केन्द्रीय भूमि जल बोर्ड

जल संसाधन, नदी विकास और गंगा संरक्षण
विभाग, जल शक्ति मंत्रालय

भारत सरकार

Central Ground Water Board

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

AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES

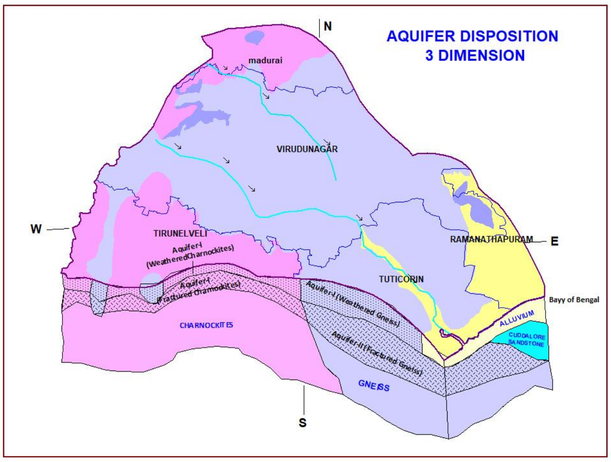
for Viappar Aquifer System
Tamil Nadu

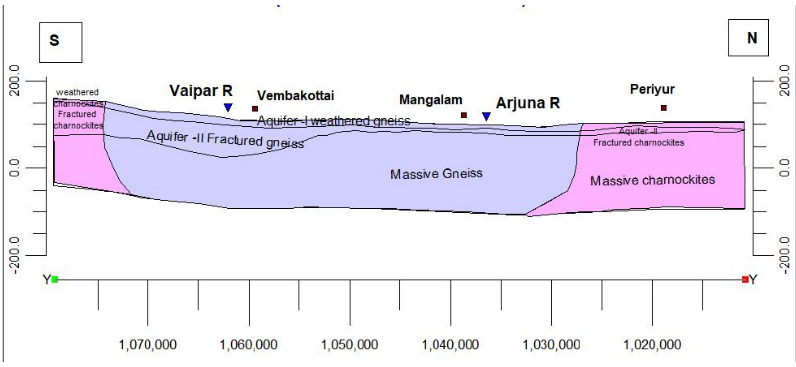
दक्षिण पूर्वी तटीय क्षेत्र, चेन्नई

South Eastern Coastal Region, Chennai

सरकारी उपयोग के लिए

REPORT ON AQUIFER MAPPING AND AQUIFER MANAGEMENT PLAN FOR VAIPPAR AQUIFER SYSTEM, TAMIL NADU





जल शक्ति मंत्रालय

जल संसाधन विभाग

नदी विकास और गंगा संरक्षण

केंद्रीय भूजल बोर्ड

दक्षिण पूर्वी तटीय क्षेत्र

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

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 resulted in 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 ground water extraction more than 100% of recharge (over exploited) and more 70% and less than 90% of recharge (Critical).

Central Ground Water Board (CGWB) has taken up the largest Aquifer mapping endeavour in the world, targeting total mapable area of country ~ 23.25 lakh sq. km to an explored depth of 300 m in soft rock area and 200 m in hard rock area. The extent of the aquifers, their potential, resource availability, chemical quality, its sustainable management options will be addressed through National Aquifer Mapping (NAQUIM). The NAQUIM programme will also facilitate participatory management of ground water to provide long term sustenance for the benefits 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 entrusted 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 Vaippar River basin covering an area of 6323sq .km including a hilly area of 602 sq.km with the total mappable area at 5829sq.km. The basin comprises of five districts, parts of Madurai, Ramanathapuram, Thirunelvelli, Thoothukudi and Virudhunagar districts with 59 firkas (19 Over Exploited & Critical), and is mainly dependent on groundwater for its agricultural needs. The major issues in the basin include declining groundwater levels and sustainability of wells. Two aquifer units were deciphered with aquifer Unit - I being the weathered zone, that occurs from ground level to 20m bgl and Aquifer Unit –II the fractured/Jointed zone existing from 10 to 200 m bgl (3-4 fractures are encountered) in the hard rock formation. In sedimentary formation, Aquifer unit I to II have been demarcated. These aquifers are highly potential. In order to arrest the declining groundwater levels and to increase the sustainability of wells groundwater management plans with 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 the resources effectively in the Vaippar aquifer system.

(Dr A Asokan)

Regonal Director

EXECUTIVE SUMMARY

Aquifer mapping studies were carried out in the Vaippar aquifer system covering a mappable area of 6323sq. km. covering parts of Madurai, Ramanathapuram, Thirunelvelli, Thoothukudi and Virudhunagar 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.

The area experiences semi-arid climate with 600-1000 mm annual normal rainfall (100 years). The rainfall decreases from the Hill to coastal areas. About 74% 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 the main aquifer units, weathered zone at the top followed by a discrete anisotropic fractured/fissured zone at the bottom in hard rock formation. In sedimentary formation, aquifers I to II have been demarcated. 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. In sedimentary formation, aquifer-I is under unconfined conditions and other aquifers are under confined conditions. Total number of firka in the basin is 59. The net annual ground water availability is 67211ham and the gross ground water draft is 50134ham and the average stage of groundwater development is of 74%. The major issues in the basin include declining groundwater levels, sustainability of wells, poor yield of quifer. The groundwater stress are occurring in the 19 firkas of the basin with groundwater development at 118%.

Aquifer systems from the area can be conceptualized as weathered zone down to ~20m 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 0.18-18m^3/hr and can sustain pumping for 1 to 2 hrs during summer period (April to June). The fractured zone is occurring in Gneiss or Charnockite which occur in limited extent, associated sometime with quartz vein. The average yield ranges from 0.18 - 18m^3/hr and can sustain for 3 to 4 hrs of pumping during summer period. In sedimentary formation, two aquifers of sedimentary formation are highly potential and the aquifers extend to a depth of 175mts.

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 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 163 Check dams, 655 ponds for rejuvenation with recharge shafts and 1429 recharge ponds in all the 19 OE & Critical firkas of the basin were recommended. The estimated recharge to groundwater system through these structures will be in the order of 85MCM. 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 48 mcm of water annually. By carrying out both supply and demand side interventions the stage of groundwater development would be lowered from 118 to 72%.

The existing regulatory measures may be modified suitably for optimal utilization of groundwater as well as for sustainable development of rural agriculturally 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 Vaippar River basin aquifer system.

Roof top rainwater harvesting is recommended for supplementing the present water supply for Virudhunagar city. Proper implentation of the roof top rainwater harvesting can reduce the burden of Municipality by 50%. Use and Return scheme should be implemented in the city. This scheme is formed to return the water what you used.

CONTRIBUTORS' PAGE

Hydrogeology & Groundwater exploration

: *Dr K Raja Rajan*
Scientist-B

Aquifer Disposition

: *Dr K Raja Rajan*
Scientist-B
Sh.Raj Kumar Mohanty
Scientist B

Groundwater Management Plan

: *Dr K Raja Rajan*
Scientist-B

Geophysical Survey

: *Dr.V. Arul Prakasam*
Scientist D

Chemical Analysis

: *Smt. Bindu. K. Viju*
Scientist B

: *Sri. K. Venkatesh*
STA(Chemist)

Map preparation

: *Smt M. Navaneetham*
Draughtsman

Overall Supervision and Guidance

: *C Paul Prabhakar*
Regional Director

Principal Author

Dr. K. Raja Rajan
Scientist-B

CONTENTS

LIST OF FIGURES

LIST OF TABLES

AQUIFER MAPPING AND AQUIFER MANAGEMENT PLAN, VAIPPAR RIVER AQUIFER SYSTEM, TAMIL NADU

1.0 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) which involves 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 agricultural practices and inorganised urban agglomeration, erratic rainfall has been detrimental to the groundwater scenario pushing the resources to stress conditions. The groundwater in stressed aquifer calls for planned and proper management with respect to 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 occur 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 the augur translating to sustainable groundwater management plan. The proposed management plans will provide the “Road Map” for ensuring sustainable and equitable distribution of ground water resources, thereby primarily enhancing drinking water security and irrigation coverage. The aquifer mapping and management plan will be shared with the groundwater user agency and stake holder. The user agencies are primarily the State Government and the Agriculturists. The application of aquifer mapping is purposeful 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,
- deciphering aquifer characteristics and their yield potential
- analysing water quality occurring at various depths,
- assessing ground water resources aquifer wise
- preparating aquifer maps and
- Formulating Firka wise ground water management plan.

This clear demarcation of aquifers and their potential will help the agencies involved in water supply in ascertaining the 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 an explored depth of 200 / 300 meters.

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

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

Compilation of existing data
(Central & State Govt.)

↓

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 Vaippar River basin aquifer system to prepare aquifer map and its management plan. The Vaippar River basin is located in the southern part of Tamil Nadu, bounded by Tamirabarani River basin aquifer system in the south, Vaigai River basin aquifer system and Kerala state on west and Vaigai and Gundar towards north. It is bounded by Bay of Bengal on east. The total geographical area of the study area is 6323sq.km in which hilly area is covered by 286 sq km. The mappable area in the study area is 5829sq.km. The study area comprises of 5 districts and 59 Firkas (the local revenue sub-divisions). The study area is shown in location map **Figure 1.1.** and the details of the study area is shown in **Table 1.1.**

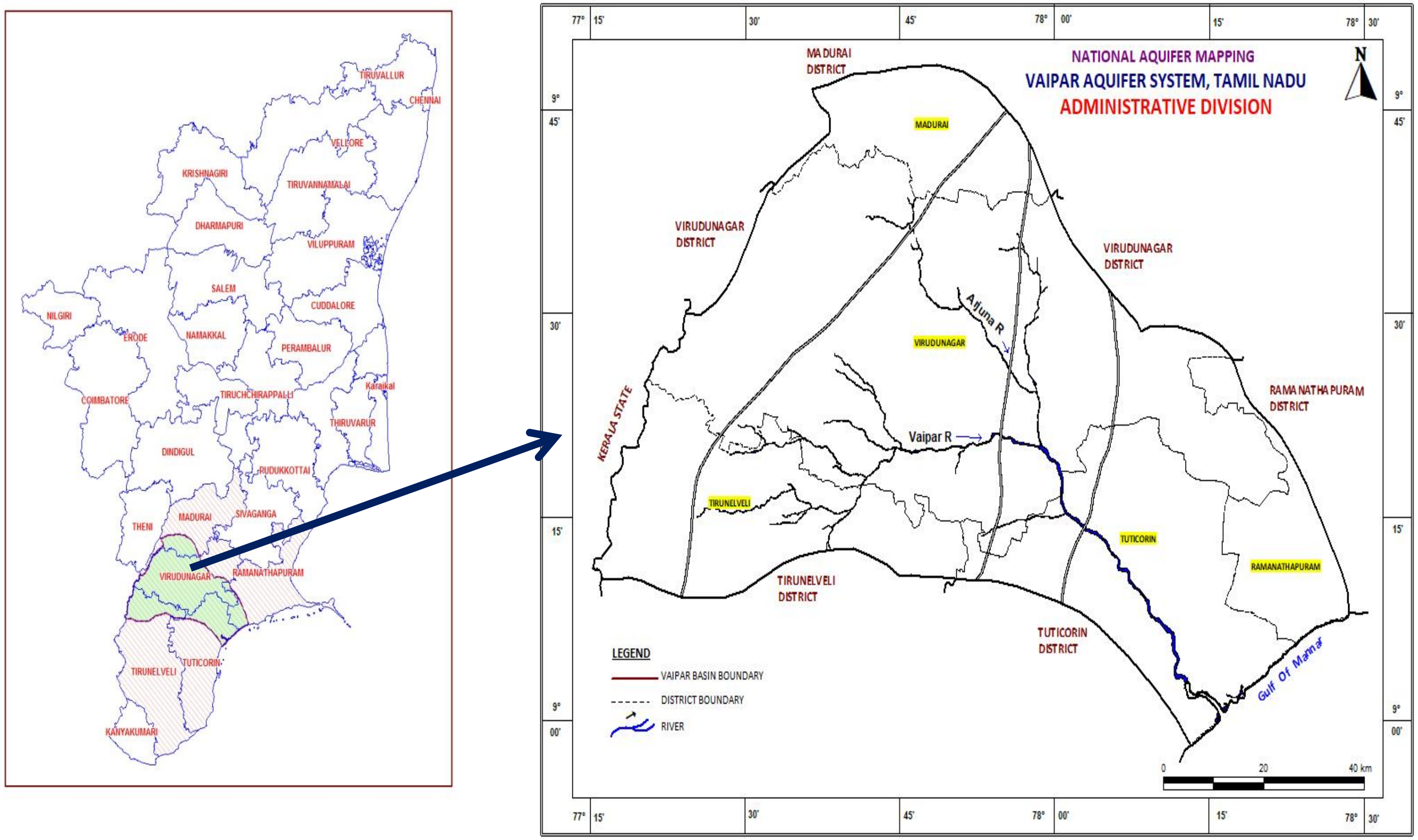


Figure.1.1: Location Map of the area

Table 1.1: The details of the study area (Based on GIS)

Sl. No	District	Area	No. of Firka
1	MADURAI	521	4
2	RAMANATHAPURAM	411	5
3	THOOTHUKKUDI	1135	10
4	TIRUNELVELI	1007	8
5	VIRUDHUNAGAR	3249	32

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 (TWAD), State Surface and Ground Water Resources Data Centre of Public Works Department, Government of Tamil Nadu were compiled and analysed as per the nomenclature for finding out adequacy of the data in the river basins aquifer system. 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	41	124	-
2	Geophysical survey	216	97	119
3	Groundwater Monitoring well	41	171	-
4	Groundwater Quality Monitoring well	41	171	-

1.5 Rainfall

The basin receives rainfall from both monsoons, south west (June-September) and north-east monsoon (October-December). The normal annual rainfall over the district varies from about 800 mm to about 1000 mm. Based on the statistical analysis, it is observed that, upper part of the basin experienced a decrease in rainfall, while there was no significant change in rainfall in the lower part of the basin. It is also observed that eastern parts of the basin experienced rainfall in a range of 600–700 mm, while in the west the range was more than 800 mm, and in the central part the range was from 700 to 800 mm. A general increase in rainfall from coastal region to hilly region of the basin could be envisaged (approximately 600 mm at the coast, to approximately 1,000 mm at the hill). It is reported that the frequency of occurrence of drought ranges from 4 to 8 years per drought over the area.

1.6 Physiography

Based on the SRTM DEM(Downloaded) contours, the study area is divided into three zones ranging from < 50m, 50 to150m and >150mts. 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 Tirunelvelli, Part of Virudhunagar and Madurai districts. The plain terrain is found in the eastern parts of the study area, falling in Virudhunagar, Ramanathapuram and Thoothukudi districts. The general slope of the study area is towards SE direction. The lower elevation is found all along the River valley of Vaipar and eastern parts of the area **(Figure-1.2).** In western part of the study area, the elevation is formed by Varushanadu hill ranges of the Western Ghat with maximum elevation of 900 mamsl.

1.7 Hydrology and Drainage

The Vaippar river rises on the Eastern slopes of the Varushanadu hill ranges of the Western Ghats near Sivagiri in Thirunelveli district in Tamil Nadu at an elevation of about 900 m. It flows generally in an Easterly direction for a length of about 125 km through Thirunelveli, Virudhunagar and Tuticorin districts in Tamil Nadu and joins the gulf of Mannar near Kalattur. The Arjunanadhi and Vijayanadhi are the important tributaries. Both the tributaries are left tributaries **(Figure-1.3).**

The Arjuna river joins with Vaippar river at Irrukkankudi. The Vaippar river has a reservoir at Vembakottai dam. The Vaippar River is used for agriculture throughout its length and is mainly used for making salt in the Tuticorin district.

The Vaippar has many dams including Vembakottai dam, Irrukkankudi dam etc., The Vaippar river flows through the following cities - Vembakottai (Virudhunagar district), Sattur (Virudhunagar district) , Villathikulam (Tuticorin district).

1.8 Agriculture, Irrigation and Cropping Pattern

In the study area, the agriculture, forest, wastelands and waterbodies are main landuse and land cover prevailing. The agriculture land is covering about 74 % of the total geographical area and forest covers 10 % of the area. The wasteland is occupied by 8% of the total geographical area. Settlement and water bodies are covering less than 8% of the total geographical area of the basin.

The total cultivable land is covering 2506 sq.km of the total mappable area and represented by 43% of the total agriculture area of the basin. The cultivable land is used for growing water intensive crops such as paddy, sugar cane and banana. Cotton, non-paddy and dry crops are also being grown in the basin which covers about 398 sq.km area. The water intensive crops are covering 244 sqkm area. The total irrigated area of the basin is 614 sqkm area which represents 24% of the cultivable land. The remaining 76% of the cultivable land mainly depends on rainwater.

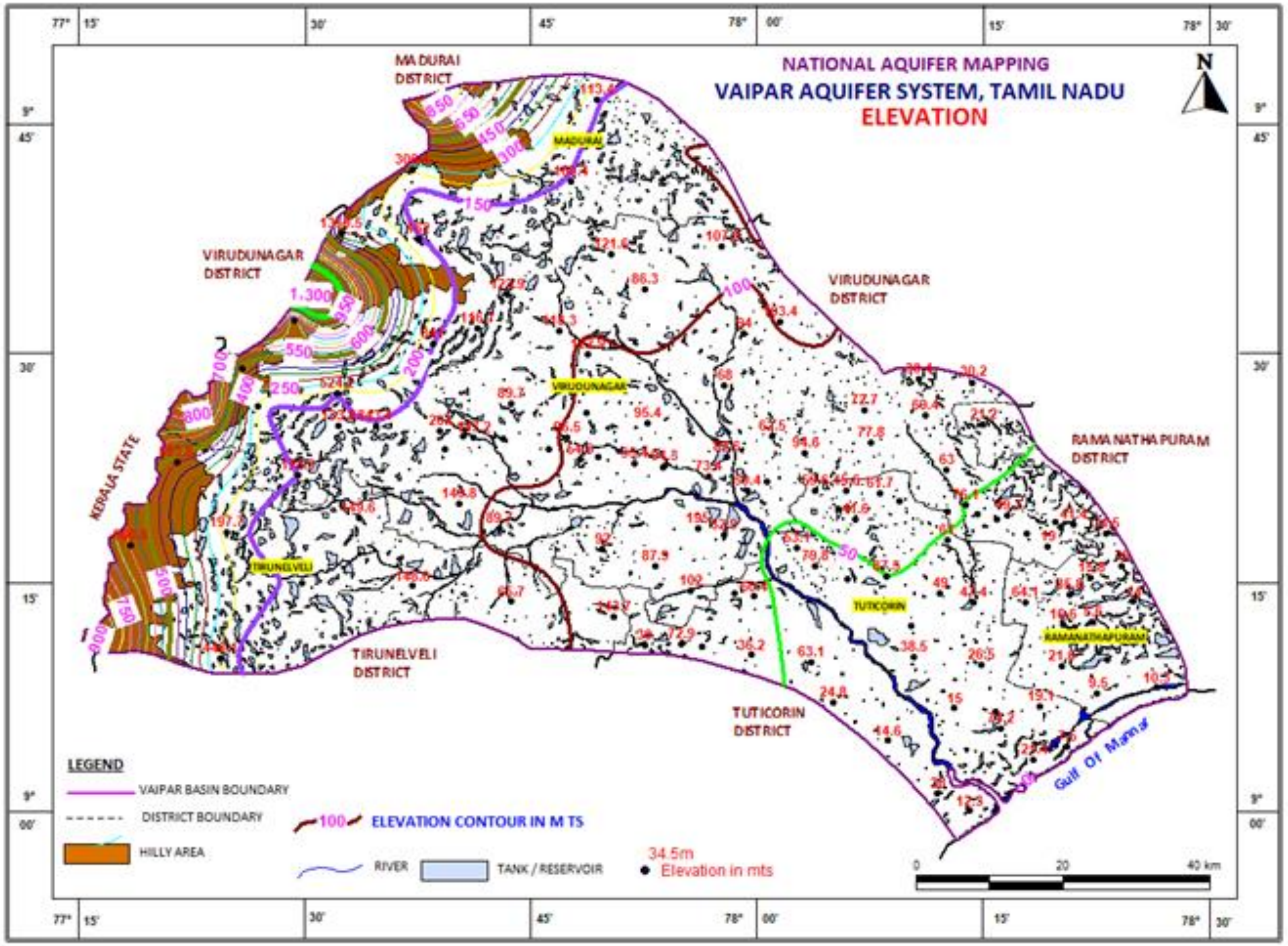


Figure 1.2: Elevation Map of the area

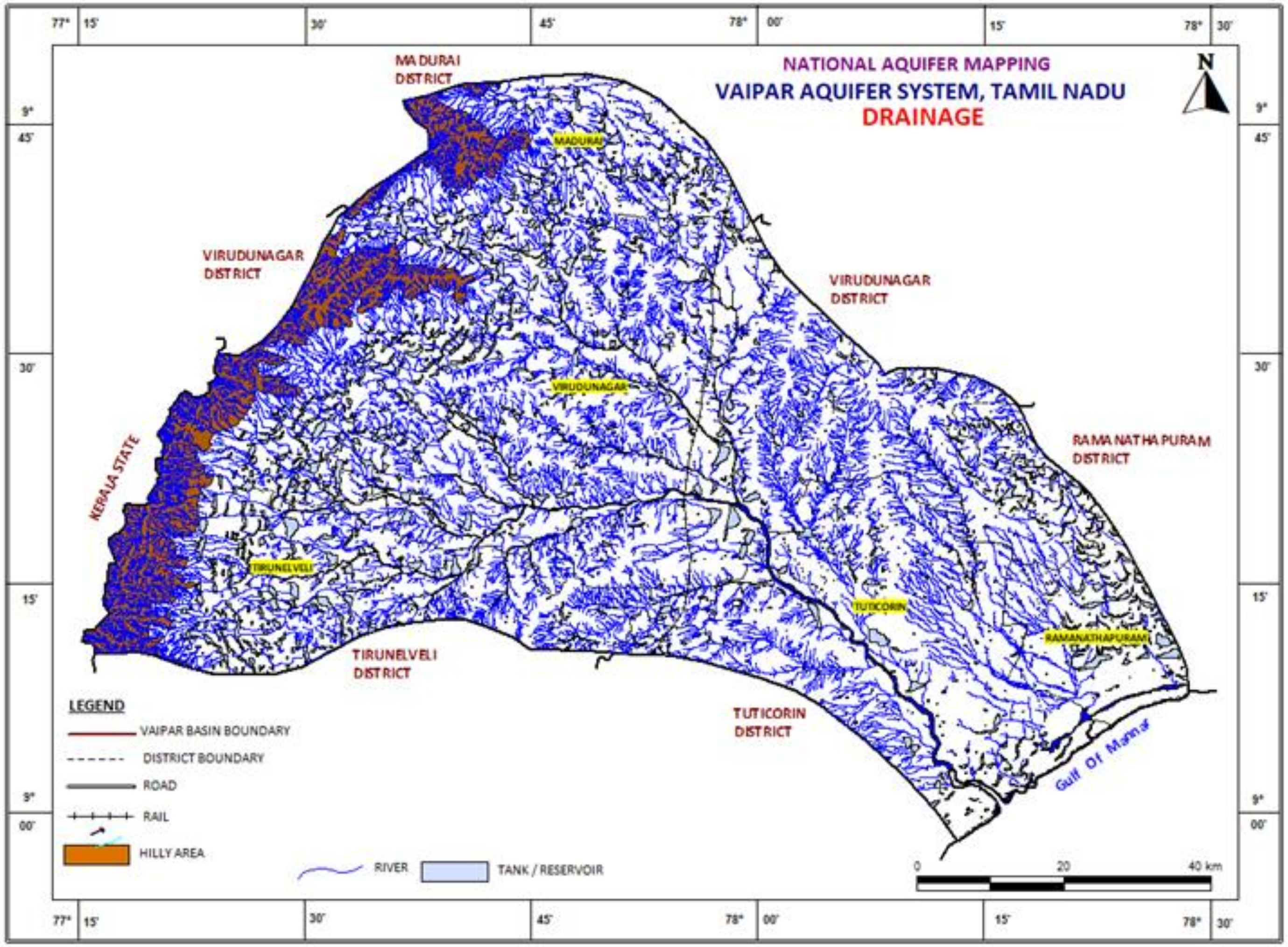


Figure1.3: Drainage Map of the area

2.0 DATA COLLECTION AND GENERATION

Hydrogeological data like quantity 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 data collected from allied departments 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 through drilling of borewell upto a depth of 200m is being carried out by CGWB, SECR to decipher the aquifer depth and its characteristics. The state departments such as TWAD and PWD are drilling the borewell for hydrogeological data and for drinking water purposes. The hydrogeological data generated from drilling were collected and synthesised for demarcating the aquifer system of the basin. As per the data collection in the study area, 57 exploratory wells drilled for NAQUIM were collected for aquifer mapping. These wells were plotted and analysed as per the norms of data gap for demarcating aquifers in the area. 67 wells were drilled in the area by state government that are also included for deciphering the aquifer system. The details of the exploratory wells are presented in **Annexure-I** and the location of the exploratory wells are shown in **Figure-2.1**

2.2 Geophysical Survey

Geophysical survey mainly of Vertical Electrical Sounding (VES) is being carried out to know the sub-surface geology of the area. In CGWB, SECR the VES was conducted for 200mts depth of investigation using Schlemberger Electrode array. In the study area, as part of the data collection, 97VES data were collected and studied the sub-surface geology. The information on sub-surface geology was 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 **Figure 2.2**

2.3 Groundwater Level Monitoring Well

Groundwater monitoring wells as observation wells were established to monitor the groundwater level four times in a year for shallow aquifer (water table aquifer) and fractured aquifers separately which will give clear picture about the groundwater recharge in aquifer system by CGWB, SECR Chennai. Dug wells which represent water table aquifer are being monitored for water level in the area. The fractured aquifer for water level is also being monitored using the bore well called piezometers. The data were incorporated for analysing the recharge to groundwater in the study area. In the study area, 25 dug wells were monitored for water table aquifer and 17 piezometers were monitored for fractured aquifers. The groundwater monitoring well locations are shown in **Figure 2.3.**

2.4 Groundwater Quality Monitoring Well

Groundwater quality monitoring wells were established by CGWB, SECR, Chennai to monitor the groundwater quality of shallow aquifer once in a year. SSGWRDC of PWD and TWAD Board are also monitoring the groundwater quality of water table aquifer mainly of dug well in each district. All the groundwater quality data are incorporated for analysing the groundwater quality issues. In the study area, 193 wells were monitored for groundwater quality. The location of groundwater quality monitoring wells is shown in **Figure 2.4**.

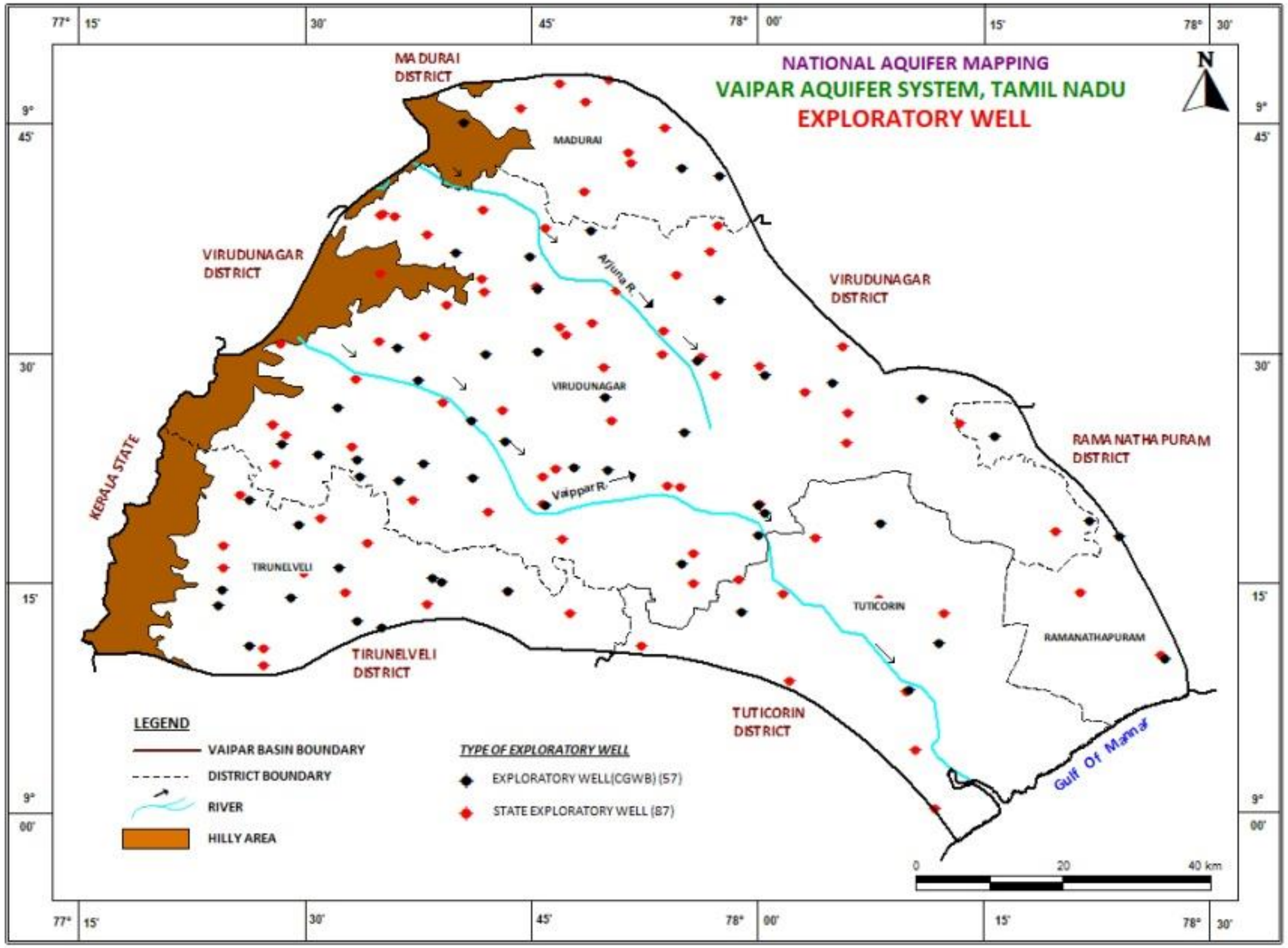


Figure 2.1: Exploratory well location map

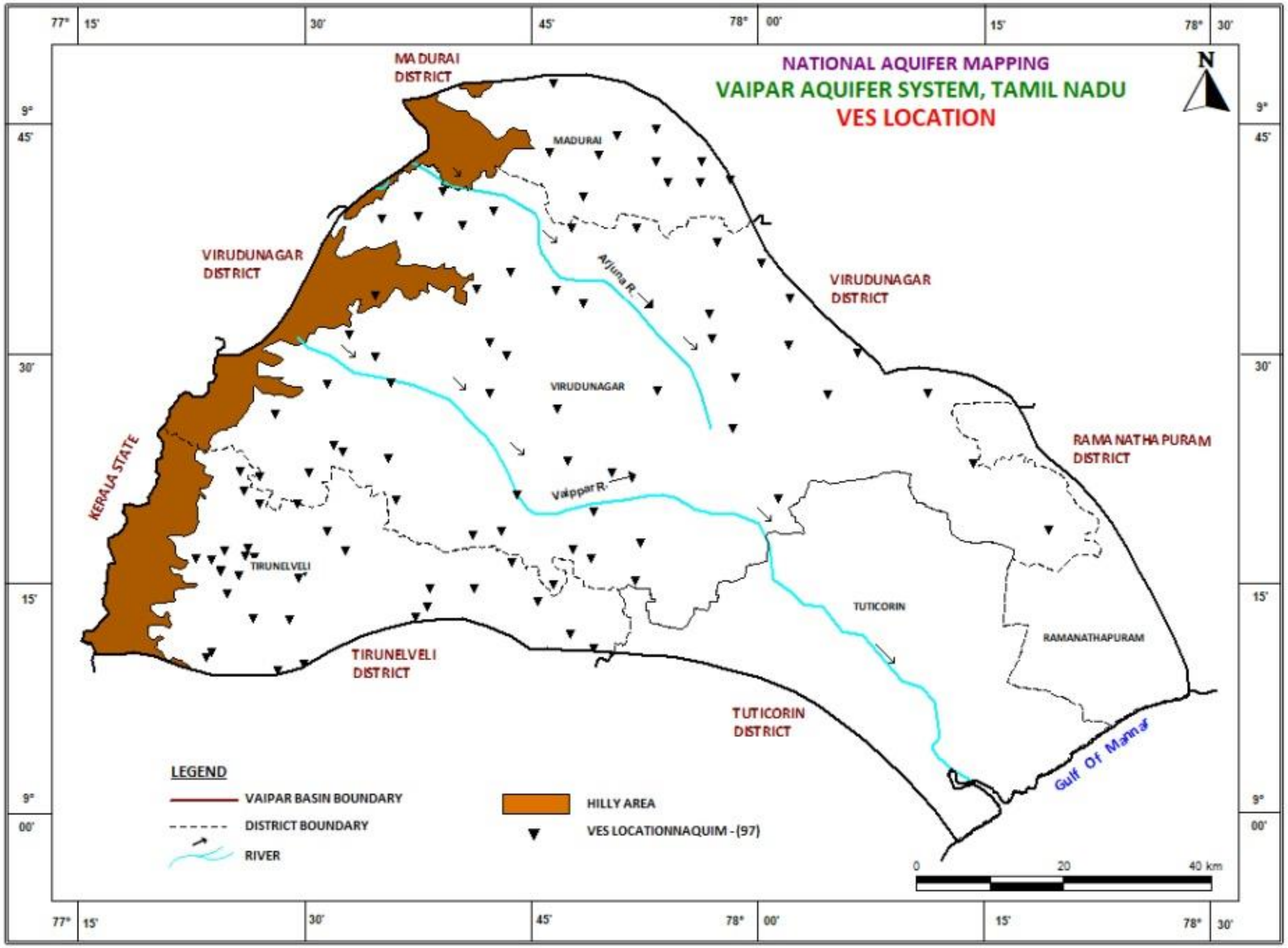


Figure 2.2: VES location map

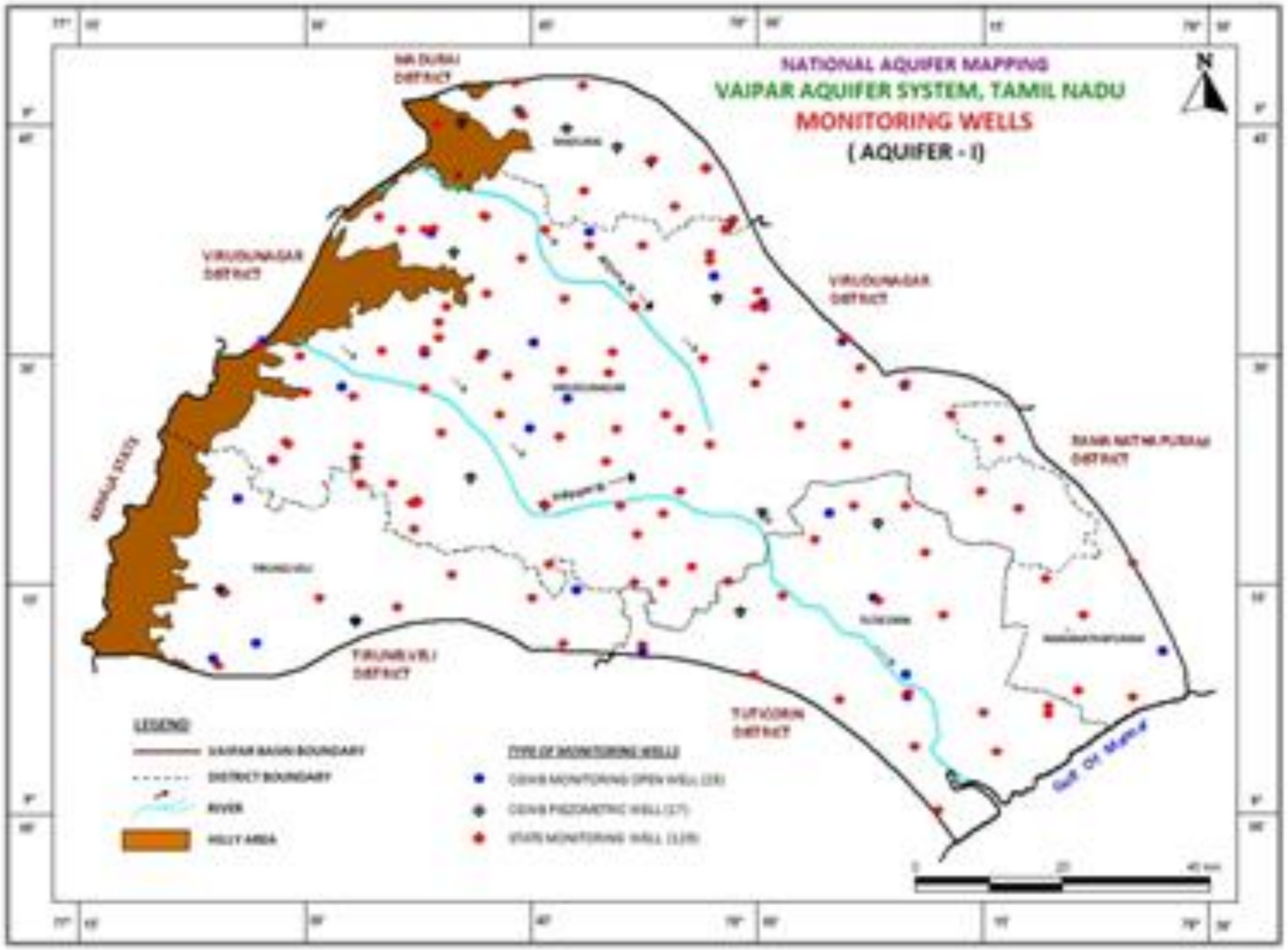


Figure 2.3: Groundwater Level Monitoring well location map

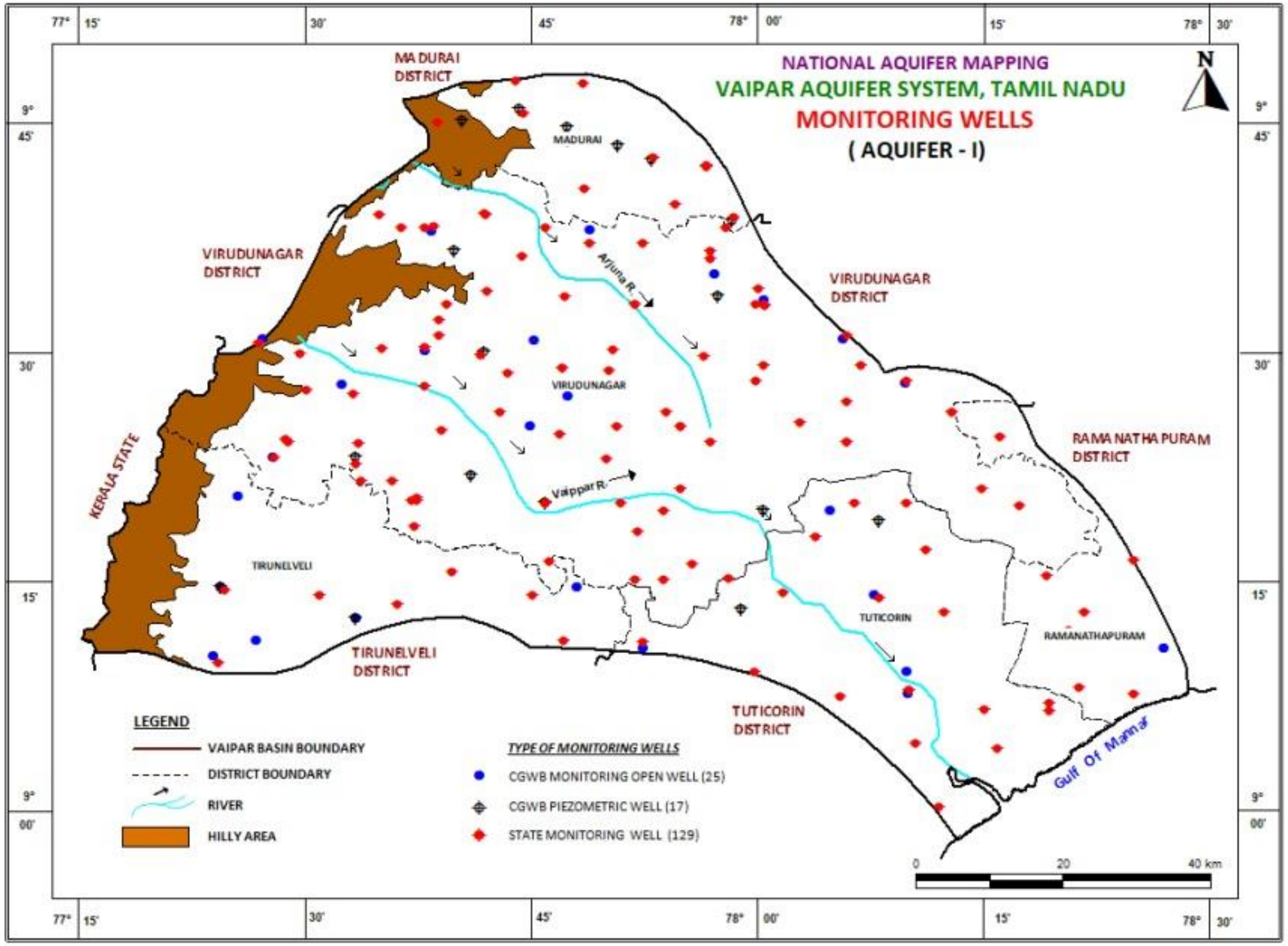


Figure 2.4: Groundwater Quality Monitoring well location map

2.5 Data Generation

Based on the data collected, 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 map and management plan. However, about 57 bore wells were drilled and generated data which was used for aquifer mapping in the area. The groundwater management plan, includes supply side and demand side intervention, 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 prepare management plan.

2.5.1 Geology

Geologically the area is underlain by the hard-crystalline formation of Archaean age, sedimentary formation of Upper Cretaceous and Cenozoic rock formation. The stratigraphic succession of the area is given below.

Sl No	AGE	FORMATION
1	CENOZOIC	Alluvium, Cuddalore Sandstone
3	PROTEROZOIC TO ARCHAEAN	Migmatites Complex (Gneiss) Charnockite Group

Gneiss and Charnockites and acidic rocks/granite are major rock types occupied predominantly in the area **(Figure 2.5).** The charnockites are emplaced in the gneissic formation. The charnockite is exposed in the western, southern and northern parts of the study area trending NE-SW direction and the remaining area is occupied by the gneissic rock formation. Acidic rocks are occupied in small area of the basin and not having any significance in aquifer system. Aquifer systems of the area are mainly formed by the gneiss and charnockites of the crystalline formation.

Cuddalore sandstone and Younger Alluvium are conformably overlain on gneiss formation of Archaean age and are occurring in the eastern parts of the area. The younger alluvium of fluvial origin and marine deposits are found all along the river course and along the beach respectively. The alluvium mainly consists of sand, silt and clay.

2.5.2 Geomorphology

The different landforms discernable on the imagery have been broadly classified into Hills and plateau, Pediment zone and plain **(Figure 2.6).**

Hills and plateau: Hills and plateau are formed in highly elevated hills prone for dissection and denudation. It is characterised by either no soil cover or very thin soil development. The landforms are un-dissected / less dissected, deflection slope, moderately dissected, highly dissected, denudational / residual hill and piedmont zone and are generally forming as runoff zone.

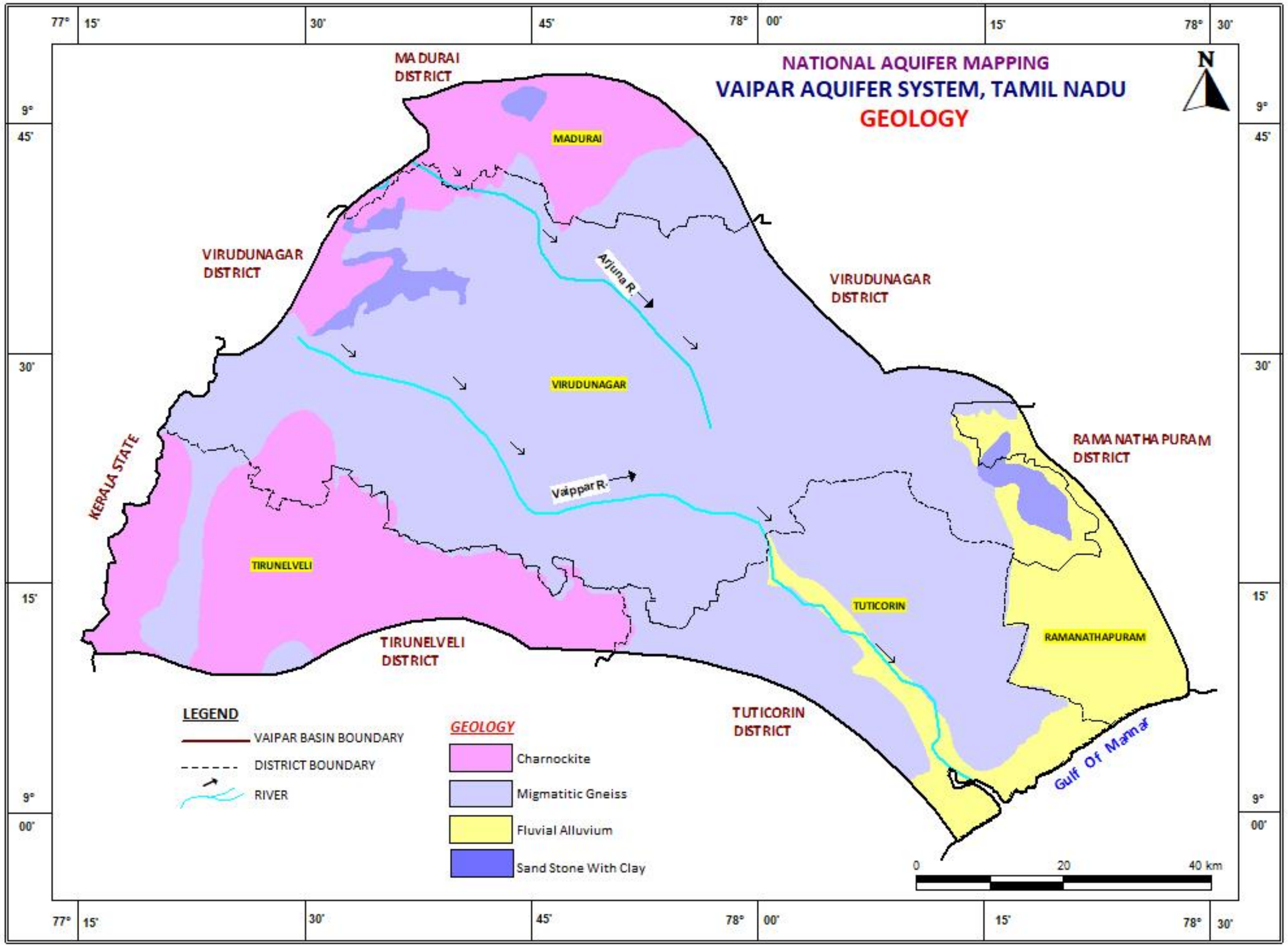


Figure 2.5: Geology map

Pediment zone: Pediment is gently undulating rock surface and wears a thin mantle 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.

In plain area, the pediment is buried by disintegration of county rock and forms buried pediment shallow, buried pediment moderate and buried pediment deep. It is classified on basis of the thickness of the soil development above pediment zone. The shallow buried pediment is having thickness of soil ranging from 1-5mts and the moderate buried pediment thickness is ranging from 5-10mts. The deep buried pediment thickness is more than 10mts

Plain has been developed mainly in the eastern part of the area due to deposition of unconsolidated materials by fluvial agencies and marine origin. The materials are silt, fine sand and at places pebbly. The landforms are generally alluvial Plain, sediment high land, beach and coastal plain and flood plain. Pediment is having thickness of soil ranging from 1-5mts and the moderate buried pediment thickness is ranging from 5-10mts. The deep buried pediment thickness is more than 10mts

Plain has been developed mainly in the eastern part of the area due to deposition of unconsolidated materials by fluvial agencies and marine origin. The materials are silt, fine sand and at places pebbly. The landforms are generally alluvial Plain, sediment high land, beach and coastal plain and flood plain.

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 **(Figure-2.7)**. The agriculture land which includes dry crops, wet crops and palnataion is the predominant landuse of the area. The forest area is occurring in the western part of the area.

2.5.4 Soil

Alfisol, Vertisol, Entisol, Inceptisol and Miscellaneous order are soil type mapped in the area **(Figure-2.8)**. Alfisols results from weathering process that leach clay minerals and other constituents out of surface layer and in to the sub-soil. They formed primarily under forest or mixed vegetative cover and are productive for most crops. In the study area, it is occupying in the western 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 occupies a large swath of the basin. Entisols type occurs in 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 in central and eastern parts of the basin. Inceptisols 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 parts of the basin. Hill soil is found in the western parts of the area.

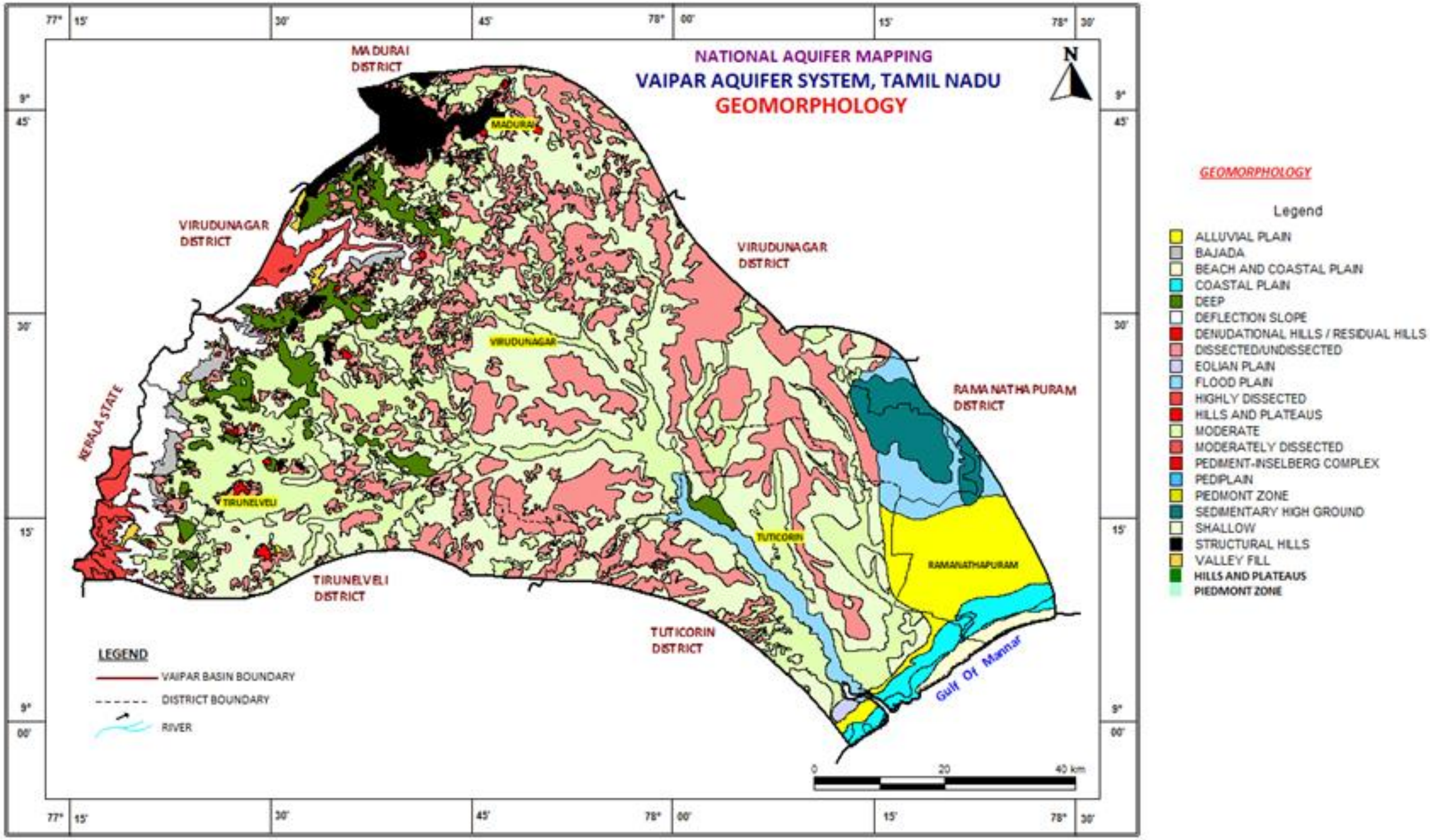


Figure 2.6: Geomorphology map

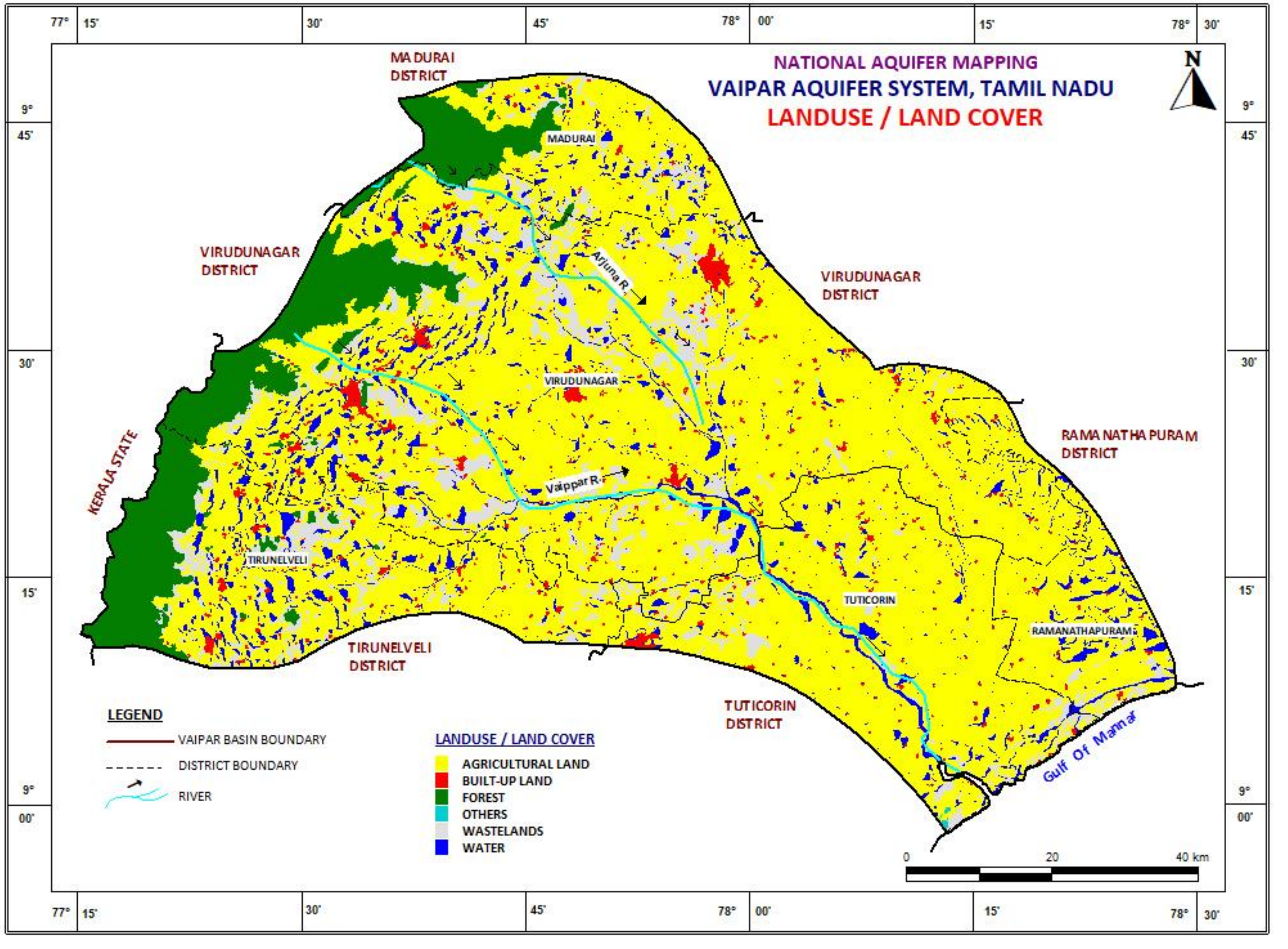


Figure 2.7: Landuse / Landcover map

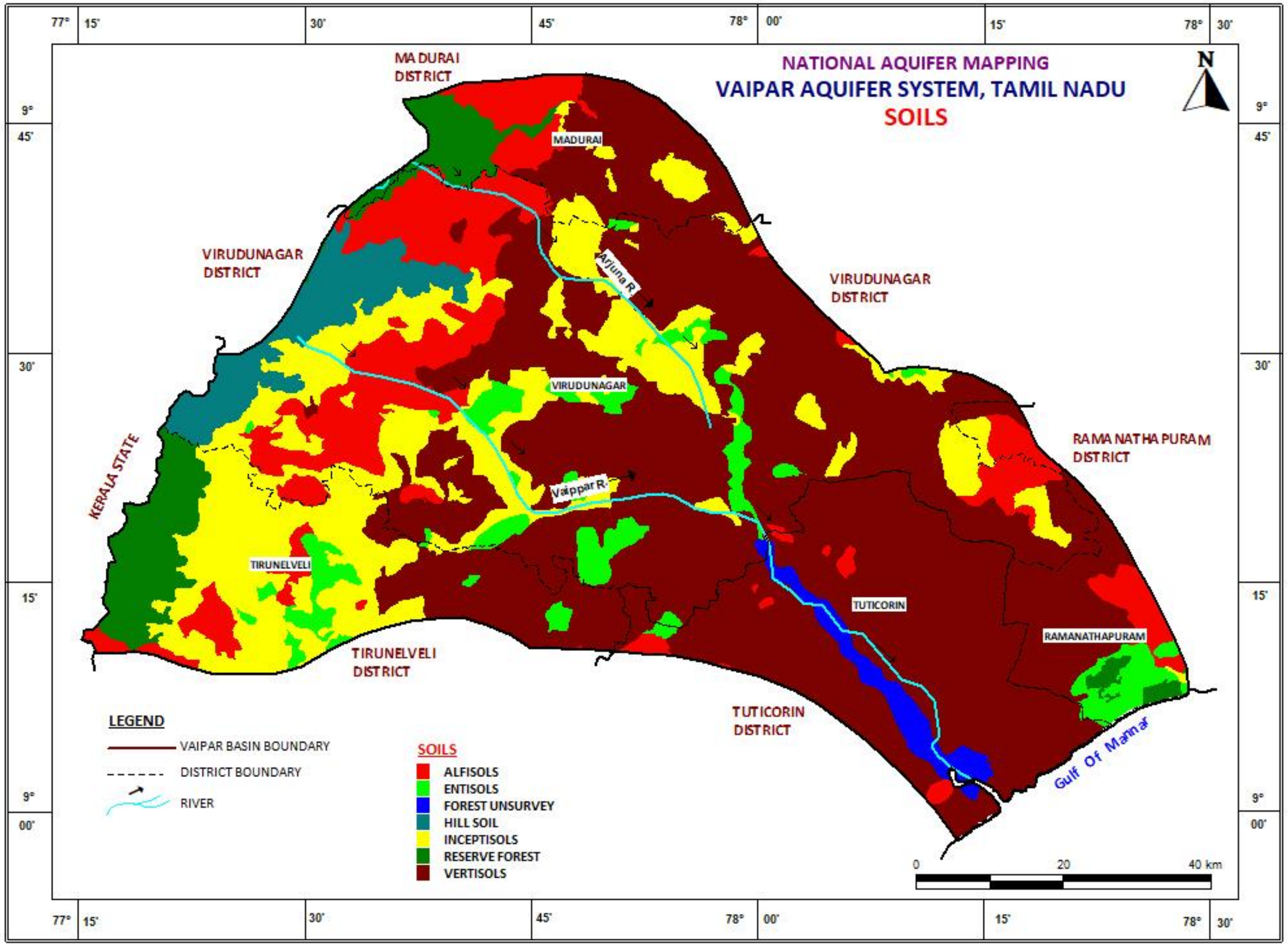


Figure 2.8: Soil map

3.0 DATA INTERPRETATION, INTEGRATION AND AQUIFER MAPPING

3.1 Hydrogeology

In hard crystalline formation, the groundwater mainly occurs in weathered and fractured rocks. In the area, Gneiss and Charnockites rocks are predominant and forms the aquifer systems. In sedimentary formation, Sandstone and Recent alluvium occurring in the eastern parts of the area are contributing groundwater to aquifer systems. The other rock formations are occupying less area and contribute less to the groundwater aquifer systems. The groundwater movement is following the general slope of the area particularly in the hilly region and in plain terrain the groundwater flow towards the major river draining in the area. It indicates that the rivers draining the area are highly influenced by the groundwater systems.

3.2 Occurrence of Groundwater in Gneiss

In the study area, gneissic formation is occupying more than 60% of the area and forms main aquifer system in the area. The gneissic formation is occurring in the central 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 200m bgl and the fractures are encountered up to the depth of 200mts.

3.3 Occurrence of Groundwater in Charnockites

In the study area, charnockite formation is occupying 20% of the area and forms the aquifer system in the area. It is occurring in the western and southern 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 hill 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 contribute to surface water sources due to base flow during non-monsoon time.

3.4 Occurrence of Groundwater in Sandstone

In the area, sandstone of Mio-Pliocene and Eocene is occurring in eastern parts of the area having thickness of about 150mbgl and forms multi-layered aquifer system. The groundwater is occurring in porous medium of sandstone under confined and unconfined conditions. The total thickness of the aquifer is explored upto the depth of 170mbgl. The groundwater is abstracted by constructing tube wells in the area. The depth of tube well is ranging from 75 to 170mbgl.

3.5 Occurrence of Groundwater in Alluvium

In the area, alluvium is formed above Cuddalore sandstone. The alluvium is formed by fresh water deposits and marine deposits. The fresh water deposits are occurring along the river course and coastal area having thickness of upto 30mts. The alluvium is mainly consisting of sand and intercalation of clay, the alluvium of marine origin is formed along the east coast. The groundwater is extracted through dug well and tube well. The groundwater quality is poor near the coastal belt when compared to that of the land.

3.6 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 water level of pre and post monsoon period. The average water level data of May (2008-17) is considered for pre-monsoon and January (2009-18) is considered for post-monsoon water level data. The water level data of the basin is sghown in **Annexure-II**

3.6.1 Pre-monsoon water level Aquifer-I

Average water level data collected from May-2008 to 17 was analysed for pre-monsoon. The water level data is depicted into four zones such as 0-2, 2-5, 5-10 and 10-20 m bgl. Water level of the basin is generally falling in two zones such as 2 to 5 and 5 to 10mts representing 10% and 78% respectively. The deepest water level is 10-20 mts and it is represented by 2% of the total observation well. The details of water level zone of pre monsoon is given in **Table-3.1.**

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

Period	**Percentage of area showing Average depth to Water Level (mbgl)**			
	0-2	**2-5**	**5-10**	**10-20**
Pre monsoon (2008-17)	1	19	78	2

Based on the water level data, water level maps have been generated in GIS environ showing four zones of 0-2, 2-5, 5-10 and10-20 bgl. The maximum area is covered by 2-5m and 05-10 mbgl. Both the zones are occurring in the gneissic formation and parts of sedimentary terrain. The 10-20 m bgl water level zone is occurring in the uplands of gneissic formation. The deepest zone is occurring in small pockets. **(Figure 3.1).**

3.6.2 Post-Monsoon water level Aquifer-I

Average water level data collected from January-2009 to 18 were taken for post-monsoon. The average water level data is analysed into four zones such as 0-2, 2-5, 5-10 and 10-20 m bgl. Average water level of the basin is generally falling in three zones, 2-5, 5-10 and 10-20m bgl representing 20%, 70% and 10% respectively. The 0-2 water level zone is completely absent in post monsoon scenario. It has been decreased from 1 to 0% from pre and post monsoon. The number of wells falling in 2-5 zone has increased considerably and decreased in 5-10m bgl water level zone. The deepest water level is 10-20 mts zone and area of this zone is increased considerably from 2 to 10% in the basin. The details of water level zone of pre and post monsoon are given in **Table-3.1**.

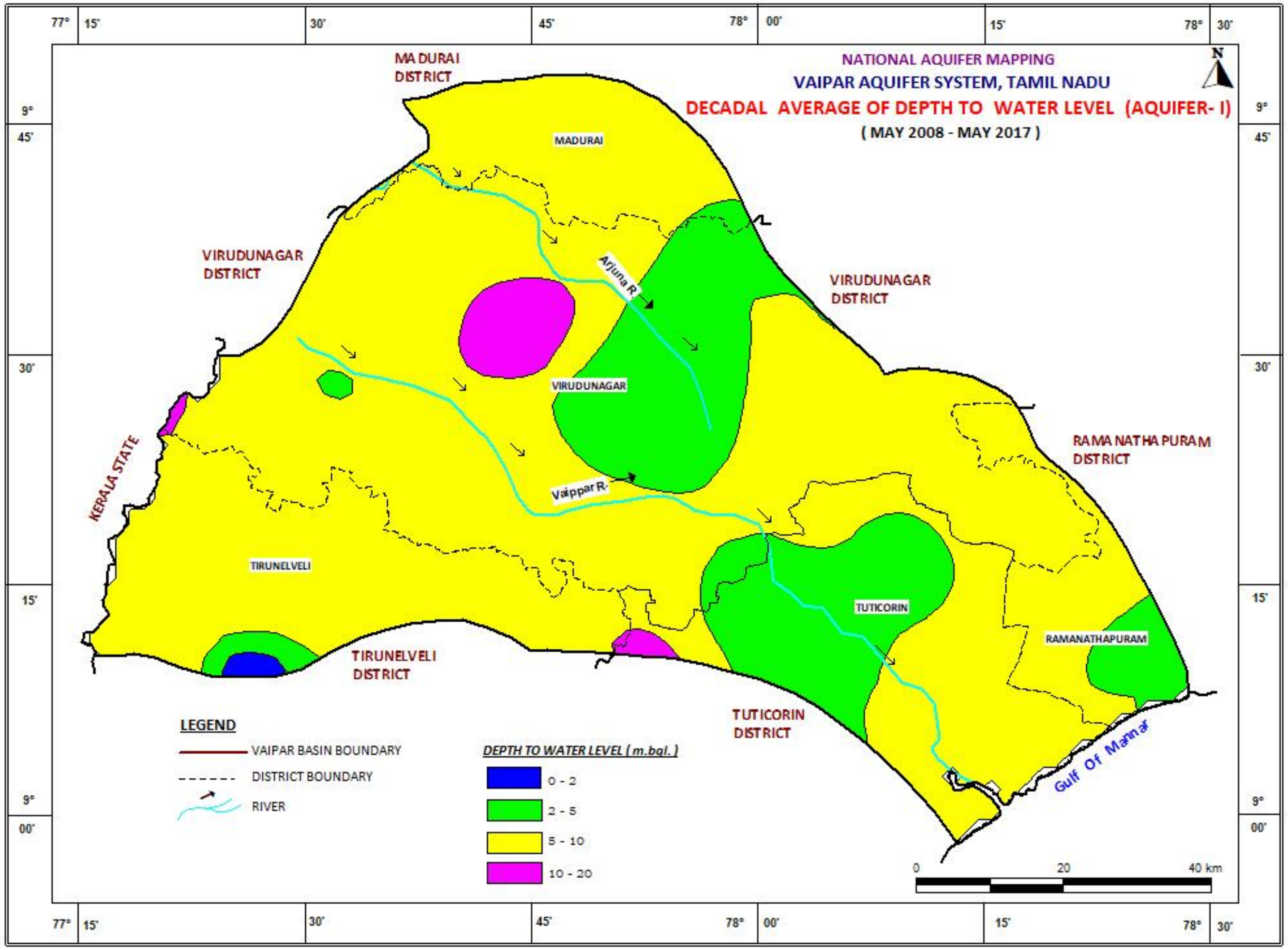


Figure 3.1: Depth to water level zone map (May 2008-17) of Aquifer-I

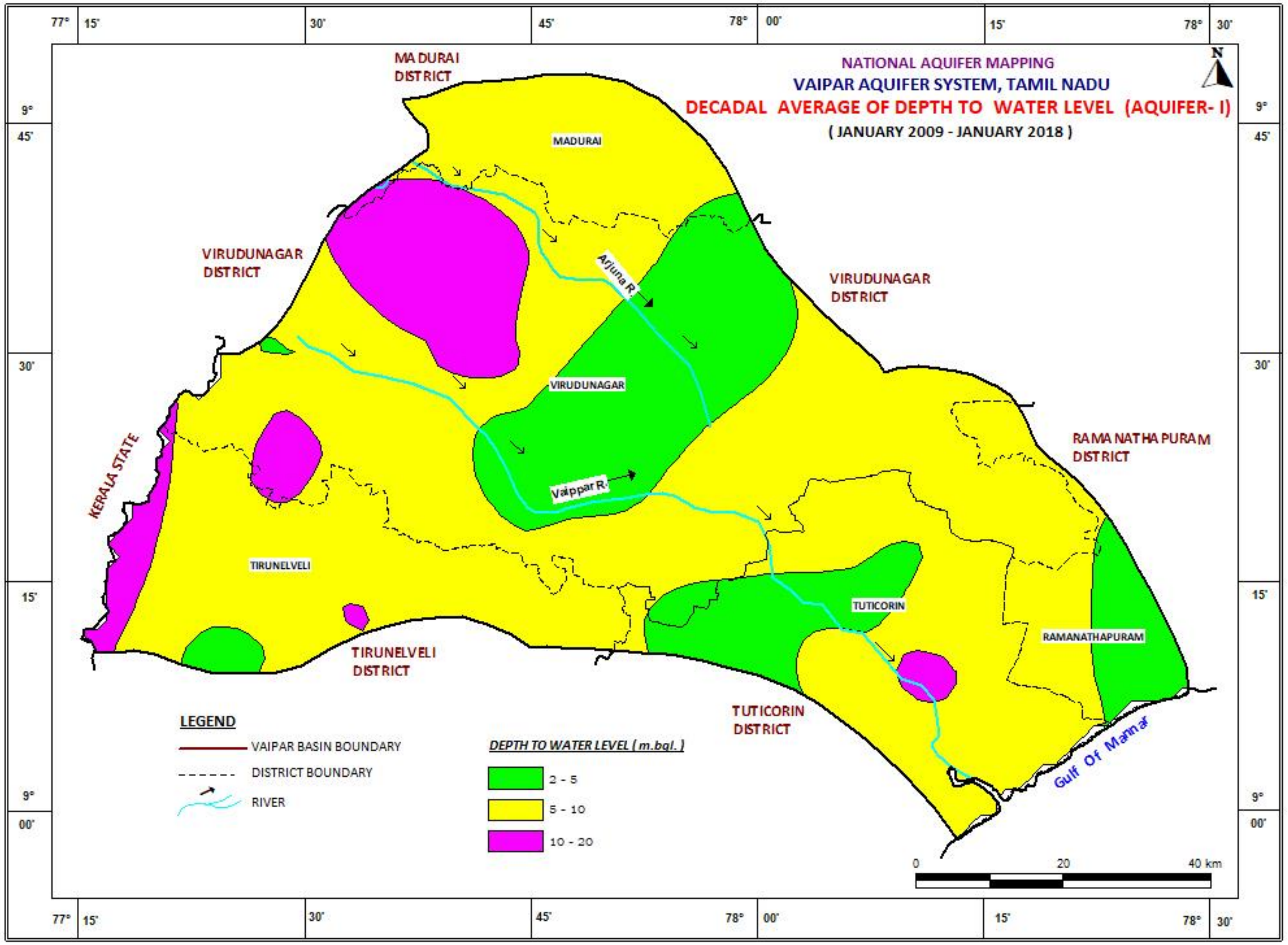


Figure 3.2: Depth to water level zone map (January 2009-18) of Aquifer-I

Table 3.2: Water level zone of post monsoon data of Aquifer-I

Period	Percentage of area showing Average depth to Water Level (mbgl)			
	0-2	2-5	5-10	10-20
Post monsoon (2009-18)	Nil	20	70	10

Based on the water level data, water level maps have been generated in GIS environ showing three zones 2-5, 5-10 and10-20 m bgl. The maximum area is covered by 2-5 and 5-10 mbgl. All three zones are occurring in the gneissic formation. In post monsoon, the 2-5m bgl water level is occurring in sedimentary formation and area pertaining to this classification has increased considerably. The 5-10 m bgl water level zone has also decreased when compared to pre-monsoon. The 10-20 m bgl water level zone occurring in the uplands of gneissic and charnockites formation has increased when compared to pre-monsoon. The 10-20m water level zone is found along the contact between gneiss and charnockites formation. It indicates that these areas are having high groundwater withdrawal **(Figure 3.2).**

3.7 Groundwater quality

Groundwater samples were collected from 25 dug wells and analysed for pH, EC, anion, cation, fluoride and nitrate concentrations. The chemical quality data of the bsin is shown in **Annexure-III.** The EC of groundwater is discussed in the report. 44% of the sample is showing EC between 750-2250 µS/cm at 25 °C which is considered as moderately fresh water.16% of the sample is falling EC of 2250 - >3000 µS/cm at 25 °C which classifies groundwater as highly mineralised. 28% of sample is showing the EC less than 750 µS/cm at 25 °C and this groundwater is considered as fresh water and highly suitable for drinking water purposes. 12% of sample is showing the EC more than 3000 µS/cm at 25 °C and this groundwater is considered as saline water and cannot be used for any purposes. (**Table-3.3**).

The EC data is represented spatially in **Figure-3.3** and it is showing EC into four zones such as 0-750, 750-2250, 2250-3000 and >3000 µS/cm at 25 °C. The maximum area is falling under EC between 750-2250 µS/cm at 25 °C. < 750 µS/cm at 25 °C is occurring in the southern and western parts of the area. The EC >3000 µS/cm at 25 °C is falling in eastern parts of the area. The high mineralisation is found in the northern and eastern parts of the area.

Table 3.3: EC of groundwater

EC (µS/cm at 25° C)	**Water Class**	**Percentage of Samples**
0-750	Fresh	**28%**
750 – 2250	Moderately Fresh	**44%**
2250 – 3000	Slightly mineralized	**16%**
>3000	Highly mineralized	**12%**

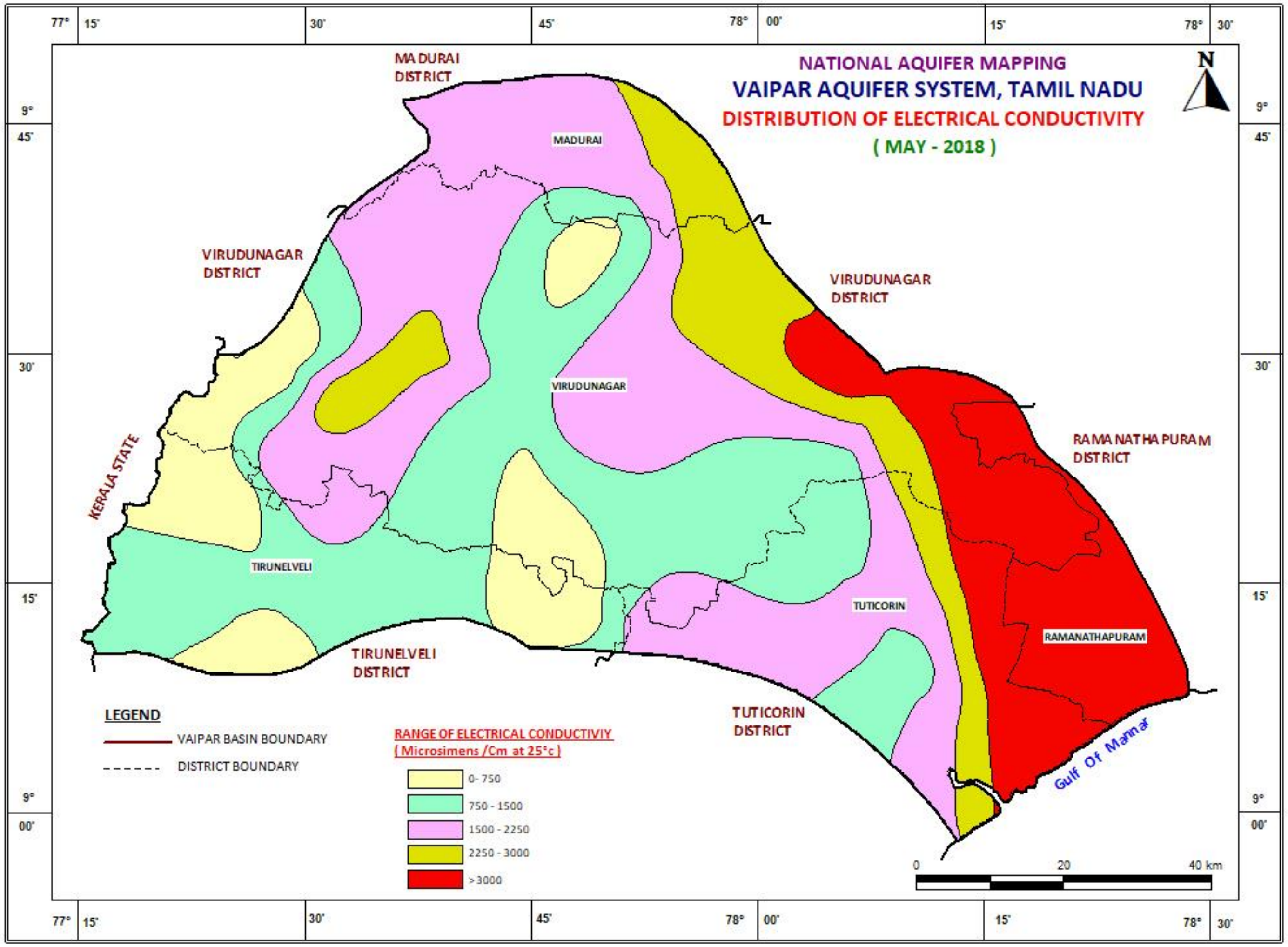


Figure 3.3: Spatial distribution of EC in groundwater

3.8 Aquifer Disposition

The aquifer disposition of the area is demarcated based on sub-surface geology 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 in hard crystalline formation. The first aquifer (Aquifer-I) is weathered layer of gneiss and charnockite formation. The second aquifer (Aquifer-II) is fractured layers of gneiss and charnockite formation. The bottom of the aquifer-II is demarcated using the lower most fractured depth encountered in the bore well.

In sedimentary formation, two aquifer systems have been demarcated of the area. The aquifer systems are divided based on the water level and piezometric head of the aquifer system. The aquifer -I is formed by alluvium and the aquifer-II is formed by Cuddalore Sandstone.

3.8.1 2D Aquifer disposition (Aquifer 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.

3.8.2 Aqquifer cross section across aquifer basin (Gneiss Formation)

The hydrogeological cross section across the aquifer basin is shown in **Figure- 3.4**. It indicates that the vertical and lateral extension of fractured aquifer is uniform in gneiss formation. The high thickness of fractured aquifer is observed in across the Arjuna River**.**

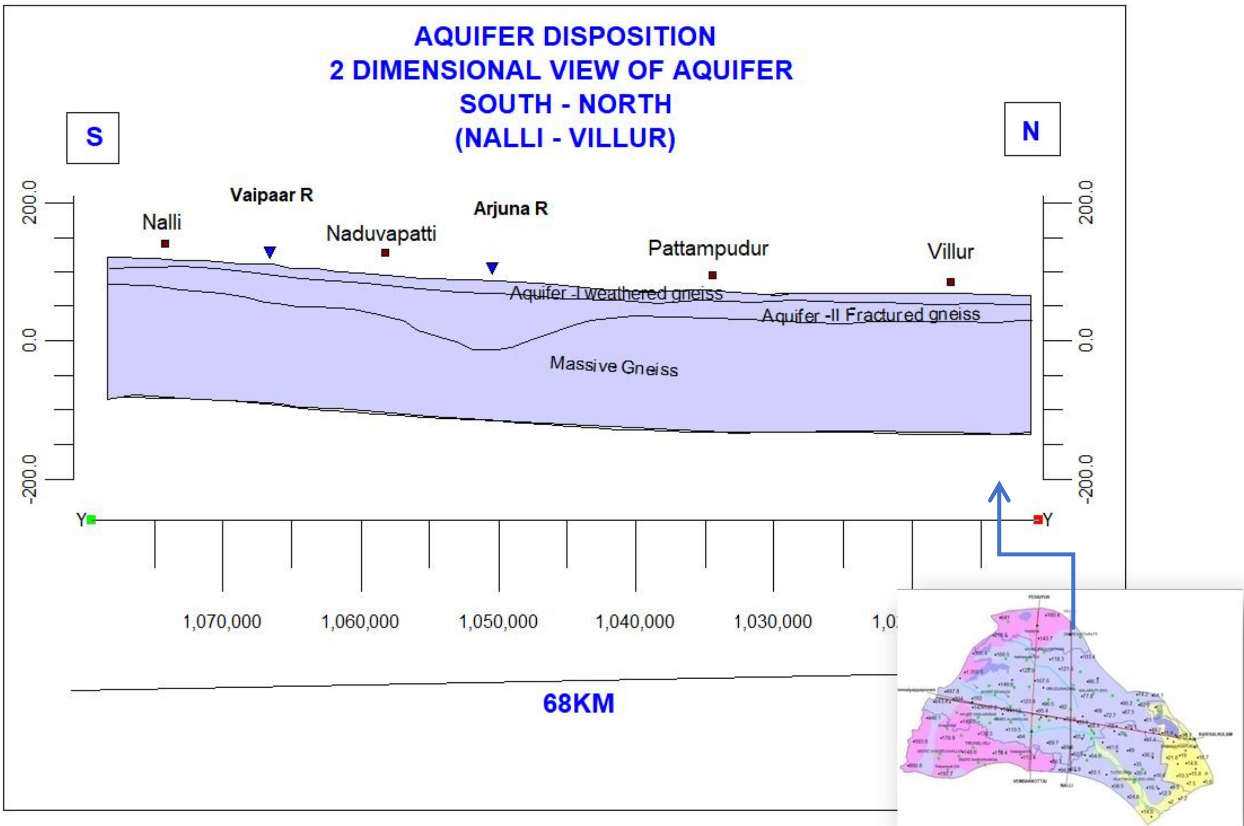


Figure 3.4: Aquifer cross section across basin

3.8.3 Aquifer cross section across aquifer basin (Charnockites Formation)

The hydrogeological cross section across the aquifer basin in charnockites is shown in **Figure- 3.5**. It indicates that the thickness of fractured aquifer is high at the contact between gneiss and charnockite formation confined only in the southern parts of the area. and also observed at Vaippar River course. The uniform thickness of the aquifer-II is observed in northern parts. The Arjuna River is not structurally disturbed and it is indicated by less thickness of the aquifer system at the river course along this section.

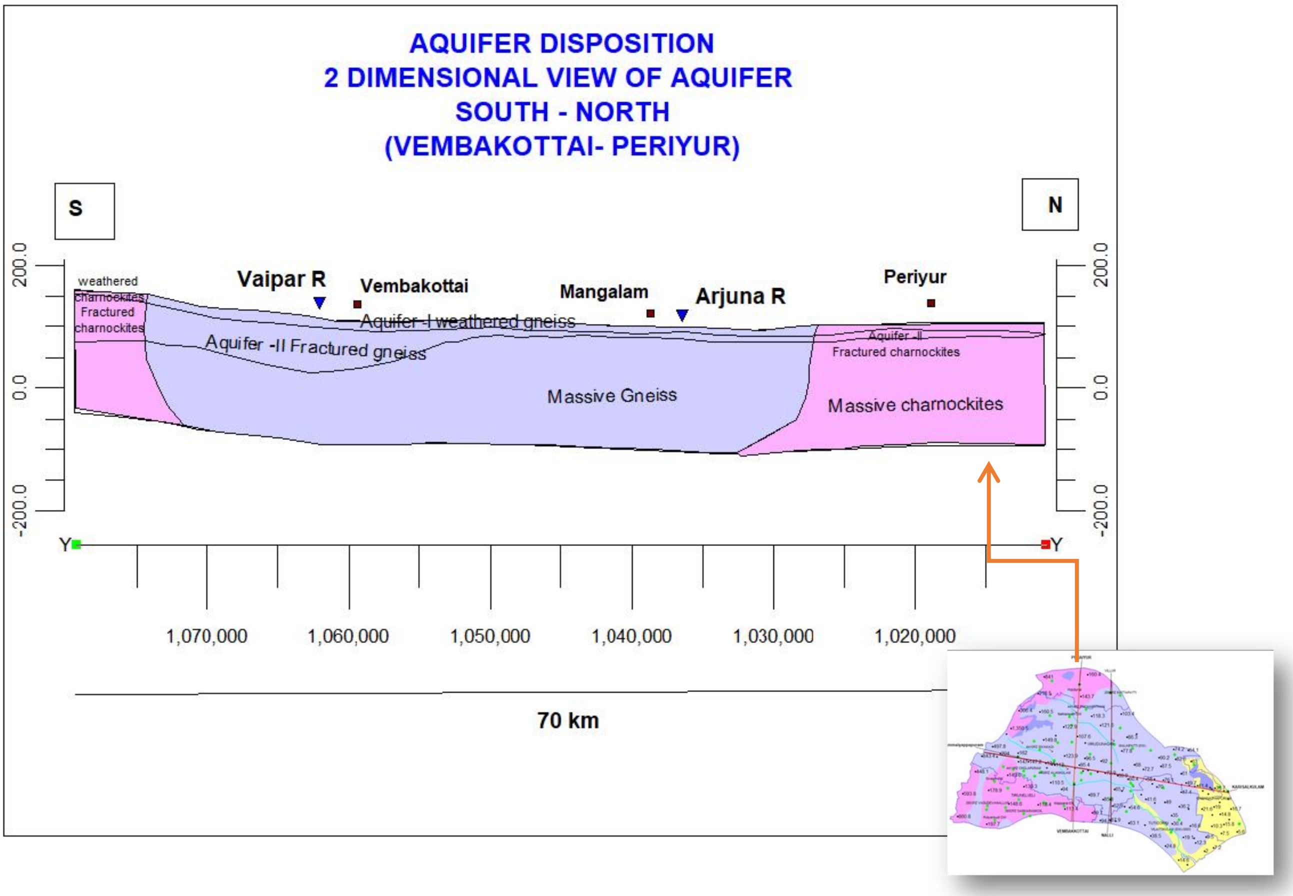


Figure 3.5: Aquifer section across the basin

3.8.4 Aquifer cross section along aquifer basin (Ammiyappapuram - Karisalkulam)

The hydrogeological cross section across the aquifer basin is shown in **Figure- 3.6**. It indicates that the thickness of two aquifers is almost parallel running for long distance. This section is running for about 110km starting from west at Ammiyappapuram to east at Karisalkulam through charnockites at west, gneiss at the canter and alluvium at east. The section is cutting across contacts between charnockite and gneiss and gneiss and sedimentary formation. It is also cutting across two rivers namely Vaippar at the centre and Arjuna river at the north. The aquifer thickness is high at the lithological contact and river course direction and the remaining area is showing the less aquifer thickness. In the eastern parts of the area the thickness of the aquifer system is high due to sedimentary formation. The thickness of the sedimentary formation is increases towards easterly.

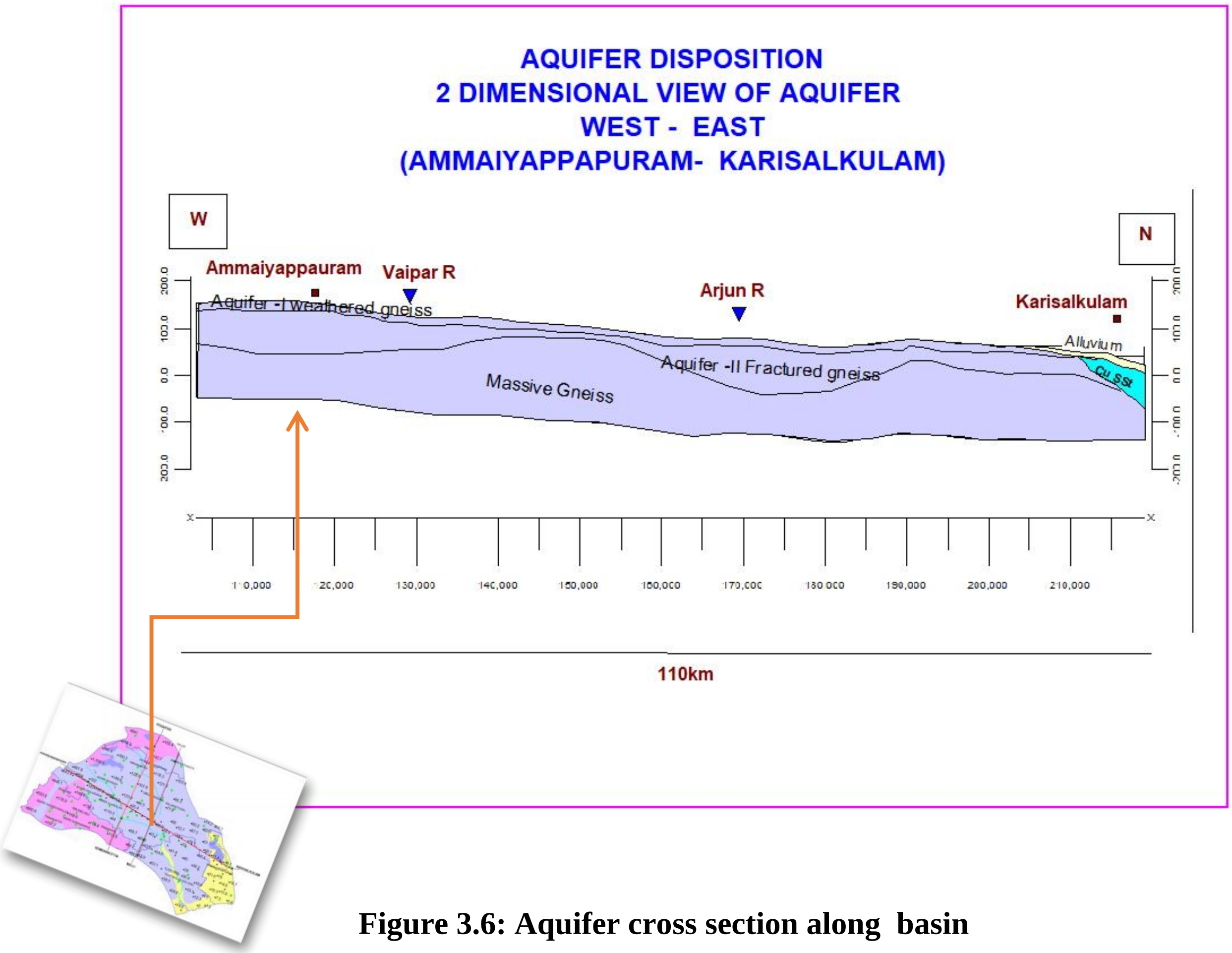


Figure 3.6: Aquifer cross section along basin

3.9 3D Aquifer disposition

3 Dimension of the aquifer system of the basin was prepared and shown in **Figure-3.7**. The thickness of the Aquifer-I is almost same in the aquifer basin in hard rock formation. The thickness of the Aquifer-II is not uniform in thickness in hard rock formation. The thickness of the Aquifer-II is high at the contact of two litho units and two river courses draining in the basin. The thickness of the aquifers is low in the centre of the basin. Low thickness is indicating the shallow fracture depth and high thickness is indicating depth of occurrences of fracture at much deeper level. The availability of the groundwater in the aquifer is mainly depends on the thickness of aquifer system. In eastern parts of the area, two aquifers are occurring in sedimentary formation. The sedimentary aquifers are gently dipping towards east direction. The thickness of the aquifers in sedimentary formation is increasing easterly towards sea. The basement of the sedimentary aquifer system is occurring at shallow depth in western parts of the sedimentary formation and deeper depth towards sea.

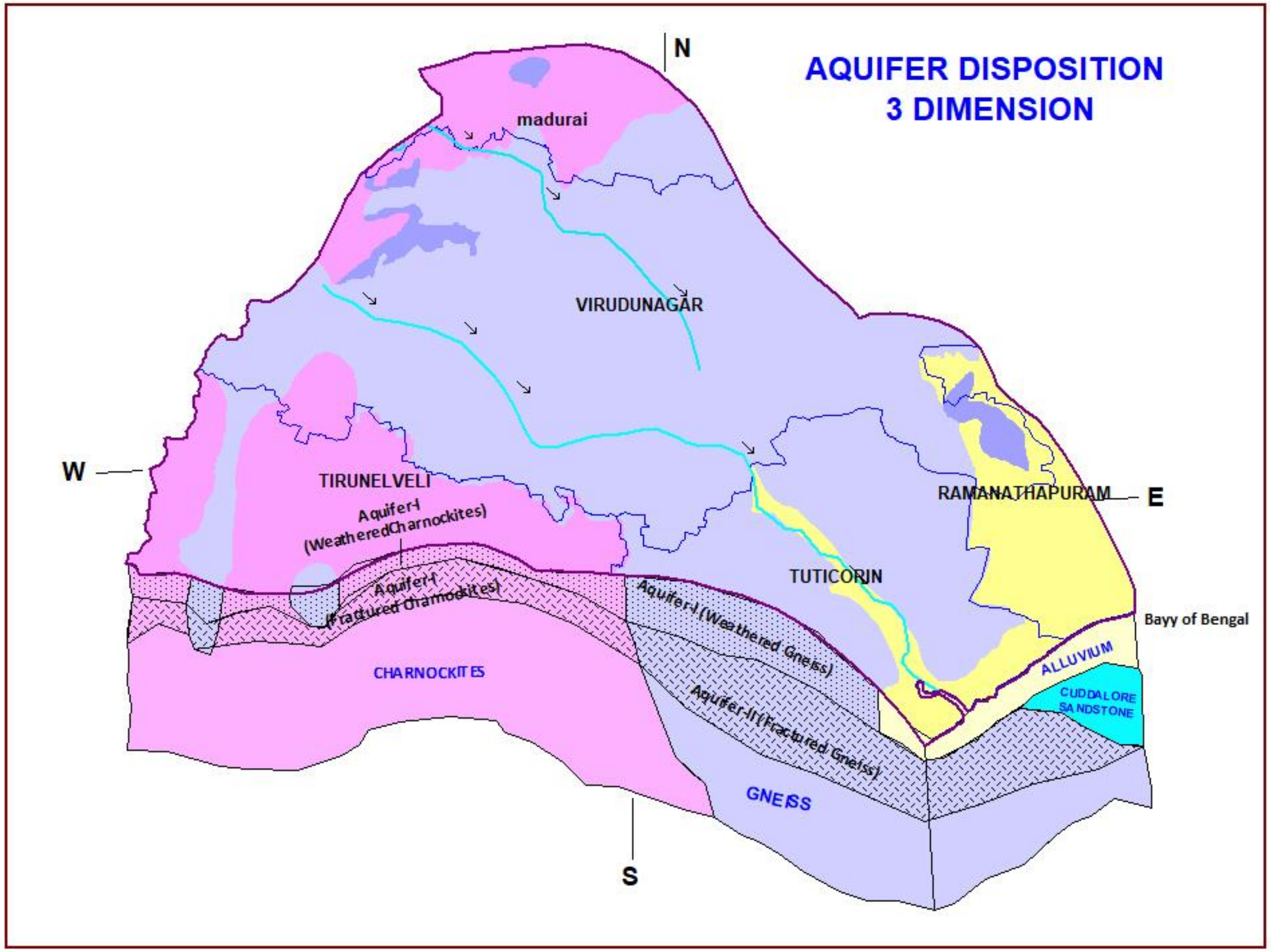


Figure 3.7: 3D view of the Aquifer Systems

3.9 Thickness of Aquifer-I

Thickness of the Aquifer-I was prepared based on the weathered thickness, shallow fracture depth which has connectivity with the weathered mantle and alluvium/sandstone. The bottom depth of the weathered/shallow layer is considered as thickness of the Aquifer-I and top of the sandstone for aquifer-I in sedimentary formation shown in **Figure 3.15**. The thickness of Aquifer-I is depicted spatially with 10m contour intervals having three zones such as less than 10mts, 10-20mts and >20mts. The maximum area of the basin is occupied by 10-20 m thickness followed by less than 10 m aquifer thickness. The thickness of 10-20 m is mainly occurring in the uplands of gneissic and charnockites formation. The thickness >20m of Aquifer-I is found in eastern parts of the study area. The thickness of Aquifer-I is directly indicating the groundwater storage in the aquifer. The average thickness of Aquifer-I is 18mts in hard rock formation and 20m in sedimentary formation

3.10 Depth of occurrence of Aquifer-II

Based on the last fracture depth encountered in bore well, the depth of occurrence of Aquifer-II was prepared for aquifer system and presented in **Figure-3.16**. Based on this, occurrence of Aquifer-II is demarcated into four zones such as <50, 50-100, 100-150 and >150mts. The <50mts depth of occurrence of aquifer-II is found in southern parts of the area and in between the rivers. The second and third zone 50 -100 mts and 100 -150 mts are occurring in the central parts of the area running from east to west parallelly. The fourth zone >150 mts is occurring in the eastern and northern parts of the area. All the zones of the second aquifers are indicating that the thickness of the second aquifer is increasing from south to north direction trending east west direction.

3.11 Fracture analysis

The aquifer-II is mapped based on fractures encountered in the borewell. The fractures are occurring in various depth of the borewell. In general, the fractures are occurring below the weathering rocks and above the massive rocks. Due to structural deformation, some fractures are formed in shallow depth and some are deeper depth. In the borewell, two to three sets of fractures are occurring in the borewell. The depth of the fractures is collected during the drilling and same has been analysed to understand the fractures system.

3.12 Depth of First fracture Occurrence

The first fractures are generally occurring below the weathered zones and are found upto the depth of 150mts. In general, the first fractures are below 50mts and are covering about 80% of the area irrespective of the geological formations. Western parts of the area are covering > 50mts depth. It indicates that the groundwater occurrence and movement are generally good in the area where the first fracture occurring <50mts depth as the fractures are having good interconnection of fractures within 50mts.

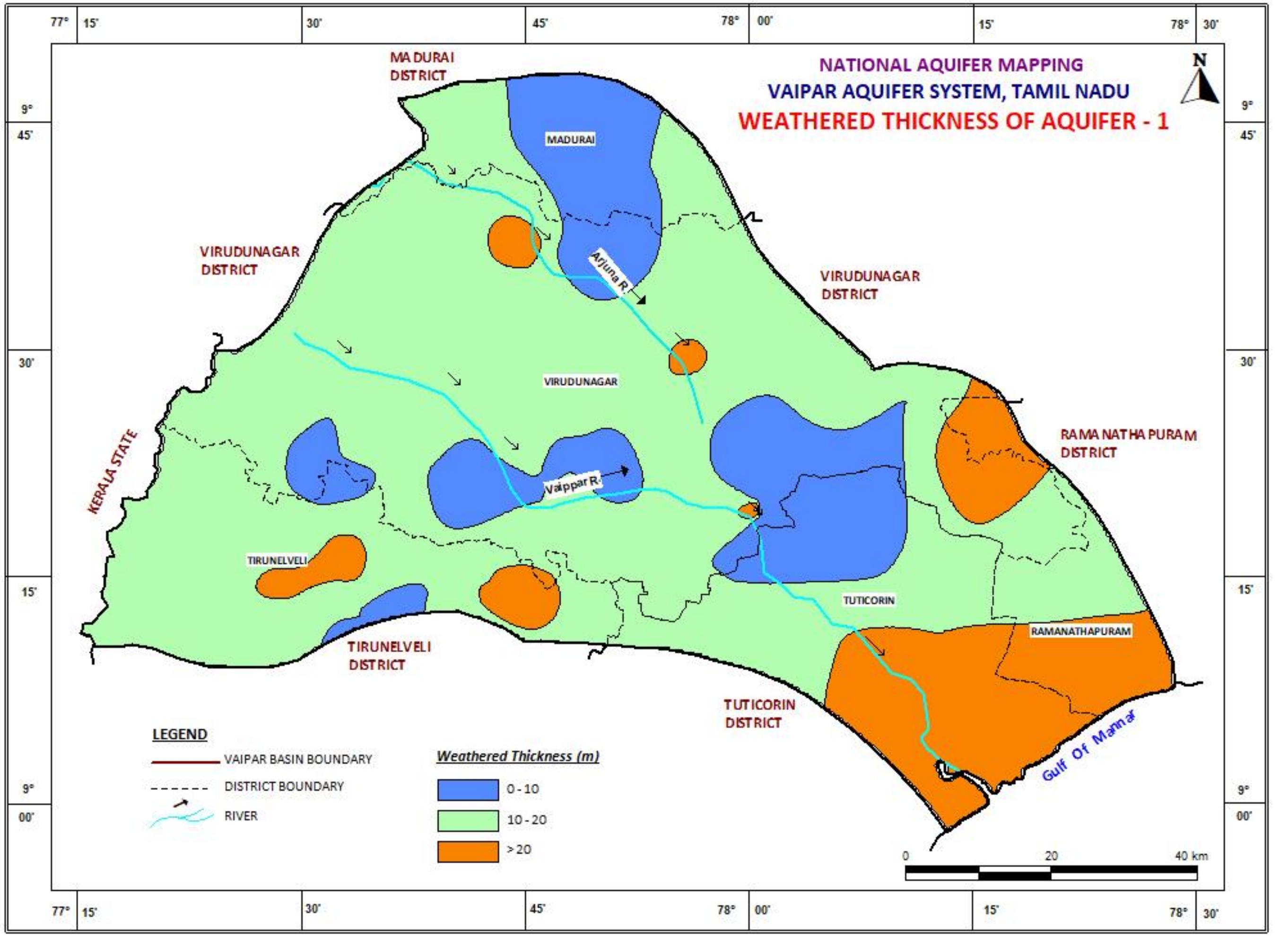


Figure 3.8: Thickness of Aquifer-I

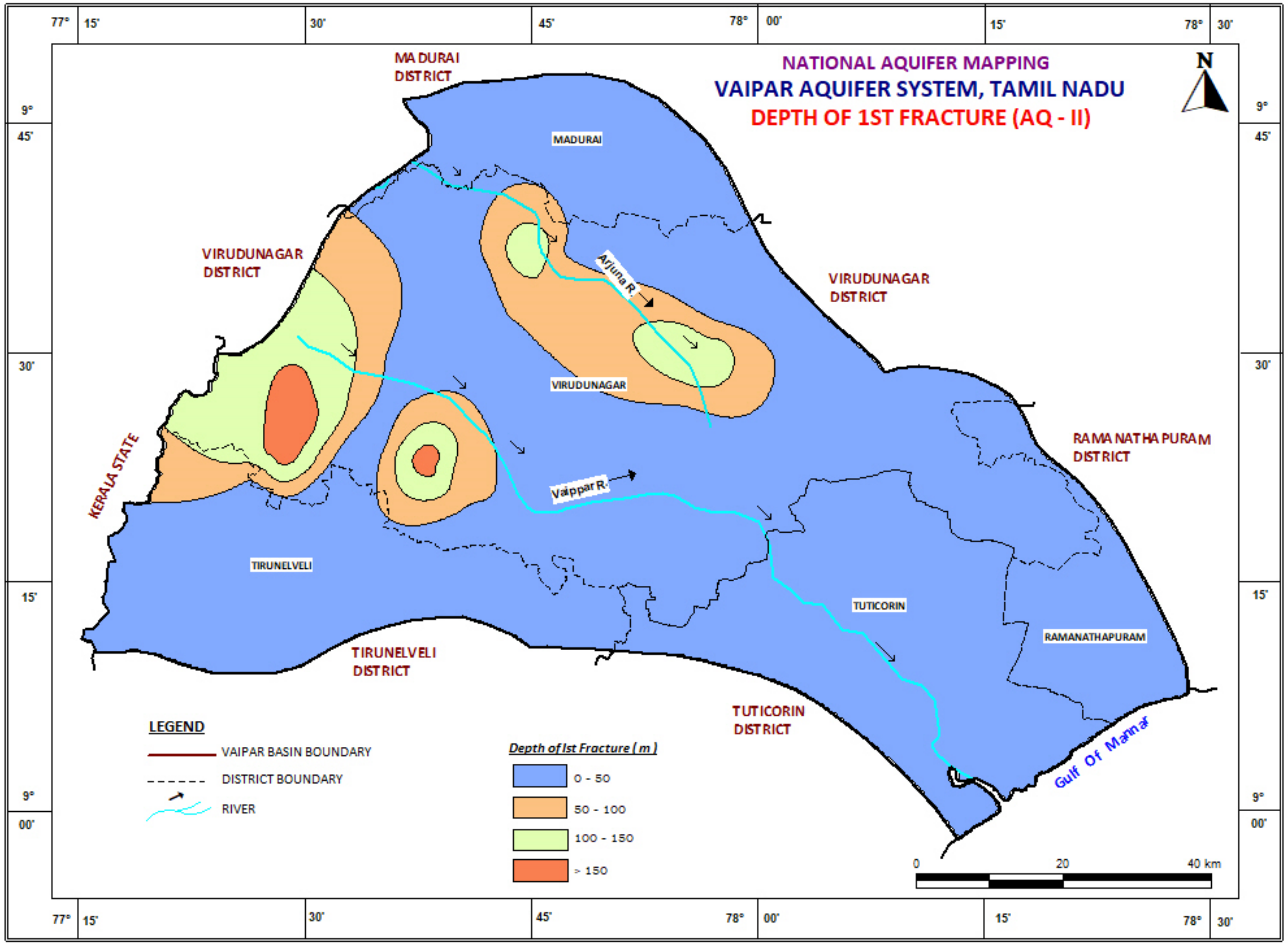
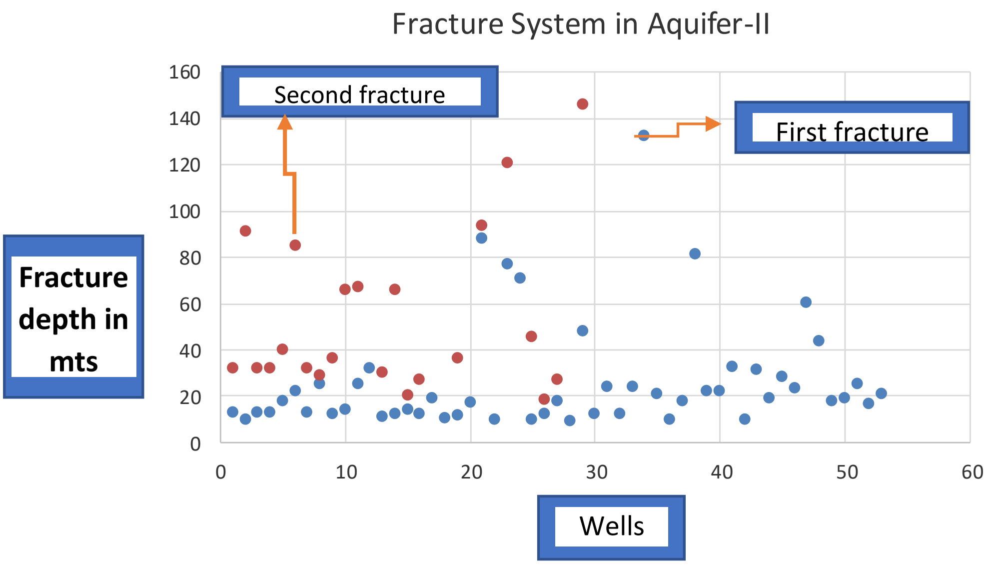


Figure 3.9: Depth of occurrence of First fracture in Aquifer-II

3.13 Depth of Second fracture Occurrence (Possible)

Based on the groundwater exploration, the depth of second fracture of aquifer-II is occurring upto the depth of 150mts. The depth of occurrence of second fractures are classified into three zones namely less than 50mts, 50-100mts and 100-150mts. The exploration data indicates that the second fractures are generally occurring upto the depth 50mts and covering in the southern parts of the area. The second zone between 50 – 100mts are found in the southwestern, north-western and eastern parts of the area which includes sedimentary formation existing in the eastern parts of the area. The third zone between 100 – 150mts are found in the northern parts of the area. The deeper are found only at the contact between gneiss and charnockites and the contack zone between hard rocks and sedimentary formation. The first and second fractures are generally falling upto the depth of 50mts in the area. It is indicating that the groundwater is occurring upto a depth of 50mts in hard rock formation.



3.14Aquifer 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 characteristics are the main parameter to demarcate the aquifer system in the area. The properties of aquifers such as specific yield, transmissivity and storativity are compiled and demarcated the aquifers system. The long duration pumping test data have been used to estimated the properties of the aquifers of the basin. The list of high yielding well is given below with aquifer property **(Table-3.4).**

Table 3.4: Details on Long duration pumping test results

No.	Location	Discharge (lpm)	Drawdown (m)	T (m2/ day)	S
1	ILLUPAIYUR	193.8	13.91	130.78	--
2	VEMBAKKOTTAI(EW)	163.8	10.54	--	--
3	KRISHNANKOIL(EW)	144	2.65	0.20	--
4	PERAIYUR (EW)	372.6	4.51	103.23	0.0087
5	PERAIYUR (OW)			196.1	--
6	SRIVILLIPUTHUR	600			
7	PILLAIYARKULAM (EW)	270	2.615	605	
8	KARISALKULAM(EW)	270	1.21	3616	

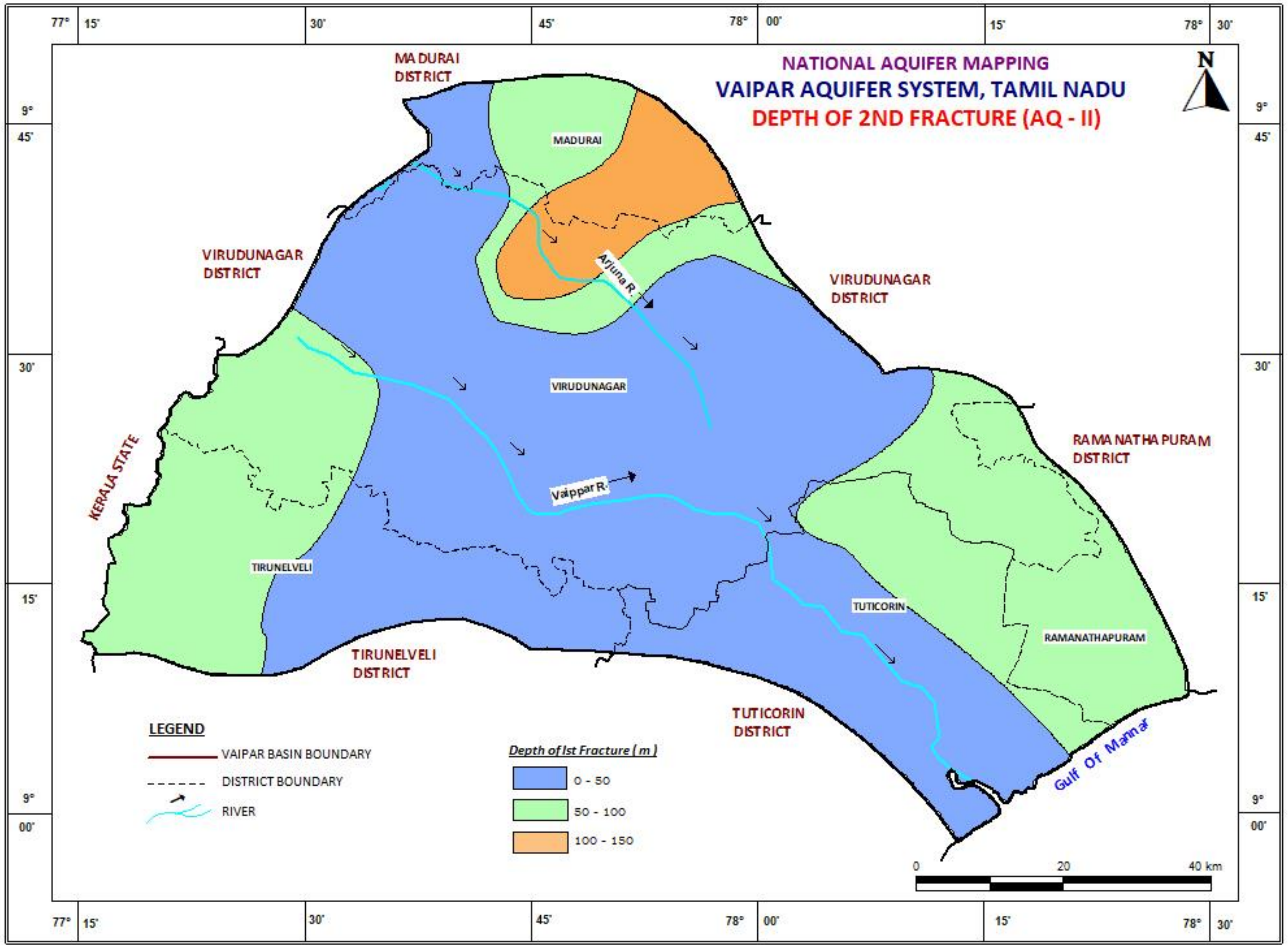


Figure 3.10: Depth of Second fracture Occurrence(Possible)

3.14.1 Aquifer-I

The weathered layer of the two lithological units such as gneiss and charnockites are considered for the Aquifer-I **(Table-3.5**). In general, the thickness of the aquifer-I in charnockite is ranging from 6 to 18 mts with an average thickness of 14.6mts. The discharge of the Aquifer- I is ranges from 1.8 to 10.8 m^3/hrs which sustains pumping for 2 -4 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 10 to 20m^2/day. Electrical Conductivity ranges from 386 to 900 µs/cm. The groundwater is found suitable for all purposes.

The thickness of the aquifer-I in gneiss is ranging from 10 to 20 mts with an average thickness of 18mts. The discharge of the Aquifer- I is ranges from 1.8 to 18 m^3/hrs which sustains pumping for 2 -4 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 10 to 70m^2/day. Electrical Conductivity ranges from 480 to 7760 µs/cm. The groundwater is found suitable for all purposes and at places the groundwater is saline nature.

The thickness of the aquifer-I in alluvium is ranging from 10 to 20 mts with an average thickness of 18mts. 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 utilisation. 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.

Table 3.5: Details on aquifer-I properties and its sustainablity

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– m^2/day)	Groundwater quality EC values (µs/cm)	Suitable for Drinking
Aquifer I	Weathered Charnockites	GL - 2	6 – 18 (Avg. -14.6 m)	1.8- 10.8 Majority (< 3.6)	Monsoon: 2-4 hrs. & Non monsoon: < 1 to 2	10- 20	386- 900	Yes
Aquifer I	Weathered Gneiss	GL or 2	10 – 20 (Avg. -17.5 m)	1.8 to 18	Monsoon: 2-4 hrs. & Non monsoon: < 1 to 2 hrs.	10 - 70	480-7760	Yes - except Saline areas
Aquifer I	Alluvium	GL	10 – 20 (Avg. -15 m)	10 to 18	Monsoon: 4to5 hrs. & Non monsoon: < 3 to 4hrs	1000= -2000	3000 -5000	Saline

3.14.2 Aquifer-II

In general, the thickness of the aquifer-II in charnockite is ranging from 40 to 50 mts with an average thickness of 45 mts **(Table 3.6).** The discharge of the Aquifer- II is ranges from 1.8 to 10.8 m^3/hrs which sustains pumping for 1 -4 hrs during monsoon period whereas in summer period 1 to 3 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 10 to 190 m^2/day. Electrical Conductivity ranges from 440 to 2500 µs/cm. The groundwater is found suitable for all purposes.

The thickness of the aquifer-II in gneiss is ranging from 60 to 130 mts with an average thickness of 100mts. The discharge of the Aquifer- II is ranges from 1.8 to 10.8 m^3/hrs which sustains pumping for 1 -4 hrs during monsoon period whereas in summer period < 1 to 3 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 10 to 130m^2/day. Electrical Conductivity ranges from 370 to 2010 µs/cm. The groundwater is found suitable for all purposes and at places the groundwater 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. 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 utilisation. Based on the long duration pumping test, the transmissivity of the aquifer is determined and it is ranging from 1000 to 3600m^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.

Table 3.6: Details on Aquifer-II properties and its sustainablity

Type of Aquifer	Formation	Top of the aquifers	Thickness/ occurrence of 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 II	Jointed & Fractured Charnockite	7 to 19	40 -50 (3 to 4 fractures exist) Nil at	1.8 – 10.8	Monsoon: 1 - 4 hrs. & Non monsoon 1 to 3 hrs.	10 - 190	440- 2500	Yes - except Saline areas
Aquifer II	Jointed & Fractured Gneiss	11 to 21	60 to 130 (3 to 4 fractures exist)	1.8 – 10.8	Monsoon: 1-4 hrs. & Non monsoon [illegible]	10 - 130	370-2010	Yes -
Aquifer II	Sandstone	11 to 21	50 to 150	10 – 18	Monsoon: 3-4 hrs. & Non monsoon	1000 - 3600	3000 - 30000	Saline

4.0 GROUNDWATER RESOURCES

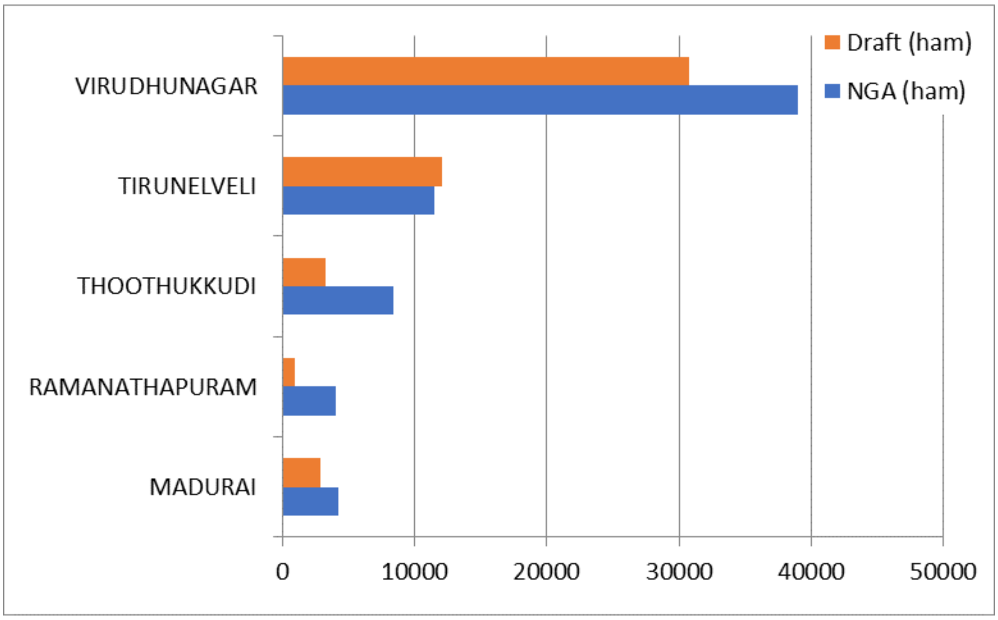
The groundwater resource of Aquifer-I was estimated as on March - 17 with Firka as the assessment unit, the smallest administrative unit of revenue division of Tamil Nadu. The estimated Firka groundwater resources have been apportioned for the district falling in the basin aquifer system. The groundwater resource of Vaippar River basin aquifer system was estimated based on GEC-1997 methodology and are pesented in **Annexure-IV.**

4.1 Groundwater Resources

Based on the groundwater resources estimation, the net groundwater availability of the area is 67211 HAM **(Table 4.1).** The existing groundwater draft from all purposes is 50134 HAM. The stage of groundwater development of the aquifer systems is 74.59%. Based on the stage of groundwater development, Firka has been categorised into safe (>70%), semi-critical (70-90%), Critical (90-100%) and over-exploited (>=100%) in the aquifer system. The western part of the basin area is over exploited where the irrigation draft is comparatively high. The basin area is categorised as semi critical **(Figure 4.1).** Among the five districts falling in the basin, Thirunelvelli district falling in the ~~basin~~ is withdrawing the groundwater more than the recharge and hence the stage of groundwater development is 105%. The stage of groundwater development of the Virudhunagar district is 79.05%. Other three districts are falling in safe category. As the major part of the basin is covered by Virudhunagar district, the groundwater recharge is more than other four districts. The five districts comprising 59 firkas falling in the basin and of 59, 13 are over exploited, 6 are critical, 10 are semi critical, 28 are safe and 2 are saline **(Table 4.2).**

Table 4.1: The details of Groundwater Resources

Groundwater Resource 2017			
Districts	**Resource (ham)**	**Draft (ham)**	Stage of GWD %
Madurai	4279.8	2918.7	**68.20**
Ramanathapuram	4012.1	993.4	**24.76**
Thoothukkudi	8428.6	3308.2	**39.25**
Tirunelveli	11537.4	12122.3	**105.07**
Virudhunagar	38953.7	30791.8	**79.05**
Total (ham)	67211.6	50134.4	74.59



District vs Resource and draft of 2017

Table 4.2: Groundwater Resource categorisation of basin

Total Firka	**59**
Over exploited	**13**
Critical	**6**
Semi-critical	**10**
Safe	**28**
Saline	**2**

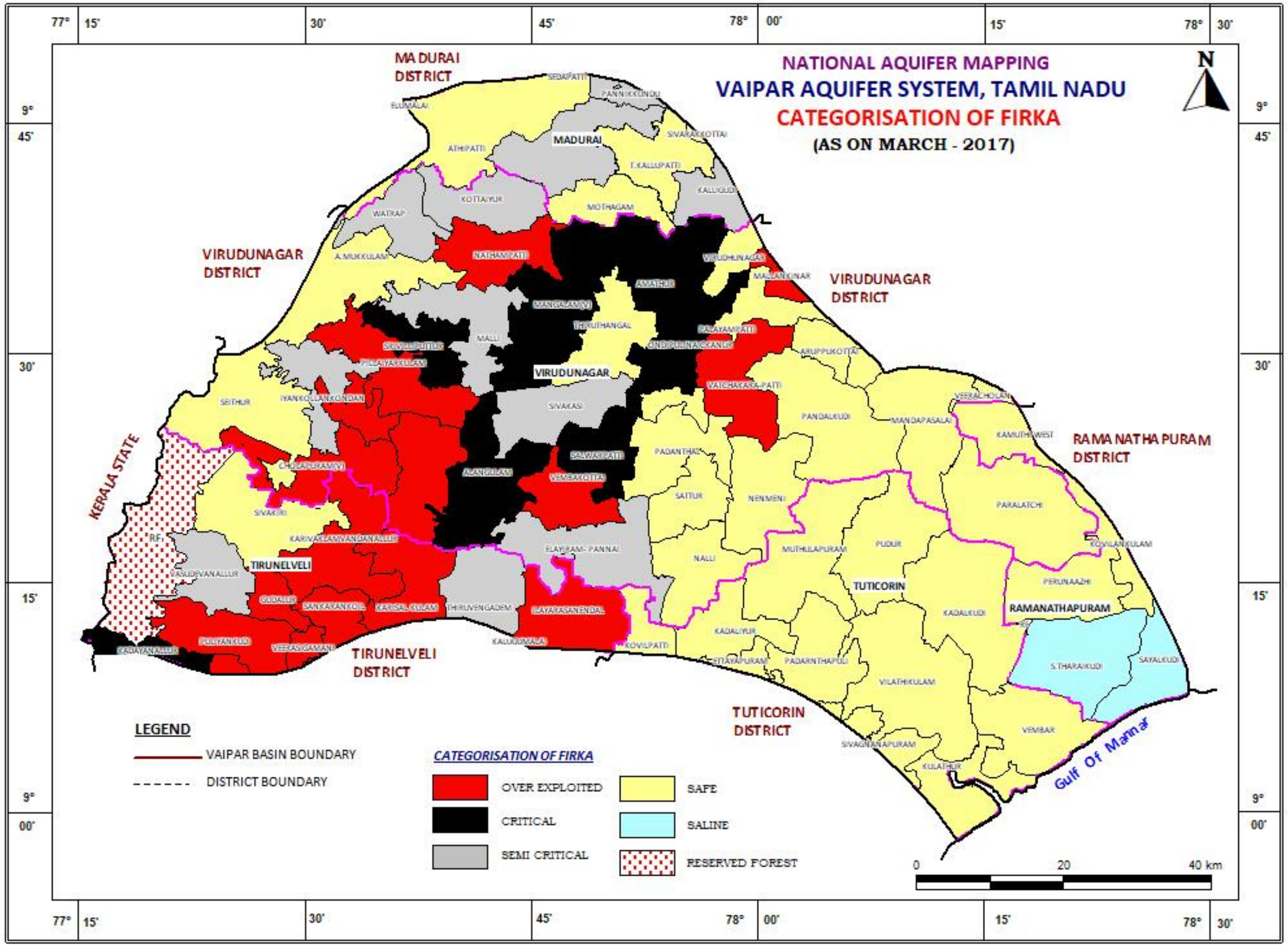


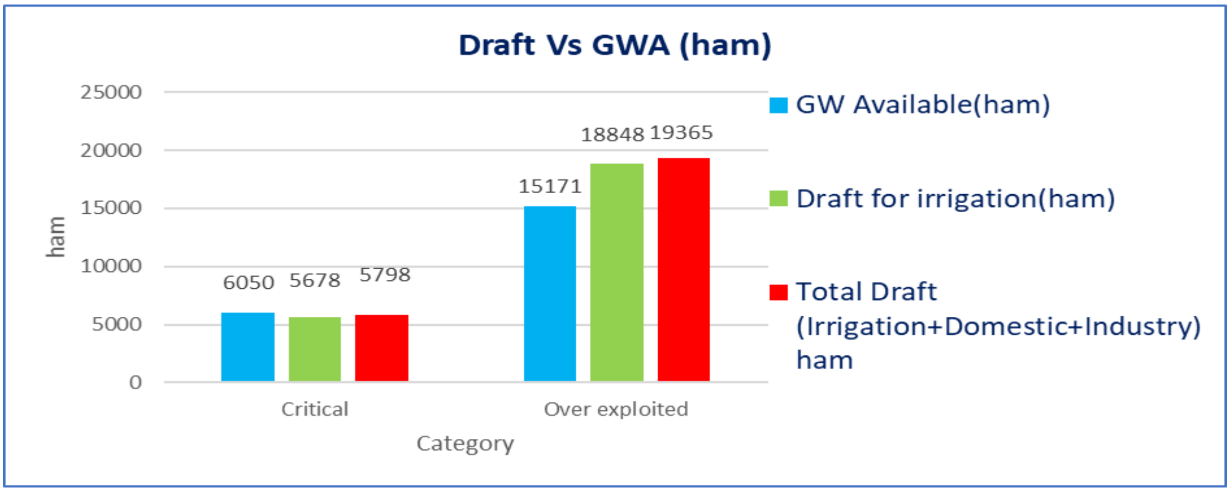
Figure 4.1: Groundwater Resources categorization of Firka

4.2 Stage of Groundwater development

As per Groundwater resources assessment, 19 Firkas fall under critical and over-exploited category out of 59 Firkas. The total extractable groundwater in OE and Critical firkas is 21220ham and total draft for all purposes is 25164ham. The stage of groundwater development is 118%. In Virudhunagar district, out of 32firkas, 7 Firkas are categorised as critical and 6 over-exploited. In Thirunelvelli District, out of 8 Firkas, 5 Firkas are categorised as over-exploited. In Thoothukudi district, out of 10 Firkas, 1 Firka falls in over-exploitation category **(Table – 4.3).** In other two districts, such as Madurai and Ramanathapuram no firkas are falling in over exploited and critical category. The groundwater management plan is concentrated only for OE and critical firkas.

Table 4.3: Firka wise Groundwater categorisation

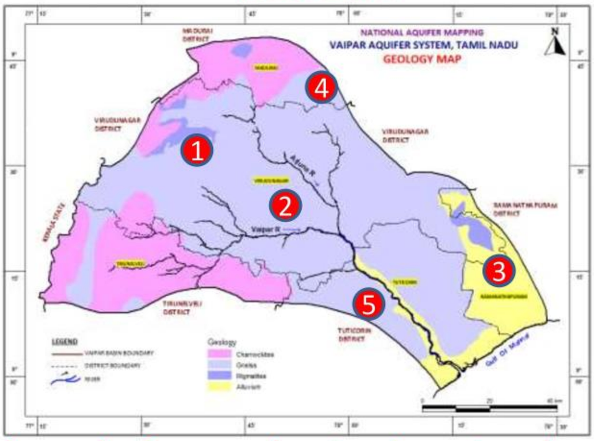
Districts	No of Firkas	Over Exploited Firkas	Critical Firkas	Total OE & Critical
Madurai	4	**Nil**	**Nil**	**Nil**
Ramanathapuram	5	**Nil**	**Nil**	**Nil**
Thoothukkudi	10	**1**	**Nil**	**1**
Tirunelveli	8	**5**	**Nil**	**5**
Virudhunagar	32	**7**	**6**	**13**
Total	**59**	**13**	**6**	**19**



5.0 GROUNDWATER RELATED ISSUE

The aquifer systems of the River Basin are highly stressed due to improper groundwater abstraction in the basin. Based on the available data, the groundwater issues of the basin have been identified and listed as follows. The identified issues are deliberated one by one.

ISSUES

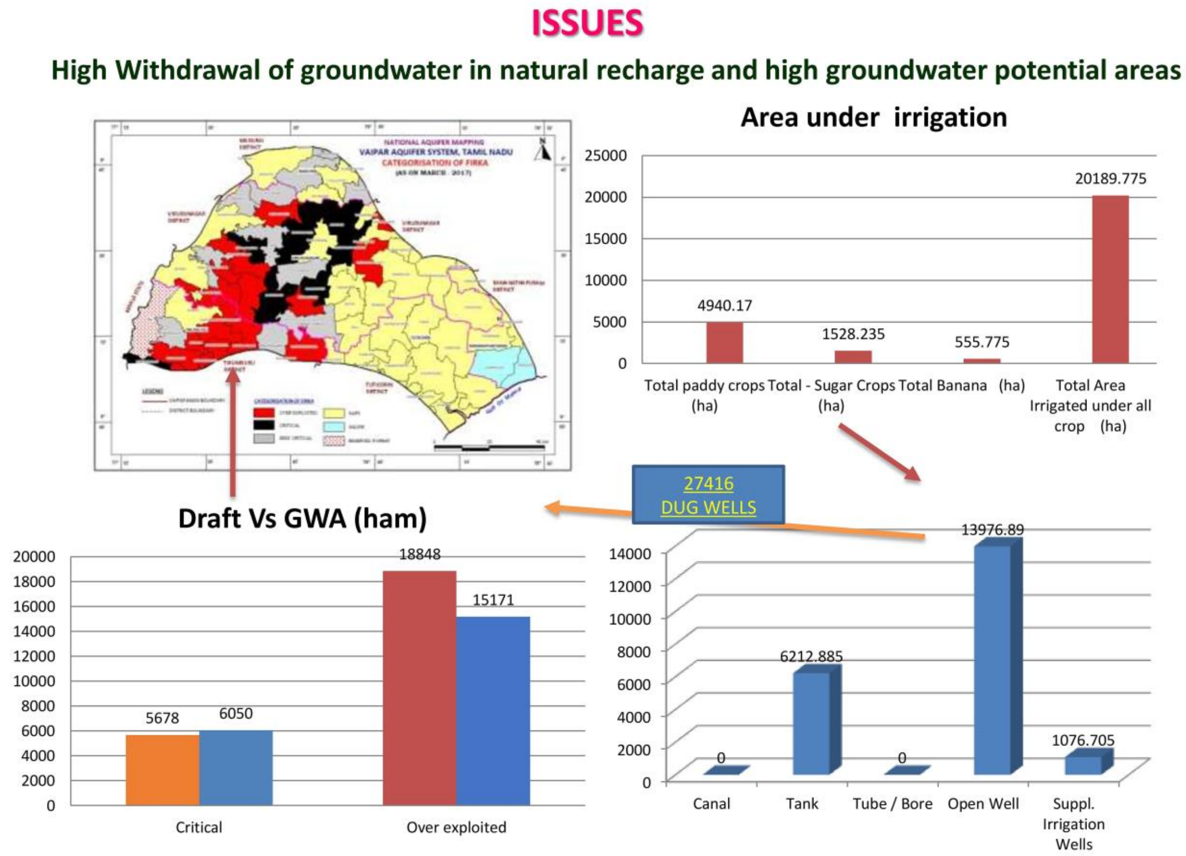


1. **High withdrawal of groundwater in natural recharge and high groundwater potential areas**
2. **Poor yielding aquifer and less groundwater movement areas**
3. **Saline aquifers**
4. **Geogenic (Fluoride) contamination in groundwater and Drinking water issues in Virudhunagar city.**
5. **Saline water in deeper aquifers of hard rock formation**

5.1 High withdrawal of groundwater in natural recharge and high groundwater potential areas:

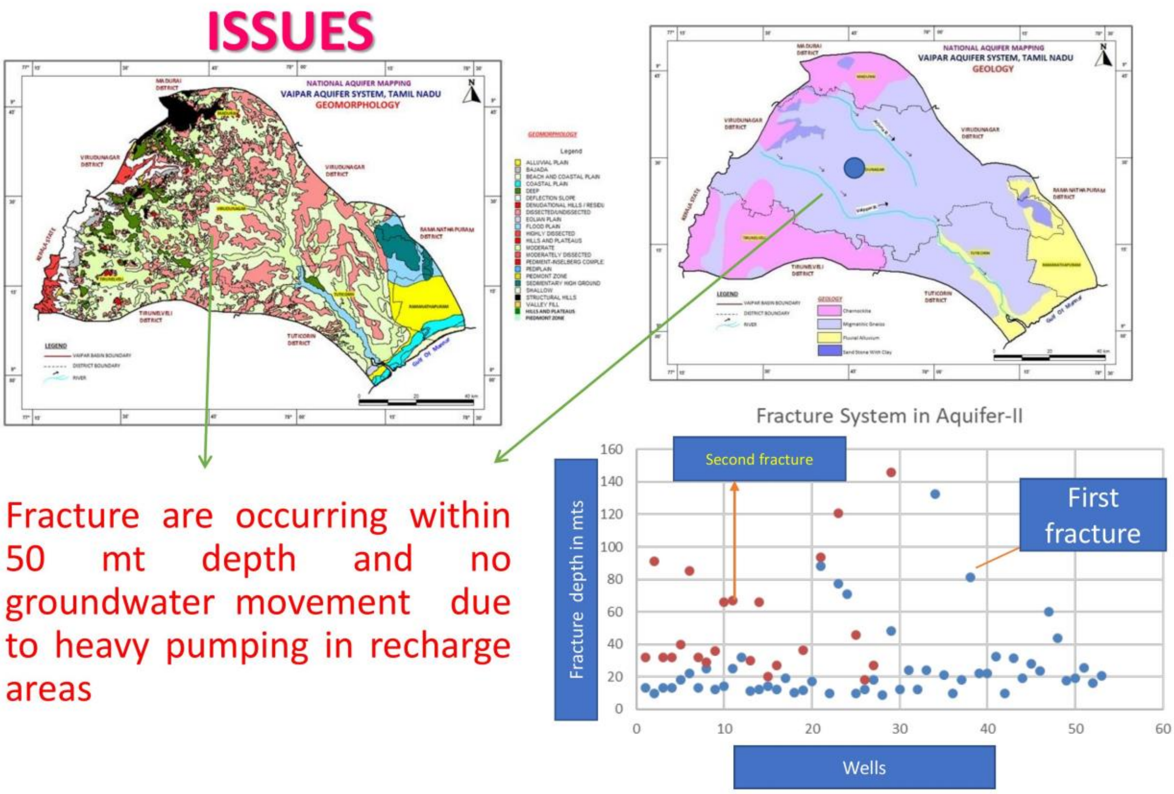
In the over exploited and critical firkas, number of borewells drilled in the zone of contact between gneiss and charnockites are having high yield and sustain for long duration. Western parts of the over exploited and critical areas are falling in higher elevation and falling sharply towards eastern direction which is formed by charnockite and gneiss formation. The difference of elevation is from 1000 to 400mamsl. It is indicating that the water falls in higher elevation will reach lower elevation with no time as run off. This water ultimately recharge the groundwater and it is proved that clusters of dug well and bore well are predominant in the area. These abstractions structures are mainly used for agriculture purposes. In the basin, total area irrigated under all crops is 20189 ha and water intensive crops such as paddy, sugar cane and banana are being cultivated using groundwater in the basin. Paddy, sugar cane and banana are irrigated in 4940 ha, 1528ha and 555ha respectively. Groundwater is main source of irrigation and the groundwater is abstracted mainly from dug well. 27146no of dug well are being used to irrigate13976.89 ha of land. High withdrawal of groundwater is noticed only in the western parts of two districts namely Virudhunagar and

Tirunelveli. In the basin, 21221ham of water is being recharged every year which is 42% of the total recharge of those districts. The total withdrawal of water every year in over exploited and critical area of the basin for irrigation purpose is 24526ham which is 115% of the total recharge. It is a continuous process every year leads to reducing the groundwater availability in the recharge areas.



5.2 Poor yielding aquifer and less groundwater movement

The aquifer of charnockite is poor yielding than gneiss and occurrence of fractures are restricted to the depth of 50mt.The yield of the aquifer is ranging from negligible to 1lps. The low yielding aquifer is generally occurring between two rivers flowing in the area which is mostly uplands. The uplands are formed by undissected plateau and low dissected plateau formed by charnockites. In the area major part of the groundwater recharge is taking place in the western part of the area. Due to availability of the groundwater, the groundwater is extensively utilised for the agriculture purposes in the groundwater recharge area. Groundwater is generally flow towards general slope of the area, high to low water level and conduce for the groundwater movement based on weathering and fracture existing in both the formation. The general slope of the area is towards east. The saturated groundwater in the western part of the area should move towards east. But the recharged water in western part of the area is taken for agriculture purposes before it started to flow downwards. Due to this, no hope for groundwater movement towards east. Due to the landforms of undissected and low dissected, groundwater neither can recharge nor transmitted to aquifer system. Due to heavy pumping in the western part of the area, water level is declined and created reverse flow of water i.e., from east to west. Hence, no hope for groundwater movement in the less potential aquifer area. The groundwater from fracture of less potential aquifer may not get from recharge areas in turn water may flow from less potential to high potential areas.

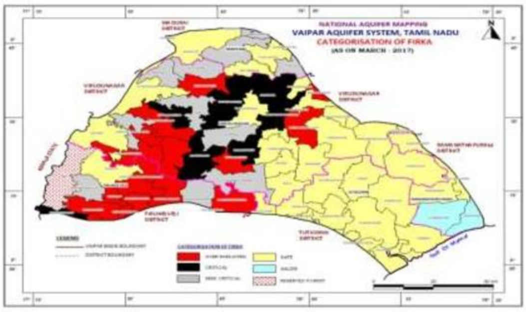


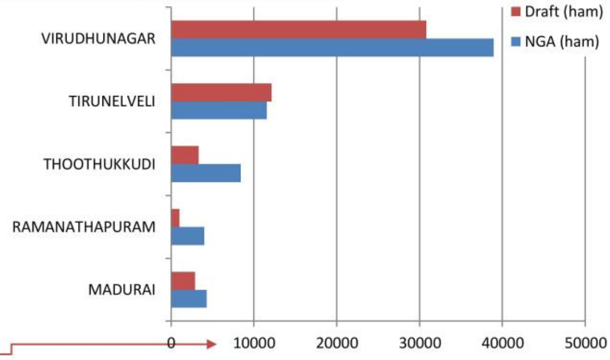
5.3 Over exploitation and safe category

As per Groundwater resources assessment, 19 Firkas fall under critical and over-exploited category out of 59 Firkas. In Virudhunagar district, out of 32firkas, 7 Firkas are categorised as critical and 6 over-exploited. In Thirunelvelli District, out of 8 Firkas, 5 Firkas are categorised as over-exploited. In Thoothukudi district, out of 10 Firkas, 1 Firka falls in over-exploitation category (Table – 4.2). In other two districts, such as Madurai and Ramanathapuram no firkas are falling in over exploited and critical category. In the basin, 28 and 10 firkas are safe and semi-critical category respectively. The semi critical firkas are falling in the peripheral area of the critical and over exploited category. The total recharge of groundwater in safe category is 31657ham which is extractable for all uses. However, only 11972ham of groundwater is being pumped for irrigation purposes. The stage of groundwater extractable for irrigation is 38% and for all purposes is 42%. In the safe area, agricultural practices are totally depending on groundwater only. The present groundwater extraction is indicating that yield of the borewell may be insufficient for irrigation and may not be suitable for irrigation purposes. Hence, the draft is very low for irrigation. The total recharge of groundwater for safe firka should not be taken in the same area instead recharge of the western part of the area may be considered. The total extractable groundwater may be reworked as it is not matching with the physical conditions. Therefore, the safe area cannot be used for further developments.

ISSUES

Over Exploitation

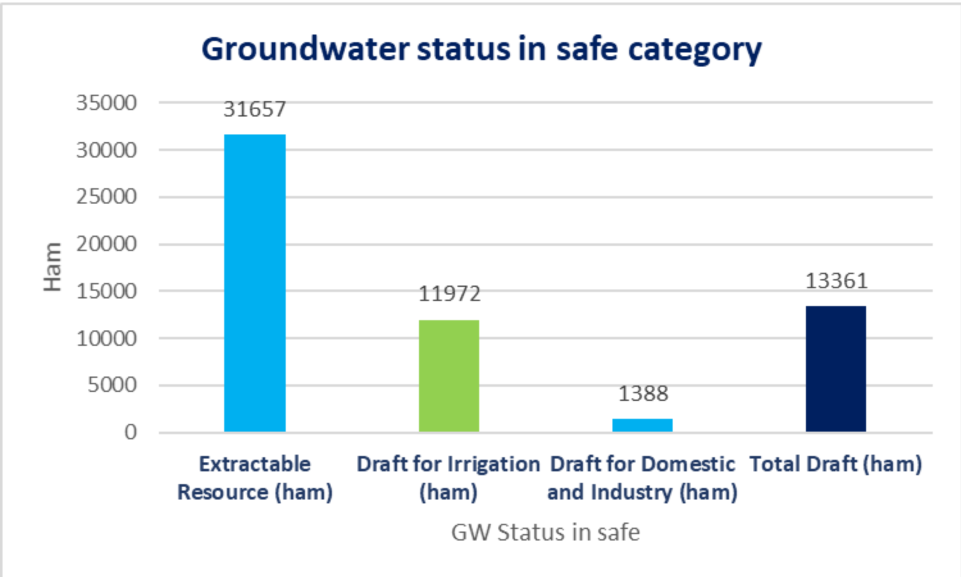




Groundwater Resource 2017			
Districts	Resource (ham)	Draft (ham)	Stage of GWD %
MADURAI	4279.8	2918.7	68.20
RAMANATHAPURAM	4012.1	993.4	24.76
THOOTHUKKUDI	8428.6	3308.2	39.25
TIRUNELVELI	11537.4	12122.3	105.07
VIRUDHUNAGAR	38953.7	30791.8	79.05
Total Basin (ham)	67211.6	50134.4	
Total Basin (MCM)	**672**		

Total Firkas – 59

- Over Exploited - 13
- Critical - 6
- Semi Critical - 10
- Safe - 28
- Saline - 2



5.5 Fluoride (F) concentration and distribution in Aquifer-I:

In the basin, Fluoride concentration in Aquifer-I is ranging from 0. 71mg.l at Mullikulam to 2.43mg/l at Kolluveerampatti. Based on BIS standard on groundwater quality for Fluoride concentration, groundwater is classified into three classes for drinking water purposes. Fluoride concentration between <1 mg/l in groundwater is comes under desirable limits which is highly suitable drinking water purposes. 16% of the water samples are having Fluoride concentration between <1 mg/l **(Table-5.1)**. Fluoride of 1-1.5mg/l concentration in groundwater are falling under permissible limits which is found in 48% of the water samples. Above permissible limits >1.5 mg/l which is not suitable drinking water purposes and it is found only in 36% of the water samples. These are mostly found in western parts of the area where the contact between gneiss and charnockite and also in the groundwater recharge areas **(Figure 5.1).**

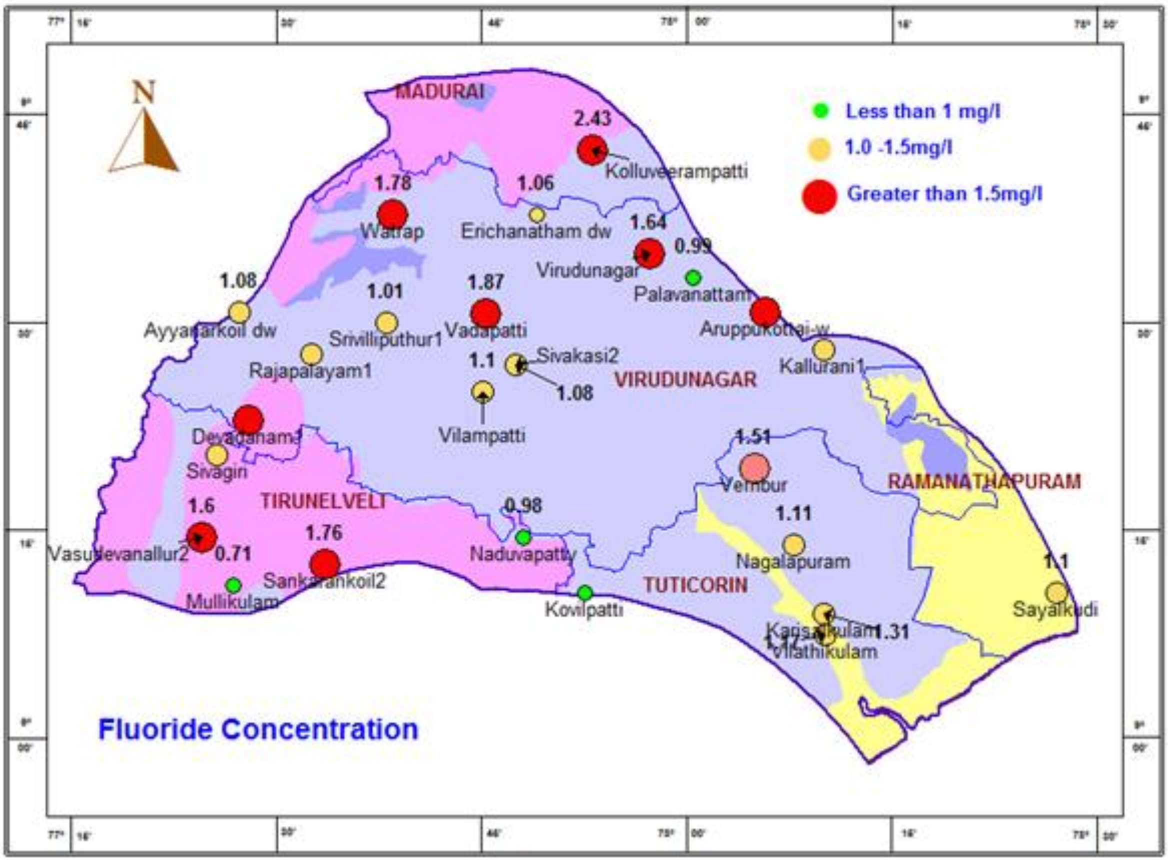


Figure 5.1: Point distribution of Fluoride in Groundwater (Aquifer-I)

Table 5.1: Groundwater Class based on Fluoride concentration

Chloride mg/L	Water Class	Percentage of Samples
0-1	Desirable limit	16
1-1.5	Permissible limit	48
> 1.5	Above permissible limit	36

5.4 Saline Aquifer

Based on the chloride concentration in groundwater and distribution of electrical conductivity in ground water, the aquifers of the basin are categorised as saline. In the basin, aquifers formed by the sedimentary formation are completely saline. The sedimentary formation is deposited by the marine agents.

5.5 Chloride (Cl) concentration and distribution in Aquifer-I and II

Based on BIS standard on groundwater quality for Chloride concentration, groundwater is classified into three classes for drinking water purposes. Chloride concentration in Aquifer-I is ranging between 14.18mg/l at Mullikulam to 1488 mg/l at Sayalkudi. Chloride concentration between 0.0 – 250 mg/l in groundwater is comes under desirable limits which is highly suitable drinking water purposes. 56% of the water samples are having chloride concentration between 0-250 mg/l. Chloride of 250-1000 mg/l concentration in groundwater are falling under permissible limits which is found in 40% of the water samples. Above permissible limits which is not suitable drinking water purposes and is found only in 4% of the water samples. In Aquifer-II, well drilled in Pillyarkulam is having the concentration of 30000 micro siemens per cm which is highly indicating that the aquifer is saline and marine origin. The groundwater of this area of the basin is not suitable for drinking and agriculture purposes.

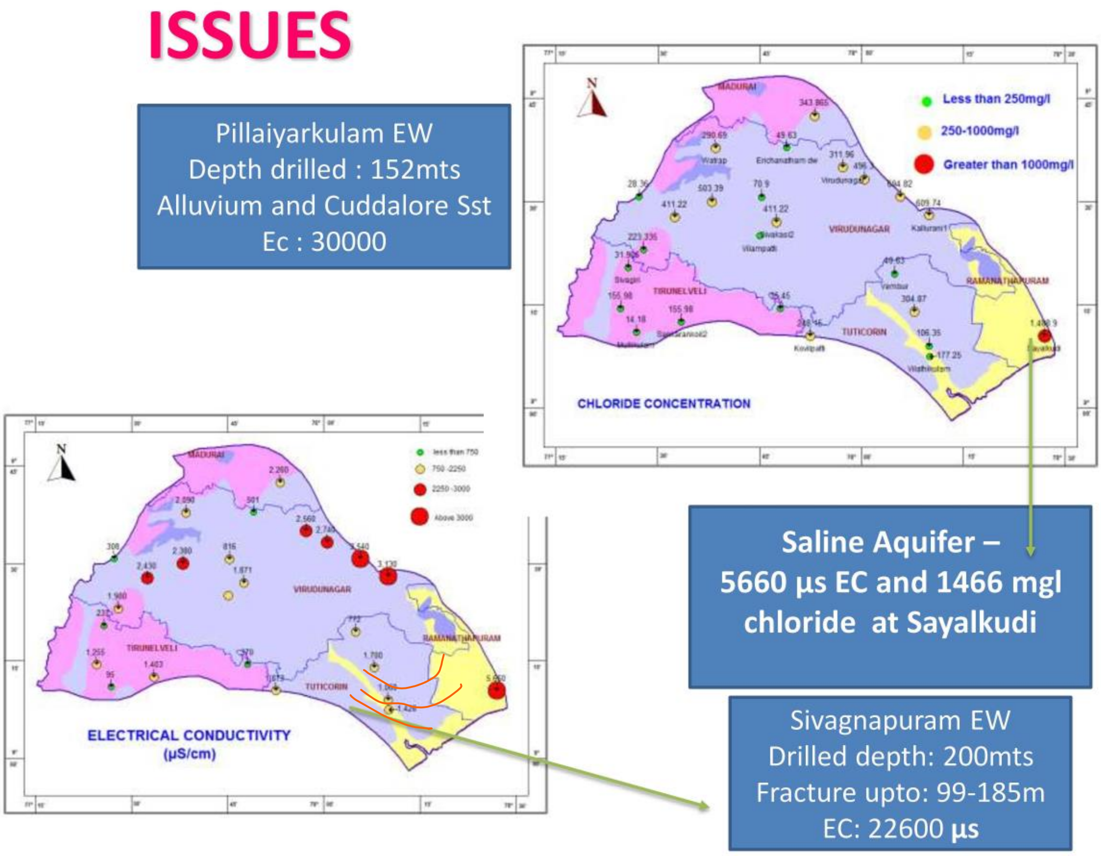


Table 5.2: Groundwater Class based on Chloride concentration

Chloride mg/L	Water Class	Percentage of Samples
0-250	Desirable limit	56
250-1000	Permissible limit	40
> 1000	Above permissible limit	4

An exploratory well at Sivagnapuram of Thoothukudi district was drilled to a depth of 200mts and fractured encountered from 99 to 185mt intermittently. The groundwater sample collected from these depths and analysed for groundwater quality. The electrical conductivity of the water sample shows 22600 micro mhos per cm. It is indicating that water may come from saline aquifers. The shallow aquifers of this area are not showing high EC. It is understood that the extractable fracture is getting water from saline aquifer due to head difference. This movement of water may be restricted upto the Vaippar river widening. It is also because of the elevation difference and extension of fault plan of sedimentary formation.

6.0 AQUIFER MANAGEMENT PLAN

6.1 Management Strategies

The stage of groundwater development in the Aquifer Basin is categorised as over exploited /critical in 19 firkas. The Net availability of the resource is 212MCM. The total ground water demand for the basin is 511MCM which includes demand for total irrigated area, drinking water, industry and also for total cultivable area in the 19 firkas. The supply of groundwater from the aquifer system is 252 MCM. The gap between demand and supply is 259MCM in the water stressed 19firkas (Table-6.1). To irrigate 100 % of the area, the groundwater alone cannot be used and it should meet from the surface waterbodies. Based on the supply of groundwater resources, the stage of groundwater development of the water stressed firkas is 118%. To bring safe groundwater development, 48% of groundwater development (i.e.,103MCM) should be added to the groundwater system of the 19 frikas. Therefore, supply side intervention is proposed in 19 firkas through groundwater augmentation plan as sufficient uncommitted surplus runoff of 214 MCM is available in those frikas. The most acceptable method for augmentation plan is artificial recharge to groundwater.

Table 6.1: Demand and supply groundwater resources of the basin

Sl.no	Management plan	In MCM
I	Demand	
1	Water Intensive Crops	121
2	Other Crops	384
3	Domestic and Industry	6
4	Total Demand	511
II	Supply	
1	Agriculture	246
2	Domestic and Industry	6
3	Total Supply	252
III	Demand - Supply Gab	259

6.2 Supply side intervention

Based on the water level monitoring in different seasons across the water stressed firkas, 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 356 MCM. The annual uncommitted runoff is 268MCM and 38 % of water from uncommitted runoff is required to fill the available void space of aquifer-I. Artificial recharge and Water conservation plan is prepared firka wise to harness 85 MCM of water with a total out lay of Rs. 107 Crores. The suggested artificial recharge structures are mainly Check Dams and Recharge Shafts in addition to the removal of silt in the surface water bodies.

6.2.1 Artificial recharge structure plan

Artificial recharge zones maps have been superimposed with drainage and surface water body maps to select suitable sites for artificial recharge structures. Check dams were selected based on the availability of drainage / streams in the basin. Check dam is constructed across the first and second order stream. Surface water body has been mapped using Remote sensing data. The village pond has been identified and those village ponds having size of less than 0.025 sq.km are selected for Recharge Rejuvenation Ponds (RRP). RRP is done through de-siltation of pond to increase storage which will induce the groundwater recharge. Percolation pond is also selected based on the size of the surface water body (more than 0.025 sq.km.) in both the ponds, recharge shaft is suggested which can recharge the fractured aquifer overlain by non-permeable layers. The list of tentative proposed loccatios of ARS are presented in **Annexure-V.** Groundwater management plan was prepared to show the location of ARS and area suitable for micro irrication for basin **(Figure-6.1)** and as well as Firka (OE and Critical) wise in the basin **(Figure-6.2-20)**.

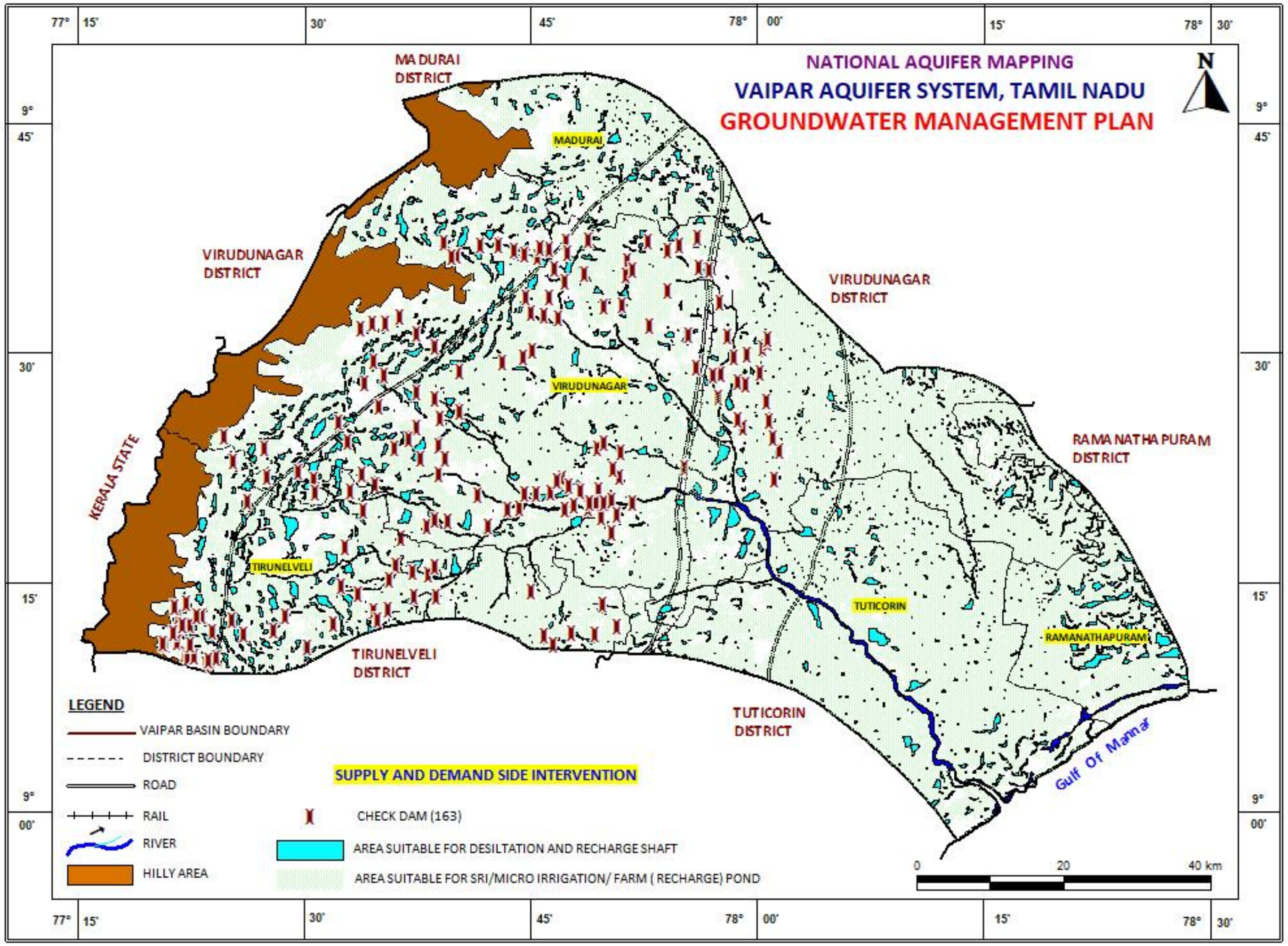


Figure 6.1: Groundwater management plan for basin

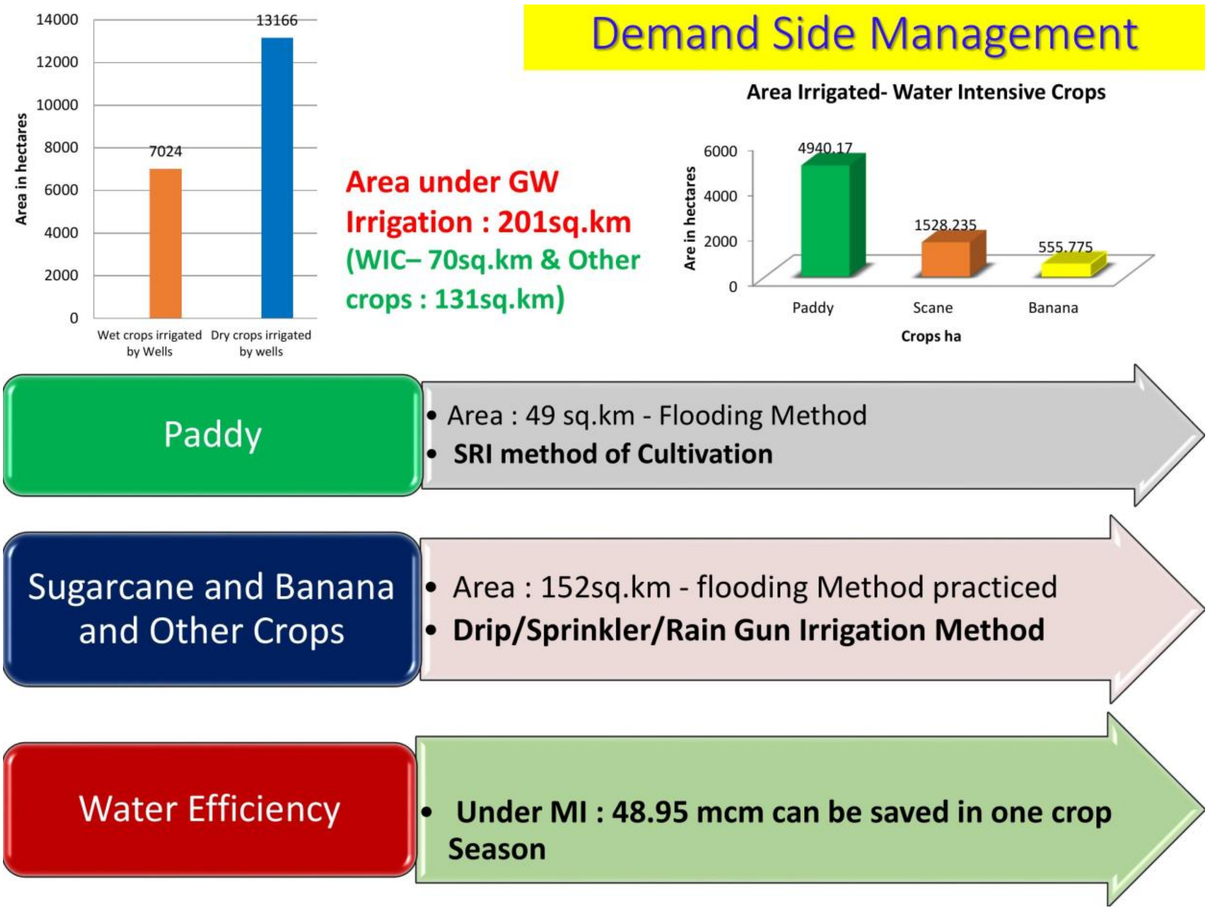
A total number of 163 check dams and 163 recharge shafts are proposed in the OE and critical firkas of the basin (Figure-6.1 and Figure 6.2 – 6.20). A total number of 655 Recharge Rejuvenation Ponds are selected for desilting followed by construction of recharge shafts within the tanks. A total number of 1470 of 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 7.6 MCM. The recharge pond area has been selected based on the wet and dry crop area from the landuse / landcover maps using remote sensing data. The expected recharge through these artificial recharge structures is 85 MCM which contributes 82% of the 103MCM.

Supply Side Management

ARTIFICIAL RECHARGE /CONSERVATION MEASURES		
Artificial Recharge Structures Proposed	Masonry Check dams : Recharge shafts (CD: 163) : Repair and Rejuvenation Recharge ponds : Recharge shaft alone in Tanks : Tanks :655 Area:145sqkm	163 163 655 1420 1101
Tentative total cost of the project (Rs.)	:	107Cr
Vol. of unsaturated zone available for Recharge (upto 3m bgl)	:	356.45 MCM
Uncommitted Surplus runoff	:	268.84 MCM
Harnessable runoff	:	214 MCM
Expected recharge	:	85 MCM
Expected outcome	Arrest Decline in Groundwater levels (or) Increase pumping hours (or) Increase in sustainability of well yield (or)	
Reduced stage of groundwater development from 118 % to 85 %		

6.3 Demand side Management Plan

Demand side management can be accomplished through change in irrigation pattern. It is recommended to change the irrigation pattern and practices for paddy, Sugarcane and Banana crops. The general practice for water intensity crops is by flooding method and covering in 70sqkm area of water stressed firkas. In the water stressed firkas, other than water intensity crops, dry crops are taken Widley which is covering in 131sqkm area. In general, water efficiency techniques would save upto 40% of the water requirements. Therefore, it is recommended ridge and furrow method for paddy and other crops drip/sprinkler/rain gun methods are suggested. The total water saved is 48.95 MCM. The total cost for the change in the irrigation pattern for those measures would be 152 crores.

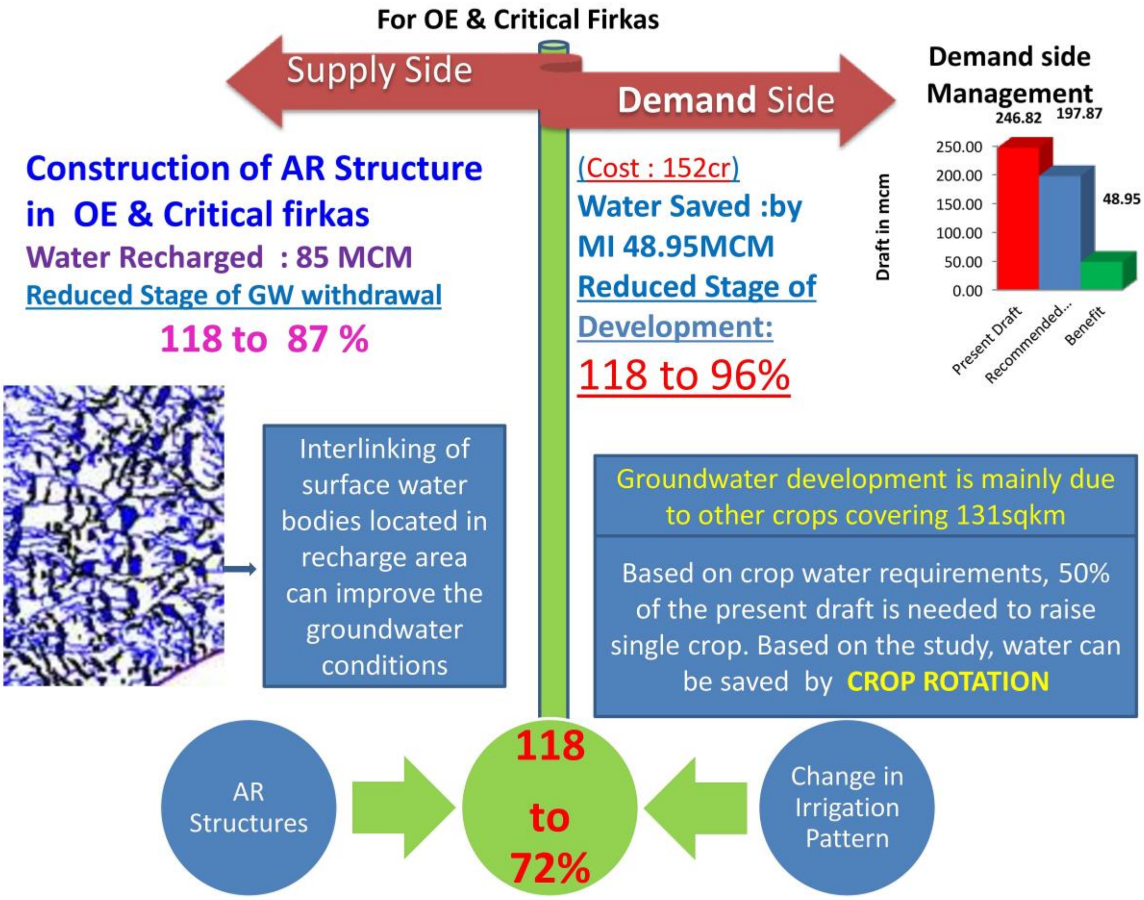


6.4 Savings of In-storage

The groundwater development in the water stressed firkas is 118% as per the prorate basis against the groundwater availability of 212MCM. Of the 212 MCM, 18% i.e., 38.16MCM of groundwater is utilised more every year from replenishable recharge. To reach the safe groundwater development in the water stressed firkas, measures are suggested and estimated the in-storage savings to groundwater systems. The water intensive and cash crops such as paddy, sugar cane and banana and also dry crops are consuming lion share of water for cultivation. By adopting the micro-irrigation systems and ridge and furrow techniques for those crops, water using efficiency varies from 13 % to 40% which save 48.95 MCM in the aquifer system. After the intervention of water conservation measures, the groundwater in-storage is increased by 260.95MCM. By enhancing these resources, the stage of groundwater development is reduced from 118% to 96%. The in-storage augmented through ARS is 85MCM. Due to this recharge, the groundwater resource is increased by 297 MCM and change of groundwater development is 84%. The additional groundwater resource available by both supply and demand side the intervention is 133MCM. The total available groundwater resource in the water stressed firka is 345MCM and the stage of groundwater development with present draft is 72%. The groundwater is mainly used for cultivating the dry crops in the area covering 133sqkm.

Based on the crop water requirements, 50% of the present irrigation draft i.e., 122MCM of water is needed to raise single crops. To reduce the present draft, it is recommended for crop rotation and agro forest by introducing Miyawaki method into the dry land agriculture.

All artificial recharge is recommended in the water stressed firkas. To make more effective of the recharge, linking of surface water bodies which is existing in the western parts of the area are suggested. The water bodies are occurring linearly trending NE-SW direction across the general flow of water. It is also added advantage that all the surface waterbodies are occurring in the natural recharge areas. All the surface waterbodies can be loaded by water from the Vaippar and Arjuna Rivers which is cutting across the areas. A simple barrier is sufficient to push the water into the surface waterbodies during the spat of rivers.



6.5 Roof Top Rainwater Harvesting

In the water stressed firkas, Virudhunagar city is located and It is a major urban sprawl in the basin. The total population of the city is 70000 and It is totally depending on surface waterbody for the drinking and domestic water purposes. Total water requirements for one year at the rate of 7MLD is 2555ML. At present, 1410ML is supplied from the River Arjuna located about 19 km from Virudhunagar. The total water demand for the city is 1145ML.

Roof Top Rainwater Harvesting Plan for Virudhunagar City

Water Demand for the Population of 70000	
Total Water Requirement per Year @ 7 MLD	2555ML
Present Water Supply	1410ML
Water Demand	1145ML

Roof Top Rainwater harvesting

Total Area (sqkm)	Total Area (sqm)	Roof Area (50% and 30%)	Roof Area *Rainfall	Total water available from roof (cum)	Total water available from roof (ML)	Sustain for No days
6.39	6390000	3195000	1917000	1917000000	1917	274
6.39	6390000	1917000	1150200	1150200000	1150	164

Roof Area (50% and 30%)	Rain fall (m)	No of days	Total water available from roof (cum)	Total water available from roof (lit)	Total water available from roof (ML)	Sustain for No days
3195000	0.1	5	1597500	1597500000	1597.5	228
1917000	0.1	5	958500	958500000	958.5	137

To meet the water demand of the Virudhunagar city, Roof Top rain water harvesting plan was suggested. The plan was prepared in two scenarios. Scenario -1 is based on annual rainfall of the area and Scenario-II is based on the frequency of the rainfall in a day.

Scenario-I: The total geographical area of the city is 6.39 sqkm and it is considered as water catchment or roof area. The estimation is made for the 50% and 30% area of the city by avoiding the open area. The average annual rainfall of the city is 600mm. Based on the estimation, total available water from 50% and 30% roof area are 1917ML and 1150ML respectively. Based on the water demand, 1917ML is sustain for 274days for drinking water purposes and 1150 ML is sustain for 164 days for drinking water purposes of the city.

Scenario-II: By assuming the rainfall in a day is 10cm and it is continuing for 5days, the total water available from 50% of the roof is 1597ML which can serve for the city upto 224 days and if the area is 30%, water available from roof is 958ML. It can used for 137days. Water collected from the either used directly or stored in the subsurface tank.

Use and Return scheme: Due to increasing population and urban development, supplying of drinking water to individual house hold is Himalayan task. It is possible to get water every house by implementing Use and Return scheme. The main aim of the scheme is to give back the water which is used. In the city, 80 to 90% of the houses are constructed with concrete roof. This roof area can used as catchment area for roof top rainwater harvesting. Collected water should be stored in the place where the source is available. In a virgin area, two pipes lines should be laid in a trench in which one is used for water supply and other one used for collecting from the individual roof. A community sub surface tank should be constructed to store the water. The water collected from the roof should be free from all contamination by filtering the water. In the market portable water filter is available to purify the water. Conventional filter bed also can be used to purify the water. The excess water can be stored in the surface waterbodies.

7.0 ACTION FOR GROUNDWATER PLANNERS

Issues identified	Remedial Measures Recommended	Action Required
High withdrawal of groundwater in natural recharge and high groundwater potential areas	• 100 % water efficiency method of irrigation • Surface water bodies linking in the recharge areas	Government /Farmers Government
Poor groundwater aquifer and less groundwater movement	• Enhancing the groundwater recharge and optimisation of pumping in the natural groundwater recharge areas allows the groundwater movement to lass groundwater areas. • Hydro-fracturing in the shallow aquifers particularly in Charnockite formation in the uplands between two river systems. • Both the endeavour will increase the groundwater potential and groundwater movement	Government Farmers
Over exploitation and safe category	• Implementation of ARS project for OE and critical category • Recharge component for safe category should be taken from groundwater recharge areas and recharge of the groundwater should match with the specific yield of the aquifers	Government Government
Fluoride (F) concentration and distribution in Aquifer-I	• Implementation of ARS project for dilution of the groundwater where the groundwater is contaminated with E ranges from1 to 1.5mg/l. • In place where F concentration is above permissible limit, my own Roof water plan may be implemented • A permanent storage tank should be fitted with filter to collect the rain water from own roof and use the water directly which is free from any contaminations. It is followed in	Government Government / Individual Individual

	island like Lakshadweep.	
Saline aquifer	✚ Deeper aquifers in hard rock formation near coastal areas are reported saline in nature. This may be due to saline water intruded from coastal aquifers and sedimentary formations. Hence, extraction of groundwater from user aquifers should not develop low piezometric head difference to avoid the saline water movement to fresh water. ✚ Recharge structures should be constricted across the basin at Vaippar river gets widen it width to recharge the deeper aquifers. It will help in recharge as well try push the saline water intrusion from the coastal aquifers.	Government Government
Water Scarcity in Virudhunagar city	✚ Roof top rain water harvesting	Government /Individual

Annexure-I: Details of aquifer properties of the Basin collected through groundwater exploration

DISTRICT: VIRUDHUNAGAR

HARD ROCK AREA

Sl. No.	Location, Well number, Co-ordinates, Toposheet Number and R.L. of G.L. (mamsl)	Depth drilled / Casing Pipe Lowered (mbgl)	Lithology	Fracture zones encountered (mbgl) / Discharge (lps)	Type of preliminary yield Test & Results (*)	Results of aquifer performance test: SWL (mbgl) / Date	Discharge (lps) / Drawdown (m)	Specific capacity (lpm/m of Draw down)	T (m²/ day)	S	EC	Cl	Remarks
1	**ILLUPAIYUR(SH-II)-4415** (09° 28' 00";78° 05' 15" - 58 K/7) 48.820	100.00 13.89	Granite associated with charnockite	13.00-16.00 / 0.50 32.00-36.00 / 0.80 60.00-63.00 / 1.80 88.00-91.00 / 2.80	--	3.768 15.3.77	3.23 13.91	13.94	130.78	--	4600	1136	
2	**M.NAGALAPURAM(EW)-4426** (09° 18' 30";78° 00' 45" - 58 K/3) 46.855	100.00 1.40	Granite Pegamatitic	25.00-26.00 / 0.254 29.00-30.00 / 0.2175 49.00-50.00 / 0.443	--	3.170 15.4.77	0.70 8.233	4.90	--	--	1675	190	
3	**N. METTUPATTI(EW)-4427** (09° 20' 15" ;78° 00' 45"- 58 K/3) 54.305	100.00 1.30	Granite Gneiss	12.00-16.00 36.00-37.00 56.00-57.00 66.00-68.00	--	7.086 27.4.77	very low 0.10 8.475	0.70	1.98	--	1140	142	
4	**VEMBAKKOTTAI(EW)-4420** (09° 20' 00";77° 46' 00" - 58 G/15) 87.110	100.00 6.30	Hornblende Biotite Gneiss	12.00-16.00 / 1.48 66.00-68.00 / 1.79	--	7.12 19.8.77	2.73 10.54	13.84	--	--	1570	53	
5	**VEMBAKKOTTAI(OW)** 87.800	50.00 10.80	Hornblende Biotite Gneiss	--	--	7.11 19.8.77	-- 3.59	--	24.09	--	--	--	
6	**SEVALPATTI(EW)-4419**	100.00	Granitic	14.00-16.00 / 0.10	--	4.83	0.63	4.41	25.07	--	985	92	

	(09° 18' 15";77° 44' 30" - 58 G/11) 94.865	3.35	Charnockite	20.00-21.00 / 0.20 66.00-68.00 / 0.35 87.00-88.00 / 0.35 96.00-97.00 / 0.35		26.8.77	8.616						
7	**SRIVILLIPUTHUR(EW)-4407** (09° 30' 35";77° 37' 50"-58 G/10) 135.105	200.00 15.40	Granite Gneiss	No fractures were encountered	--	--	--	--	--	--	--	--	DRY
8	**KRISHNANKOIL(EW)-4409** (09° 33' 55";77° 41' 20"-58 G/10) 141.50	200.00 7.50	Granite, Gneiss Charnockite	11.80-12.80 / 0.20 36.20-37.20 / 1.70 92.10-93.10 / 3.39	--	4.60 4.1.95	2.40 2.65	--	0.20	--	436	14	
9	**KRISHNANKOIL (OW)** 141.500	120.00 9.40	Granite Gneiss Charnockite	27.20-28.20 / 0.70 at 42.50 / 4.90	--	--	--	--	--	--	--	--	
10	**KURICHIYARPATTI (EW)** 9°21'40";77°36'15"-58G/11	201 12.5	Charnockite	132.50-133.00/0.078		11.3 02.11.04	0.078 --	--	--	--	823	78	No test was conducted 0.22
11	**MALAIPATTI (EW)** 9°28'30";78°00'30"-58K/3	174.9 11.5	Charnockite	10.00-11.00/0.078 164.00-165.00/3.34	--	8.06 11.12.04	1.79 58.16	1.8	1.89	--	3180	980	0.3

DISTRICT: RAMANATHAPURAM

SOFT ROCK AREA

Sl. No.	Location Co-ordinates Toposheet Number and R.L. of G.L. (amsl)	Depth drilled / constructed (mbgl)	Lithology	Depth to Bed rock (mbgl)	Granular zones deciphered (mbgl)	Aquifer zones tapped (mbgl)	Type of Test & depth range of zone tested (mbgl)	Results of zone test & yield (lps)	SWL (mbgl) / Date	Results of Aquifer Performance Test: Discharge (lps) / Drawdown (m)	Specific capacity (lpm/m of DD)	T (m² / day)	S	EC	Cl
1	**PILLAIYARKULAM (EW)-2634** (09° 10' 30" ; 78° 27' 00"-58 K/8) 9.420	152.16 / 43.50	Sand and Clay with limestone garnetiferrous Gneiss	150.16	12.50-16.50 23.70-29.70	22.50-40.50	Zone Test 12.00-18.00 22.00-28.00	EC-5415 EC-5415	5.565 / 26.1.89	4.50 / 2.615	10.50	603	--	30000	9048
2	**PILLAIYARKULAM (OW)**	36.00 / 34.50	Sand and Clay with limestone	--	--	22.50-31.50	--	--	--	--	--	--	--	20000	--
3	**KARISALKULAM(EW)-2626** (09° 18' 00"; 78° 24' 00"-58 K/8) 33.265	68.85 / 40.15	Sand and clay weathered granite	68.00	10.00-24.00 28.00-37.00	10.00-22.04 28.08-37.12	--	--	7.98 / 20.9.88	4.50 / 1.21	223	3616.84	--	--	7900

DISTRICT: MADURAI

HARD ROCK AREA

Sl. No.	Location, Well number, Co-ordinates, Toposheet Number and R.L. of G.L. (mamsl)	Depth drilled / Casing Pipe Lowered (mbgl)	Lithology	Fracture zones encountered (mbgl) / Discharge (lps)	Type of preliminary yield Test & Results (*)	Results of aquifer performance test: SWL (mbgl) / Date	Discharge (lps) / Drawdown (m)	Specific capacity (lpm/m of Draw down)	T (m²/ day)	S	EC	Cl	Remarks
1	**PERAIYUR (EW)-2032** (09° 44' 22" ;77° 47'21"-58 G/14) 169.255	136.00 / 6.00	Granite Gneiss Charnockite	20.21 / 0.20 63.57 / 0.70 64.57 / 1.20 97.05 / 8.40 99.05 / 12.02	--	12.17 / 10.6.94	6.21 / 4.51	82.61	103.23	8.7×10^{-3}	555	14	
2	**PERAIYUR (OW)** 169.745	102.00 / 5.50	Granite Charnockite	90.43-91.43 / 2.40 96.05-98.05 / 3.3	--	11.75 / 11.6.94	--	--	196.1	--	530	21	
3	**VILLUR (EW)-2034** (09°42' 30" ;77° 55'00"-58 G/14) 442.850	180.00 / 5.50	Granitic Gneiss and Charnockite	43.00-43.20 / Nil 135.0-135.75 / 1.20	--	7.53 / 14.9.94	--	--	--	--	--	--	DRY

DISTRICT: TIRUNELVELI

HARD ROCK AREA

S. No.	Location, Well number, Co-ordinates, Toposheet Number and R.L. of G.L. (mamsl)	Depth drilled / Casing Pipe Lowered (mbgl)	Lithology	Fracture zones encountered (mbgl) / Discharge (lps)	Type of preliminary yield Test & Results (*)	Results of aquifer performance test: SWL (mbgl) / Date	Discharge (lps) / Drawdown (m)	Specific capacity (lpm/m of Draw down)	T (m²/day)	S	EC	Cl	Remarks
1	**SIVAGIRI (EW) - 3801** (09° 14' 30";77° 29' 30" 58 G/8) 168.380	212.00 / 18.00	Chamockite	6.75-16.75 / 2.50	Air Test T1 =4.762 T2= 32.94 Slug Test T=15.17	3.30 / 23.7.91	--	--	--	--	933	28	Pumping Test was not cond-ucted due to low yield.
2	**VASUDEVANALLUR(EW) -3802** (09°14' 30";77° 29' 30" 58 G/8) 176.750	205.00 / 15.00	Chamockite	6.00-15.00 / 3.10	Air Test T=33.8 Slug Test T=22.8	6.05 / 9.8.91	--	--	--	--	1500	192	Pumping Test was not cond-ucted due to low yield
3	**VASUDEVANALLUR (OW)** 176.305	20.40 / 15.00	Chamockite	6.00-15.00 / 1.43	--	5.90 / 17.8.91	--	--	--	--			
4	**SANKARAN KOIL (EW)- 3804** (09° 09' 10";77° 32'15"-58 G/11) 147.830	196.00 / 12.00	Chamockite	10.00-10.50 / 0.77 (Arrested ByPipe) 20.20-21.20 / 0.10	Slug Test T = 5.2	6.30 / 27.8.91	--	--	--	--	2010	596	Pumping Test was not cond-ucted due to low yield

5	**THIRUVENGADAM(EW)-3803** (09° 15' 25"; 77° 39'45"-58 G/11) 101.560	200.00 12.50	Chamockite	03.00-04.00 / 1.00 (Arrested ByPipe) 20.30-21.30 / 0.10	Slug Test T = 0.875	3.10 10.9.91	- --	--	--	--	2010	596	Pumping Test was not cond-ucted due to low yield
6	**KOVILUR (EW)** 09°18'45";77°29'35"-58G/7	201 10.90	Charnockite	21.00-21.50/1.00	--	13.2 22.11.04	1.49 5.21	17.2	20.04	--	390	18	1.01

DISTRICT: TUTICORIN

HARD ROCK AREA

S.No.	Location Co-ordinates Toposheet Number and R.L. of G.L. (amsl)	Depth drilled pipe lowered (mbgl)	Geology	Fracture zones encountered (m.b.g.l)/ Discharge (lps)	Type of preliminary yield Tests & Results (*)	Results of aquifer performance test SWL (mbgl) Date	Discharge (lps) Drawdown (m)	Specific capacity (lpm/m) of DD	T (m² / day)	S	EC	Cl	Remarks
1	**VILATTIKULAM(EW)-5003** (09° 08' 10" ; 78° 10' 25"-58 K/4)	93.00 24.50	Chamockite	24.50-30.00 / 3.34 60.9-62.0 / 4.28	APT	5.45 (16.8.93)	0.70 65.5	0.645	0.252	--	2860	319	--
2	**VILATTIKULAM (OW)**	150.00 24.50	Chamockite	79.10-80.0 / 1.00 89.40-90.40 / 1.50	Slug Test T = 3.79	--	--	--	--	--	--	--	--
3	**VADALAKARAI(EW)-5004** (09° 11' 15" ; 78° 12' 40")	116.90 20.00	Chamockite	10.00-12.00 / 2.00 (Arrested) 30.40-31.5 / 1.50	--	--	--	--	--	--	--	--	--

Annexure-II: Groundwater level of pre-and post-monsoon in the basin (Aquifer-I)

S.no	District	Location	Latitude	Longitude	Decadal average Water level in mts (May 08-May 17)	Decadal average water level in mts (Jan 09-Jan 18)
1	Madurai	Sedapatti	9.7500	77.6750	6.68	7.02
2	Ramanathapuram	Sayalkudi	9.1750	78.4500	4.30	4.73
3	Tirunelveli	Chintamani	9.1667	77.4000	2.55	4.78
4	Tirunelveli	Naduvapatty	9.2417	77.8014	7.57	7.62
5	Tirunelveli	Sankarankoil1	9.2083	77.5583	8.93	9.76
6	Tirunelveli	Sivagiri	9.3403	77.4278	7.68	8.43
7	Tirunelveli	Vasudevanallur2	9.2417	77.4083	8.50	10.54
8	Tuticorin	Karisalkulam	9.1500	78.1667	8.65	11.45
9	Tuticorin	Mettupanaiyur dw	9.0317	78.2522	6.94	8.14
10	Tuticorin	Nagalapuram	9.2333	78.1306	2.42	5.08
11	Tuticorin	Vembur	9.3250	78.0819	6.03	7.50
12	Virudhunagar	Aruppukottai-w	9.5125	78.0958	5.04	6.45
13	Virudhunagar	Ayyanarkoil dw	9.5117	77.4542	5.73	8.23
14	Virudhunagar	Choolapuram	9.3833	77.5583	9.40	8.81
15	Virudhunagar	Devadanam1	9.3833	77.4656	8.97	13.29
16	Virudhunagar	Erichanatham dw	9.6308	77.8167	8.35	8.42
17	Virudhunagar	Kalloorani dw	9.4639	78.1650	9.65	10.76
18	Virudhunagar	Mullikulam	9.1833	77.4472	10.74	11.47
19	Virudhunagar	Nenmeni1	9.3250	78.0083	5.21	8.49
20	Virudhunagar	Rajapalayam1	9.4625	77.5417	4.76	8.28
21	Virudhunagar	Sivakasi2	9.4500	77.7917	3.97	3.75
22	Virudhunagar	Srivilliputhur1	9.5000	77.6333	8.04	10.48
23	Virudhunagar	Vadapatti	9.5108	77.7550	12.39	11.90
24	Virudhunagar	Vilampatti	9.4169	77.7506	6.49	11.35
25	Virudhunagar	Virudunagar	9.5833	77.9542	2.51	2.25

Annexure-III: The details of Chemical quality of groundwater (Aquifer-I)

S.No	Location	Latitude	Longitude	District	Block	EC micro siemens/cm	Cl mg/l	F mg/l
1	Kolluveerampatti	9.7069	77.8856	Madurai	T.Kallupatti	2260	343.865	2.43
2	Sayalkudi	9.1750	78.4500	Ramanathapuram	KADALADI	5660	1488.9	1.1
3	Mullikulam	9.1833	77.4472	Tirunelveli	MELANEELITHANALLUR	95	14.18	0.71
4	Sivagiri	9.3403	77.4278	Tirunelveli	VASUDEVANALLUR	237	31.905	1.1
5	Naduvapatty	9.2417	77.8014	Tirunelveli	KURUVIKULAM	370	35.45	0.98
6	Sankarankoil2	9.2083	77.5583	Tirunelveli	SANKARANKOIL	1403	155.98	1.76
7	Vasudevanallur2	9.2417	77.4083	Tirunelveli	VASUDEVANALLUR	1255	155.98	1.6
8	Vembur	9.3250	78.0819	Tuticorin	PUDUR	772	49.63	1.51
9	Karisalkulam	9.1500	78.1667	Tuticorin	VILATHIKULAM	1060	106.35	1.31
10	Vilathikulam	9.1250	78.1681	Tuticorin	VILATHIKULAM	1426	177.25	1.17
11	Kovilpatti	9.1750	77.8750	Tuticorin	KOVILPATTI	1873	248.15	0.93
12	Nagalapuram	9.2333	78.1306	Tuticorin	PUDUR	1700	304.87	1.11
13	Ayyanarkoil dw	9.5117	77.4542	Virudhunagar	RAJAPALAYAM	308	28.36	1.08
14	Erichanatham dw	9.6308	77.8167	Virudhunagar	SIVAKASI	501	49.63	1.06
15	Vadapatti	9.5108	77.7550	Virudhunagar	SIVAKASI	816	70.9	1.87
16	Vilampatti	9.4169	77.7506	Virudhunagar	SIVAKASI	773	81.535	1.1
17	Devadanam1	9.3833	77.4656	Virudhunagar	RAJAPALAYAM	1900	223.335	1.76
18	Watrap	9.6303	77.6417	Virudhunagar	WATRAP	2090	290.69	1.78
19	Virudunagar	9.5833	77.9542	Virudhunagar	VIRUDHUNAGAR	2560	311.96	1.64
20	Rajapalayam1	9.4625	77.5417	Virudhunagar	RAJAPALAYAM	2430	411.22	1.36
21	Sivakasi2	9.4500	77.7917	Virudhunagar	SIVAKASI	1871	411.22	1.08
22	Palavanattam	9.5542	78.0083	Virudhunagar	ARUPPUKOTTAI	2740	496.3	0.99
23	Srivilliputhur1	9.5000	77.6333	Virudhunagar	SRIVILLIPUTTUR	2380	503.39	1.01
24	Kallurani1	9.4667	78.1667	Virudhunagar	TIRUCHCHULI	3130	609.74	1.1
25	Aruppukottai-w	9.5125	78.0958	Virudhunagar	ARUPPUKOTTAI	3540	694.82	1.84

Annexure-IV: Groundwater Resources of basin (GEC-2017)

S.No	DISTRICT	TALUK	BLOCK	FIRKANAME	EXTRACTABLE GROUNDWATER (HaM)	DRAFT FOR IRRIGATION (HaM)	DOMESTIC AND INDUSTRY DRAFT(HaM)	TOTAL DRAFT (HaM)	Provision for domestic and industrial requirement supply to 2025	Net Ground Water Availability for future irrigation development (10-11-14)	GROUNDWATER DEVELOPMENT (%)	CATEGORY
1	THOOTHUKKUDI	KOVILPATTI	Kurivikulam	ILAYARASANENDAL	824.19	933.00	37.03	970.03	45.49	0.00	117.694	Over exploited
2	TIRUNELVELI	SIVAGIRI	Vasudevanallur	Gudalur	1116.92	1245.25	40.38	1285.63	48.10	0.00	115.104	Over exploited
3	TIRUNELVELI	SANKARANKOIL	Kurivikulam	Karisal kulam	1086.62	1888.80	52.79	1941.59	62.89	0.00	178.682	Over exploited
4	TIRUNELVELI	SANKARANKOIL	Sankarankoil	KARIVAKLAMVANDANALLUR	1132.88	1708.00	66.71	1774.71	79.46	0.00	156.654	Over exploited
5	TIRUNELVELI	SIVAGIRI	Vasudevanallur	Puliyankudi	1872.56	2009.00	12.33	2021.33	14.69	0.00	107.945	Over exploited
6	TIRUNELVELI	SANKARANKOIL	Sankarankoil	Sankarankoil	1148.76	1258.40	30.25	1288.65	36.04	0.00	112.178	Over exploited
7	VIRUDHUNAGAR	SIVAKASI	Sivakasi	ALANGULAM	1079.38	1046.48	17.43	1063.90	20.76	12.15	98.5658	Critical
8	VIRUDHUNAGAR	VIRUDHUNAGAR	Virudhunagar	Amathur	730.17	718.20	13.54	731.74	16.13	0.00	100.215	Critical
9	VIRUDHUNAGAR	RAJAPALAYAM	Rajapalayam	Cholapuram(V)	1383.38	2152.35	19.61	2171.96	23.36	0.00	157.004	Over exploited
10	VIRUDHUNAGAR	RAJAPALAYAM	Rajapalayam	Keelarajakularaman	889.27	1327.73	24.23	1351.96	28.86	0.00	152.03	Over exploited
11	VIRUDHUNAGAR	SIVAKASI	Sivakasi	Mangalam(V)	2170.44	1969.20	37.49	2006.69	44.66	156.59	92.4552	Critical
12	VIRUDHUNAGAR	SRIVILLIPUTHUR	Vathirairuppu	Nathampatti	873.48	1301.40	15.64	1317.04	18.63	0.00	150.78	Over exploited
13	VIRUDHUNAGAR	VIRUDHUNAGAR	Virudhunagar	Ondipulinaickanur	603.23	575.10	20.30	595.40	24.19	3.94	98.7029	Critical
14	VIRUDHUNAGAR	SRIVILLIPUTHUR	Srivilliputhur	Pillaiyarkulam	1510.87	1604.70	19.21	1623.91	22.88	0.00	107.482	Over exploited
15	VIRUDHUNAGAR	RAJAPALAYAM	Rajapalayam	Rajapalayam	1865.37	1960.20	99.86	2060.06	118.95	0.00	110.437	Over exploited
16	VIRUDHUNAGAR	SIVAKASI	Vembakottai	Salwarpatti	471.46	444.60	7.91	452.51	9.42	17.44	95.9792	Critical
17	VIRUDHUNAGAR	SRIVILLIPUTHUR	Srivilliputhur	Srivilliputtur	994.95	924.30	23.87	948.17	28.43	42.22	95.2981	Critical
18	VIRUDHUNAGAR	VIRUDHUNAGAR	Virudhunagar	Vatchakara-patti	936.51	867.00	79.09	946.09	94.21	0.00	101.022	Over exploited
19	VIRUDHUNAGAR	SIVAKASI	Vembakottai	VEMBAKOTTAI	529.92	592.43	19.80	612.23	23.59	0.00	115.532	Over exploited

Annexure-V: The proposed tentative ARS location

S.no	Structure	Longitude	Latitude	Firka name	District
1	Checkdam	77.8239	9.39724	Salwarpatti	VIRUDHUNAGAR
2	Checkdam	77.8319	9.551	THIRUTHANGAL	VIRUDHUNAGAR
3	Checkdam	77.8565	9.58485	Amathur	VIRUDHUNAGAR
4	Checkdam	77.852	9.55275	THIRUTHANGAL	VIRUDHUNAGAR
5	Checkdam	77.829	9.32255	VEMBAKOTTAI	VIRUDHUNAGAR
6	Checkdam	77.7375	9.33159	ALANGULAM	VIRUDHUNAGAR
7	Checkdam	77.8142	9.33159	VEMBAKOTTAI	VIRUDHUNAGAR
8	Checkdam	77.8633	9.33772	Elayiram- Pannai	VIRUDHUNAGAR
9	Checkdam	77.7722	9.34881	VEMBAKOTTAI	VIRUDHUNAGAR
10	Checkdam	77.7443	9.34764	ALANGULAM	VIRUDHUNAGAR
11	Checkdam	77.8094	9.5863	Mangalam(V)	VIRUDHUNAGAR
12	Checkdam	77.7713	9.61402	Nathampatti	VIRUDHUNAGAR
13	Checkdam	77.9198	9.37536	PADANTHAL	VIRUDHUNAGAR
14	Checkdam	77.9476	9.59156	Amathur	VIRUDHUNAGAR
15	Checkdam	77.7146	9.61795	Nathampatti	VIRUDHUNAGAR
16	Checkdam	77.7809	9.53853	Mangalam(V)	VIRUDHUNAGAR
17	Checkdam	77.7877	9.57882	Mangalam(V)	VIRUDHUNAGAR
18	Checkdam	77.7891	9.62298	Mangalam(V)	VIRUDHUNAGAR
19	Checkdam	77.7906	9.61028	Mangalam(V)	VIRUDHUNAGAR
20	Checkdam	77.8147	9.62429	Mangalam(V)	VIRUDHUNAGAR
21	Checkdam	77.6952	9.6186	Nathampatti	VIRUDHUNAGAR
22	Checkdam	77.6544	9.62064	Nathampatti	VIRUDHUNAGAR
23	Checkdam	77.6692	9.60736	Nathampatti	VIRUDHUNAGAR
24	Checkdam	77.6635	9.60502	Nathampatti	VIRUDHUNAGAR
25	Checkdam	77.7316	9.61305	Nathampatti	VIRUDHUNAGAR
26	Checkdam	77.7577	9.60546	Nathampatti	VIRUDHUNAGAR
27	Checkdam	77.7768	9.5932	Nathampatti	VIRUDHUNAGAR
28	Checkdam	77.7604	9.61466	Nathampatti	VIRUDHUNAGAR
29	Checkdam	77.7504	9.54459	Mangalam(V)	VIRUDHUNAGAR
30	Checkdam	77.766	9.54226	Mangalam(V)	VIRUDHUNAGAR
31	Checkdam	77.7709	9.56167	Mangalam(V)	VIRUDHUNAGAR
32	Checkdam	77.7456	9.56109	Mangalam(V)	VIRUDHUNAGAR
33	Checkdam	77.743	9.60794	Nathampatti	VIRUDHUNAGAR

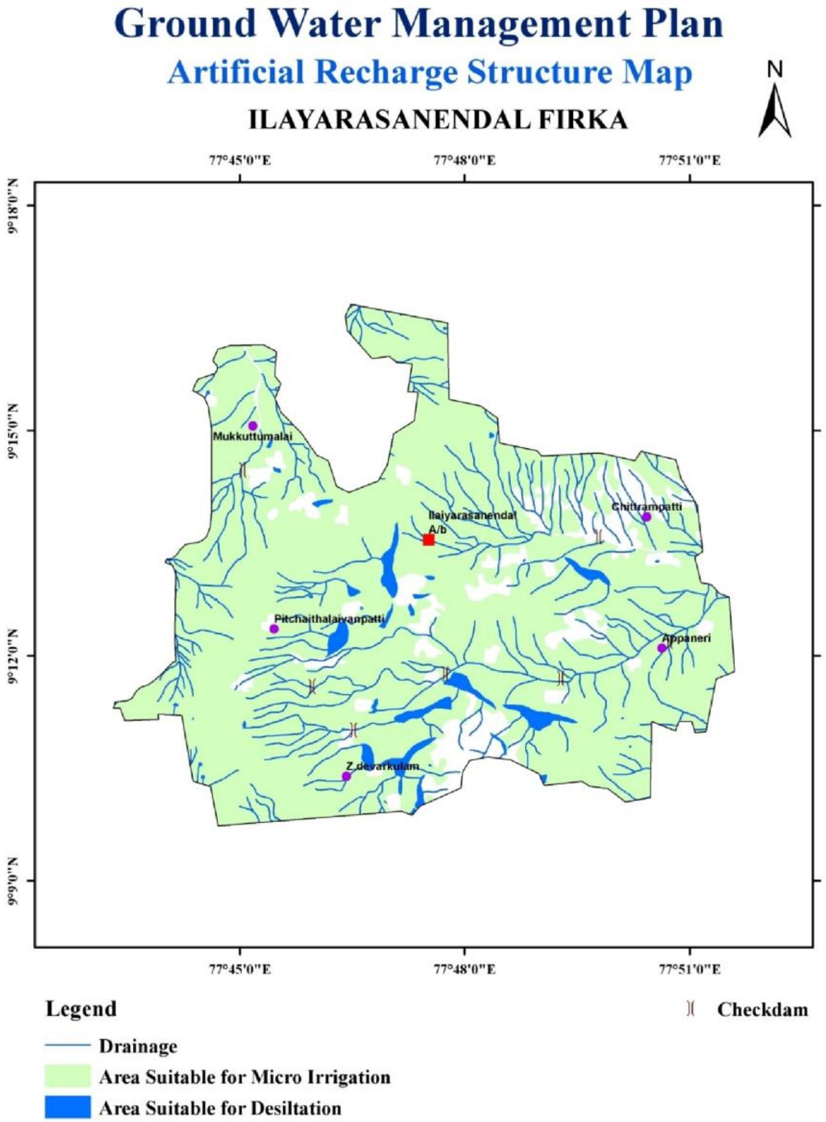
34	Checkdam	77.742	9.49555	Mangalam(V)	VIRUDHUNAGAR
35	Checkdam	77.7525	9.50387	Mangalam(V)	VIRUDHUNAGAR
36	Checkdam	77.7199	9.49058	Mangalam(V)	VIRUDHUNAGAR
37	Checkdam	77.5888	9.47613	Pillaiyarkulam	VIRUDHUNAGAR
38	Checkdam	77.5667	9.46752	Pillaiyarkulam	VIRUDHUNAGAR
39	Checkdam	77.5829	9.44241	Pillaiyarkulam	VIRUDHUNAGAR
40	Checkdam	77.6252	9.45774	Pillaiyarkulam	VIRUDHUNAGAR
41	Checkdam	77.6447	9.45132	Pillaiyarkulam	VIRUDHUNAGAR
42	Checkdam	77.6712	9.43687	Pillaiyarkulam	VIRUDHUNAGAR
43	Checkdam	77.5765	9.49161	Pillaiyarkulam	VIRUDHUNAGAR
44	Checkdam	77.5621	9.5281	Pillaiyarkulam	VIRUDHUNAGAR
45	Checkdam	77.5385	9.42534	Cholapuram(V)	VIRUDHUNAGAR
46	Checkdam	77.5487	9.40461	Cholapuram(V)	VIRUDHUNAGAR
47	Checkdam	77.4122	9.4103	Cholapuram(V)	VIRUDHUNAGAR
48	Checkdam	77.4563	9.39716	Cholapuram(V)	VIRUDHUNAGAR
49	Checkdam	77.4588	9.36636	Cholapuram(V)	VIRUDHUNAGAR
50	Checkdam	77.4936	9.37133	Cholapuram(V)	VIRUDHUNAGAR
51	Checkdam	77.5109	9.36315	Cholapuram(V)	VIRUDHUNAGAR
52	Checkdam	77.5123	9.34841	Cholapuram(V)	VIRUDHUNAGAR
53	Checkdam	77.5644	9.36811	Cholapuram(V)	VIRUDHUNAGAR
54	Checkdam	77.5792	9.35688	Cholapuram(V)	VIRUDHUNAGAR
55	Checkdam	77.6282	9.38505	Keelarajakularaman	VIRUDHUNAGAR
56	Checkdam	77.649	9.36899	Keelarajakularaman	VIRUDHUNAGAR
57	Checkdam	77.6484	9.40023	Keelarajakularaman	VIRUDHUNAGAR
58	Checkdam	77.6499	9.42957	Pillaiyarkulam	VIRUDHUNAGAR
59	Checkdam	77.6245	9.4192	Keelarajakularaman	VIRUDHUNAGAR
60	Checkdam	77.6159	9.40723	Keelarajakularaman	VIRUDHUNAGAR
61	Checkdam	77.6003	9.39702	Keelarajakularaman	VIRUDHUNAGAR
62	Checkdam	77.6566	9.38636	Keelarajakularaman	VIRUDHUNAGAR
63	Checkdam	77.6923	9.34651	ALANGULAM	VIRUDHUNAGAR
64	Checkdam	77.725	9.33104	ALANGULAM	VIRUDHUNAGAR
65	Checkdam	77.6354	9.31235	Keelarajakularaman	VIRUDHUNAGAR
66	Checkdam	77.6453	9.31907	ALANGULAM	VIRUDHUNAGAR
67	Checkdam	77.6591	9.31834	ALANGULAM	VIRUDHUNAGAR
68	Checkdam	77.7031	9.31162	ALANGULAM	VIRUDHUNAGAR
69	Checkdam	77.7858	9.36403	VEMBAKOTTAI	VIRUDHUNAGAR

70	Checkdam	77.78	9.36184	VEMBAKOTTAI	VIRUDHUNAGAR
71	Checkdam	77.7883	9.33002	VEMBAKOTTAI	VIRUDHUNAGAR
72	Checkdam	77.8157	9.33702	VEMBAKOTTAI	VIRUDHUNAGAR
73	Checkdam	77.8058	9.34958	VEMBAKOTTAI	VIRUDHUNAGAR
74	Checkdam	77.7981	9.33454	VEMBAKOTTAI	VIRUDHUNAGAR
75	Checkdam	77.7919	9.35614	VEMBAKOTTAI	VIRUDHUNAGAR
76	Checkdam	77.7561	9.34782	VEMBAKOTTAI	VIRUDHUNAGAR
77	Checkdam	77.8228	9.33761	Salwarpatti	VIRUDHUNAGAR
78	Checkdam	77.8307	9.33819	VEMBAKOTTAI	VIRUDHUNAGAR
79	Checkdam	77.84	9.33965	VEMBAKOTTAI	VIRUDHUNAGAR
80	Checkdam	77.8464	9.32491	VEMBAKOTTAI	VIRUDHUNAGAR
81	Checkdam	77.8489	9.36651	Salwarpatti	VIRUDHUNAGAR
82	Checkdam	77.8319	9.40242	Salwarpatti	VIRUDHUNAGAR
83	Checkdam	77.8507	9.3922	Salwarpatti	VIRUDHUNAGAR
84	Checkdam	77.8416	9.37483	Salwarpatti	VIRUDHUNAGAR
85	Checkdam	77.8259	9.35191	VEMBAKOTTAI	VIRUDHUNAGAR
86	Checkdam	78.0102	9.44796	Vatchakara-patti	VIRUDHUNAGAR
87	Checkdam	78.0144	9.42723	Vatchakara-patti	VIRUDHUNAGAR
88	Checkdam	78.0176	9.40767	Vatchakara-patti	VIRUDHUNAGAR
89	Checkdam	77.9851	9.41964	Vatchakara-patti	VIRUDHUNAGAR
90	Checkdam	77.9787	9.42855	Vatchakara-patti	VIRUDHUNAGAR
91	Checkdam	78.0037	9.47891	Pandalkudi	VIRUDHUNAGAR
92	Checkdam	77.9787	9.46956	Vatchakara-patti	VIRUDHUNAGAR
93	Checkdam	77.9578	9.45292	Vatchakara-patti	VIRUDHUNAGAR
94	Checkdam	77.925	9.52094	Ondipulinaickanur	VIRUDHUNAGAR
95	Checkdam	77.881	9.53073	THIRUTHANGAL	VIRUDHUNAGAR
96	Checkdam	77.9678	9.51876	Vatchakara-patti	VIRUDHUNAGAR
97	Checkdam	78.0073	9.50562	Vatchakara-patti	VIRUDHUNAGAR
98	Checkdam	77.9888	9.4989	Vatchakara-patti	VIRUDHUNAGAR
99	Checkdam	77.9747	9.49555	Vatchakara-patti	VIRUDHUNAGAR
100	Checkdam	77.9601	9.47745	Vatchakara-patti	VIRUDHUNAGAR
101	Checkdam	77.9885	9.46664	Vatchakara-patti	VIRUDHUNAGAR
102	Checkdam	77.9522	9.47569	Vatchakara-patti	VIRUDHUNAGAR
103	Checkdam	77.9328	9.48489	Vatchakara-patti	VIRUDHUNAGAR
104	Checkdam	78.0122	9.51131	Vatchakara-patti	VIRUDHUNAGAR
105	Checkdam	78.0129	9.51584	Vatchakara-patti	VIRUDHUNAGAR

106	Checkdam	77.7956	9.19601	ILAYARASANENDAL	THOOTHUKKUDI
107	Checkdam	77.8213	9.1949	ILAYARASANENDAL	THOOTHUKKUDI
108	Checkdam	77.8454	9.20318	ILAYARASANENDAL	THOOTHUKKUDI
109	Checkdam	77.8297	9.22638	ILAYARASANENDAL	THOOTHUKKUDI
110	Checkdam	77.6216	9.23576	Karisal kulam	TIRUNELVELI
111	Checkdam	77.6373	9.25896	Karisal kulam	TIRUNELVELI
112	Checkdam	77.6199	9.26227	Karisal kulam	TIRUNELVELI
113	Checkdam	77.6451	9.26834	Karisal kulam	TIRUNELVELI
114	Checkdam	77.5035	9.18055	Veerasigamani	TIRUNELVELI
115	Checkdam	77.3883	9.21368	Puliyankudi	TIRUNELVELI
116	Checkdam	77.5449	9.28877	KARIVAKLAMVANDAnallur	TIRUNELVELI
117	Checkdam	77.5662	9.32908	KARIVAKLAMVANDAnallur	TIRUNELVELI
118	Checkdam	77.5517	9.35062	KARIVAKLAMVANDAnallur	TIRUNELVELI
119	Checkdam	77.5595	9.23852	Sankarankoil	TIRUNELVELI
120	Checkdam	77.5768	9.21975	Karisal kulam	TIRUNELVELI
121	Checkdam	77.5807	9.20926	Karisal kulam	TIRUNELVELI
122	Checkdam	77.3748	9.20484	Puliyankudi	TIRUNELVELI
123	Checkdam	77.3821	9.21423	Puliyankudi	TIRUNELVELI
124	Checkdam	77.4336	9.19435	Puliyankudi	TIRUNELVELI
125	Checkdam	77.4202	9.20926	Puliyankudi	TIRUNELVELI
126	Checkdam	77.404	9.16849	Veerasigamani	TIRUNELVELI
127	Checkdam	77.356	9.19632	Puliyankudi	TIRUNELVELI
128	Checkdam	77.3618	9.21399	Puliyankudi	TIRUNELVELI
129	Checkdam	77.3569	9.22449	Puliyankudi	TIRUNELVELI
130	Checkdam	77.3708	9.22877	Puliyankudi	TIRUNELVELI
131	Checkdam	77.3656	9.20378	Puliyankudi	TIRUNELVELI
132	Checkdam	77.3599	9.18582	Puliyankudi	TIRUNELVELI
133	Checkdam	77.375	9.18361	Puliyankudi	TIRUNELVELI
134	Checkdam	77.3993	9.19742	Puliyankudi	TIRUNELVELI
135	Checkdam	77.466	9.19853	Puliyankudi	TIRUNELVELI
136	Checkdam	77.5333	9.20502	Sankarankoil	TIRUNELVELI
137	Checkdam	77.5931	9.22076	Karisal kulam	TIRUNELVELI
138	Checkdam	77.6465	9.23498	Karisal kulam	TIRUNELVELI
139	Checkdam	77.6012	9.26978	Karisal kulam	TIRUNELVELI
140	Checkdam	77.6072	9.29919	Karisal kulam	TIRUNELVELI
141	Checkdam	77.5419	9.24728	KARIVAKLAMVANDAnallur	TIRUNELVELI

142	Checkdam	77.7506	9.2412	ILAYARASANENDAL	THOOTHUKKUDI
143	Checkdam	77.766	9.19316	ILAYARASANENDAL	THOOTHUKKUDI
144	Checkdam	77.7752	9.1835	ILAYARASANENDAL	THOOTHUKKUDI
145	Checkdam	77.5945	9.2539	KARIVAKLAMVANDAnallur	TIRUNELVELI
146	Checkdam	77.4789	9.21442	Gudalur	TIRUNELVELI
147	Checkdam	77.4224	9.38257	SIVAKIRI	TIRUNELVELI
148	Checkdam	77.4375	9.33922	SIVAKIRI	TIRUNELVELI
149	Checkdam	77.6054	9.53967	Srivilliputtur	VIRUDHUNAGAR
150	Checkdam	77.5754	9.53305	Srivilliputtur	VIRUDHUNAGAR
151	Checkdam	77.5894	9.53305	Srivilliputtur	VIRUDHUNAGAR
152	Checkdam	77.6244	9.52228	Srivilliputtur	VIRUDHUNAGAR
153	Checkdam	77.6451	9.5082	Srivilliputtur	VIRUDHUNAGAR
154	Checkdam	77.6722	9.48114	Srivilliputtur	VIRUDHUNAGAR
155	Checkdam	77.8804	9.62223	Amathur	VIRUDHUNAGAR
156	Checkdam	77.9022	9.61312	Amathur	VIRUDHUNAGAR
157	Checkdam	77.863	9.59048	Amathur	VIRUDHUNAGAR
158	Checkdam	77.8577	9.60152	Amathur	VIRUDHUNAGAR
159	Checkdam	77.9014	9.56866	Amathur	VIRUDHUNAGAR
160	Checkdam	77.9369	9.59462	Amathur	VIRUDHUNAGAR
161	Checkdam	77.9347	9.62692	Amathur	VIRUDHUNAGAR
162	Checkdam	77.9151	9.61836	Amathur	VIRUDHUNAGAR
163	Checkdam	77.959	9.55541	Ondipulinaickanur	VIRUDHUNAGAR

Figure 6.2 – 6.20 Groundawater Management plan for Firka

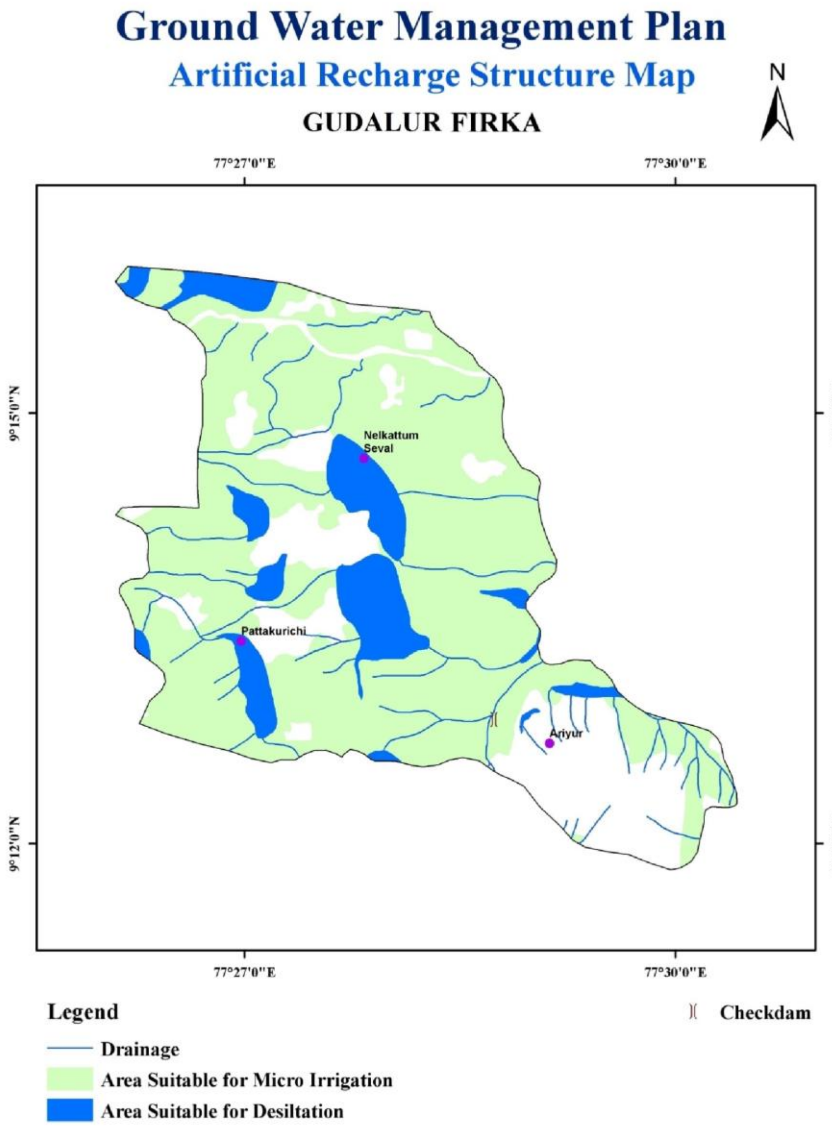


Location of ARS

Structure	Longitude	Latitude
Checkdam	77.79560	9.19601
Checkdam	77.82130	9.19490
Checkdam	77.84540	9.20318
Checkdam	77.82970	9.22638
Checkdam	77.75060	9.24120
Checkdam	77.76600	9.19316
Checkdam	77.77520	9.18350

Location of Waterbodies

Latitude	Longitude	Area in sqkm
9.2728	77.7956	0.0061
9.2585	77.7429	0.0082
9.2490	77.8059	0.0139
9.2474	77.7568	0.0245
9.2412	77.7583	0.0183
9.2340	77.7683	0.0548
9.2199	77.7835	0.3960
9.2255	77.8314	0.1745
9.2185	77.8275	0.2270
9.2212	77.8132	0.0036
9.2210	77.8428	0.0060
9.2173	77.7923	0.0200
9.2144	77.7750	0.0584
9.2133	77.7901	0.0321
9.2132	77.7658	0.0054
9.2125	77.7446	0.0050
9.2101	77.7881	0.0286
9.2083	77.7827	0.0605
9.2106	77.7771	0.0053
9.2038	77.7718	0.2772
9.1932	77.8002	0.2777
9.1929	77.7492	0.0064
9.1878	77.7910	0.2913
9.1887	77.7800	0.0389
9.1891	77.7358	0.0088
9.1864	77.8163	0.4163
9.1860	77.7396	0.0022
9.1861	77.8350	0.0033
9.1856	77.8529	0.0045
9.1848	77.7510	0.0113
9.1841	77.7642	0.0092
9.1836	77.7730	0.0058
9.1806	77.8080	0.0474
9.1773	77.7869	0.3184
9.1775	77.7784	0.1601
9.1798	77.8368	0.0029
9.1759	77.7412	0.0074
9.1757	77.7923	0.0047
9.1731	77.7418	0.0086
9.1709	77.7857	0.0319
9.1675	77.7824	0.0033
9.1641	77.7580	0.0045

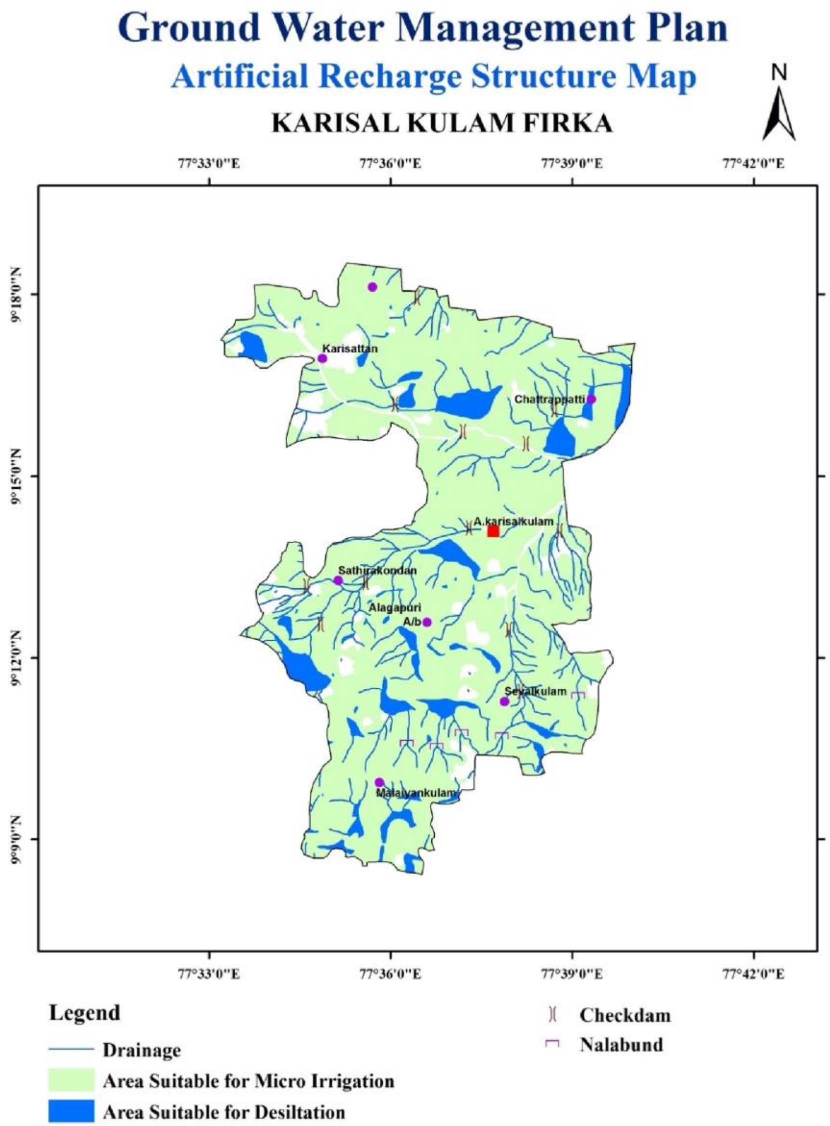


Location of ARS

Structure	Longitude	Latitude
Checkdam	77.4789	9.21442

Location of Waterbodies

Latitude	Longitude	Area in sqkm
9.2407	77.4642	0.8495
9.2385	77.4507	0.2153
9.2304	77.4528	0.1821
9.2270	77.4654	1.0487
9.2184	77.4511	0.4340
9.2146	77.4828	0.0239



Location of ARS

Structure	Longitude	Latitude
Checkdam	77.6216	9.23576
Checkdam	77.6373	9.25896
Checkdam	77.6199	9.26227
Checkdam	77.6451	9.26834
Checkdam	77.5768	9.21975
Checkdam	77.5807	9.20926
Checkdam	77.5931	9.22076
Checkdam	77.6465	9.23498
Checkdam	77.6012	9.26978
Checkdam	77.6072	9.29919

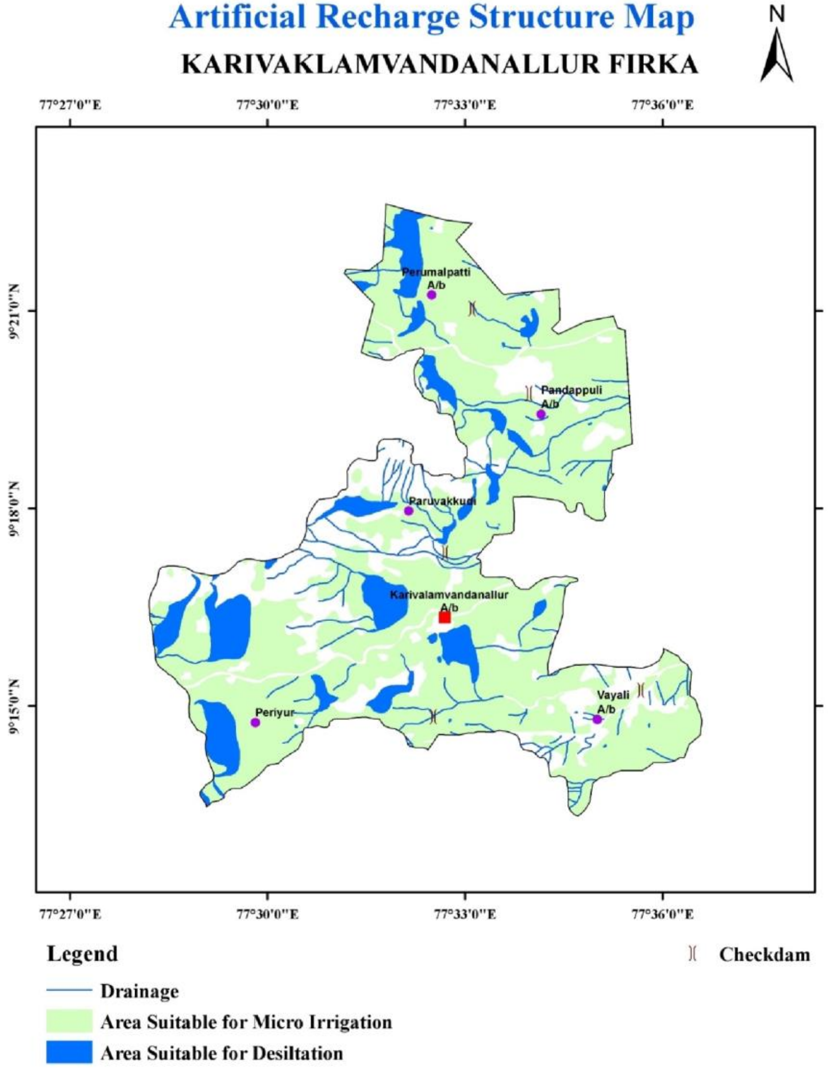
Location of Waterbodies

Latitude	Longitude	Area in sqkm
9.2965	77.6001	0.0078
9.2960	77.6051	0.0074
9.2935	77.5750	0.0086
9.2919	77.5800	0.0061
9.2900	77.6263	0.0055
9.2892	77.5990	0.0095
9.2881	77.6432	0.0094
9.2824	77.5923	0.1054
9.2774	77.6055	0.1497
9.2715	77.6047	0.2616
9.2701	77.6215	1.2369
9.2695	77.6547	0.2452
9.2599	77.6468	0.7634
9.2453	77.6128	0.0049
9.2376	77.6066	0.0050
9.2282	77.6172	0.7377
9.2217	77.6179	0.0059
9.2189	77.6229	0.0131
9.2196	77.6150	0.0147
9.2182	77.5995	0.0466
9.2182	77.5684	0.0049
9.2171	77.6272	0.0122
9.2174	77.5778	0.0098
9.2172	77.5800	0.0013
9.2155	77.5942	0.0104
9.2128	77.5741	0.0079
9.2128	77.5902	0.0051
9.2105	77.5988	0.0292
9.2092	77.5713	0.1649
9.2101	77.5931	0.0142
9.2026	77.6059	0.3782
9.2055	77.5881	0.0501
9.2031	77.6183	0.0720
9.2020	77.6122	0.0494
9.2034	77.6466	0.0030
9.1994	77.6278	0.1557
9.1994	77.5865	0.0053
9.1956	77.6218	0.0049
9.1953	77.5842	0.0058
9.1877	77.6005	0.4664
9.1909	77.6215	0.0044
9.1866	77.6154	0.5211
9.1857	77.5904	0.0164
9.1805	77.5900	0.1510
9.1831	77.6270	0.0035
9.1814	77.6450	0.0328
9.1799	77.6420	0.2009
9.1777	77.6106	0.0255
9.1760	77.6482	0.0070
9.1706	77.6009	0.0045
9.1688	77.5932	0.0016
9.1671	77.6216	0.0053
9.1618	77.6057	0.1136
9.1623	77.5813	0.0037
9.1547	77.5906	0.2610
9.1549	77.6017	0.3751

Ground Water Management Plan

Artificial Recharge Structure Map

KARIVAKLAMVANDANALLUR FIRKA

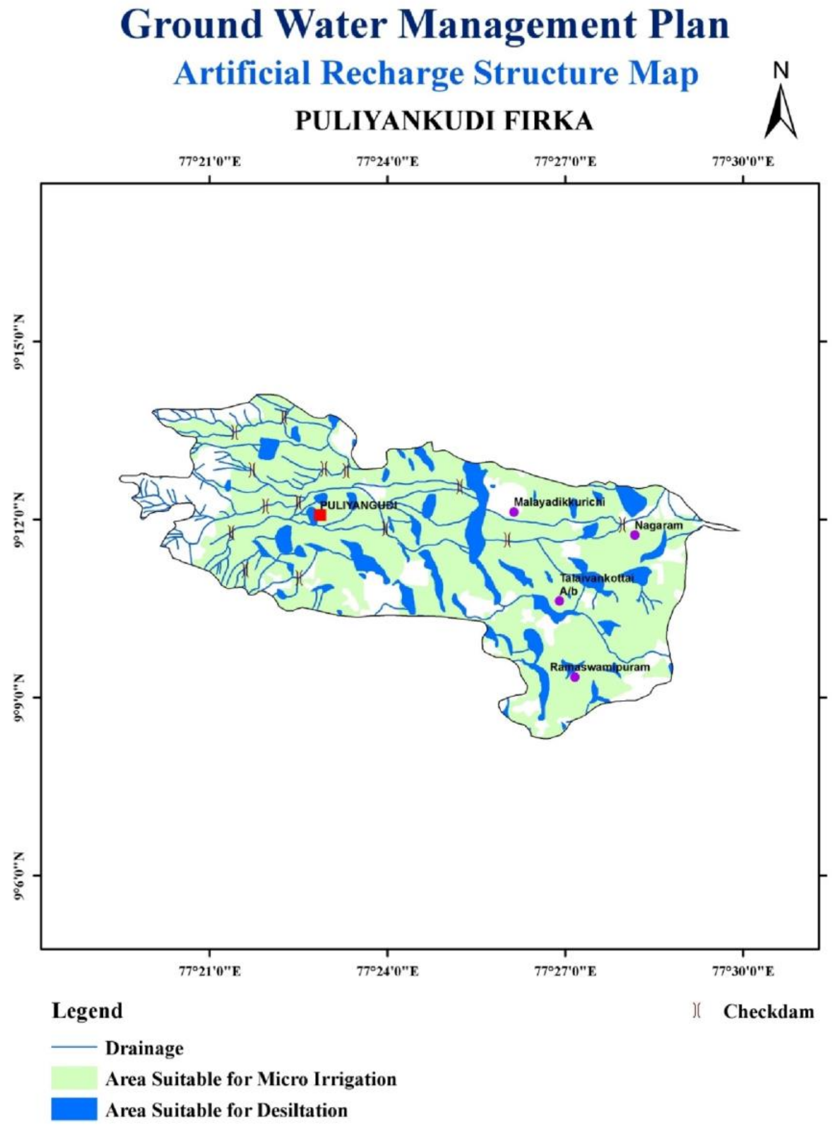


Location of ARS

Structure	Longitude	Latitude
Checkdam	77.5449	9.28877
Checkdam	77.5662	9.32908
Checkdam	77.5517	9.35062
Checkdam	77.5419	9.24728
Checkdam	77.5945	9.2539

Location of Waterbodies

Longitude	Latitude	Area in sq km
77.5378	9.3693	2.4446
77.5237	9.3561	0.1729
77.5365	9.3481	0.2996
77.5662	9.3469	0.2655
77.5598	9.3414	0.0095
77.5432	9.3319	0.6411
77.5586	9.3228	0.2481
77.5817	9.3214	0.0062
77.5572	9.3062	0.2796
77.5498	9.2992	0.2027
77.5225	9.3000	0.7031
77.5451	9.2942	0.1503
77.5586	9.2959	0.0029
77.5583	9.2950	0.0049
77.5008	9.2861	0.0646
77.5290	9.2763	1.4296
77.4763	9.2730	0.8873
77.4899	9.2711	1.9962
77.5688	9.2741	0.1311
77.5485	9.2631	1.0112
77.5417	9.2671	0.0595
77.5271	9.2507	0.8807
77.4870	9.2418	1.5884
77.5782	9.2484	0.0046
77.5462	9.2463	0.0072
77.5504	9.2453	0.0061
77.5966	9.2451	0.0057
77.5855	9.2398	0.0066
77.5415	9.3710	0.0043
77.5639	9.3166	0.2211
77.5435	9.2618	0.0183
77.5145	9.2533	0.3528



Location of ARS

Structure	Longitude	Latitude
Checkdam	77.3883	9.21368
Checkdam	77.3748	9.20484
Checkdam	77.3821	9.21423
Checkdam	77.4336	9.19435
Checkdam	77.4202	9.20926
Checkdam	77.356	9.19632
Checkdam	77.3618	9.21399
Checkdam	77.3569	9.22449
Checkdam	77.3708	9.22877
Checkdam	77.3656	9.20378
Checkdam	77.3599	9.18582
Checkdam	77.375	9.18361
Checkdam	77.3993	9.19742
Checkdam	77.466	9.19853

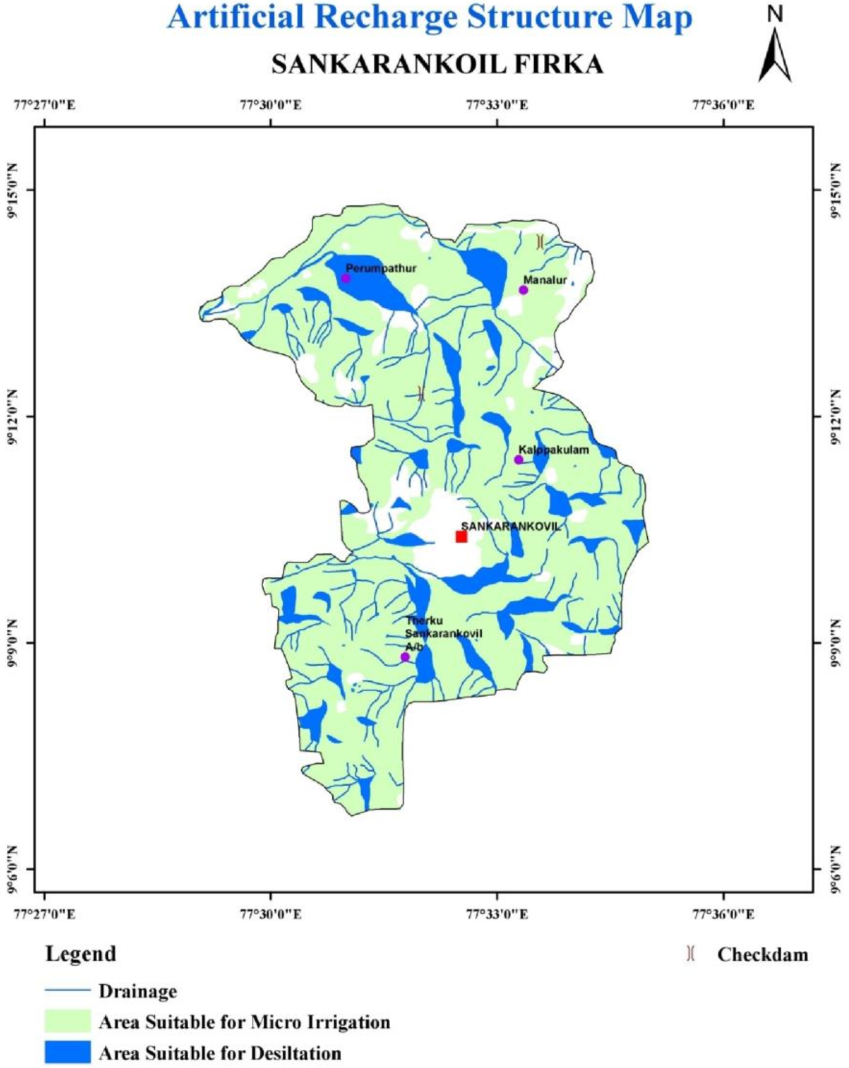
Location of Waterbodies

Latitude	Longitude	Area in sqkm
9.2240	77.3741	0.1049
9.2199	77.3664	0.3549
9.2156	77.4067	0.0419
9.2126	77.3995	0.0688
9.2095	77.3551	0.0555
9.2094	77.4296	0.0163
9.2066	77.4413	0.0285
9.2063	77.4592	0.0850
9.2077	77.3614	0.0039
9.2053	77.3901	0.1389
9.2059	77.3814	0.1196
9.2038	77.4117	0.2532
9.2034	77.4523	0.1205
9.2010	77.3789	0.1535
9.1973	77.4080	0.1880
9.1986	77.4009	0.0507
9.1968	77.4569	0.1859
9.1944	77.3710	0.3772
9.1915	77.4756	0.2588
9.1884	77.3936	0.6556
9.1913	77.3651	0.1259
9.1907	77.4049	0.0581
9.1922	77.3801	0.0889
9.1910	77.3754	0.1011
9.1843	77.4131	0.4576
9.1837	77.4569	0.5968
9.1847	77.4366	0.2817
9.1864	77.3727	0.0626
9.1844	77.4706	0.3481
9.1839	77.4454	0.0439
9.1843	77.3931	0.0292
9.1782	77.4055	0.3335
9.1808	77.3821	0.1050
9.1790	77.3702	0.0667
9.1763	77.4200	0.1149
9.1786	77.4511	0.0155
9.1749	77.4460	0.4564
9.1774	77.4706	0.0101
9.1740	77.3865	0.0204
9.1700	77.4621	0.1742
9.1587	77.4423	0.8258
9.1585	77.4516	0.1650
9.1578	77.4636	0.0908
9.1421	77.4496	0.0228

Ground Water Management Plan

Artificial Recharge Structure Map

SANKARANKOIL FIRKA



Location of ARS

Structure	Longitude	Latitude
Checkdam	77.5595	9.23852
Checkdam	77.5333	9.20502

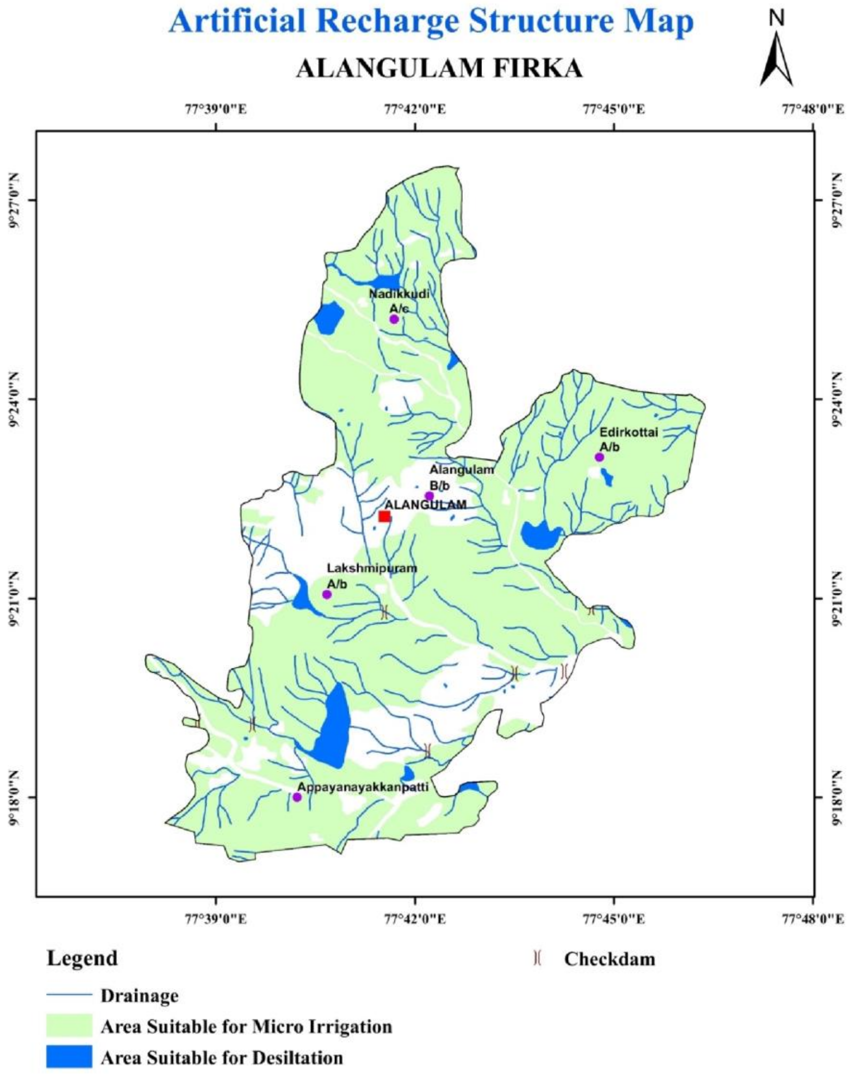
Location of Waterbodies

Latitude	Longitude	Area in sqkm
9.2323	77.5476	0.9772
9.2299	77.5210	1.7262
9.2350	77.5351	0.0030
9.2293	77.5668	0.0055
9.2267	77.5098	0.2110
9.2239	77.5027	0.0829
9.2197	77.5183	0.1637
9.2177	77.5492	0.2252
9.2078	77.5404	0.6077
9.2107	77.5486	0.0202
9.2083	77.5208	0.0270
9.2072	77.5460	0.0052
9.2010	77.5577	0.0046
9.1983	77.5504	0.2222
9.1914	77.5596	0.2256
9.1935	77.5415	0.1574
9.1907	77.5331	0.1699
9.1890	77.5672	0.0026
9.1814	77.5666	0.5372
9.1806	77.5288	0.0798
9.1723	77.5542	0.1958
9.1726	77.5302	0.2280
9.1721	77.5704	0.1760
9.1642	77.5470	0.7746
9.1689	77.5271	0.0088
9.1674	77.5128	0.0039
9.1668	77.5059	0.0063
9.1538	77.5333	0.9403
9.1650	77.5185	0.0247
9.1598	77.5117	0.0935
9.1571	77.5560	0.6274
9.1563	77.5235	0.0062
9.1533	77.5676	0.1067
9.1465	77.5452	0.3600
9.1515	77.5257	0.0040
9.1506	77.5454	0.0033
9.1494	77.5161	0.0031
9.1423	77.5144	0.1723
9.1408	77.5186	0.0063
9.1404	77.5197	0.0018
9.1395	77.5181	0.0062
9.1326	77.5096	0.3472
9.1326	77.5211	0.0670
9.1286	77.5139	0.0369

Ground Water Management Plan

Artificial Recharge Structure Map

ALANGULAM FIRKA

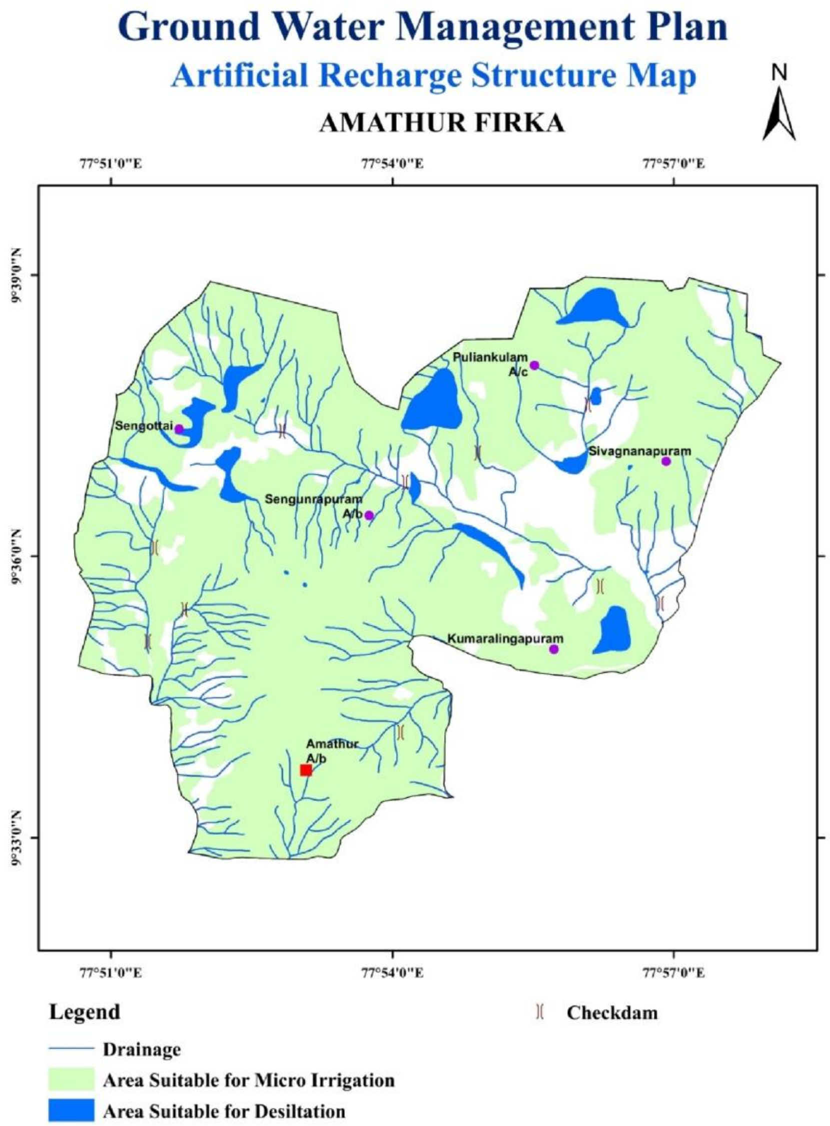


Location of ARS

Structure	Longitude	Latitude
Checkdam	77.7375	9.33159
Checkdam	77.7443	9.34764
Checkdam	77.6923	9.34651
Checkdam	77.725	9.33104
Checkdam	77.6453	9.31907
Checkdam	77.6591	9.31834
Checkdam	77.7031	9.31162

Location of Waterbodies

Longitude	Latitude	Area in sq km
77.6904	9.4292	0.4913
77.6768	9.4209	0.5717
77.7028	9.4153	0.0056
77.7098	9.4100	0.1011
77.6928	9.3976	0.0067
77.6814	9.3972	0.0083
77.7607	9.3959	0.0093
77.6834	9.3937	0.0074
77.7687	9.3930	0.0127
77.7366	9.3914	0.0079
77.7483	9.3804	0.0914
77.7005	9.3779	0.0059
77.7066	9.3769	0.0043
77.7094	9.3702	0.0128
77.7319	9.3660	0.6366
77.6898	9.3676	0.0070
77.6963	9.3571	0.0048
77.6723	9.3476	0.3547
77.6768	9.3182	1.6506
77.7077	9.3282	0.0081
77.7246	9.3278	0.0082
77.7226	9.3267	0.0063
77.6575	9.3148	0.0102
77.6980	9.3060	0.1074
77.7122	9.3032	0.1185



Location of ARS

Structure	Longitude	Latitude
Checkdam	77.8565	9.58485
Checkdam	77.9476	9.59156
Checkdam	77.8804	9.62223
Checkdam	77.9022	9.61312
Checkdam	77.863	9.59048
Checkdam	77.8577	9.60152
Checkdam	77.9014	9.56866
Checkdam	77.9369	9.59462
Checkdam	77.9347	9.62692
Checkdam	77.9151	9.61836

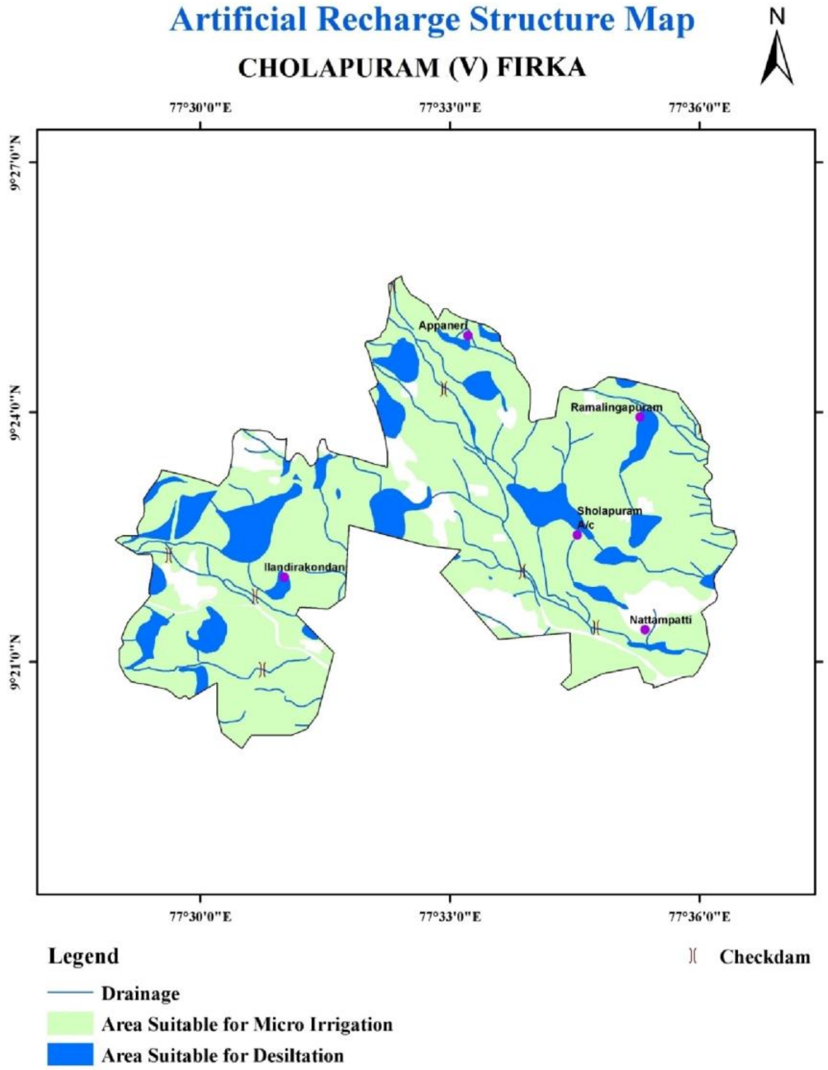
Location of Waterbodies

Longitude	Latitude	Area in sq km
77.9355	9.6442	0.5856
77.8251	9.6397	0.0003
77.9630	9.6429	0.0036
77.9648	9.6391	0.0106
77.8728	9.6326	0.3254
77.9070	9.6279	0.9522
77.8570	9.6310	0.0054
77.9361	9.6285	0.0641
77.8660	9.6265	0.3779
77.9319	9.6171	0.1747
77.8584	9.6145	0.1910
77.9422	9.6158	0.0070
77.9040	9.6121	0.0958
77.8938	9.6133	0.0059
77.9155	9.6035	0.2836
77.8812	9.5971	0.0057
77.9451	9.5971	0.0058
77.8844	9.5949	0.0059
77.9389	9.5869	0.4671
77.8571	9.5808	0.0179
77.8709	9.6175	0.3305

Ground Water Management Plan

Artificial Recharge Structure Map

CHOLAPURAM (V) FIRKA



Location of ARS

Structure	Longitude	Latitude
Checkdam	77.5385	9.42534
Checkdam	77.5487	9.40461
Checkdam	77.4122	9.4103
Checkdam	77.4563	9.39716
Checkdam	77.4588	9.36636
Checkdam	77.4936	9.37133
Checkdam	77.5109	9.36315
Checkdam	77.5123	9.34841
Checkdam	77.5644	9.36811
Checkdam	77.5792	9.35688

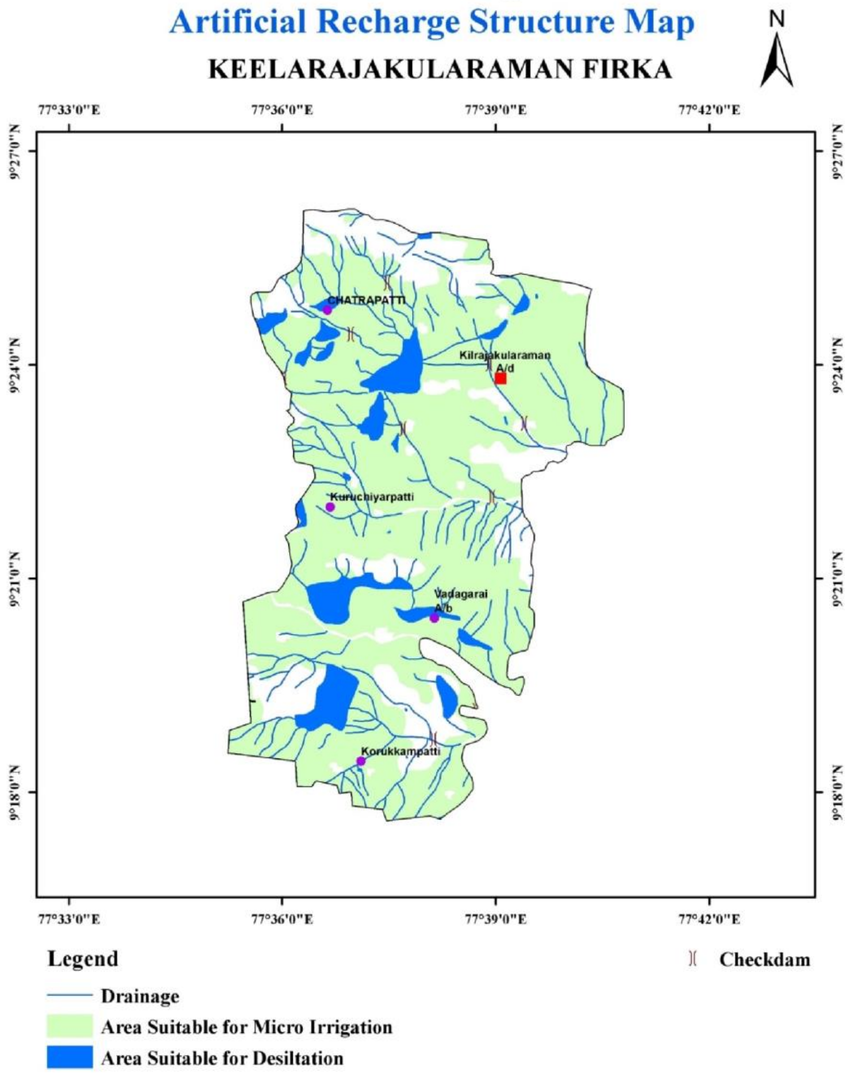
Location of Waterbodies

Longitude	Latitude	Area in sq km
77.5592	9.4150	0.1375
77.4274	9.4082	0.2888
77.5507	9.4145	0.1300
77.5391	9.4104	0.5689
77.5569	9.4042	0.3937
77.4091	9.4050	0.0085
77.4407	9.3952	0.8146
77.5879	9.3943	0.4764
77.5172	9.3895	0.0574
77.5245	9.3881	0.1756
77.4740	9.3877	0.3323
77.4918	9.3859	0.1466
77.4584	9.3852	0.0152
77.5117	9.3779	1.4458
77.5701	9.3802	1.0596
77.5276	9.3837	0.0199
77.4632	9.3816	0.0357
77.5891	9.3763	0.3337
77.4576	9.3715	0.2273
77.4414	9.3671	0.0185
77.4904	9.3669	0.1978
77.5153	9.3654	0.2020
77.5802	9.3633	0.2401
77.4421	9.3581	0.1632
77.5012	9.3564	0.5128
77.4706	9.3494	0.1240
77.5914	9.3528	0.1605
77.4784	9.3494	0.2211
77.4999	9.3426	0.1755
77.5171	9.3470	0.0895
77.4661	9.3427	0.1688
77.5096	9.3427	0.1369
77.4870	9.3414	0.1191
77.5380	9.4005	0.5041
77.5541	9.3966	0.0717
77.4431	9.3846	0.4837
77.4692	9.3840	0.0703
77.4991	9.3800	0.4983
77.5833	9.3713	0.2355
77.4892	9.3545	0.4306
77.4762	9.3428	0.0711
77.4623	9.3367	0.1798
77.4907	9.3754	0.2201

Ground Water Management Plan

Artificial Recharge Structure Map

KEELARAJAKULARAMAN FIRKA

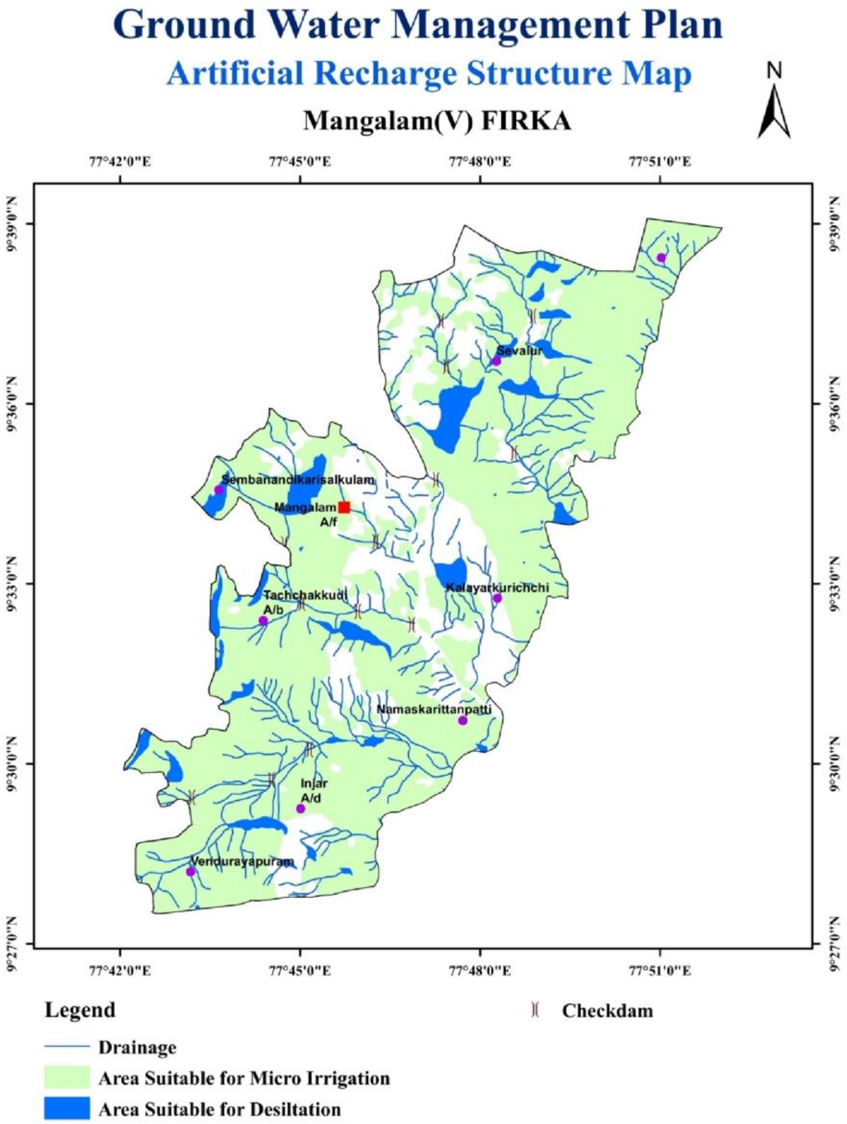


Location of ARS

Structure	Longitude	Latitude
Checkdam	77.6282	9.38505
Checkdam	77.649	9.36899
Checkdam	77.6484	9.40023
Checkdam	77.6245	9.4192
Checkdam	77.6159	9.40723
Checkdam	77.6003	9.39702
Checkdam	77.6566	9.38636
Checkdam	77.6354	9.31235

Location of Waterbodies

Longitude	Latitude	Area in sq km
77.6437	9.4280	0.0359
77.6558	9.4143	0.1311
77.6596	9.4161	0.0074
77.6099	9.4142	0.1754
77.6213	9.4146	0.0061
77.5961	9.4100	0.3730
77.6408	9.4112	0.2058
77.6493	9.4083	0.1514
77.6105	9.4080	0.2068
77.6255	9.3963	1.3609
77.6049	9.4027	0.1474
77.6176	9.4007	0.0086
77.6523	9.3870	0.0127
77.6265	9.3818	0.0586
77.6151	9.3739	0.0305
77.6029	9.3656	0.2600
77.6249	9.3609	0.0056
77.6160	9.3490	1.5041
77.6452	9.3358	0.1905
77.6104	9.3221	1.5553
77.6306	9.3297	0.0040
77.6308	9.3283	0.0074
77.6385	9.3223	0.3726
77.6312	9.3258	0.0042
77.6289	9.3193	0.0055
77.6292	9.3082	0.0038
77.6181	9.3052	0.0096
77.6500	9.4102	0.0083
77.6360	9.4065	0.1332
77.6099	9.4032	0.1277
77.6210	9.3880	0.5075
77.6339	9.3416	0.3913

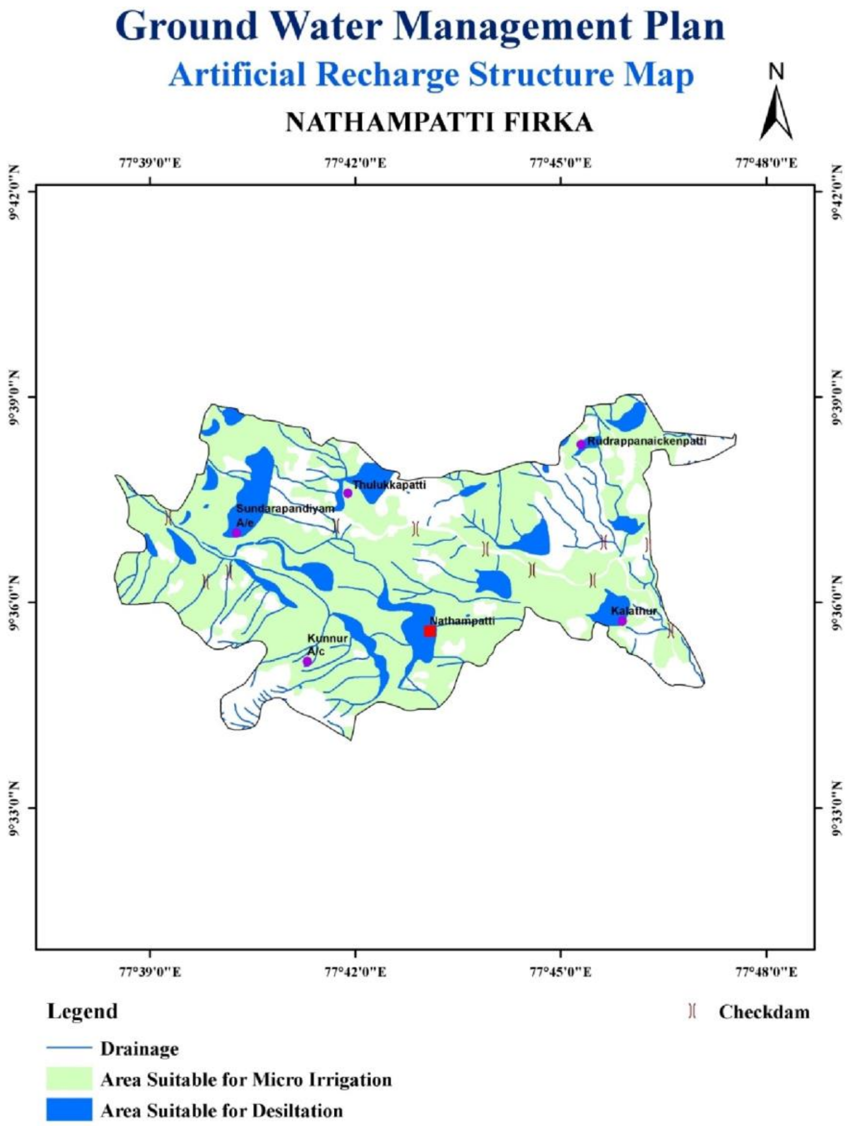


Location of ARS

Structure	Longitude	Latitude
Checkdam	77.8094	9.5863
Checkdam	77.7809	9.53853
Checkdam	77.7877	9.57882
Checkdam	77.7891	9.62298
Checkdam	77.7906	9.61028
Checkdam	77.8147	9.62429
Checkdam	77.7504	9.54459
Checkdam	77.766	9.54226
Checkdam	77.7709	9.56167
Checkdam	77.7456	9.56109
Checkdam	77.742	9.49555
Checkdam	77.7525	9.50387
Checkdam	77.7199	9.49058

Location of Waterbodies

Longitude	Latitude	Area in sq km
77.8522	9.6458	0.0061
77.8182	9.6379	0.2436
77.8154	9.6294	0.1375
77.8371	9.6266	0.0068
77.8208	9.6250	0.2141
77.8058	9.6136	0.2980
77.8167	9.6167	0.3480
77.8136	9.6046	0.5489
77.7912	9.5968	1.7639
77.8034	9.5932	0.0034
77.7483	9.5888	0.0064
77.7506	9.5775	1.3663
77.8133	9.5819	0.0557
77.7660	9.5842	0.0050
77.7985	9.5842	0.0033
77.7280	9.5757	0.3271
77.7432	9.5794	0.0109
77.8042	9.5748	0.0056
77.8242	9.5688	0.3198
77.8173	9.5671	0.0067
77.8172	9.5656	0.0039
77.7276	9.5491	0.4439
77.7910	9.5613	0.0077
77.7503	9.5597	0.0113
77.7913	9.5529	0.7618
77.8122	9.5558	0.0033
77.7392	9.5492	0.2388
77.8056	9.5500	0.0053
77.8146	9.5495	0.0070
77.7456	9.5491	0.0086
77.8161	9.5423	0.0077
77.7639	9.5346	0.7328
77.7325	9.5199	0.2567
77.7079	9.5091	0.0756
77.7485	9.5118	0.0125
77.7700	9.5063	0.1576
77.7601	9.5065	0.0952
77.8004	9.5043	0.0684
77.7152	9.4963	0.3214
77.7484	9.5016	0.0048
77.7380	9.4828	0.4957
77.7723	9.4839	0.0145
77.7523	9.4758	0.1126
77.7470	9.4720	0.0763
77.7198	9.4716	0.0066
77.7626	9.4700	0.0599
77.7551	9.4669	0.0033
77.7214	9.4601	0.0150
77.8247	9.6341	0.0605
77.7271	9.5273	0.1491
77.7066	9.5053	0.2178



Location of ARS

Structure	Longitude	Latitude
Checkdam	77.7713	9.61402
Checkdam	77.7146	9.61795
Checkdam	77.6952	9.6186
Checkdam	77.6544	9.62064
Checkdam	77.6692	9.60736
Checkdam	77.6635	9.60502
Checkdam	77.7316	9.61305
Checkdam	77.7577	9.60546
Checkdam	77.7768	9.5932
Checkdam	77.7604	9.61466
Checkdam	77.743	9.60794

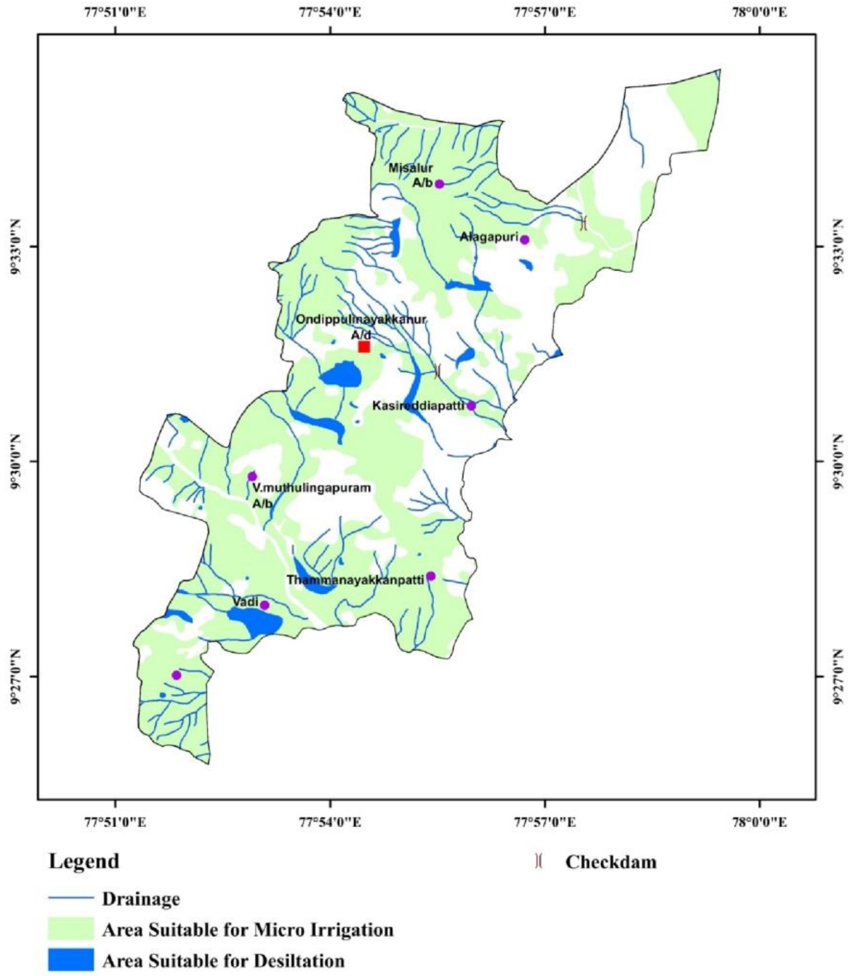
Location of Waterbodies

Longitude	Latitude	Area in sq km
77.7800	9.6410	0.0057
77.6710	9.6467	0.2088
77.7511	9.6398	0.0406
77.6643	9.6414	0.1184
77.6740	9.6269	1.7414
77.7022	9.6290	0.9715
77.6645	9.6305	0.1874
77.7463	9.6327	0.0334
77.7348	9.6285	0.0056
77.7285	9.6275	0.1187
77.7128	9.6268	0.0045
77.6637	9.6235	0.0122
77.6585	9.6207	0.0452
77.7659	9.6189	0.2890
77.7408	9.6161	0.6342
77.6576	9.6137	0.3208
77.6502	9.6140	0.1173
77.6899	9.6078	0.6303
77.6731	9.6141	0.0892
77.7335	9.6045	0.5408
77.7126	9.5934	1.4980
77.7614	9.5988	0.6781
77.7274	9.5968	0.0071
77.7719	9.5849	0.0035
77.6867	9.5795	0.0065
77.7658	9.6453	0.4312
77.7563	9.6382	0.1742
77.6781	9.6047	0.3759
77.7513	9.5945	1.4310
77.6997	9.5934	0.6991

Ground Water Management Plan

Artificial Recharge Structure Map

ONDIPULINAICKANUR FIRKA

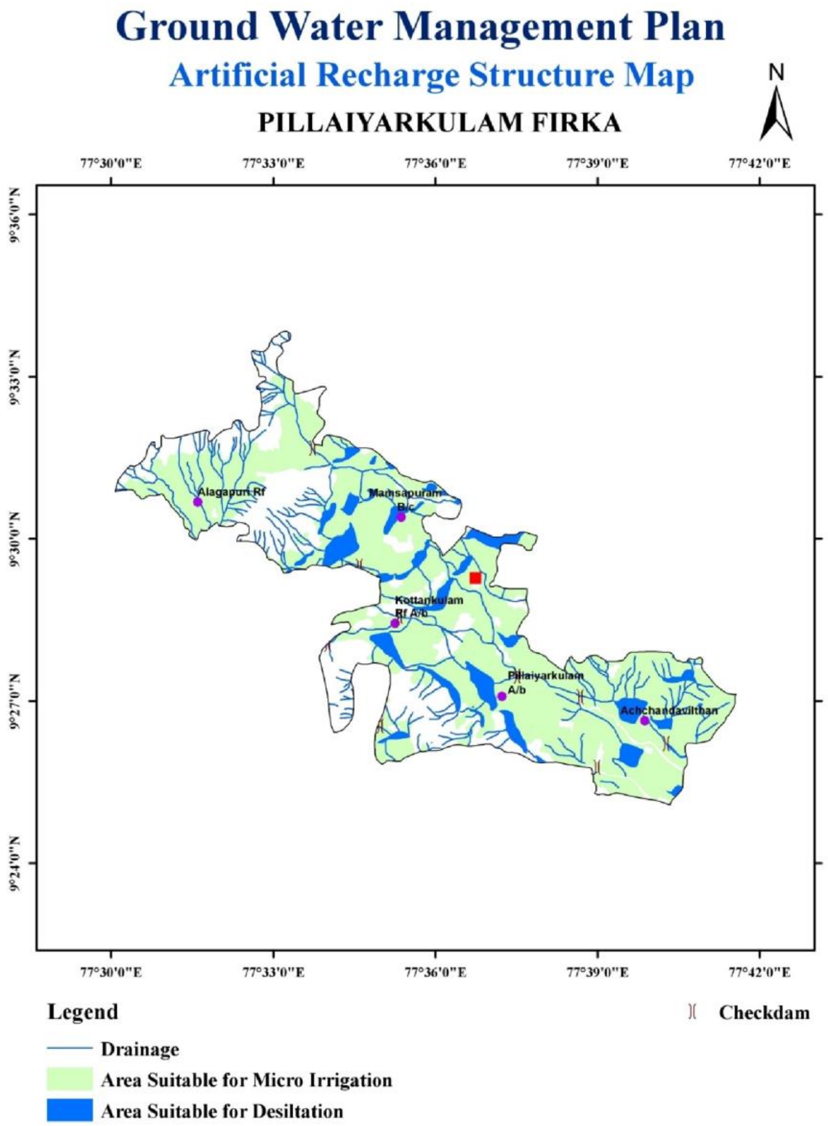


Location of ARS

Structure	Longitude	Latitude
Checkdam	77.925	9.52094
Checkdam	77.959	9.55541

Location of Waterbodies

Longitude	Latitude	Area in sq km
77.9116	9.5767	0.0044
77.9318	9.5621	0.0057
77.9151	9.5520	0.1835
77.9340	9.5476	0.0097
77.9455	9.5457	0.0526
77.9336	9.5456	0.0055
77.9321	9.5410	0.2387
77.9008	9.5278	0.0102
77.9531	9.5251	0.0631
77.9315	9.5239	0.1203
77.9124	9.5246	0.0155
77.9198	9.5168	0.2914
77.9023	9.5204	0.5279
77.9059	9.5127	0.0162
77.8632	9.5107	0.0088
77.8981	9.5091	0.3632
77.9063	9.5092	0.0072
77.8867	9.4892	0.0585
77.8698	9.4892	0.0076
77.9208	9.4783	0.0056
77.8978	9.4710	0.3215
77.9026	9.4769	0.0178
77.8807	9.4729	0.0067
77.8661	9.4698	0.0526
77.8627	9.4644	0.1332
77.8824	9.4625	0.6859
77.8552	9.4565	0.0024
77.8703	9.4462	0.0101
77.8611	9.4456	0.0180
77.8667	9.5100	0.0316

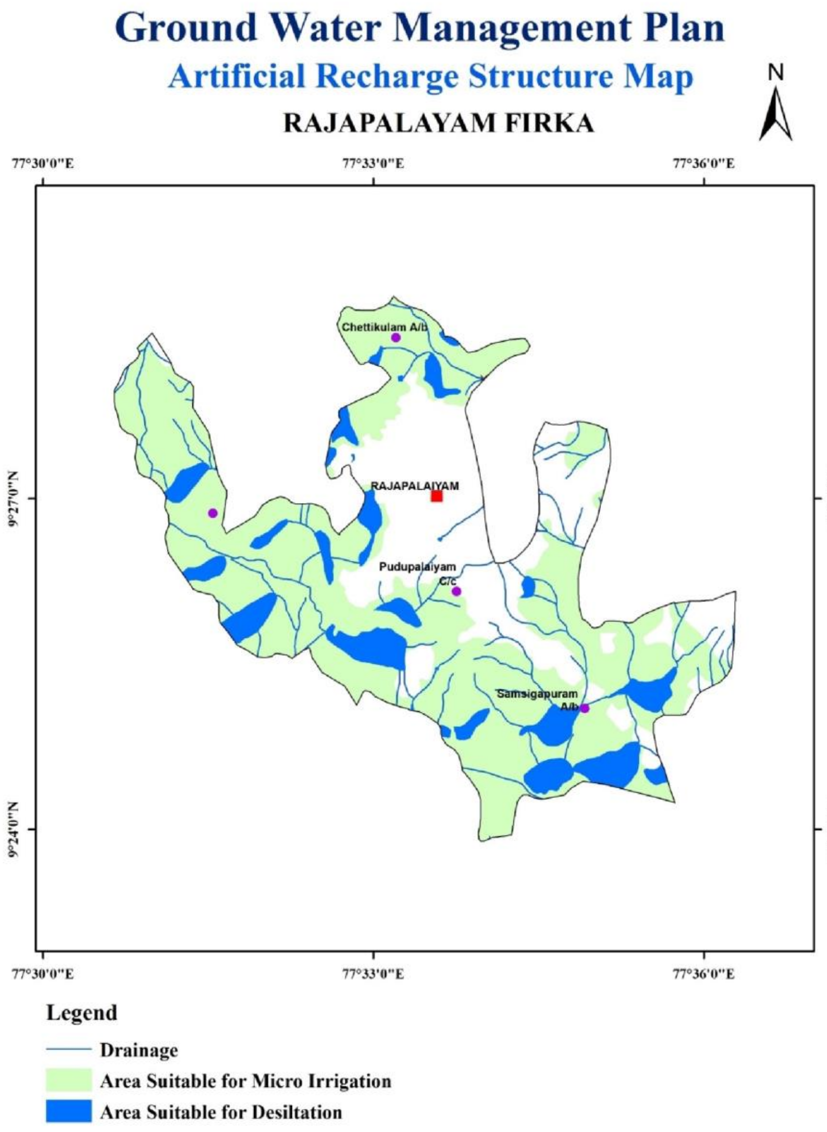


Location of ARS

Structure	Longitude	Latitude
Checkdam	77.5888	9.47613
Checkdam	77.5667	9.46752
Checkdam	77.5829	9.44241
Checkdam	77.6252	9.45774
Checkdam	77.6447	9.45132
Checkdam	77.6712	9.43687
Checkdam	77.5765	9.49161
Checkdam	77.5621	9.5281
Checkdam	77.6499	9.42957

Location of Waterbodies

Longitude	Latitude	Area in sq km
77.5726	9.5259	0.2066
77.5808	9.5244	0.0445
77.5688	9.5221	0.0132
77.5982	9.5161	0.0917
77.5802	9.5149	0.0947
77.6028	9.5142	0.0507
77.5736	9.5109	0.2772
77.5945	9.5099	0.0630
77.5666	9.5063	0.2722
77.5890	9.5089	0.1543
77.5595	9.4942	0.1119
77.6084	9.4919	0.1948
77.5548	9.4901	0.0226
77.5833	9.4876	0.1368
77.6012	9.4799	0.4770
77.6230	9.4687	0.3447
77.5853	9.4655	0.5746
77.6103	9.4656	0.3389
77.6529	9.4622	0.0090
77.6142	9.4547	0.8004
77.6800	9.4618	0.0115
77.6504	9.4611	0.0067
77.6033	9.4554	0.4616
77.6760	9.4572	0.2825
77.6532	9.4576	0.0072
77.6602	9.4471	0.6805
77.6817	9.4488	0.0164
77.6240	9.4406	0.4926
77.6331	9.4415	0.2435
77.6698	9.4434	0.2079
77.5872	9.4389	0.1967
77.6806	9.4392	0.0099
77.5988	9.4372	0.0030
77.6597	9.4333	0.4938
77.6329	9.4314	0.1125
77.5864	9.5047	0.1890
77.5699	9.4971	0.9697
77.5955	9.4948	0.3079
77.6130	9.4466	0.0932



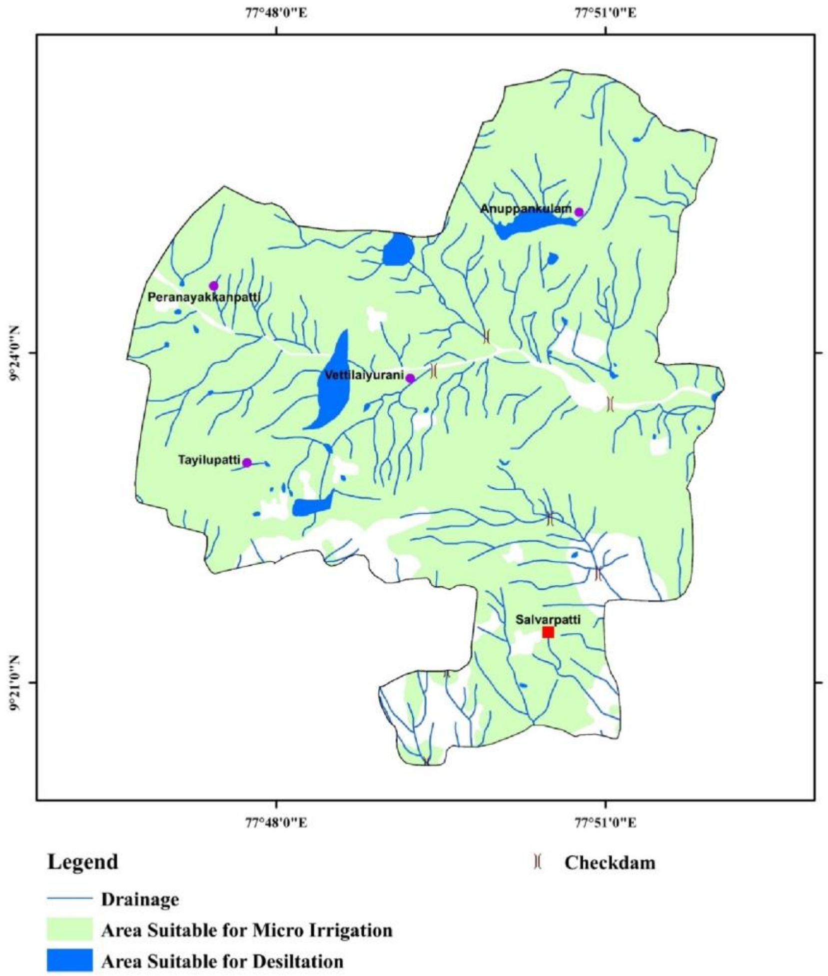
Location of Waterbodies

Longitude	Latitude	Area in sq km
77.5616	9.4742	0.0385
77.5445	9.4765	0.0002
77.5503	9.4716	0.0418
77.5610	9.4665	0.1892
77.5457	9.4639	0.1510
77.5541	9.4682	0.0087
77.5261	9.4547	0.0044
77.5469	9.4561	0.0049
77.5214	9.4524	0.2479
77.5495	9.4469	0.2532
77.5342	9.4446	0.1084
77.5425	9.4411	0.1433
77.5601	9.4439	0.0049
77.5235	9.4393	0.1911
77.5733	9.4366	0.0681
77.5308	9.4319	0.3885
77.5536	9.4327	0.1754
77.5596	9.4243	0.0035
77.5906	9.4211	0.3771
77.5768	9.4158	0.3887
77.5649	9.4159	0.1375
77.5766	9.4080	0.3510
77.5436	9.4563	0.0401
77.5489	9.4275	0.6212
77.5853	9.4091	0.6089

Ground Water Management Plan

Artificial Recharge Structure Map

SALWARPATTI FIRKA



Location of ARS

Structure	Longitude	Latitude
Checkdam	77.8239	9.39724
Checkdam	77.8228	9.33761
Checkdam	77.8489	9.36651
Checkdam	77.8319	9.40242
Checkdam	77.8507	9.3922
Checkdam	77.8416	9.37483

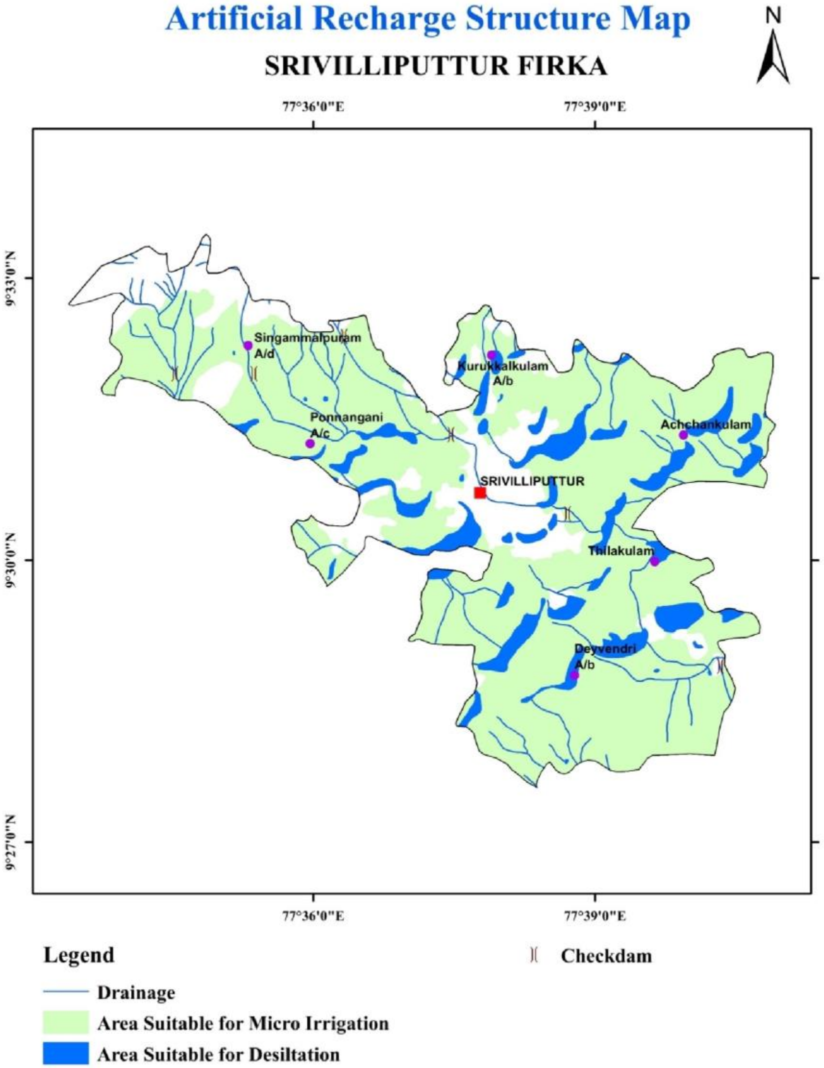
Location of Waterbodies

Longitude	Latitude	Area in sq km
77.8547	9.4323	0.0082
77.8185	9.4158	0.2352
77.8391	9.4195	0.3413
77.8420	9.4143	0.0282
77.8405	9.4080	0.0436
77.8438	9.4048	0.0092
77.8076	9.3960	0.5959
77.7834	9.4013	0.0060
77.8666	9.3934	0.0169
77.8513	9.3970	0.0141
77.7900	9.3939	0.0064
77.8138	9.3917	0.0116
77.8228	9.3913	0.0059
77.8642	9.3886	0.0039
77.8575	9.3873	0.0048
77.8078	9.3855	0.0170
77.8347	9.3831	0.0084
77.7987	9.3832	0.0058
77.8102	9.3810	0.0073
77.8012	9.3796	0.0090
77.7993	9.3793	0.0036
77.8057	9.3774	0.1606
77.7970	9.3756	0.0085
77.8453	9.3694	0.0086
77.8375	9.3495	0.0081
77.7857	9.4107	0.0076
77.7851	9.4062	0.0086
77.7879	9.4036	0.0083
77.8478	9.3932	0.5330
77.8023	9.3788	0.0055

Ground Water Management Plan

Artificial Recharge Structure Map

SRIVILLIPUTTUR FIRKA

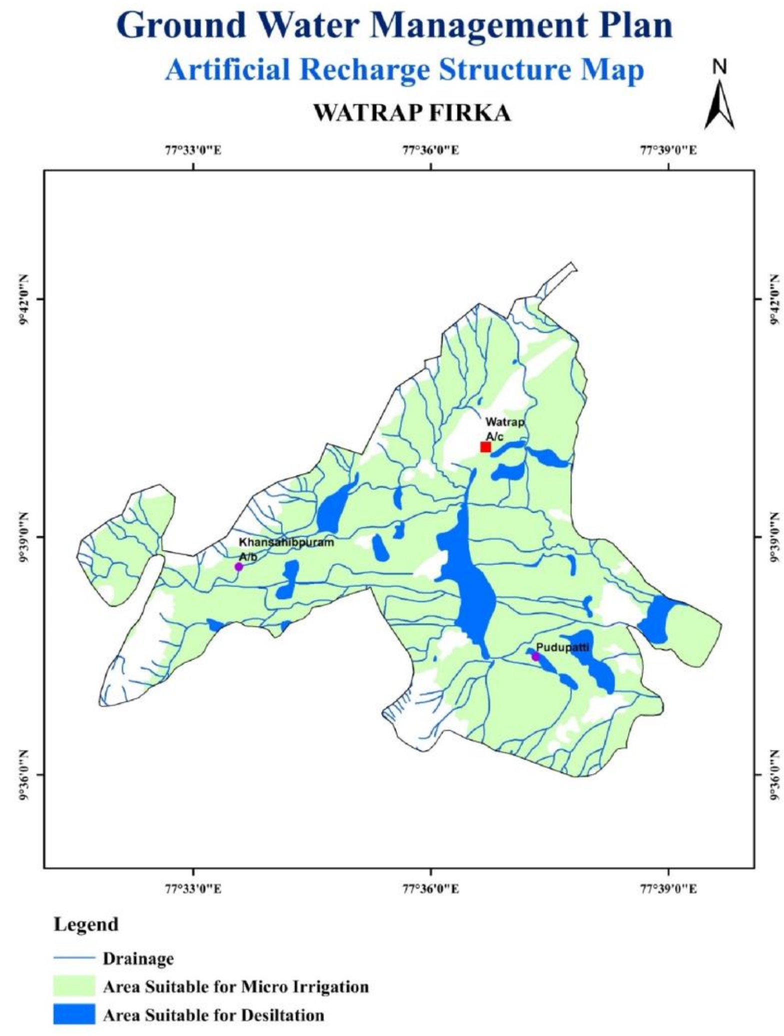


Location of ARS

Structure	Longitude	Latitude
Checkdam	77.6054	9.53967
Checkdam	77.5754	9.53305
Checkdam	77.5894	9.53305
Checkdam	77.6244	9.52228
Checkdam	77.6451	9.5082
Checkdam	77.6722	9.48114

Location of Waterbodies

Longitude	Latitude	Area in sq km
77.6471	9.5377	0.0319
77.6553	9.5363	0.0364
77.5859	9.5368	0.0038
77.6360	9.5365	0.0402
77.6325	9.5351	0.0985
77.6260	9.5341	0.0697
77.6712	9.5241	0.2181
77.6332	9.5287	0.0087
77.6022	9.5286	0.0088
77.5986	9.5286	0.0052
77.6420	9.5220	0.5718
77.6803	9.5259	0.0080
77.6771	9.5218	0.1263
77.5875	9.5233	0.1222
77.6301	9.5237	0.0526
77.6130	9.5225	0.2014
77.6649	9.5183	0.1724
77.5985	9.5182	0.0670
77.6062	9.5179	0.1432
77.6264	9.5146	0.0112
77.6417	9.5104	0.1116
77.6173	9.5089	0.3584
77.6536	9.5100	0.0864
77.6621	9.5027	0.0454
77.6424	9.5068	0.0395
77.6387	9.5043	0.1031
77.6344	9.5040	0.0348
77.6648	9.4994	0.0296
77.6033	9.4985	0.0346
77.6506	9.4966	0.0672
77.6339	9.4938	0.0902
77.6743	9.4914	0.0864
77.6449	9.4915	0.2081
77.6649	9.4898	0.4170
77.6542	9.4853	0.3866
77.6682	9.4850	0.0159
77.6458	9.4788	0.2412
77.6609	9.4804	0.0069
77.6703	9.4800	0.0063
77.6449	9.4642	0.0063
77.6299	9.5296	0.1391
77.6394	9.5232	0.0840
77.6524	9.5231	0.1377
77.6678	9.5233	0.0788
77.6771	9.5178	0.1732
77.6600	9.5145	0.1851
77.6196	9.4993	1.2289
77.6506	9.5024	0.1539
77.6352	9.4867	0.4604



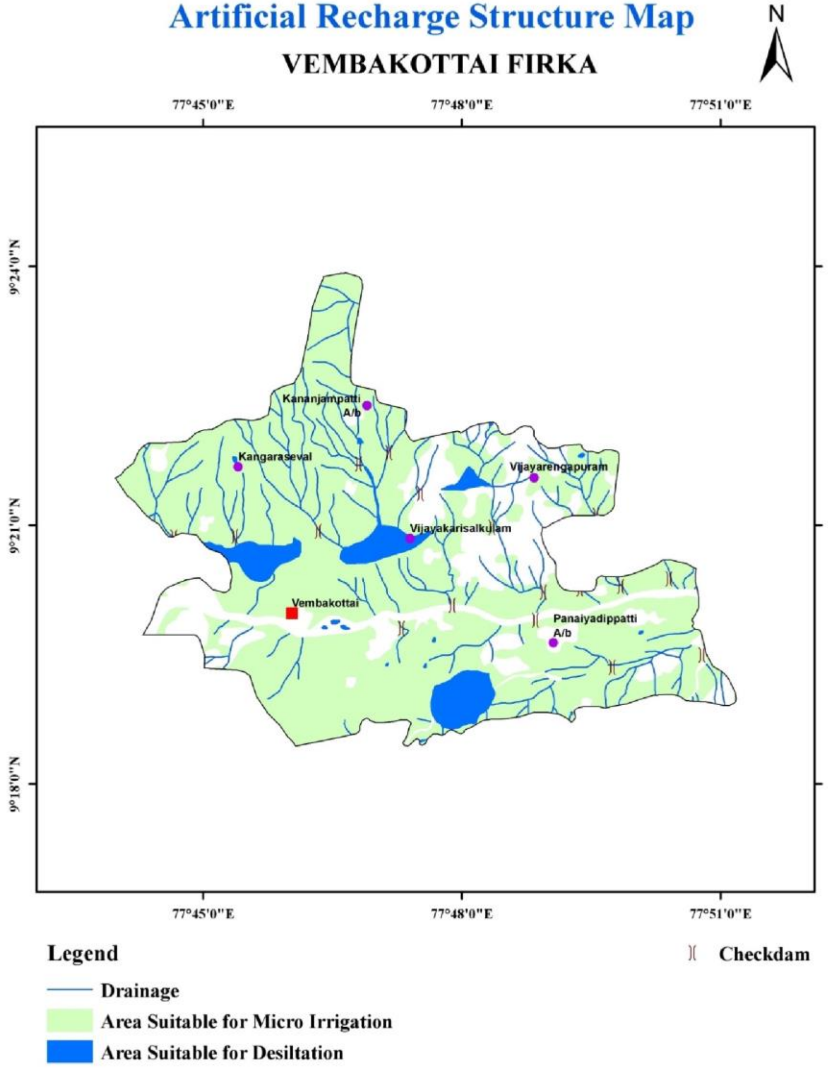
Location of Waterbodies

Longitude	Latitude	Area in sq km
77.9990	9.5334	0.0042
78.0084	9.5256	0.0164
77.9862	9.5229	0.0230
77.9827	9.5229	0.0165
78.0000	9.5198	0.1305
77.9891	9.5208	0.0056
77.9819	9.5176	0.0457
77.9666	9.5189	0.0036
78.0045	9.5142	0.0093
77.9485	9.5073	0.0075
77.9933	9.5046	0.0117
77.9372	9.5024	0.0736
78.0261	9.5039	0.0078
77.9915	9.4991	0.0035
77.9511	9.4946	0.3812
78.0041	9.4962	0.0039
77.9858	9.4816	0.0026
77.9855	9.4792	0.1150
77.9430	9.4712	0.4050
77.9845	9.4747	0.0055
77.9711	9.4668	0.0059
77.9696	9.4438	1.3537
77.9840	9.4648	0.0037
78.0145	9.4585	0.0003
78.0060	9.4527	0.0031
77.9604	9.4490	0.0040
78.0120	9.4473	0.0042
77.9447	9.4462	0.0096
77.9981	9.4425	0.0163
77.9890	9.4418	0.0048
78.0163	9.4411	0.0043
77.9834	9.4379	0.0059
77.9975	9.4356	0.0054
77.9700	9.4245	0.0428
77.9986	9.4320	0.0050
78.0119	9.4300	0.0038
77.9921	9.4192	0.0167
77.9618	9.4180	0.0332
78.0105	9.4192	0.0079
77.9666	9.4157	0.0888
77.9805	9.4147	0.0728
78.0064	9.4120	0.0040
78.0179	9.4061	0.0397
78.0193	9.4271	0.0075
78.0188	9.4251	0.0062
78.0181	9.4036	0.0068

Ground Water Management Plan

Artificial Recharge Structure Map

VEMBAKOTTAI FIRKA



Location of ARS

Structure	Longitude	Latitude
Checkdam	77.829	9.32255
Checkdam	77.8142	9.33159
Checkdam	77.7722	9.34881
Checkdam	77.7858	9.36403
Checkdam	77.78	9.36184
Checkdam	77.7883	9.33002
Checkdam	77.8157	9.33702
Checkdam	77.8058	9.34958
Checkdam	77.7981	9.33454
Checkdam	77.7919	9.35614
Checkdam	77.7561	9.34782
Checkdam	77.8307	9.33819
Checkdam	77.84	9.33965
Checkdam	77.8464	9.32491
Checkdam	77.8259	9.35191

Location of Waterbodies

Longitude	Latitude	Area in sq km
77.7804	9.3663	0.0139
77.7561	9.3627	0.0135
77.7852	9.3463	0.9626
77.8007	9.3591	0.2291
77.7589	9.3434	1.0145
77.7756	9.3313	0.0177
77.7775	9.3303	0.0149
77.7734	9.3302	0.0088
77.8347	9.3292	0.0080
77.7946	9.3279	0.0077
77.7855	9.3231	0.0056
77.7929	9.3229	0.0067
77.8261	9.3222	0.0258
77.8002	9.3163	1.2903
77.8212	9.3137	0.0042
77.7926	9.3083	0.0161