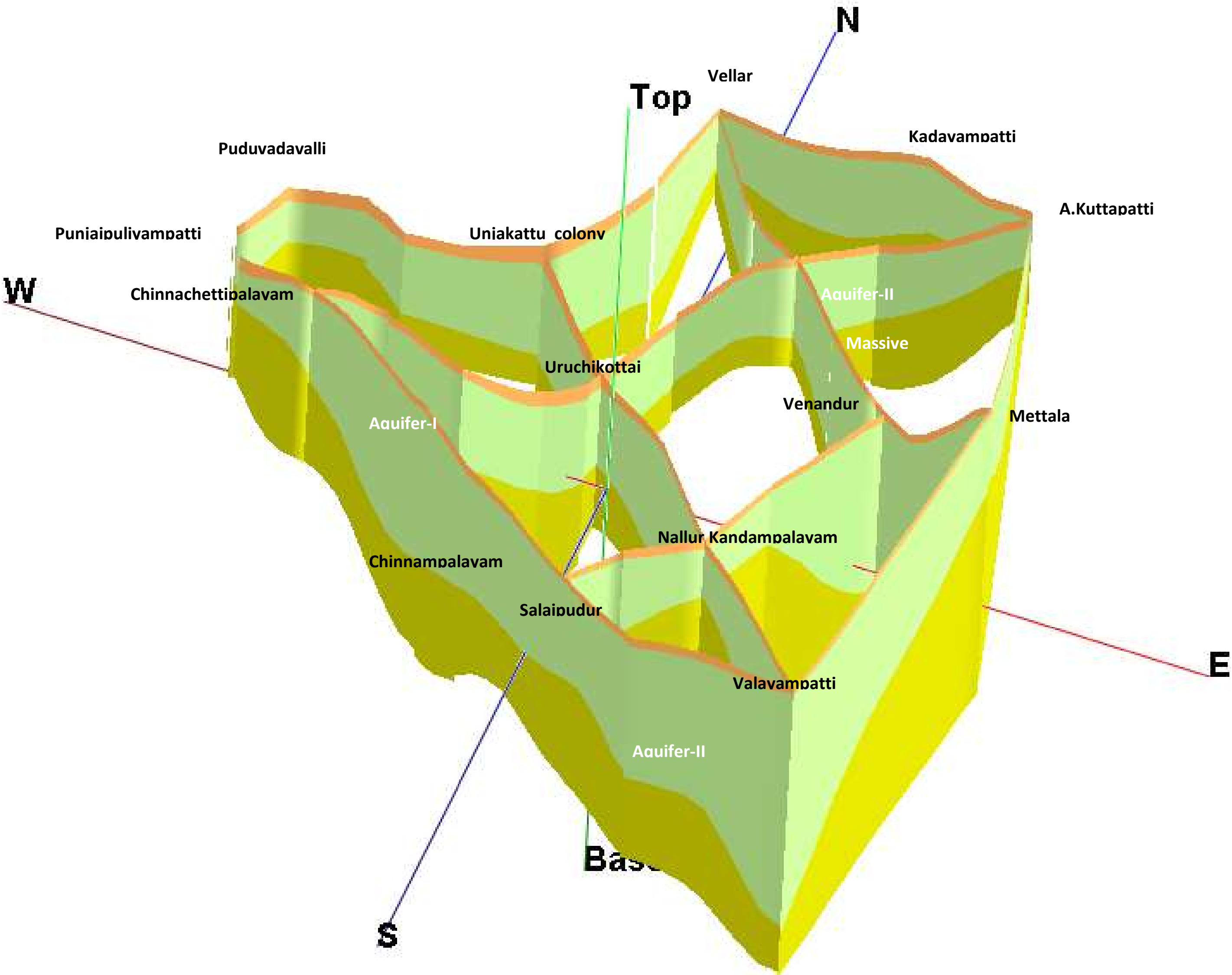


Fig-3.14 3D view of Aquifer Systems

Aquifer-II is extending latterly in uniform thickness and it fallow the general topography of the area. The thickness of Aquifer - II indicates the fracture depth. Less the thickness shallow fracture depth and more the depth deeper fracture. This indicates that the shallow fractures can be recharged faster than deeper fracture in the area. The recharging of deeper aquifer is mainly depending upon the amount of water available for groundwater recharge.

3.10 Thickness of Aquifer-I

Thickness of the Aquifer-I was prepared based on the groundwater exploration data. The bottom depth of the weathered layer is considered as thickness of the Aquifer-I and shown in Fig- 3.15.

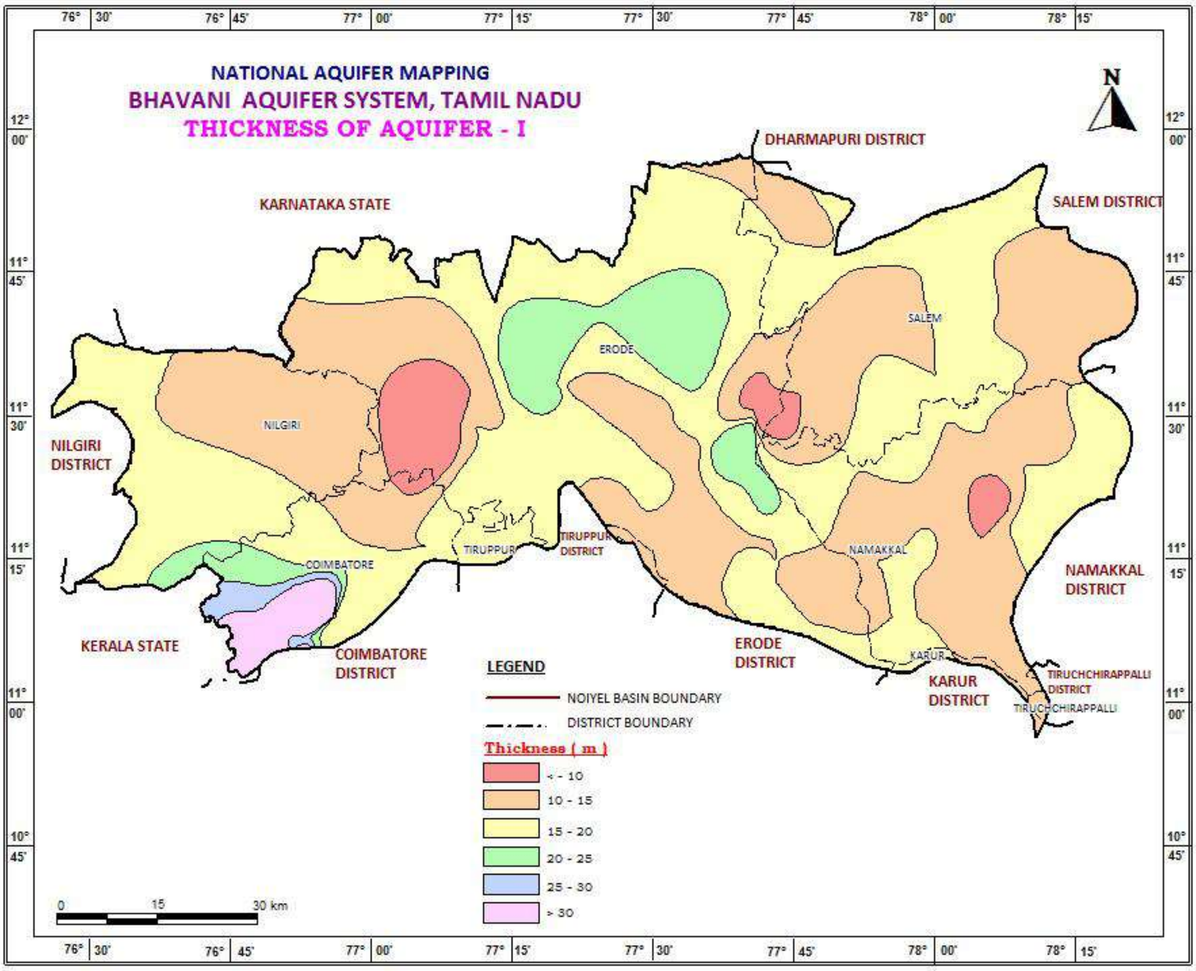


Fig-3.15 Thickness of Aquifer-I

The thickness of Aquifer-I is prepared with 5m contour intervals. The maximum area of the basin is occupied by 15 – 20 m thickness followed by 10-15 m aquifer thickness. The thickness of 10-15 m thickness is mainly occurring in the uplands of gneissic formation. The thickness between 20-25m of Aquifer-I is found in northern parts of the study area. The thickness of more than 25 m thickness is found southwestern parts of the study area. The thickness of Aquifer-I is directly indicating the water holding capacity of the aquifer.

3.11 Depth of occurrence of Aquifer-II

Based on the first fracture depth encountered in bore well, the depth of occurrence of aquifer-II was prepared for basin aquifer system and presented in Fig-3.16. Most of the area, the depth of occurrence of the aquifer-II is between 50-100 m and found in the eastern and western parts of the study area followed by 100-150 m occurring in the eastern parts of the study area. The depth of occurrence of aquifer-II above 150m is small pockets and found in the central parts of the study area. More than 50 % of the well is showing fracture less than 100 m.

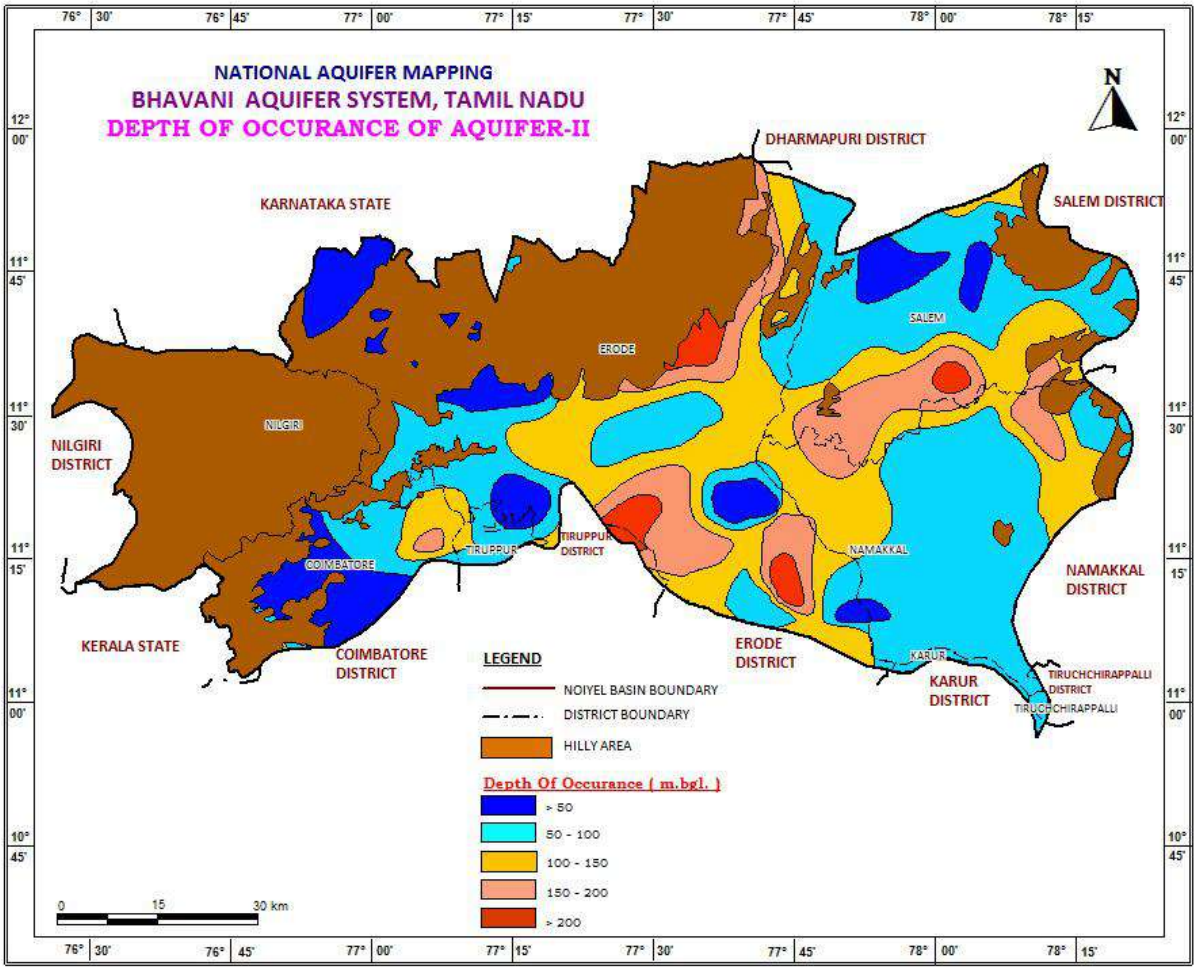


Fig-3.16 Depth of occurrence of Aquifer-II

3.12 Aquifer Characteristics

Based on the aquifer configuration and characteristics, two aquifer systems such as Aquifer – I & II have been demarcated for the basin aquifers. The hydraulic characteristic is main parameter to demarcate the aquifer system in the area.

3.12.1 Aquifer-I

The weathered layer of the all three lithology such as gneiss, charnockites and granite is considered for the Aquifer-I. In general, the thickness of the aquifer is ranging from 7 to 38 mts with an average thickness of 18mts. The specific yield of the aquifer- I is ranging from 15 to 20 m^3/hrs which sustain for 2 -5 hrs during monsoon period whereas in summer period < 1 to 2 hrs of pumping for groundwater utilisation. Based on the long duration pumping test, the transmissivity of the aquifer is determined and it is ranging from 5 to 26 m^2/day. Total Dissolved Solution (TDS) is ranging from 150 to 4670 µs/cm and in and around the industrial area, the TDS is upto 20,000 µs/cm. The groundwater is found suitable except at industrial areas.

3.12.2 Aquifer-I I

The weathered layer of the all three lithology such as gneiss, charnockites and granite is considered for the Aquifer-I. In general, the thickness of the aquifer is ranging from 7 to 38 mts with an average thickness of 18mts. The specific yield of the aquifer- I is ranging from 15 to 20 m^3/hrs which sustain for 2 -5 hrs during monsoon period whereas in summer period < 1 to 2 hrs of pumping for groundwater utilisation. Based on the long duration pumping test, the transmissivity of the aquifer is determined and it is ranging from 5 to 26 m^2/day. Total Dissolved Solution (TDS) is ranging from 150 to 4670 µs/cm and in and around the industrial area, the TDS is upto 20,000 µs/cm. The groundwater is found suitable except at industrial areas.

4. AQUIFER MANAGEMENT PLAN

4.1 Management Strategies

The ground water management strategies are inevitable either when there is much demand to the resource than the available quantity or when the quality of resource deteriorates due to contamination in a given geographical unit. In recent years water resources are used extensively both for irrigation and industrial needs. In addition, to meet the domestic requirements of the fast growing urban agglomerations the administrators are compelled to allocate a considerable quantum of resource which otherwise is being used for irrigation purpose. So, the urbanization has a negative impact on the food production as well as grabbing the employment of the agricultural laborers. Hence, it is the need of the hour to formulate sustainable management of the ground water resource in a more rational and scientific way. In the present study area of Bhavani aquifer system, the sustainable management plan for ground water is being proposed after a thorough understanding of the aquifer disposition down to a depth of 200m bgl. The study area is characterized by weathered and fractured system with very heavy abstraction of ground water for irrigation practices.

4.2 Sustainable Management Plan

The stage of groundwater development in the Aquifer Basin is over exploted /critical in 52 firkas.

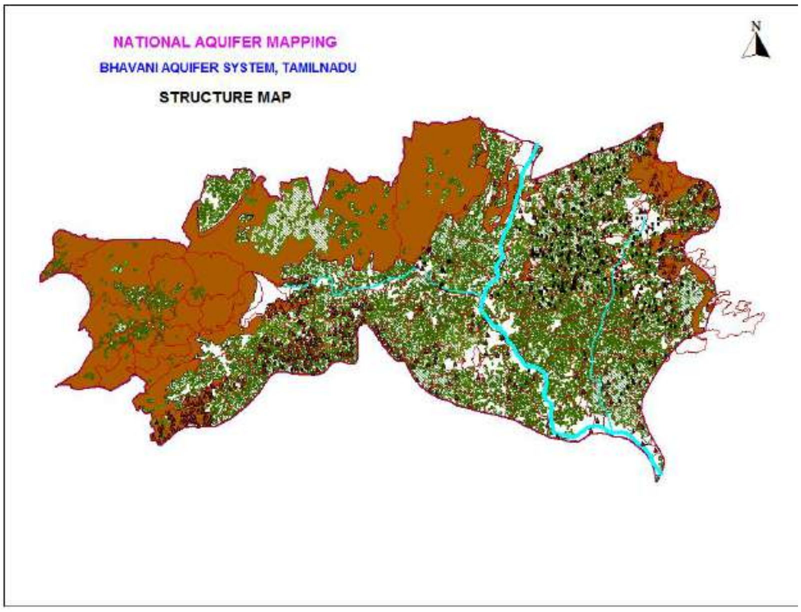
The Net availability of the resource of 1264 MCM. A total of 348 MCM in excess is being drawn from the ground water system of Bhavani basin. Therefore, the usage of groundwater has to be reduced by 40 percent of the existing draft for the sustainability of the resource. Or else the availability has to be augmented through artificial recharge methods to bridge the gap between draft and availability. The draft can be reduced through application of water efficiency methods in irrigation sector and through changing the irrigation practices from wet to dry cash crops.

4.3 Augmentation Plan

Augmentation of groundwater can be achieved through construction of percolation ponds and recharge shafts where the top soil zone is clayey which does not allow infiltration. Normally it can be achieved through capturing surface runoff. Surface water transfer also can be planned in the absence of surface runoff during droughts. It needs uncommitted runoff from the adjoining localities to transport to the needy areas through diversion channels. In the study area eastern and southern parts are subjected to Over-exploitation. Normally due to over exploitation of groundwater the water levels are depleting in this zone. The natural rainfall recharge is insufficient to recoup the extracted groundwater. Artificial Recharge and Water Conservation Plans are proposed in the OE & Critical firkas of the basin through utilizing the uncommitted surface runoff of 558 MCM.

4.4 Artificial Recharge Plan

Based on the water level monitoring in different seasons across the basin, as well as after having better understanding of the disposition and extent of the aquifer system through exploratory drilling, pumping tests etc. the volume of unsaturated zone available for recharge (upto 3m bgl) is 1149 MCM. But the annual uncommitted runoff is only 620 MCM which is about 50% of required water to fill the available void space of aquifer-I. Artificial recharge and Water conservation plan is prepared for the over exploited and critical firkas of the basin area through harnessing just less than 15% of the annual uncommitted runoff of 620 MCM only with a total out lay of Rs.187.17Crores. The suggested artificial recharge structures are mainly Nala bunds, Check Dams and Recharge Shafts in addition to removal of silt in the surface tanks. Selection of the site locations of these structures are based on the critical analysis of the hydrogeological, geophysical and exploration data of the basin. Particularly geomorphological and drainage aspects are being given more weightage in selection of the Artificial Recharge structures. A total number of 81 check dams, 412 nala bunds and 1266 recharge shafts are proposed in the OE and critical firkas of the basin. A total number of 480 Recharge Rejuvenation ponds are selected for desilting followed by construction of recharge shafts within the tanks. The expected recharge through these artificial recharge structures is in the order of 80 MCM. The expected benefit by the recharge structures in the 52 OE & critical firka area will be creation of additional crop area of Paddy of 5000 ha or Sugarcane of 4000 ha (or) Banana of 8000 ha (or) Irrigated Dry crops of 13300 ha.



4.5 Water Conservation Plan

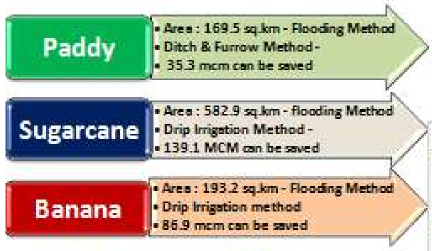
Low pressure water distribution system is being proposed in 1630.3 Ha of cropped area which otherwise is under irrigation through earth channels. The expected savings of water through this method is expected to be 3.12 MCM./ yr. A total number of 6370 recharge ponds are proposed which will act as storage tanks in farm as well as augment groundwater recharge and the expected annual groundwater recharge through these ponds is in the order of 7.93 MCM.

4.6 Demand side Management Plan

Demand side management can be accomplished through change in irrigation pattern. It is recommended to change the irrigation pattern for paddy, Sugarcane and Banana crops. The general practice for paddy irrigation is by flooding method. It is recommended for ridge and furrow method instead of flooding method in 169.5 sq.km and this would save 35.3 mcm of water annually. Similarly for sugarcane and banana crops shift from flooding to drip irrigation would save 139.1and 86.9 mcm respectively. The total water saved is 261.3 mcm.

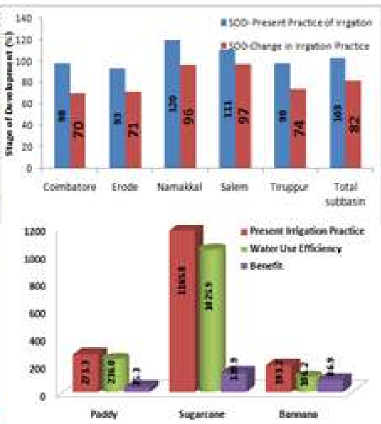
The total cost for the change in the irrigation pattern for those water intensive crops would be 465 crores. If Scenario 1 - 30% Area is changed then water saved would be 78.6 MCM. The cost would be 133 crore and the Stage of Development would be lowered from 103 to 97%. In case of Scenario II wherein 50% Area is changed then Water saved would be 131.3 MCM and the Cost would be 231 crore. The stage of Development would be lowered from 103 to 93 %.

Demand Side Management



Quantitative impact on GW Resources

Total Area : 10,391 Sq.km
Hilly area : 1,198 Sq.km
WIC : 945 Sq.km



District	Stage of Gw Development (%)	Stage of Gw development after change in Irrigation practice (%)
Coimbatore	98	70
Erode	93	71
Namakkal	120	96
Salem	111	97
Tiruppur	96	74
Total Basin	103	82

4.7 Future Demand Stress Aspects

In views of rapid urbanization the domestic water needs are increasing multifold. In this urbanization process the water wastage component is increasing mainly because of leakages through distributor system. Whereas in the agricultural irrigation sector the water demand mainly due to the enthusiasm of the farmers to increase the crop irrigation area. Hence the policy makers at higher administrative level and rural development authorities at block level should educate the farmers in their jurisdiction in such a way that they should not venture to increase the farm irrigation area. Rather these authorities have to suggest high yielding crop varieties and high-value crops to grow with minimum water requirement with the technical guidance of local agricultural/ agronomic experts.

4.8 Strategies to overcome the future stresses

Future stresses are only hypothetical. If the sustainable management is taken up in a true spirit in consultation with local village level bodies the groundwater depletion will not occur in future. However, it is very difficult to overcome gluttonous user attitude thrives for fullest use of the resource to get maximum output. In this process the vital resource is lost. Therefore a thorough understanding of the consequences of indiscriminate usage of the water should be propagated among users mainly among farmers as they are bulk users of the resource in the study area. The demand side strategies to overcome future stresses are mainly

- Promoting irrigation pattern change
- Agronomic Water Conservation
- Reducing Water use reduction in Urban areas