केंद्रीय भूमि जल बोर्ड

जल संसाधन, नदी विकास और गंगा संरक्षण

विभाग, जल शक्ति मंत्रालय

भारत सरकार

Central Ground Water Board

Department of Water Resources, River Development and Ganga Rejuvenation,
Ministry of Jal Shakti
Government of India

AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES

AGNIYAR AQUIFER SYSTEM,Tamil Nadu

दक्षिण पूर्वी तटीय क्षेत्र, चेन्नई

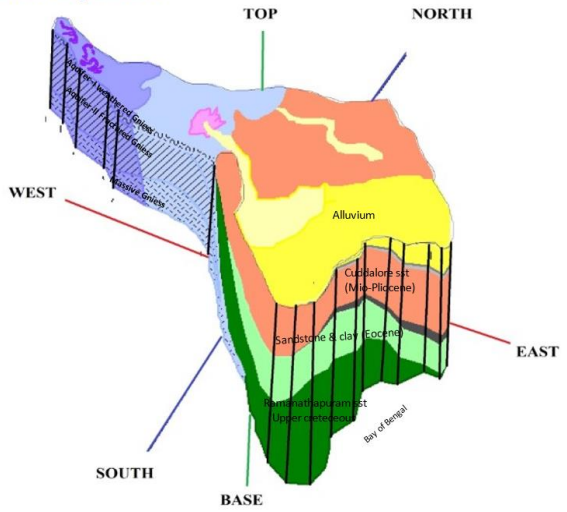
South Eastern Coastal Region, Chennai

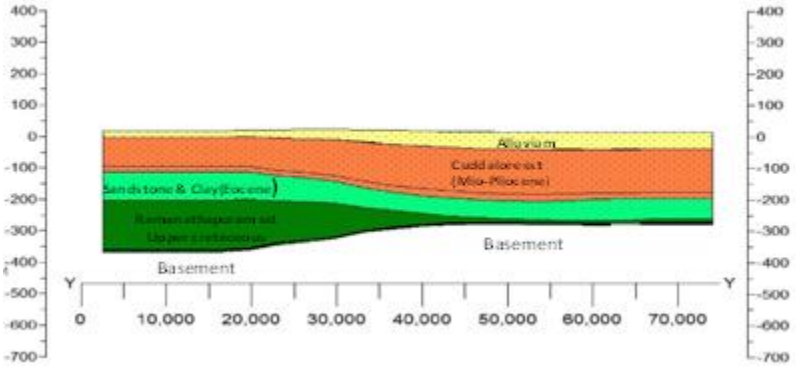
सरकारी उपयोग के लिए

अग्निआर एक्वीफर सिस्टम, तमिल नाडु पर जलभृत मानचित्रण और जलभृत प्रबंधन योजना

REPORT ONAQUIFER MAPPING AND AQUIFER MANAGEMENT PLAN OF AGNIYAR AQUIFER SYSTEM, TAMIL NADU

3D Aquifer disposition





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चेन्नई

GOVERNMENT OF INDIA

MINISTRY OF JAL SHAKTI

DEPARTMENT OF WATER RESOURCES

RIVER DEVELOPMENT AND GANGA REJUVENATION

CENTRAL GROUND WATER BOARD

SOUTH EASTERN COASTAL REGION

CHENNAI

Foreword

Ground water is being increasingly recognized as a dependable source of supply to meet the demands of domestic, irrigation and industrial sectors of the country. The development activities over the years have adversely affected the ground water regime in many parts of the country. Hence, there is a need for scientific planning in development of ground water under different hydrogeological situations and to evolve effective management practices with involvement of community for better ground water governance. Out of 6607 ground water assessment units (Blocks/ mandals / taluks/ firkas 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 than 90% of recharge (Critical).

Central Ground Water Board (CGWB) has taken up largest Aquifer mapping endeavor 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 Groundwater Board, 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 Agniyar aquifer system covering an area of 4973.1 sq.km with a mappable area of 4843 sq.. km. covering Pudukkottai, Thanjavur Tiruchirappalli, Sivagangai, and Dindigul districts of Tamilnadu. Totally the basin covers 55 firkas out of which 9 are either over exploited or critical, 12 are semi critical 31 are safe and 3 are saline firkas. The major issues in the basin include declining groundwater levels, poor aquifer formations in the crystalline formation, sustainability of wells, low yielding aquifers, groundwater pumping for paddy cultivation in delta area, threat of seawater intrusion and groundwater mining for urban city. An attempt to decipher the aquifer units firkas wise and identification of potential aquifers and its sustainability has been made. In hard rock the fractured/Jointed regions form two aquifer Units namely weathered and Aquifer Unit –II. Firka wise groundwater management plans including supply and demand side have been prepared, to arrest the declining groundwater levels and increase the sustainability of groundwater abstraction structures.

I hope this report on Agniyar aquifer system will be useful for the district administrators of the districts falling in the basin, water managers, stakeholders including farmers in knowing the aquifer and managing it resources effectively.

M SIVAKUMAR

Regional Director

EXECUTIVE SUMMARY

Detailed hydrogeological studies were conducted in the study area, Agniyar aquifer system region wherein huge existing data pertinent to geology, geophysics, hydrology, hydrochemistry was collected, synthesised and analysed to bring out this report. This report mainly comprises of the lateral and vertical extent of the aquifer with its geometry, 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.

The area experiences semi-arid climate with 924 mm annual normal rainfall covering 4973.1 km^2 area in Pudukkottai, Thanjavur Tiruchirappalli, Sivagangai, and Dindigul districts of Tamil Nadu. Under agricultural activity the wet crops covering 47% the dry crops covering 16%, the plantation crops covering 27% and the fallow land covering with 10%. The main crops irrigated are paddy, sugarcane, groundnut, maize, cotton, ragi and other minor crops are turmeric, vegetables and flowers.

Two main aquifers units exists they constitute, namely 1. weathered zone at the top followed by a discrete anisotropic fractured/fissured zone at the bottom in the western and southern part of the study area. 2.Alluvium in the central and eastern portion underlined compact conglomerates of the Gondwana formation. Groundwater occurs under unconfined condition in the weathered zone & in the alluvial formation and unconfined to semi-confined conditions in the conglomerates and fractured/fissured zone. The predominant water levels are in the range of 5-20 m bgl during pre-monsoon season and 2-10 mbgl during post-monsoon season of 2015. The net annual ground water availability is 1017.40 MCM and the gross ground water draft is 607.81 MCM and the stage of groundwater development is of 61%.

The major issues in the region are Decline in Ground water Level and low sustainability, threat of Sea water Intrusion, Groundwater Mining for Agniyar aquifer basin area. Groundwater Contamination due to Landfill sites, Groundwater contamination by Industries (Petrochemicals, Tanning &Electro-plating), Urbanization and huge demand for ground water to cater growing Agniyar aquifer system study area, population and low yielding aquifer units. The Agniyar aquifer basin area requires 2000 HAM of water for drinking purposes and state government is able to supply 1800 HAM of water, which leaves a huge gap between the demand and supply.

In hard rock regions aquifer systems can be conceptualized as weathered zone down to ~30m with average thickness of 18 m and fractured zone between ~190 m bgl. 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 transmissivity varying between 4–32.3 m^2/day and specific yield of 0.5 -3%. The fractured zone is fractured gneiss or Charnockite which occur in limited extent, associated sometime with quartz vein. The average transmissivity of this zone varies between 3.5–25 m^2/day and storativity varies from 2.16 to 4.9*10-5

In alluvial regions the first aquifer unit comprising of sand, gravel has thickness ranging from 5 to 50 m with yields ranging from 68 to 140 m^3/hr and transmissivity values ranging from 1271 -4180 m^2/day. Gondwana formation comprising of compact conglomerates underlie the alluvial formation and have poor yields ranging from 2 to 27 m^3/hr with transmissivity values ranging from 100 to 500 m^2/day.

Fast growing urban agglomerations 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 7 Check dams, 23nala bands, 5 recharge shafts in addition to the 361 ponds earmarked for rejuvenation with recharge shafts in all the 9 OE1 Critical firkas of the basin. The estimated cost for construction of these structures is to be Rs. 3.875 Crores. The estimated recharge to groundwater system through these structures will be in the order of 2.03 MCM within additional area of Paddy 7438 ha or Sugarcane: 5950 ha (or) Banana: 11900 ha (or) Irrigated Dry crops : 23800 ha.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.

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 of may be incorporated in the regulatory acts.

REPORT ON

AQUIFER MAPPING FOR SUSTAINABLE MANAGEMENT OF GROUNDWATER RESOURCES IN AGNIYAR AQUIFER SYSTEM

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AQUIFER MAPPING FOR SUSTAINABLE MANAGEMENT OF GROUNDWATER RESOURCES FOR AGNIYAR AQUIFER SYSTEM

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AQUIFER MAPPING AND MANAGEMENT PLAN FOR AGNIYAR AQUIFER SYSTEM, TAMIL NADU

1.0. INTRODUCTION

To identity and map the aquifers at the micro level with their characteristics, to quantify the available groundwater resources, propose plans appropriate to the scale of demand and institutional arrangements for participatory management in order to formulate a viable strategy for the sustainable development and management of the precious resource which is subjected to depletion and contamination due to indiscriminate development in the recent past, Ministry of Water Resources, River Development and Ganga Rejuvenation, Government of India has initiated National Project on Aquifer Mapping (NAQUIM).

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.

Aquifer Mapping has been taken up in Lower Cauvery Aquifer system basin in a view to formulate strategies for sustainable management plan for the aquifer system in accordance with the nature of the aquifer, the stress on the groundwater resource and prevailing groundwater quality which will help in drinking water security and improved irrigation facility. It will also result in better management of vulnerable areas.

1.1 Objective

The objectives of the aquifer mapping project in Lower Cauvery aquifer system can broadly be stated as

- To determine the ground water regime scenario
- To define the aquifer geometry, type of aquifers and their lateral and vertical extent
- To estimate the availability of groundwater resources in the aquifer system
- 2D and 3-D disposition of the aquifer units.
- To determine the hydrogeochemical characteristics of the aquifer units
- To develop an sustainable groundwater management plan for the aquifer system.

1.2. Scope of the Study

The important aspect of the aquifer mapping programme is the synthesis of the large volume of data already generated during specific studies carried out by Central Ground Water Board and various Government organizations with a new data set generated that broadly describe the aquifer system. The available generated data are assembled, analysed, examined, synthesized and interpreted from available sources. These sources are predominantly non-computerized data, which is to be converted into computer-based GIS data sets.

Data gaps have been identified after proper synthesis and analysis of the available data collected from different state organisations like TWAD Board, PWD, Agricultural Engineering Department. In order to bridge the data gap, data generation programme has been formulated in an organised way in the basin. Exploration work has been carried out in different segments of the regions and aquifer parameters have been estimated. Groundwater monitoring regime has been strengthened by establishing additional monitoring wells. 2D and 3D sections have been prepared twice, one prior to the generation of data based on the data collected, assembled and synthesized through different sources and two, after generation of data at identified gaps. The latter prepared maps are of more realistic as the data points are more closure.

1.3 Major groundwater Issues

1. Over exploitation and Declining GW levels
2. Poor Aquifers – Massive & Compact Formations
3. Seawater intrusion - Threat of SWI along the coast
4. Heavy GW withdrawal – Thanjavur, Pudukottai cities water supply
   Heavy GW withdrawal – For paddy in delta area
   Once Perennial River-Cauvery River now ephemeral.
   Sand mining

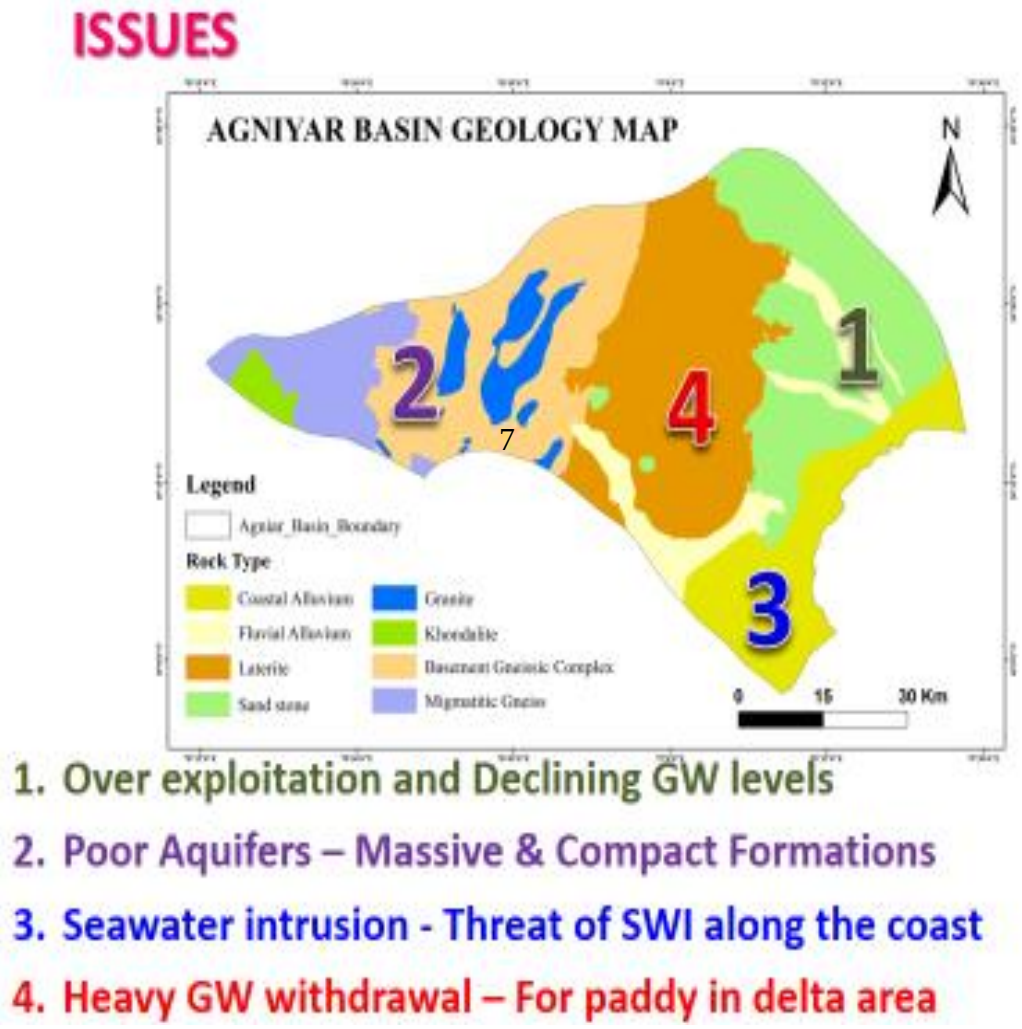


Figure.1 Issues pertaining to Agniyar Aquifer system

1.4. Approach & Methodology

Integrated multi-disciplinary approach involving geological, geophysical, hydrological and hydrogeological and hydrogeochemical components was taken up in 1:50000 scale to meet the objectives of study. Geological map of the basin has been generated based on the GSI maps, geophysical data has been generated through vertical electrical soundings and geoelectrical layers with different resistivity have been interpreted in corroboration with the litho stratigraphy of the observation wells and exploratory wells down to depths of 200m and 300 m bgl for hard rock & soft rock respectively. Hydrological and Hydrometeorological data has been collected from state PWD and IMD departments. Drainage, Soil and Geomorphology of the sub basin was prepared based on the IRS –IC data, obtained from Institute of Remote Sensing, Anna University, and Chennai.

Based on the data gap analysis data generation process has been scheduled through establishing key observation wells, pinpointing exploratory sites for drilling through in-house and outsourcing, collecting geochemical samples in order to study groundwater regime, geometry of the aquifer and aquifer parameters, and quality of the groundwater respectively. Groundwater recharge and draft have been computed through different methods and resources of the basin estimated through groundwater balance method.

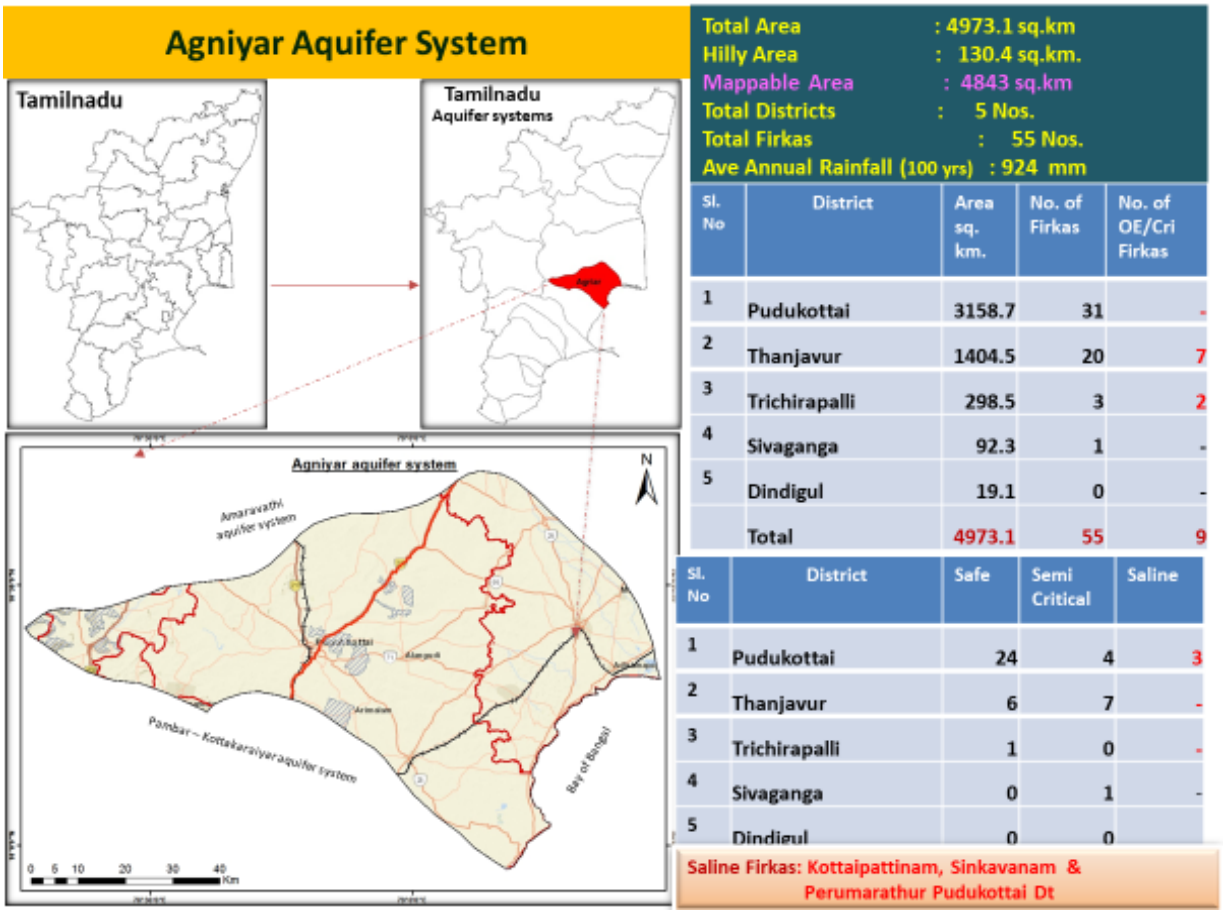
Based on the above studies Management strategies both on the supply side through augmentation of groundwater through artificial recharge and water conservation and on demand side through change in irrigation pattern have been formulated for sustainable management of the groundwater resource.

1.5. Study area

The Agniyar aquifer system covering an area of 4973.1 sq.km comprises of 130.4 sq.km of hilly area and 4843 sq.km of mappable area is situated between latitudes 9°59'28" N and 10°44'25" N and longitudes 78°14'58" E and 79°29'30" E at the central part of Tamilnadu. It is bounded by Cauvery Basin the north; Bhavani and Amaravathy aquifer systems in the west, Pambar-Kottakaraiyar Aquifer system in south and the Bay of Bengal Sea on the east. Ambuliyar and South Vellar are the other rivers of the Aquifer System. There are 55 firkas out of which 9 are over exploited/critical, 12 semi critical, 31safe firkas and 3 saline firkas (Table.1). The major part of the basin area comes under, Thanjavur, Pudukottai, Thiruchirapalli Sivagangai, and Dindigul districts. The administrative map of the Agniyar aquifer system is presented as **Figure.2.**

Table.1 Districts and Firkas of the Agniyar aquifer system

Sl. No	District	Area	No. of Firkas	OE and Critical
1	Pudukottai	3158.7	31	3 saline firkas
2	Thanjavur	1404.5	20	7
3	Thiruchirapalli	298.5	3	2
4	Sivagangal	92.3	1	-
5	Dindigul	19.1	0	-
	Total	**4973.1**	**55**	**9**



Total Area : 4973.1 sq.km
Hilly Area : 130.4 sq.km.
Mappable Area : 4843 sq.km
Total Districts : 5 Nos.
Total Firkas : 55 Nos.
Ave Annual Rainfall (100 yrs) : 924 mm

Sl. No	District	Area sq. km.	No. of Firkas	No. of OE/Cri Firkas
1	Pudukottai	3158.7	31	-
2	Thanjavur	1404.5	20	7
3	Trichirapalli	298.5	3	2
4	Sivaganga	92.3	1	-
5	Dindigul	19.1	0	-
	Total	4973.1	55	9

Sl. No	District	Safe	Semi Critical	Saline
1	Pudukottai	24	4	3
2	Thanjavur	6	7	-
3	Trichirapalli	1	0	-
4	Sivaganga	0	1	-
5	Dindigul	0	0	

Saline Firkas: Kottaipattinam, Sinkavanam & Perumarathur Pudukottai Dt

Figure 2: Administrative setup of the Agniyar aquifer system

1.6. Data Availability

During the Aquifer mapping period, existing data of CGWB i.e. exploration, depth to water level, water quality, geophysical logging and groundwater resource data have been collected and compiled. In addition to this, bore well data, Water quality & Water level data have been collected from Tamil Nadu water Supply and Drainage Board. Cropping pattern and Soil data has been collected from Agricultural Department. Groundwater level and groundwater exploration data have been collected from Public Works Department. Thematic layers such as; geology, (Source: Geological Survey of India (GSI) soils, land use/land cover, geomorphology, etc., from various State Government agencies were collected, complied and used in this study.

1.7 Data adequacy

Exploratory well data is available for 112 wells, drilled by CGWB (78nos) and State Departments (34nos). Geophysical sounding data of 125 Points (CGWB) are also available.

Water level (98nos) and 8 Deep Piezometers and Water Quality monitoring data (65nos) was available for a long period i.e., more than ten years. Cropping pattern, Soil data, Land use, Cropping and irrigation data have been collected from Statistical department. After plotting the available historical data on 1:50,000 scale maps, data gaps were identified and data generation process was taken up in those gap areas to complete the Aquifer map on the desired resolution of 1:50,000 scale.

1.8. Climate and Rainfall

The basin area experiences tropical climate being hot and dry for the greater part of the year. The period from March to June is generally hot. The temperature ranges from 20 to 38°C. The area receives rainfall through both south-west and north-east monsoons. About 40% of the precipitation is contributed by south-west monsoon and north-east monsoon accounts for 50 to 60 %. The average annual rainfall for the basin area is 924mm with minimum rainfall of 655 mm to maximum rainfall of 1293 mm.

1.9. Physiography and Drainage

The term physiography deals with the actual existing in-situ conditions of the land, depending upon the structures, formational changes and available natural agencies such as Hydrogiene and Epigiene agents. Physiographically the Agniyar aquifer system region comprises of interdependent river basin of Cauvery **(Figure.3)** all rivers mostly flow from west to east. The river Cauvery also referred as Ponni, is an Indian river flowing through the states of Karnataka and Tamil Nadu. It is the third largest after Godavari and Krishna in south India and the largest in Tamil Nadu which on its course, bisects the state into North and South. Originating in the foothills of Western Ghats at Talakaveri, Kodagu in Karnataka it flows generally south and east through Karnataka and Tamil Nadu and across the southern Deccan plateau through the southeastern lowlands, emptying into the Bay of Bengal through two principal mouths in Poompuhar, Tamil Nadu. At Tiruchirappalli the river becomes wide, with a sandy bed, and flows in an eastern direction until it splits into two at upper Anicut about 14 kilometres (9 mi) west of Tiruchirappalli. The northern branch of the river is called the Kollidam while the southern branch retains the name Kaveri and then goes directly eastwards into Thanjavur District. These two rivers join again and form the Srirangam island that is a part of the city of Tiruchirappalli. The oldest functional dam Grand Anicut or Kallanai

was present at this place. From Thanjavur, the river splits and goes to few places in the Delta Cauvery.

The length of the river is 202 km. in Lower Cauvery basin. The basin is more or less fan shaped and has a length of about 192 km from west to east and maximum width of 129 km from north to south.

After Mettur, the river loses its height and its erosional capacity is drastically reduced and it becomes depositional. From here, the river flows at lower elevation at around 300 mts above MSL. Hence, the Cauvery in Agniyar basin is mostly depositional river. Further downstream at Kulitalai the river channel is around three kms wide. At Mukambhu the river Cauvery bifurcates into two, the northern Coleroon and southern branch still retaining the 10 names of the main channel. These two branches are separated by an island formed by deposition of sediments, which is around 30 km long. Hereafter, the two branches join again at Kallanai to bifurcate again into several branches to form the wide deltaic plains before all these distributaries join the Bay of Bengal.

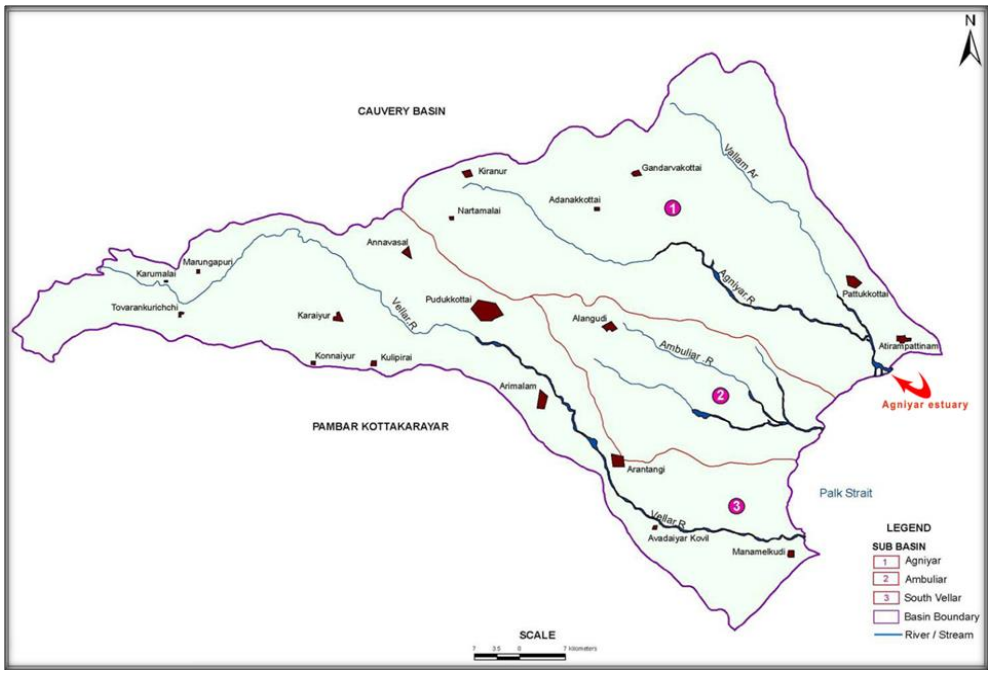


Figure 3: Drainage map of the Agniyar aquifer system

1.10. Geomorphology

The geomorphology of an area is the external appearance of land forms that gives a reliable picture of the underground strata and its physio-chemical condition. The different formations

and the layer confirm and cogent to its geomorphology. Two major geomorphic units can be demarcated hills and Plateaus pediments in Hard rock region, Plains (alluvial sediments) in sedimentary rocks. The eastern part adjoining to beach and shores covers coastal geomorphic units. The inland topographical units are being described as the piedmont geomorphology.

The coastal landforms include the beaches, beach ridges and beach terraces: The beaches are landforms covered by sand and sandy materials having high porosity and unconsolidated loose formation with voids and spaces. Beach Ridges are elevated sandy tops adjoining the beaches and are good horizons for groundwater presence. The step like projection bordering the sandy terrain and the shoreline are called as beach terraces. These terraces are undulated and according to the forces of the tide and their deposition. These terraces were having a very low ground water gradient that too towards the sea as they are slopping towards them.

Nearly 59% of the region is covered by Plains and. 37% of the region is covered by pediments. Flood plains consisting of sand clay are found along the Agniyar river in the crystalline rocks area. **Figure 4** illustrates the classification of geomorphological features of the Agniyar Aquifer aquifer system.

1.11. Land use and Land cover

Agricultural land occupies nearly 1529.24 sq.km i.e., 30.63% of the Agniyar aquifer system area and is spread throughout the study area. Deciduous forest occupies nearly 181.05 sq.km (3.88 %) of the area taking the waste land to nearly 2953 sq.km 63.50% Water bodies, and built up/urban area occupies 3% and 2.39%, respectively. Land use/Land analysis diagram of the Agniyar aquifer system is presented in **Figure-5**

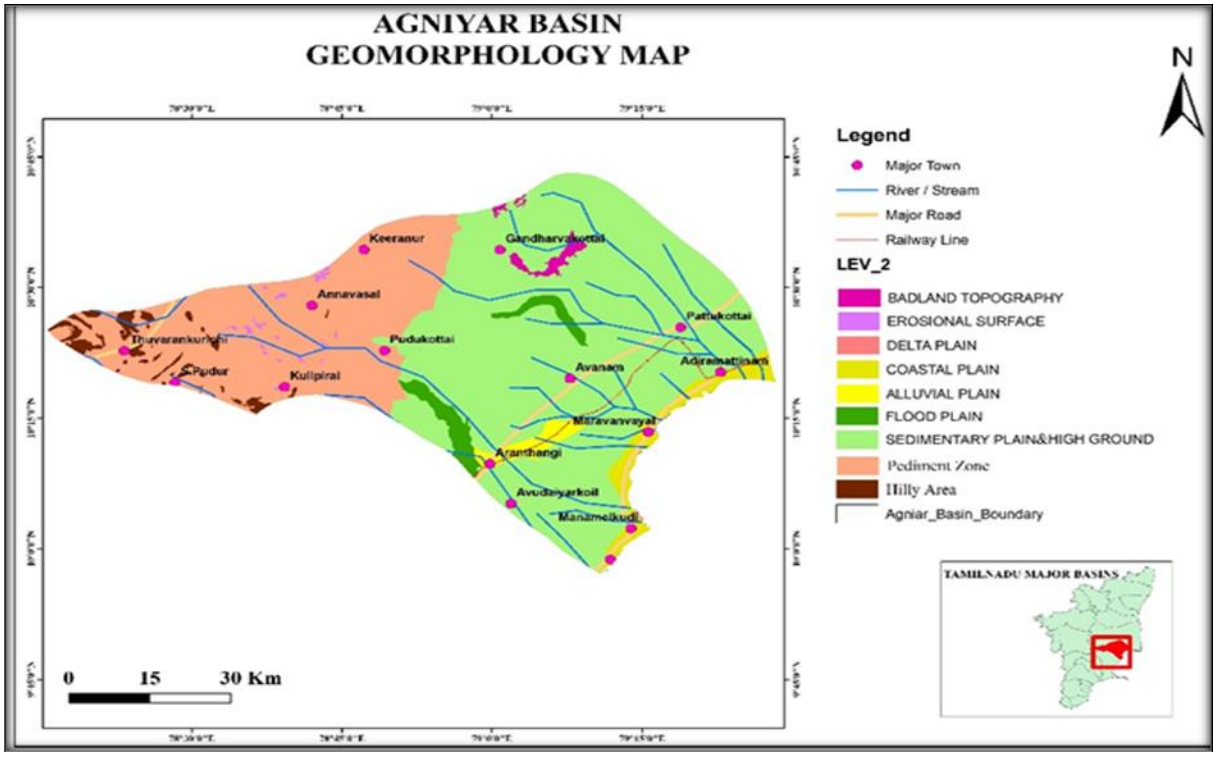


Figure 4. Geomorphology map of the Agniyar aquifer system

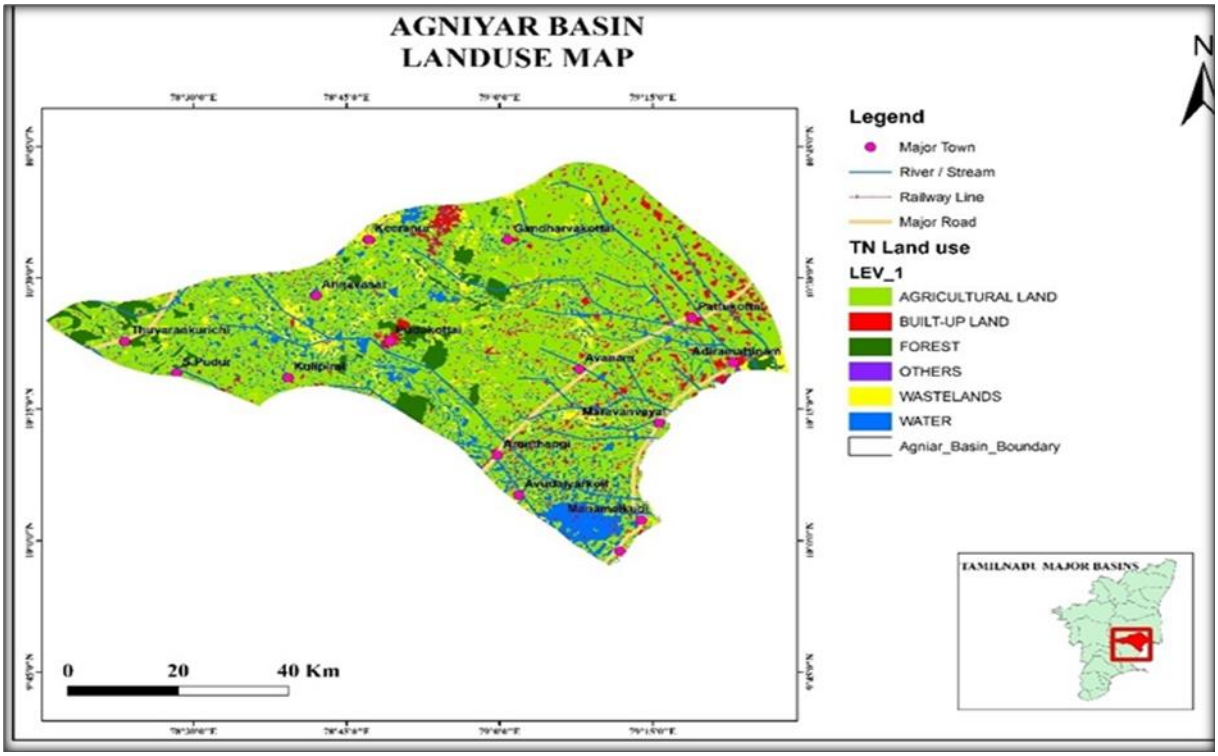


Figure 5. Land use/Land analysis diagram of the Agniyar aquifer system

1.12. Soils

Soils play a major role in hydrologic control of the infiltrating water. Soils are generally classified by taking their color, texture, fertilities and chemical combinations includes salts, minerals and the solution effect over them. The major soil types in the study area are alfisols presented in **Figure.6.**

Alfisols are arable soils with water content adequate for at least three consecutive months of the growing season. Prior to cultivation they are covered with natural broad-leaved deciduous forest vegetation, sometimes interspersed with needle-leaved evergreen forest or with grass. Occupying just under 10 percent of the nonpolar continental land area on Earth, they are found primarily in cool, moist regions of the Northern Hemisphere (the north-central United States and north-central Europe extending into Russia) and in subhumid or Mediterranean climatic regions of both hemispheres (western Africa south of the Sahara, northeastern Brazil, and southern Australia). The principal agricultural crops grown on Alfisols are corn (maize), wheat, and wine grapes.

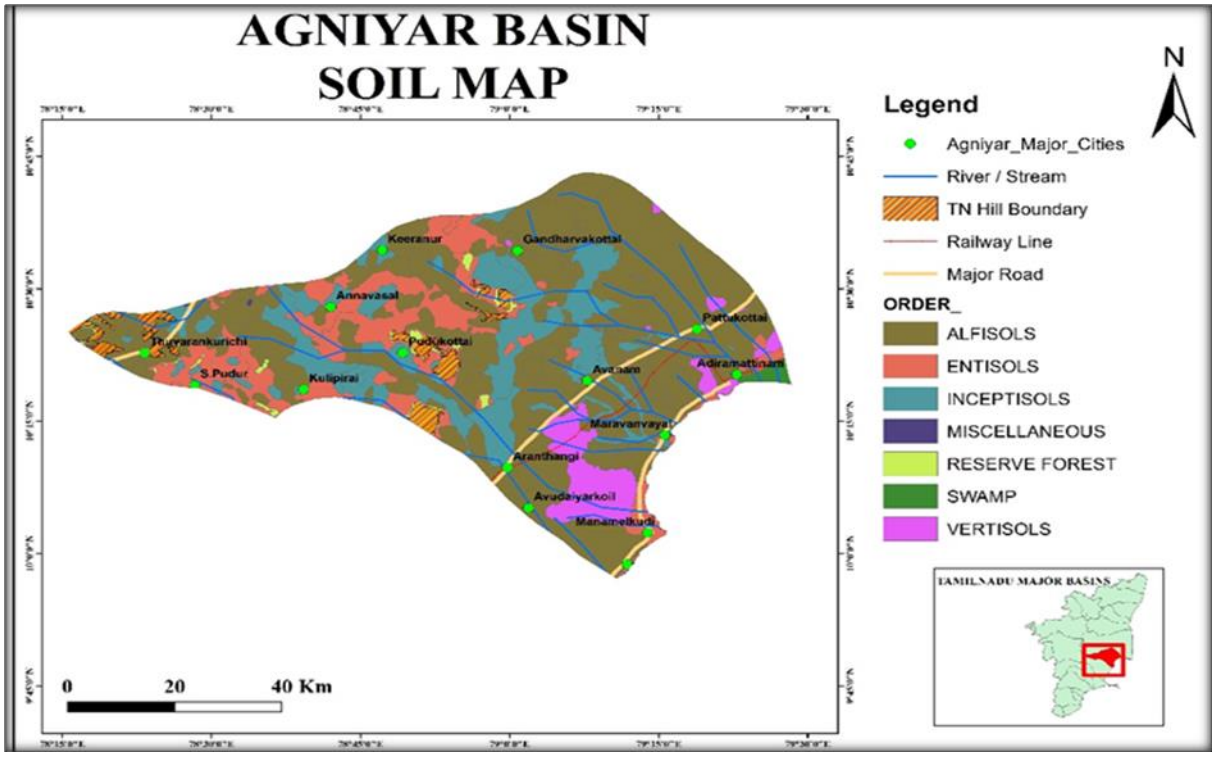


Figure.6 Soil map of Agniyar aquifer system

Alfisols typically exhibit well-developed, contrasting soil horizons (layers) depleted in calcium carbonate but enriched in aluminium- and iron-bearing minerals. Below the surface horizon lies a region with significant accumulation of translocated (migrated) layer silicate clay. This region, called the argillic horizon, is characterized by a relatively high content of available calcium, magnesium, potassium, and sodium ions.

1.13. Agriculture

Agriculture is the main stay of the rural population in the entire study area. The total area of the Agniyar aquifer system is 4973.1 sq.km with main water intensive wet crops covering about 2337 sq.km, (47%) dry crops covering about 796 sq.km (16%) and plantation crops covering about 1343 sq.km. (27%) (Figure.9). The fallow land area covering about 497 sq.km (10%). The less water intensive crops irrigated are maize, tomato, groundnut, chilly and Jasmine. The other crops include cotton, ragi etc., other minor crops are turmeric, flowers and vegetables. Crop wise distribution in the Agniyar aquifer system is given in Figure-7

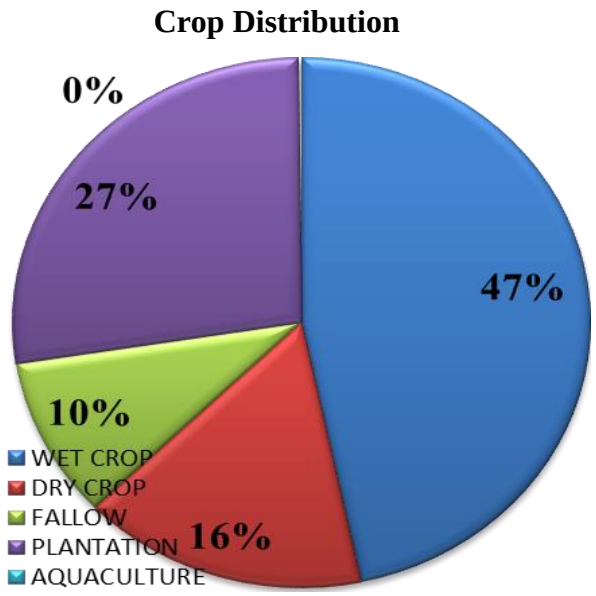


Figure.7 Crop wise distribution in the Agniyar aquifer system

1.14. Irrigation

In this basin, tank irrigation plays an important role and there are about 3975 irrigation tanks irrigating about 76350 ha. Out of the above, 346 are system tanks and 3629 are non-system tanks. The approximate storage capacity of these tanks is 560 MCM. The abstract of total command area of each sub basin is given below:

The ayacut of Maharajasamudram river is 6769 Ha. The total registered command area in Agniyar sub basin including MaharajaSamudram river basin is 24,073 Ha. In the Upper Ambuliyar sub basin, there are 2118 system and non-system tanks irrigating an extent of 22,231 Ha. In the Lower Ambuliyar sub basin, there are 416 tanks (system and non-system) with a total registered Command area of 24,699 Ha. The total ayacut in Ambuliyar sub basin is 46930 Ha. The total registered Command area in the Upper Vellar sub basin is 2676 Ha with 22 system tanks and 114 non-system tanks. The total registered command area in the Lower Vellar sub basin is 2671 Ha excluding the command area of non-system tanks. The total ayacut in South Vellar sub basin is 5347 Ha excluding the command area of non-system tanks.

1.15. Geology

Geologically, the Agniyar aquifer system comprises of marine, estuarine and fluvial alluvium underlined by Precambrian Gneisses and Charnockites. The Gneisses form the major rock types and spreaded over the half of the basin in the western side. The western part is underlain entirely by Archaean Crystalline formations with Recent alluvial deposits occurring along the river and streams courses. Weathered, fissured and fractured crystalline rocks and the recent alluvial deposits constitute the important aquifer systems in this part. The Geological map of the Agniyar Aquifer system is given in **Figure 8**.

The unconsolidated and semi consolidated formations in the Middle and Western part include shales, sandstones and clays of Jurassic age (Upper Gondwana), marine sediment of Cretaceous age, sandstones of Tertiary age and Recent alluvial formations.

The Middle and Eastern parts of the basin is underlain by the various geological formations ranging in age from Archaean to Recent. Ground water occurs in six different aquifers in this district. They are Archaean aquifers, Cretaceous aquifers, Eocene Aquifers, Miocene Aquifers, Pliocene Aquifers and Quaternary Aquifers.

Archaean Formations: The depth of weathered zone ranges from 10 to 12 m. Ground water

occurs to a limited extent in weathered and fractured rocks under unconfined and semi-confined to confined conditions respectively.

Cretaceous Formation: It occurs as a small strip in the central and eastern portion of the basin around Pudukottai –Thanjavur district border. The Pudukottai, Thanjavurand Thiruchinapoly formations consisting of Calcareous and Fossiliferous sandstone and lime stone for this Cretaceous formation. The maximum thickness of these formation is 50 m. Ground water occurs under confined conditions.

Eocene Formations: This formation do not exposed out anywhere but encountered in the bore holes at the depth of 130 m in the middle of the basin and >450 min the eastern side. Sand, silt and clay constitute these aquifers. The thickness of the aquifer is around 80 m and ground water occur under confined conditions.

Miocene Formations: Friable variegated coarse to fine grained clay bounded Sandstone with gravel. The thickness of this formation ranges from less than a metre in the west to > 600 m in the east. The aquifer can be divided into two hydraulically interconnected i) lower Orathanadu (Lower Miocene) aquifer zone and ii) upper or main flowing zone (Middle and upper Miocene).

Orathanadu Formations: Sandy and gravelly deposits typical of deltaic facies, Clay and clay bounded sand and coralline limestone form this formation. The thickness of the aquifer ranges between 30 and 120 m and occurs at the depth of 420 to 540 m bgl.

Main flowing Formations: Coarse-grained sand constitutes these aquifers in Cauvery sub basin, while fine-grained sands constitute the aquifer in New Delta area. Their thickness increases from 0 to 180 from west to east.

Pliocene Formations: The exposure of the Pliocene sediments found in the whole New Delta area. Sand, gravel, sandy clay and variegated clay constitute the formation. The thickness of the aquifer ranges from 40 to 115 m and ground water occurs under unconfined to confined conditions.

Quaternary Aquifers: The aquifers comprise of sand, clay and silt. The wide variation in the proportion, both laterally and vertically has resulted in the wide variation in aquifer parameters and yields. They are deposited in fluvial and semi marine environment. The thickness of aquifer ranges from 3 to 40 m. Geologic succession of the Agniyar Aquifer System is

presented in **Table-2**

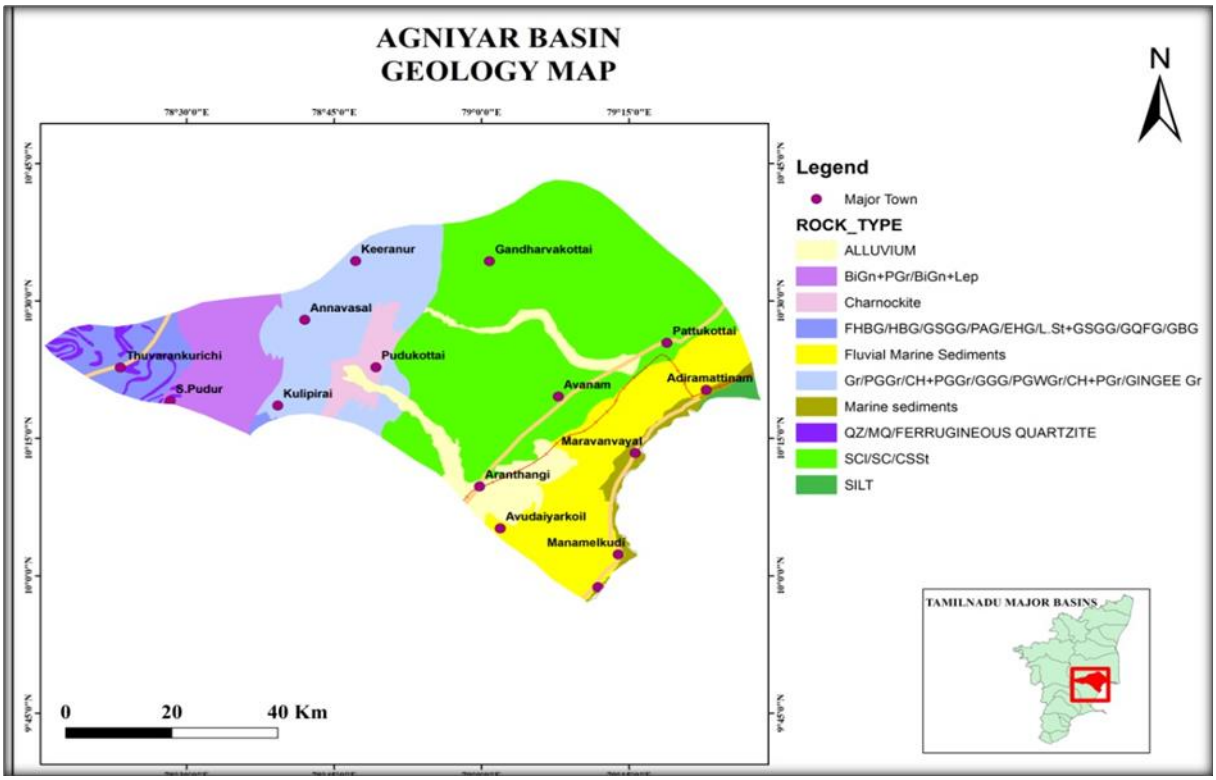


Figure 8: Geological maps of the Agniyar Aquifer system

Table 2. Geological succession of the Agniyar aquifer System

S.No	Group	System	Lithology	Groundwater relevance
1.	Quaternary	Recent – Sub-recent	Soils, coastal /river Alluvium (sand & silt), Laterite	Moderate to very good porous aquifer system
2.	Tertiary	Sandstone (Eocene to Pliocene)	Podakkudi Cuddalore sandstones and Orathanadu aquifer	Moderate to high porous Aquifer.
3.	Mesozoic	Cretaceous	Kuppakudi formation calcareous Sandstone, clays, Marls and siltstone	Moderately porous Aquifer.
4.	Azoic	Archaean	Gneisses Charnockites, Granites,	Weathered and Fractured Aquifer units.

2. 0 DATA COLLECTION AND GENERATION

Periodical data pertaining to groundwater levels, quality, pumping tests and slug tests were collected during aquifer mapping studies apart from water sample collection to assess the

groundwater quality. In addition to, Geophysical data has been generated through conducting Geo electrical soundings after evaluation of data gap analysis.

2.1. Hydrogeological data:

The periodical monitoring of ground water level implies the groundwater recharge and discharge (natural and manmade) occurring in the aquifer systems. It also reveals that the interaction between surface and sub-surface water systems. In Agniyar aquifer system area, in shallow aquifer 98no's of groundwater monitoring wells, which included 22 CGWB monitoring wells, 76 State department wells and 8 piezometers of CGWB. In deeper aquifer system 65 nos of groundwater monitoring wells, in which 8 CGWB monitoring wells, and 57state department wells, which are monitored periodically. This was useful to record the temporal and special changes in aquifer system. The locations of monitoring wells are presented as **Figure 9**. Pumping test data of 65 bore wells was collected and analyzed for the aquifer parameters.

Water level monitoring	**Confined aquifers**
Un-confined aquifers	Total Nos. wells : 65
Total Nos. wells : 98	CGWB Pz (Deep): 8
CGWB Dug wells : 22	State Govt. Dug wells: 57
CGWB Pz (Shallow): 8	(PWD& TWAD)
State Govt. Dug wells: 76	
(PWD& TWAD)	

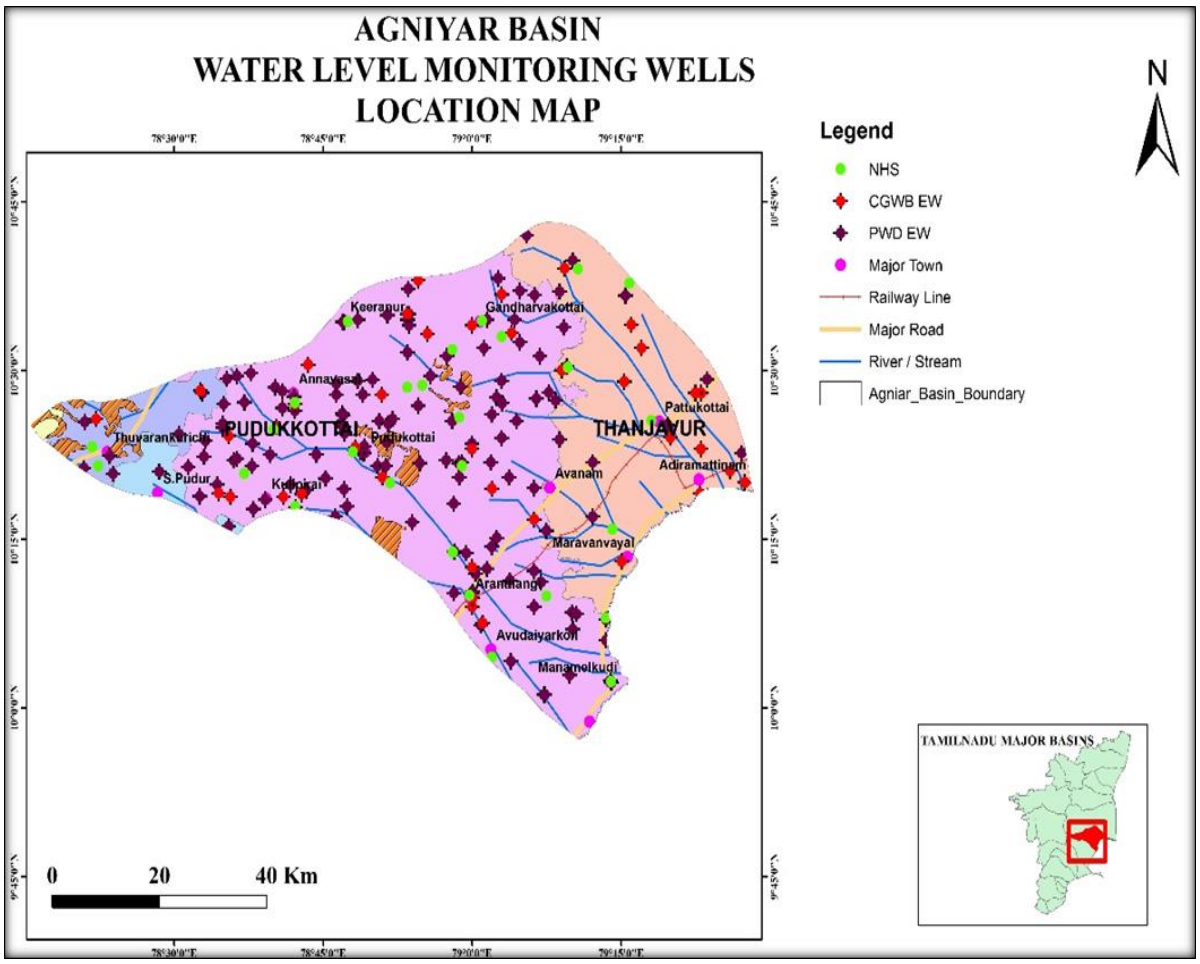


Figure 9: Location of Groundwater Monitoring Wells

2.2. Hydro chemical data

The groundwater quality of the Lower Cauvery aquifer system was studied by collecting water samples from dug well and bore well. Groundwater samples were collected for 28 locations. Ground water quality data has been collected from TWAD, Govt.of Tamil Nadu and SG&SWRDC, PWD in respect of 65 locations. The Location of Groundwater quality Monitoring Wells in Agniyar Aquifer system is given in **Figure 10.**

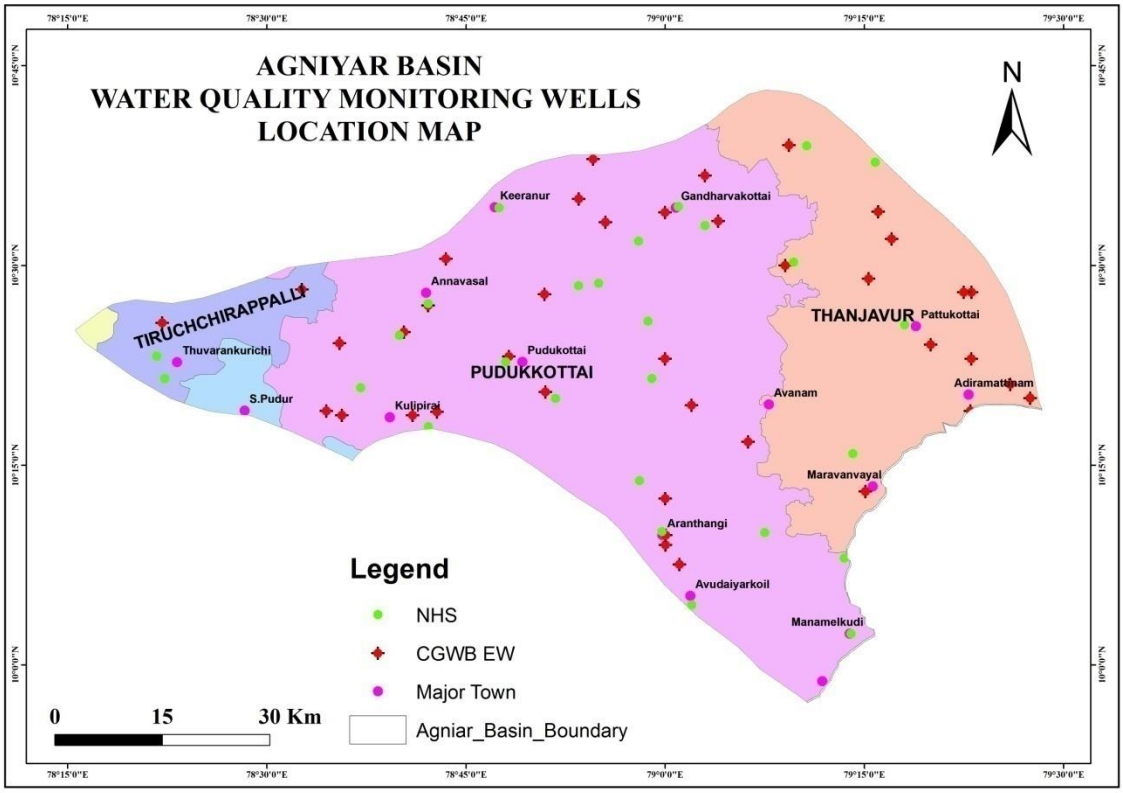


Figure 10: Location of Groundwater quality Monitoring Wells

2.3. Geophysical data

The geophysical survey was conducted in the study area consisting of Vertical Electrical Soundings (VES) by employing Schlumberger configuration with maximum half current electrode separation of 300 m. The objective of the study area is to decipher the sub surface conditions such as weathered and fractured layer resistivity and thicknesses and massive formations up to the depth of 200 m. A total number of 125 VES were carried out and geo electric layers inferred through interpretation of the results obtained. The locations of the. VES in Agniyar Aquifer system is presented in the following **Figure 11.**

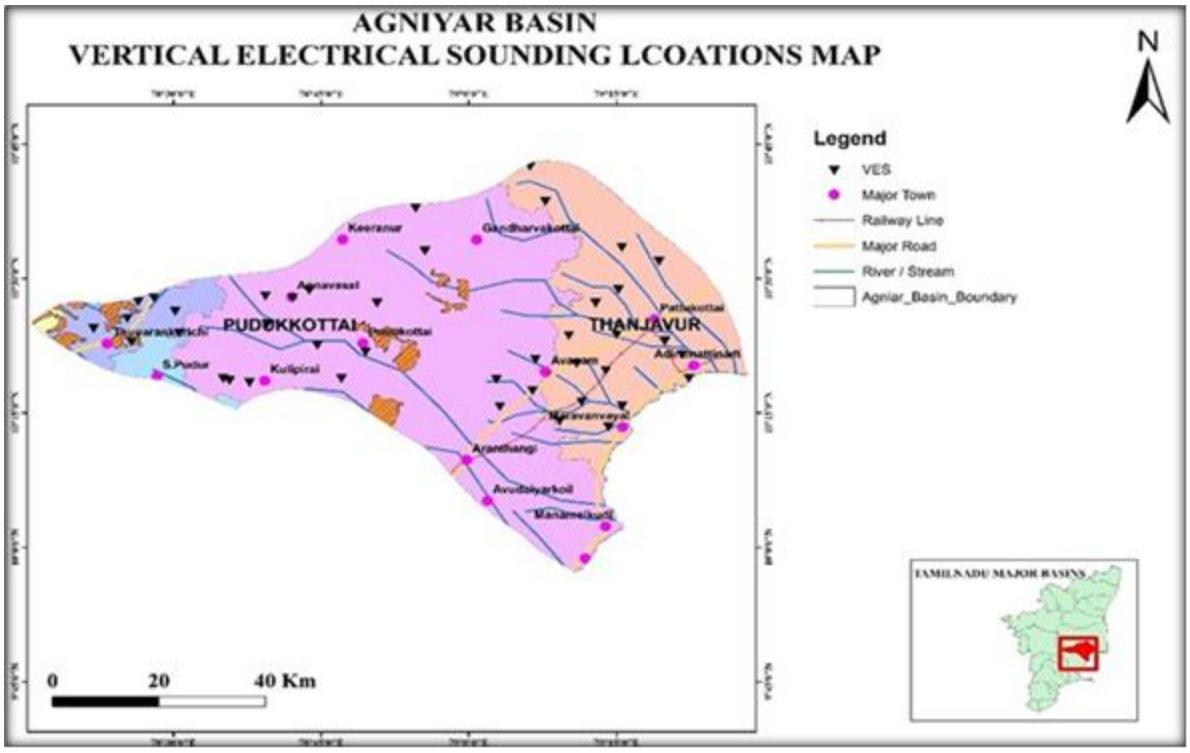


Figure 11: Locations of the VES in Agniyar Aquifer system

2.4 Groundwater Exploration data

Data of 112 Nos of exploratory wells were drilled in the Agniyar aquifer system (78nos CGWB and 34 nos State department wells) prior to National Aquifer Mapping project was compiled and analysed **(Figure.12).** These wells were plotted on the 1:50,000 scale topographical map and as per the NAQUIM guidelines for the hard rock & soft rocks, data requirements were identified on the plotted topographical map. The data such as lithology, fracture depth, yield, water level, aquifer properties were generated and utilized to depict the prevailing aquifer systems of the basin. Similarly, the piezometer drilled by CGWB 8 nos. up to the depth of 45 m bgl was used for deciphering the first aquifer.

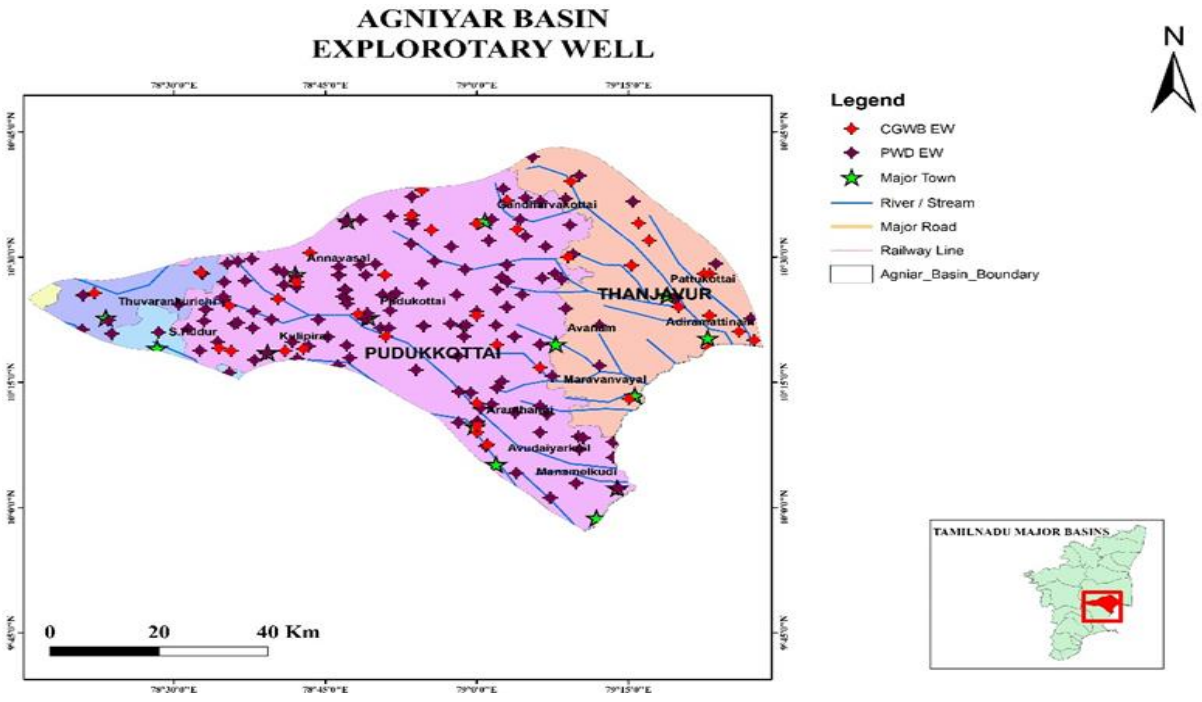


Figure 12 : Location of Exploratory well in Agniyar Aquifer system

3. 0 DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING

3.1 Hydrogeological Data Interpretation

Aquifer Maps- 2D models showing Aquifer Disposition:

Based on the lithologs of the exploratory wells and the well sections observed during field studies as part of Aquifer Mapping studies, 2D models of the aquifer system of the basin has been deciphered by using ROCKWORKS software. The data input for ROCKWORKS is prepared in following format as shown in Table-8, to generate 2D models of the basin along different selected sections.

3.1.1 Hard rock region:

Hard rock region comprising of gneissic and Charnockite rocks is found in the western portion of the Agniyar aquifer system. Hard rock regions cover an area of 440.90 sq,km. The soft rock covers an area of 4563.20 (figure and Table). The Gneissic formation and Charnockite formation form two aquifer units namely the weathered and fracture/jointed aquifer unit.

Aquifer Unit I – Weathered: The weathered aquifer unit occurs from the groundwater level and has a minimum thickness of 8 m and maximum thickness of 30 m with average thickness

of 18 m. 2D disposition along west to east (figure. 13) clearly shows the vertical and lateral distribution of the gneissic and Charnockite formation. Yield of this weathered aquifer unit ranges from 0.8 to 16 m^3/hr. During monsoon period the wells tapping this aquifer unit sustains for 2 to 4 hrs/day while during non-monsoon period (April to June) sustains for less than 1 hour/day. Groundwater occurs in unconfined condition.

Table 3. Name of firkas in hard rock regions

Formation	Name of the firkas
Gneissic and Charnockite formation	Senthurai, Thuvarankurichi, Maunganui, Vallanadu.

The aquifer parameter such as transmissivity in this aquifer unit ranges from less than1 to 5 m^2/day. The Specific yield of this aquifer unit ranges from 1 to 1.5% with highly portable groundwater quality. The general EC of this aquifer unit ranges from 750-2250µS/cm and is suitable for drinking. There are some isolated pockets adjoining the industrial cluster in Pudukkottai and Tiruchirapally district, where the groundwater quality is beyond permissible limit for drinking and irrigation purposes.

Aquifer Unit II (Fractured/Jointed) – This aquifer unit comprises of fractured and jointed gneissic and Charnockites formed due to tectonic activity. Top of this aquifer unit occurs from 8 to 30 m bgl. Based on the analysis of the 44 wells it is observed that there is a possibility of occurrence of 3 to 4 Fractures/joints exists up to 200 m bgl in the gneissic region. In Charnockites region 3 to 4 fractures are likely to be encountered and they exit only up to 155 m bgl. Salient features of the aquifer units in hard rock region of the Agniyar Aquifer system is given in table -4. The distribution hard rock formation in the Agniyar Aquifer system is given in table-5. The yield of this aquifer unit II ranges from 2 to 23 m^3/hr. During monsoon period the wells tapping this aquifer unit sustains for 2 to 6 hrs /day while during non-monsoon period (April to June) sustains for 1 to 3 hour/day. Transmissivity of this aquifer unit ranges from 1.00 to 25.00 m^2/day **(Table 4).** The general EC of this aquifer unit ranges from 750 to 1500µS/cm and is suitable for drinking.

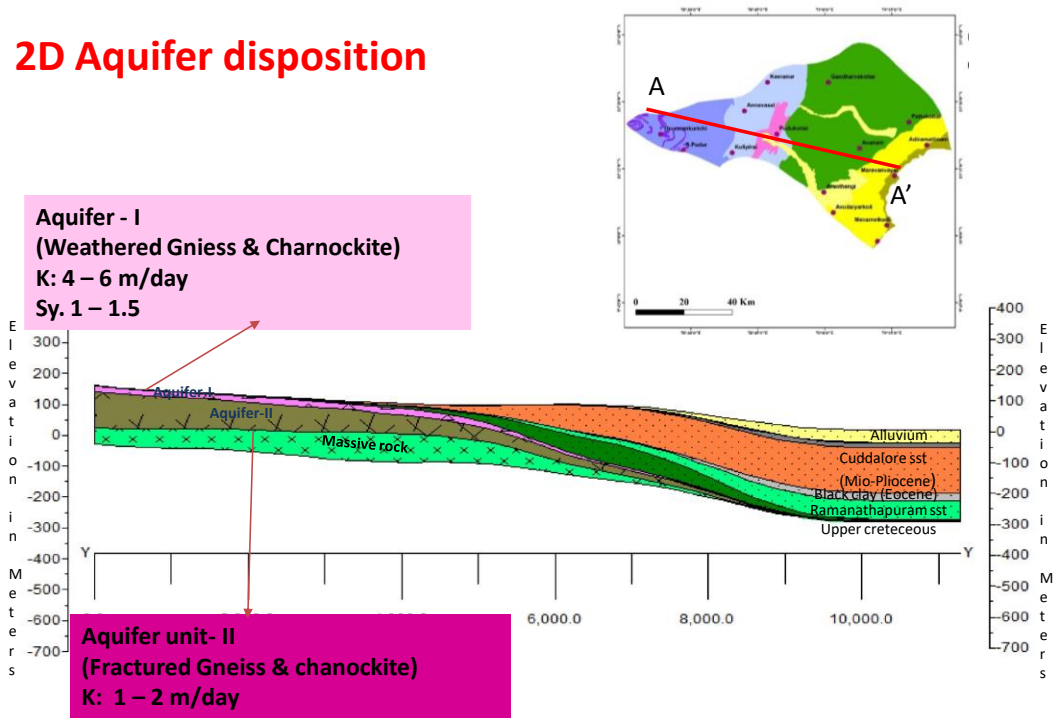


Figure 13: 2D disposition along west to east direction

Table.4 Salient features of the aquifer units in hard rock region of Agniyar aquifer System

Type of Aquifer	Formation	Top of the aquifers (mbgl)	Thickness/ occurrence of fractures (m)	Range of Yield (m^3/h)	Sustainability (hrs)	Aquifer parameter (Transmissivity)	Groundwater EC quality values (us/cm)	Suitable for Drinking
Aquifer unit - I	Weathered gneiss & Charnockite	GL	5 – 20 (Avg. - 18 m)	2.0-13	Monsoon: 2-4 hrs & non monsoon (May,Jun&July) < 1 hrs/day	1 to 5	750-1500	yes
Aquifer Unit -II	Jointed & Fractured Gneiss/ charnockite	8 to 30	8 -200 (3 to 4 fractures exist)	2.0-23	2-6 hrs in monsoon & 1-3 hrs in non - monsoon	1.00-25.00 -	750-2250	yes

Table .5. Distribution of fractures in the hard rock formation

Gneissic formation (24 wells)		Charnockite region (20 wells)	
Depth (m bgl)	% of fractures	Depth (m bgl)	% of fractures
Upto 50	63	Upto 50	48
50 to 100	18	50 to 100	30
100 to 150	14	100 to 150	14
150-200	5	150-200	8

Gondwana region

This Gondwana region comprises of highly compacted Conglomerates of upper Cretaceous formation and is located in the north/central periphery. Gondwana region covers an area of 92 sq.km. Gondwana region with laterite capping covers an area of 60 sq.km encompassing 1 firka in the Agniyar aquifer system. The maximum thickness of laterite capping is 6.4 m. Gondwana region forms aquifer unit comprising weathered Gondwana with laterite capping and fractured Conglomerates. These are generally poor yielding aquifer units.

Gondwana region : Name of the firka

(1 firka) : Varappur

Gondwana Aquifer

This aquifer unit comprises of completely weathered conglomerates and conglomerates with laterite cappings. The top of this aquifer unit occurs from ground level to 6.5 m bgl. The thickness of this aquifer unit ranges from 9 to 13.50 m bgl. The maximum thickness of the laterite deposit is 8.4 m and is observed in the southern portion of the Agniyar aquifer system. 2D aquifer disposition along southwest, south-east is represented in figure 14 Yield of this aquifer unit ranges from 2 to 27 m^3/hr. The aquifer unit comprising conglomerate formations yield very low. While conglomerates with lateritic capping have high yield and they range from 4 to 27 m^3/hr. Wells tapping complete conglomerates aquifer unit sustain for 2 to 3 hrs during monsoon and less than hour during non-monsoon period i.e., April to June. Wells tapping the conglomerates with laterite capping sustain for 3 to 5 hrs during monsoon and less than 1 hr/day during non-monsoon (April to June). Transmissivity value ranges from 2.23 to 142.2 m^2/d. Transmissivity are very low in the completely conglomerate region while they

have high values in laterite capped regions. Specific yield of this aquifer unit estimated through a long duration pumping test (7200 min) of the well tapping conglomerate aquifer unit resulted in specific yield value of 1 (CGWB 2014). Groundwater occurs in unconfined condition. EC in this aquifer unit ranges from 150 to 2500 µS/cm. Salient features of this aquifer unit is presented in **Table-6.**

Table 6: Salient features of the aquifer units in Gondwana region of Agniyar aquifer System

Type of Aquifer	Formation	Top of the aquifers (mbgl)	Thickness/ occurrence of first	Range of Yield (m^3/h)	Sustainability (hrs)	Aquifer parameter (Transmissivity	Groundwater EC quality (µs/cm)	Suitable for Drinking
Aquifer unit - I	Laterite capping on Gondwanas (Conglomerates) Tertiary sandstones	GL – 6.5	9 - 13.50	2-27	Monsoon: 2-3 hrs & non monsoon (May,Jun&July) < 1 hr/d	2.234 to 142.2	150-2500	yes

3.1.2 Alluvium Region

The thickness of the aquifer-I in alluvium is ranging from 10 to 20 mts with an average thickness of 18 mts. The discharge of the Aquifer- I is ranges from 10 to 18 m^3/hrs which sustains pumping for 4 - 5 hrs during monsoon period whereas in summer period 3 to 4 hrs of pumping for groundwater utilization. Based on the long duration pumping test, the transmissivity of the aquifer is determined and it is ranging from 1000 to 2000m^2/day. Electrical Conductivity ranges from 3000 to 5000 µs/cm. The groundwater is found not suitable for all purposes and it is saline nature.

The thickness of the aquifer-II in sandstone of cuddalore sandstone is ranging from 50 to 150 mts with an average thickness of 60mts. 2D disposition along North-east to south west presented in **Figure.14.** The discharge of the Aquifer- II is ranges from 10 to 18 m^3/hrs which sustains pumping for 3 -4 hrs during monsoon period whereas in summer period 2 to 3 hrs of pumping for groundwater utilization. Based on the long duration pumping test, the transmissivity of the aquifer is determined and it is ranging from 1000 to 3000m^2/day.

Electrical Conductivity ranges from 3000 to 30000 µs/cm. The groundwater is found not suitable for all purposes and it is saline nature. The salient features of the 3D Aquifer disposition of the Agniyar Aquifer system is given in **Figure-15**

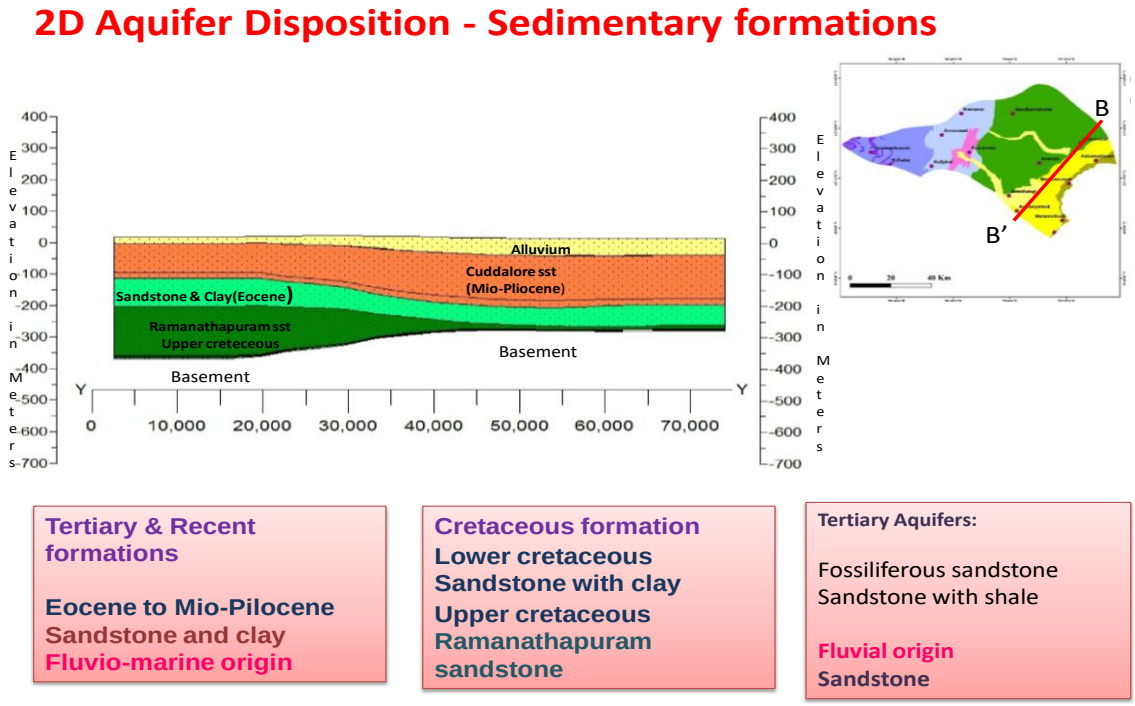


Figure-14. 2D disposition along North-east to south west direction

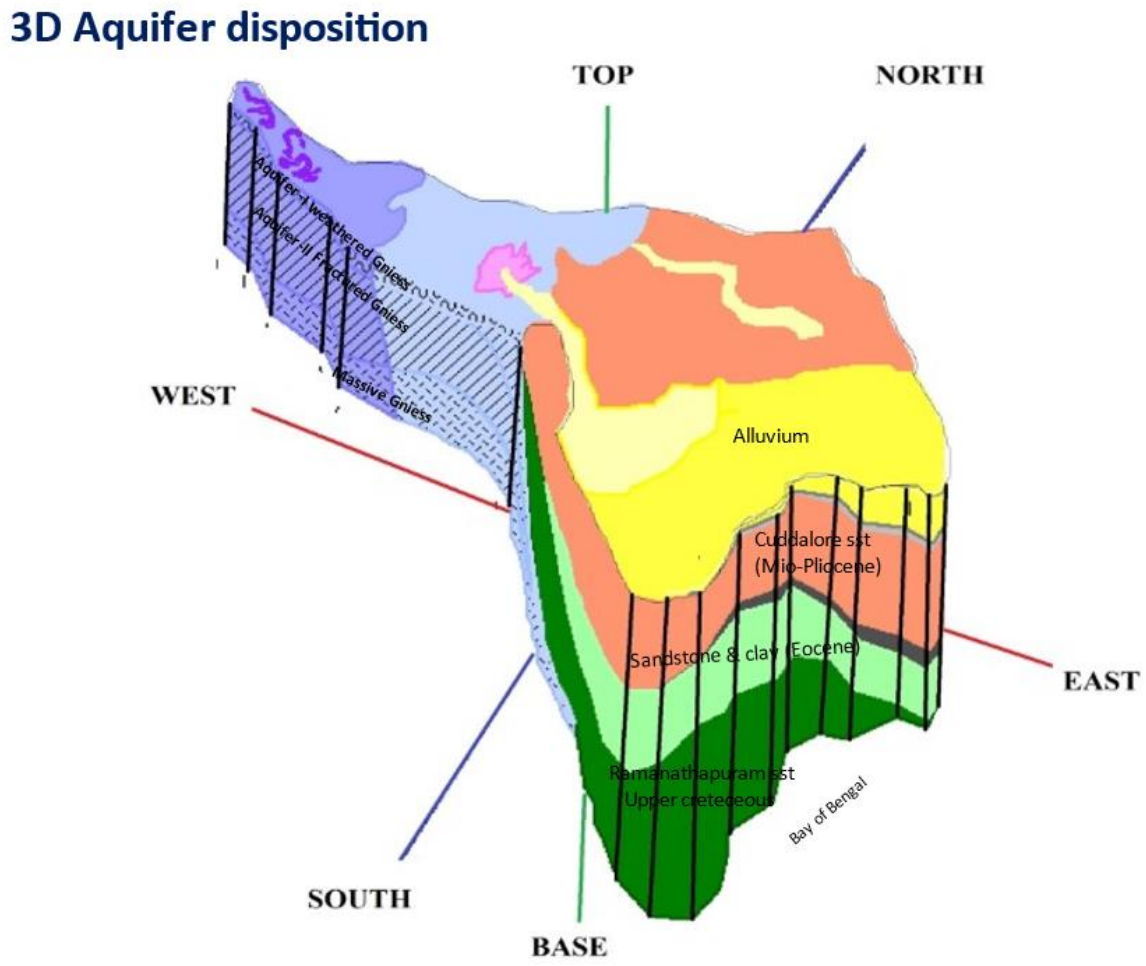


Figure-15 3D Aquifer disposition of Agniyar Aquifer system

Table. 7. Number of firkas in Alluvium regions

Formation	Number of firkas
Alluvium region (50 firka)	50 firkas

Table.8 Salient features of the aquifer units in Alluvium region of Agniyar aquifer System

Type of Aquifer	Formation	Top of the aquifers (mbgl)	Thickness/ occurrence of first fractures (m)	Range of Yield (m^3/h)	Sustainability (hrs)	Aquifer parameter – (Transmissivity m2/day)	Groundwater quality EC values (µs/cm)	Suitable for Drinking
Aquifer unit - I	Alluvium Laterites	GL	1-20	10-18	-	1000-2000	3000-5000	Yes. except sea water intruded area (EC-6800-13k)
Aquifer Unit -II	Tertiary sandstones Gondwana (Sandstone, Gravels)	50-150	20-60	10-18	for 3-4 hours in monsoon and < 2-4 hours in non monsoon	1000-3000	3000-20000	Yes. except sea water intruded area

3.2 Groundwater Level

During Aquifer Mapping studies in Agniyar aquifer system 420 Groundwater monitoring wells which were monitoring regularly were used along with 119 key wells established in different formations in order to know the behavior of the groundwater regime. Out of total 420 wells 119 wells were established by CGWB, 301 wells were established by State Govt. Along with 8 deep, 23 shallow piezometers and 12 shallow wells were established to observe the behavior of the groundwater regime in this aquifer system. The water levels were monitored from May 2019 to January 2020 (four times in a year). The depth of key wells ranged from 6.00 to 27.75 mbgl. The hydrogeology of Agniyar Aquifer system is presented in **Figure-16.**

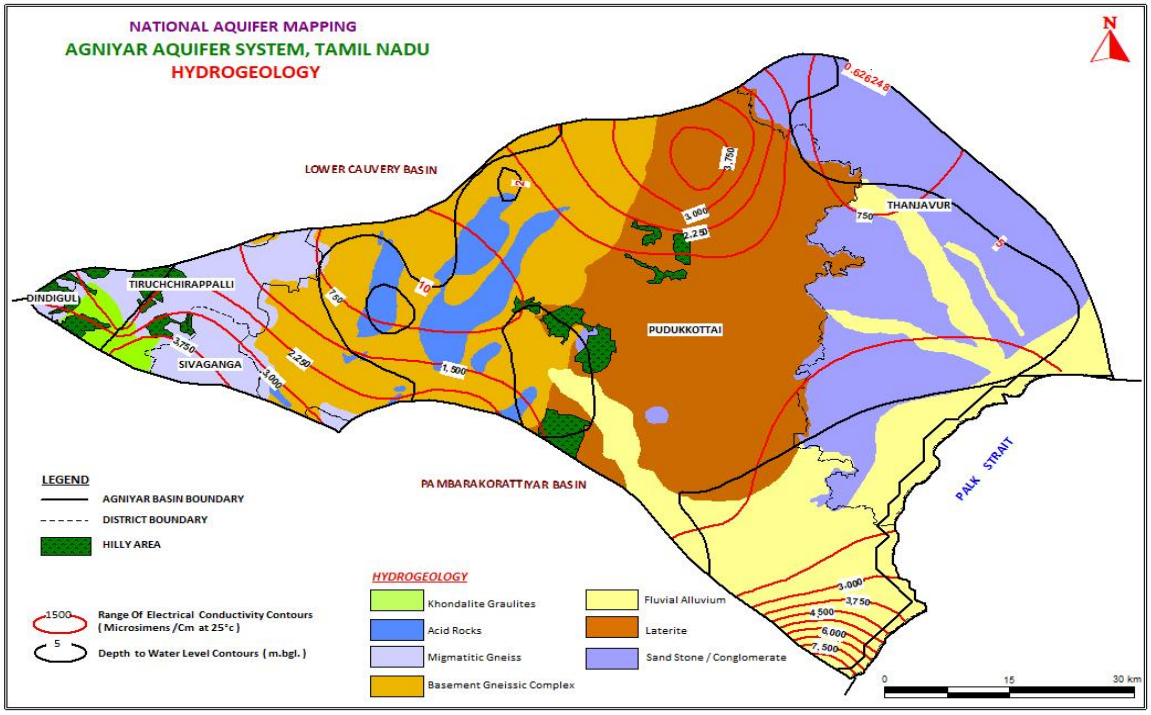


Figure-16. Hydrogeology of Agniyar aquifer system

3.2.1. Depth to Water level for aquifer I (May-2019)

Based on the data of key well inventoried and NHS wells, the water level data pertaining to the period of May 2019 (pre monsoon) was used for the preparation of depth to water level map of the basin presented in **fig-17**. The depth to water level during May 2019 is varied from 2.0 m bgl to 18 mbgl. Depth to water level ranging from 0 to 2 mbgl was observed during this period only in 46 wells. Water level ranging from 2 to 5 mbgl is shown in 49 wells (51%), water level ranging from 5 to 10 m bgl shows in 3 wells (3 %). Major part of the basin shows water level in the range of 5 to 20 m bgl. Patches recorded water level in the range of 2 to 5 m bgl and found in central and eastern portion of the basin. Water levels ranging 5 to 10 m bgl are

observed in the whole western part, central part & northern part of the basin.

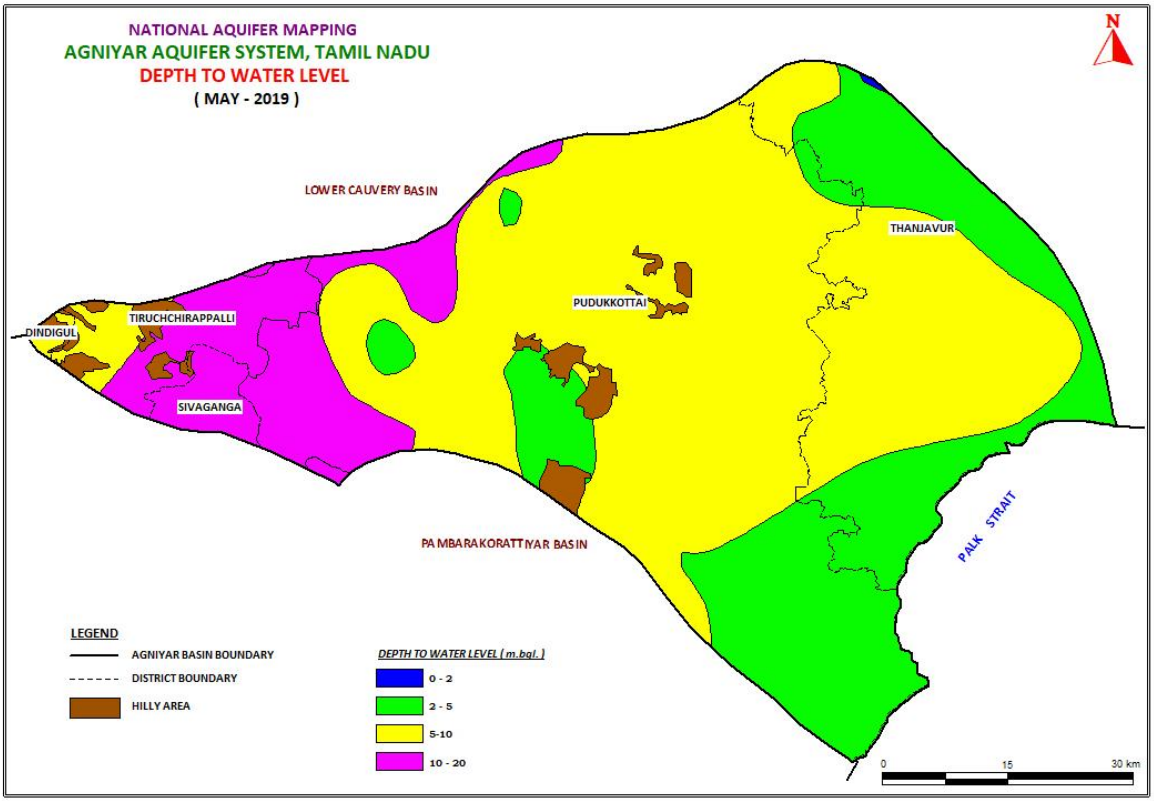


Figure 17: Depth to water level during May -2019

3.2.2. Depth to Water level for aquifer I (January-2020):

The depth to water level map for the period of January 2020 based on the key well and NHS data collected from the basin area is presented as **Figure 18**. The depth to water level during Jan 2020 is varied from 0.85 m bgl to 14.55 mbgl. Depth to water level ranging from 0 to 2 mbgl was observed in 7 wells (5%). Water level ranging from 2 to 5 mbgl is shown in 35 wells (60 %), water level ranging from 5 to 10 m bgl shows in 18 wells (35%). Major part of the basin (61%), shows water level in the range of 2 to 5 m bgl, covering almost entire basin area.

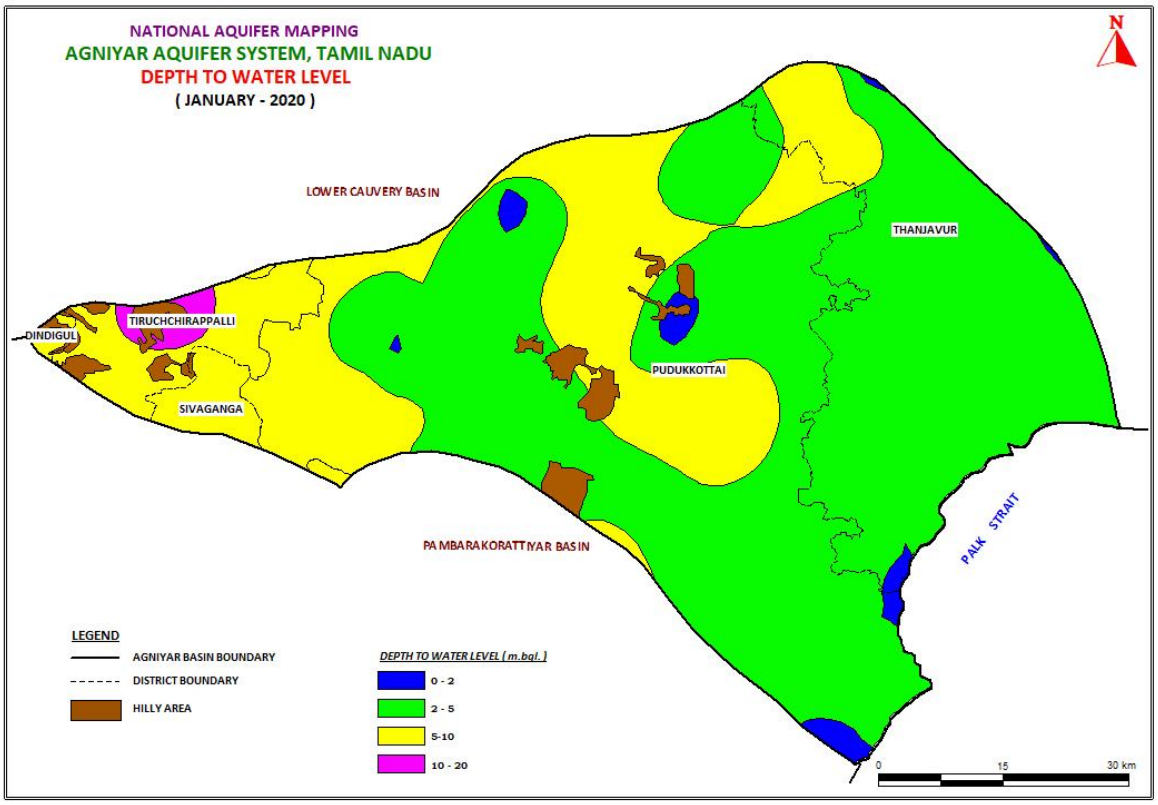


Figure 18: Depth to water level during January-2020

3.2.3. Decadal water level Scenario

Water level fluctuation in the observation wells in an area between two periods is indicative of the net changes in the ground water storage during the period in response to the recharge and discharge components and is an important parameter for planning for sustainable ground water development. The decadal water level scenario in the area has been analysed using the water level data of January 2009 and January 2018 presented in **Figure 19.** As both southwest and northeast monsoons are active in the area the fluctuation recorded in ground water levels of January 2009 in comparison to the water levels of January 2019 indicate the extent of replenishment of the shallow aquifer due to the monsoon rainfall. Depth to water level ranging from 0 to 2 mbgl was observed in 9 wells (5%). Water level ranging from 2 to 5 m bgl is shown in 30 wells (45 %), water level ranging from 5 to 10 m bgl shows in 35 wells (50%). Major part of the basin (60%), shows water level in the range of 2 to 5 m bgl, covering almost entire basin area.

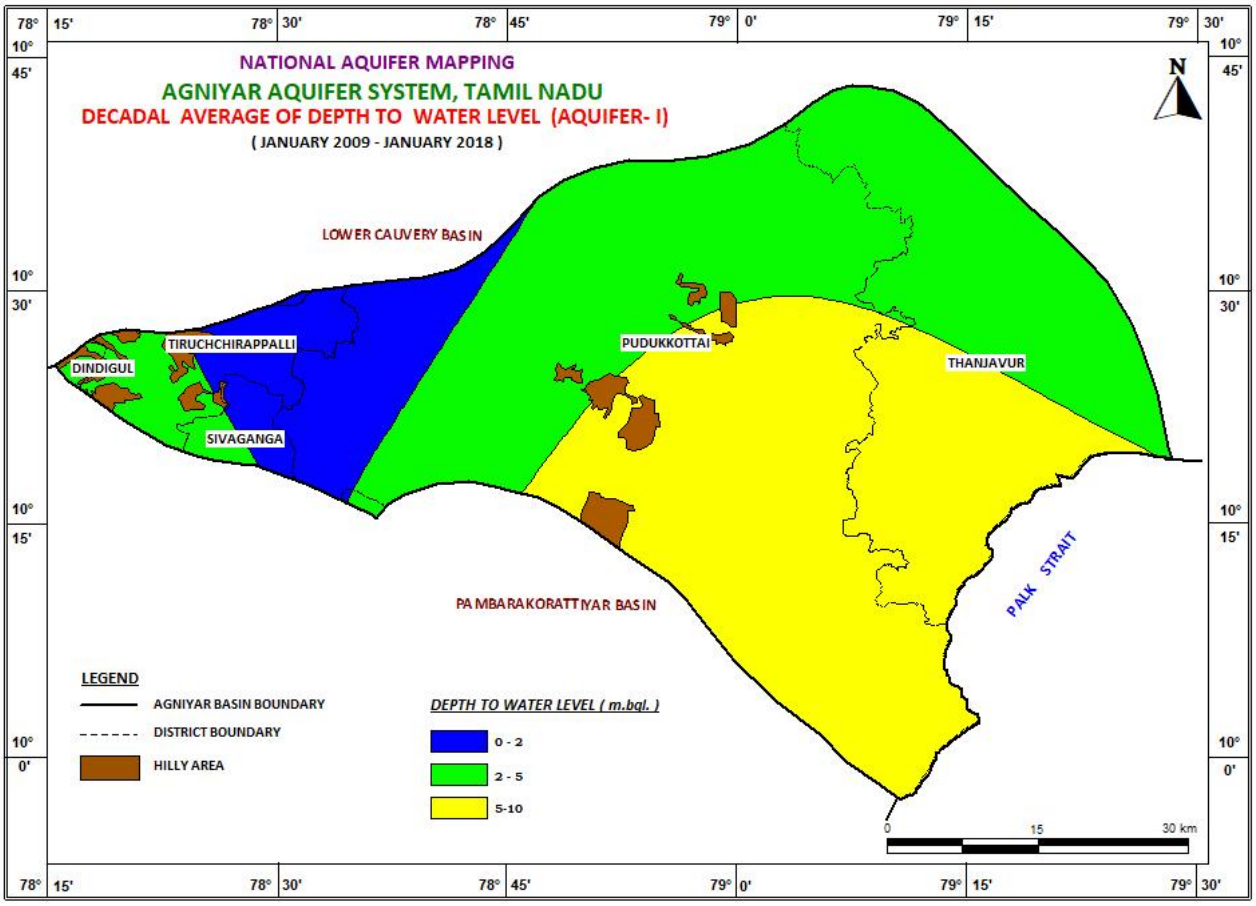


Figure 19: Decadal water level scenario for the period Jan 2009 and Jan2018

3.3. Pumping Tests

The yields of the wells in the study area are widely varied. Many of Dug wells in the area have less than two-meter water Colum during most of the year and about 50 to 60 % of wells get dry during summers. Most of the time dug wells are used as storage tanks to collect water from a number of bore wells and to distribute the collected water for irrigation as the yield of each bore well is much less to support irrigation. The wells located in favorable hydrogeological settings like shear zones, topographic lows, river alluvium etc. are able to sustain at a rate of 2 to 4 lps for 2 to 4 hrs of pumping. The yield of large diameter wells tapping the weathered mantle of crystalline rocks ranges from 22-46 m^3/day for a drawdown of 2-3 m and are able to sustain 1-3 hours of pumping. The specific capacity of the porous weathered formation ranges from 7 to 35 lpm/m/dd. The Transmissivity values of the weathered formation computed from pumping tests ranges from 1to 25 m^2 /day and storativity ranges from 2.16 $x10^{-5}$ to $4.9x10^{-5}$. At a very few places the weathered mantle extends down to 20 m bgl.

3.4. GROUNDWATER QUALITY

3.4.1. Electrical Conductivity

Electrical conductivity is the indicator of the total mineral content of water and hence it indicates the total dissolved solids (TDS) present in water. TDS of water determin usefulness to various purposes. Generally, water having TDS <500 mg/L is good for drinking and other domestic uses. However, in the absence of alternative sources TDS up to 2000 mg/L may be used for drinking purposes. The distribution of EC in different aquifers are given in **Figure 20.**

The phreatic aquifer ground water quality is fresh in about 54%, as indicated by the EC value less than 750 µs/cm at 25ºC. In about 21% of the Ground Water indicating the moderately fresh showing the EC varies between 751 -2250µs/cm at 25º C, 25% of Ground Water showing EC between 2251-3000 µs/cm at 25º C indicating that the ground water is slightly mineralized. The fractured zone ground water quality is fresh in about 18%, as indicated by the EC value less than 750 µs/cm at 25ºC. In about 85% of the Ground Water, the EC varies between 751 -2250µs/cm at 25º C indicating that groundwater is moderately fresh and 05% of groundwater are between 2251-3000 µs/cm at 25º C indicating that the ground water is slightly mineralized.

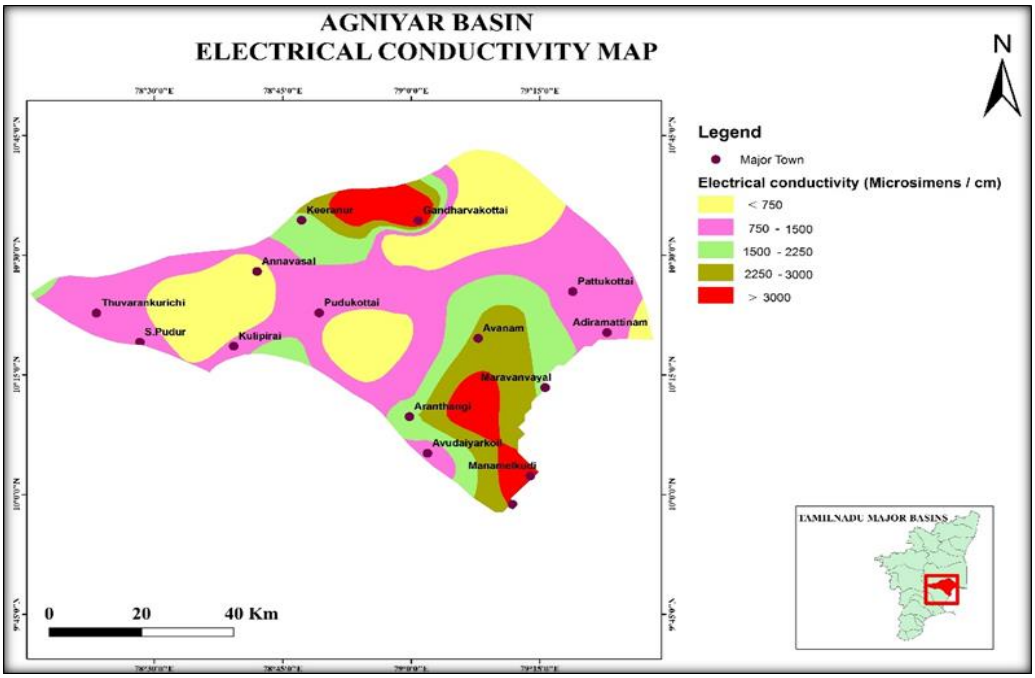


Figure 20: Electrical conductivity map of Agniyar Aquifer system

3.4.2. Chloride:

The classification of concentration of chloride in phreatic aquifer groundwater is that about 75% shows with in desirable limit, where as in fractured aquifer 91%shows with in desirable limit., 15% of samples in phreatic aquifer and 9% of samples in fractured aquifer are within permissible limit respectively. There were no water samples shows above permissible limit of Chloride concentration either in phreatic aquifer or in fracture aquifer presented in **Figure. 21.**

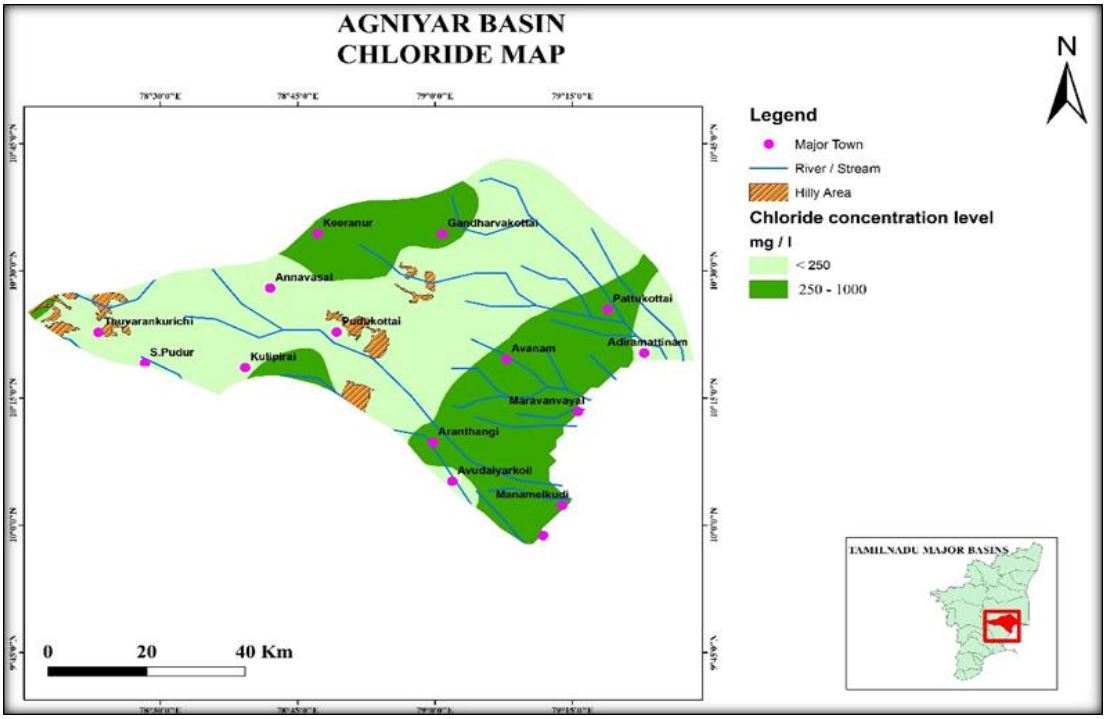


Figure 21: Chloride concentration map of Agniyar Aquifer system

Table.9. Distribution of EC and Chloride concentration in Agniyar Aquifer system

Ec (us/cm)	Nos.	%	Cl (mg/l)	Nos.	%
0-750	15	54	<1000	21	75
751-2250	6	21	>1000	7	25
2251-3000	7	25			

3.4.3 Nitrate

The concentration of Nitrate in the phreatic groundwater shows that about 45% of the samples nitrate below 45 mg/L, the desirable limit, 55% of the samples showed nitrate between 46-100 mg/L and no samples showed nitrate 100 mg/L, which are above permissible. Nitrate

concentration in the fractured aquifer shows that about 49% of the samples nitrate below 45 mg/L, the desirable limit for drinking and 41% of the samples showed nitrate between 46-100 mg/L and about 10% of the samples showed nitrate more than 100 mg/L, which are above permissible limit of Burea of Indian standard (IS 10500:2012).The Nitrate concentration in phreatic aquifer or in fracture aquifer presented in **Figure 22**

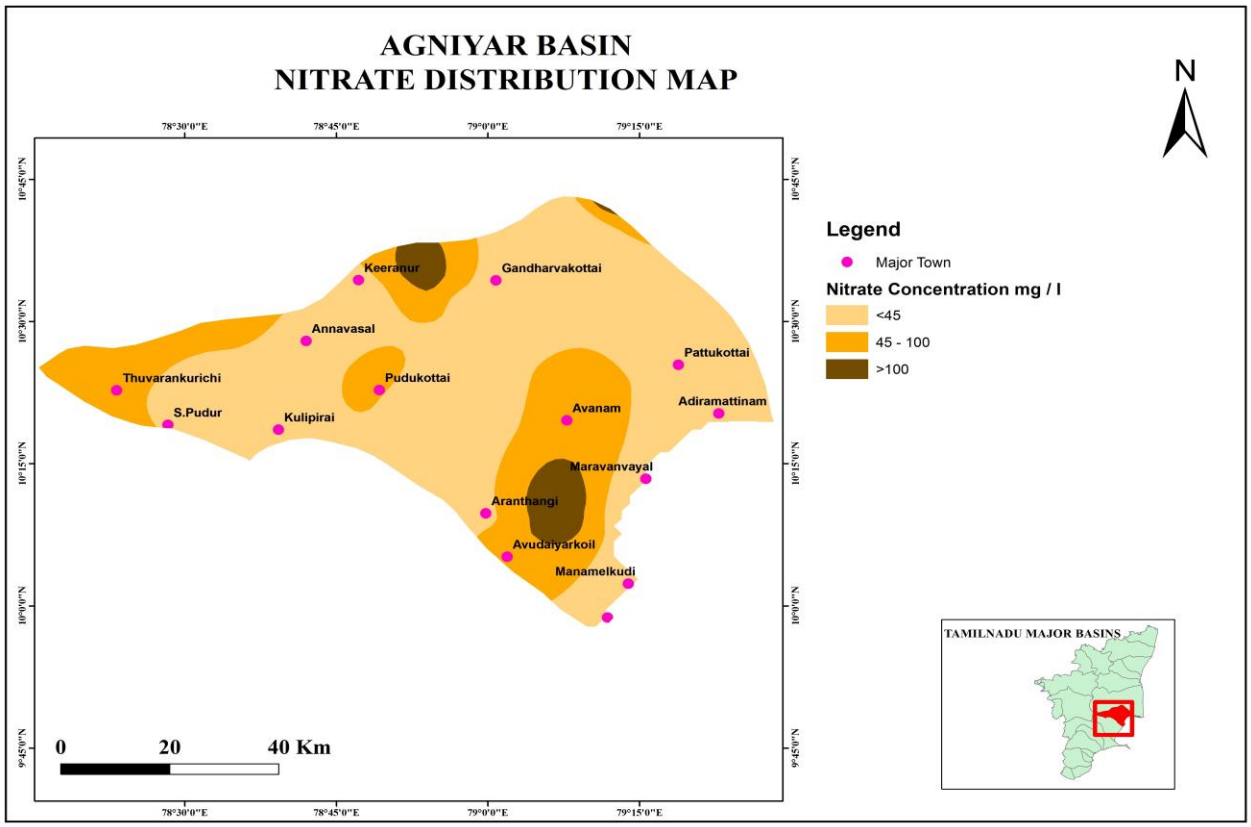


Figure 22: Nitrate concentration map of Agniyar Aquifer system

4.0. GROUND WATER RESOURCES

The dynamic ground water resources are estimated as on 2017 based on the methodology suggested by Ground Water Estimation Committee (GEC) 1997.

The ground water recharge is calculated both by ground water fluctuation-specific yield method and by rainfall infiltration method. The annual replenishable ground water recharge is the summation of four components viz.,

i) Monsoon recharge due to rainfall

ii) Monsoon recharge from other sources

iii) Non-monsoon recharge due to rainfall

iv) Non-monsoon recharge due to other sources

Firka-wise dynamic ground water resources have been taken from the approved resources estimation done as on March 2017, jointly by State PWD of Tamil Nadu and CGWB, to arrive at the total resources available in the study basin. 55 numbers of Firkas falling in the basin. The Firka wise groundwater resources have been appended in **Table 10.**

4.1. Net Ground Water Availability

The net ground water availability refers to the available annual recharge after allowing for natural discharge in the monsoon season in terms of base flow and subsurface inflow/outflow. This annual ground water potential includes the existing ground water withdrawal, natural discharge due to base flow and subsurface inflow/ outflow in the monsoon season and availability for future development. As the ground water development progresses the natural discharge gets suitably modified and comes down to negligible quantities due to interception by different ground water structures. Hence, natural discharges in the monsoon season may not be considered and the total annual ground water recharge may be taken as net groundwater availability.

The net ground water availability of the basin for the year 2017 is arrived at 10,1740.08 Ham, covering 31 firkas of Pudukottai district resources are 63494.17 ham, 20 firkas of Thanjavur district 30617.20 ham, 3 firkas of iruchirapalli district 5317.57ham and 1 firka of Sivaganga district 2311.14 ham **(Table 10)**

Table 10:. Firka-wsie groundwater resources of Agniar aquifer system.

District Name	Firka Name	Net GW available	Total Draft	Stage of Development	Category
Pudukkottai	Alangudi(P)	2670.63	2026.80	75.89	Semi-Critical
Pudukkottai	Keeramangalam	2043.06	1740.00	85.17	Semi-Critical
Pudukkottai	Gandarvakottai	2190.65	560.42	25.58	Safe
Pudukkottai	Pudunagar	2793.13	1851.57	66.29	Safe
Pudukkottai	Kallakkottai	2219.94	1290.77	58.14	Safe
Pudukkottai	Karambakudi	2576.55	1071.13	41.57	Safe
Pudukkottai	Kunnandarkoil	2957.17	778.70	26.33	Safe
Pudukkottai	Vallanadu	2010.85	1253.12	62.32	Safe
Pudukkottai	Vennavalkudi	2368.13	1212.10	51.18	Safe
Pudukkottai	Arasarkulam	1726.83	1367.75	79.21	Semi-Critical
Pudukkottai	Poovathakudi	2839.85	677.04	23.84	Safe

Pudukkottai	Silattur	2637.76	435.36	16.50	Safe
Pudukkottai	Avudaiyarkoil	3470.13	55.54	1.60	Safe
Pudukkottai	Kudumiyanmalai	1978.53	951.76	48.10	Safe
Pudukkottai	Narthamalai	1100.00	746.49	67.86	Safe
Pudukkottai	Pudukkottai	1589.27	678.96	42.72	Safe
Pudukkottai	Kottaipattinam	0.00	0.00	0.00	Saline
Pudukkottai	Manamelkudi	3107.49	249.53	8.03	Safe
Pudukkottai	Sinkavanam	0.00	0.00	0.00	Saline
Pudukkottai	Sengeerai	2873.79	946.37	32.93	Safe
Pudukkottai	Kottur(P)	1112.68	337.72	30.35	Safe
Pudukkottai	Virachilai	1444.14	50.43	3.49	Safe
Pudukkottai	Karaiyur	1675.14	1189.91	71.03	Semi-Critical
Pudukkottai	Keeranur	2049.94	1044.72	50.96	Safe
Pudukkottai	Arasamalai	1680.80	938.88	55.86	Safe
Pudukkottai	Malaiyur(P)	5765.18	3505.15	60.80	Safe
Pudukkottai	Athani	1078.84	426.42	39.53	Safe
Pudukkottai	Nagudi	1659.27	256.38	15.45	Safe
Pudukkottai	Sithanavasal	1567.74	509.52	32.50	Safe
Pudukkottai	Aranthangi	2306.68	349.13	15.14	Safe
Pudukkottai	Perumaruthur	0.00	0.00	0.00	Saline
Sivaganga	Varappur	2311.14	1983.40	85.82	Semi-Critical
Thanjavur	Perumagalur	954.73	443.29	46.43	Safe
Thanjavur	Avanam	1139.88	1627.37	142.77	Over Exploited
Thanjavur	Kuruvikarambai	1442.31	2172.29	150.61	Over Exploited
Thanjavur	Adirampattinam	856.05	759.88	88.77	Semi-Critical
Thanjavur	Thondarampattu	2104.38	2761.68	131.23	Over Exploited
Thanjavur	Madukkur	1130.93	508.96	45.00	Safe
Thanjavur	Orathanad	2663.72	1713.95	64.34	Safe
Thanjavur	Eachankottai	2040.46	941.82	46.16	Safe
Thanjavur	Sillathur	1715.60	1462.79	85.26	Semi-Critical
Thanjavur	Thuvarankurichi	1333.31	1413.47	106.01	Over Exploited
Thanjavur	Kurichi(T)	1191.71	983.70	82.55	Semi-Critical
Thanjavur	Kavalipatti	1623.93	1361.89	83.86	Semi-Critical
Thanjavur	Thekkur	2743.30	1338.34	48.79	Safe
Thanjavur	Andikkadu	1263.26	1096.39	86.79	Semi-Critical
Thanjavur	Tiruchitrambalam	1561.86	1825.59	116.89	Over Exploited

Thanjavur	Peravurani	1238.50	790.96	63.86	Safe
Thanjavur	Nambivayal	1248.03	1015.18	81.34	Semi-Critical
Thanjavur	Thambikkottai	811.52	579.08	71.36	Semi-Critical
Thanjavur	Pattukkottai	1736.90	1618.85	93.20	Critical
Thanjavur	Nanjikottai	1816.82	2947.18	162.22	Over Exploited
Tiruchirappalli	Valanadu	1958.51	1264.09	64.54	Safe
Tiruchirappalli	Marungapuri	1489.63	1755.73	117.86	Over Exploited
Tiruchirappalli	Thuvarangurichi	1869.43	1913.39	102.35	Over Exploited

4.2. Ground Water Draft

The gross ground water draft has been assessed by using Unit draft method for irrigation draft component and by adopting formula suggested by GEC 1997 for domestic and industrial draft components.

The existing total groundwater draft of the aquifer system is 60780.92 ham. The groundwater draft maximum in Thanjavur District (29346.07 ham) followed by Pudukottai district (26501.65 ham), Tirichirapplai District (4933.20 ham) and Sivaganga District (1983.40 ham) respectively.

4.3. Stage of Development and Categorization:

The stage of development is defined by stage of ground water development (%)

= (Existing ground water draft/ Net Ground water availability) x 100

The stage of ground water development is calculated for all the 109 firkas of the basin. The Categorization has been done by considering the two factors as suggested by GEC 97, viz.,

i) Stage of Development

ii) Long term trend of pre and post monsoon water levels.

The following FOUR categories have been suggested by GEC-97 based on the above two factors.

a) Safe b) Semi-critical c) Critical d) Over-exploited

Based on the above categorization 55 out of the 9 firkas of the agniar aquifer system falls under over exploited and critical category, covering 7 firkas in Thanjavur district and 2 district in Tirichirapalli district. 12 Firkas falling in semi-critical and 31 firkas fall in safe category. There

3 Firkas namely, Kottaipattinam, Sinkavanam and Perumaruthur of Pudukottai district fall in saline category, The total state of development of Lower Cauvery aquifer system is 61%.

5.0. GROUND WATER RELATED ISSUES

Ground water is extensively utilized for irrigation in the entire basin area for the past two decades, especially in the 8 over-exploited firkas and I Critical firka of Thanavur and Tirichirappalli district. There is no anthropogenic contamination in the basin as there is much urbanization.

5.1 Insitu salinity, Seawater intrusion - Threat along the coast

High values of electrical conductivity and Chloride values are observed in coastal tract of Kottaipattinam, Sinkavanam and Perumaruthur of Pudukottai district. High values of electrical conductivity and Chloride values are seen in 5-10 km from the coast in Kottaipattinam area. Tertiary and coastal alluvial aquifers are affected in the aquifer system. Following measures can be taken up in the coastal region.

- Stopping of heavy pumping of GW in the seawater intruded area.
- Construction of percolation tanks in the affected area to make fresh water ridge.
- Coconut and saline resistance crops are grown in areas having TDS 1500– 2500 mg/l)
- Mounds on the upstream side of ponds shows groundwater with low EC even in pre monsoon period there are positive indications of recharge. More ponds can be constructed parallel to the coast and this can create huge mounds of freshwater.

5.2. Poor yielding aquifers:

Hard and compact formations comprising Charnockites and gneissic rocks are occurring in Sendurai, Thuvarankuruchi, Mangarai and Vallanadu firkas. Very low yielding aquifers with discharge of less than 1 lps are observed in the above mentioned firkas. The specific yield values are in the range of 0.01 to 0.1 and the transmissivity values are in the range of 0.1 to 2 m^2/day.

5.3. Nitrate contamination in groundwater:

High concentration above 45 mg/l of Nitrate observed in patches of Aratnagi, (Pudukottai District (229 mg/l), Keeranur, Sivaganga District(100 mg/l), Thuvarankuruchi, Tirichirapalli District (80 mg/l) and Pudukottai, Pudukottai District (70 mg/l) are observed. The high

concentration of nitrate in groundwater is due to applied irrigation in Aranthandi and Keeranur areas and untreated sewerage in Pudukottai town.

Future Demand Scenario and Stress on Aquifer system:

Future demand projected for domestic utilization by 2025 would be 3000 ham which would be 10% increase in comparison to the present gross draft. Already the dependency on ground water for domestic and drinking needs is increasing and the stage of groundwater development would also increase. There are sufficient groundwater resources available to meet the future demands for domestic, industrial and other sectors.

6.0. 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 Agniar 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.

Sustainable Management Plan

The groundwater resource is over-exploited in 8 firkas of the basin comprising an area of 900.40 Sq.km. out of the 4973.1 sq.km area of the basin. Irrigation draft of 195.89 MCM is estimated as per the GEC 2017 against the Net availability of the resource of 142.78 MCM. A total of 53 MCM in excess was drawn from the ground water system of the 8 OE firkas. 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.

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 western parts of the aquifer system are facing over-exploitation of groundwater resources. 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 2.03 MCM.

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 potential volume of void space available within the weathered zone of first aquifer of the basin has been estimated as 14.50 MCM. But the annual uncommitted runoff is only 14.20 MCM which is almost equal to the required water to fill the available void space of aquifer-I. Artificial recharge and Water conservation plan is prepared for the over exploited firkas of the basin area through harnessing just less than 70% of the annual uncommitted runoff of 11.367 MCM only with a total out lay of 3.877 Crore rupees.

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 7 check dams, 21 nala bunds and 5 recharge shafts are proposed in the OE and critical firkas of the basin. A total number of 361 Recharge Rejuvenation ponds are selected for de silting followed by construction of recharge shafts within the tanks. The expected recharge through these artificial recharge structures is in the order of 2.03 MCM.

The expected benefit by the recharge structures in the 8 OE & 1 critical firka area will be creation of additional crop area of Paddy of 7438 ha or Sugarcane of 5950 ha (or) Banana of 11900 ha (or) Irrigated Dry crops of 23800 ha.

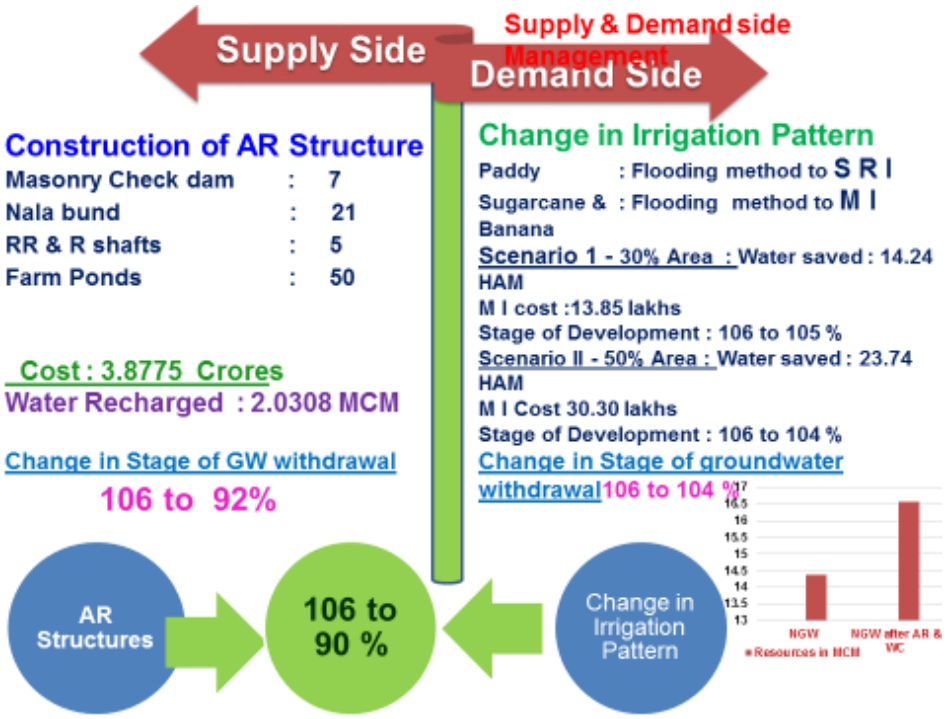
Water Conservation Plan

Low pressure water distribution system is being proposed in 1780 Ha of cropped area which otherwise is under irrigation through earth channels. The expected savings of water through this method is expected to be 0.023 MCM./ yr. A total number of 50 Farm 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 0.25 MCM.

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 101 Ha. and this would save 0.185 mcm of water annually. Similarly for sugarcane and banana crops shift from flooding to drip irrigation would save 0.052 mcm. The total water saved is 0.273 mcm.



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.

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