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# Evaluation of Groundwater potential Zones using RS and GIS Application in Malattar watershed, Tamil Nadu, India

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**Abstract.** Groundwater is one of the major sources of water both in the semi-arid and arid regions like Tamil Nadu, India. It is of fundamental importance to any social or economic development. In recent decades, as surface water supplies have been depleted or contaminated and hence more attention has been given to groundwater resources. The advances in the technology especially in the field of remote sensing satellite technology, geophysics, etc. have resulted in enormous increase in the extraction of groundwater. The reservoirs and tanks of the surface water body mainly depending on rainfall. Due to various reasons the capacity of these structures is also reduced. Hence the storage conditions of these structures are poor during monsoon seasons. In many parts of the state, the declination of groundwater level is a major concern because of continuous pumping of groundwater and poor storage in tanks and reservoirs. Variation of temperature, wind velocity, sunshine hours and evapotranspiration were analyzed. Seasonal average rainfall for 46 years was used to analyze spatial distribution. Geomorphology, land use and lineaments derived from satellite data and geology and soil prepared from district resource maps. Depth to bed rock and weathered rock derived from geophysical survey data to evaluate aquifer thickness. Groundwater potential zonation map was generated using Geographical Information system (GIS) by integration of various thematic maps in the Malattar watershed

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## 1. Introduction

Tamil Nadu is an agrarian State. A water resource is one of the main resources for agricultural activities, domestic uses and food production in Tamil Nadu, India. In the absence of adequate surface water resources, groundwater has emerged as an important and indispensable resource for different uses. The development of recent technology especially in the field of geomatics technology, geophysics, geochemistry etc. have resulted in enormous increase in the extraction of groundwater

Due to vagaries of monsoon, the surface water bodies such as reservoirs and tanks do not get adequate filling and could not fulfill the needs of entire command areas. The capacity of these structures is also reduced due to various reasons resulting in poor storage conditions. During monsoon seasons these structures do not get fully stored because of reduction in storage capacity. In the above situation,

survival of the people in these areas are major threat and most of them migrated to adjoining states and urban centers for other occupation, and ultimately leaving their agricultural land as barren land.
The scientific community is to identify the problems in agricultural sectors and to suggest the farming community for suitable measures of artificial recharge structures to increase agriculture production. This will encourage the farmers for their agricultural activities. The remote sensing data combined with the available collateral data are useful to evaluate the groundwater potential in Malattar watershed. Groundwater potential is expected to be available in the alluvium, sedimentary zone and buried pediment deep, lineament zone area. Using Remote Sensing (R S) data, various thematic layers were generated with limited field check. The thematic maps were analyzed under GIS environ to determine groundwater potential zonation map.

The LISS III data of IRS P6 2016 were used to prepare satellite image map of Malattar watershed of Pennaiyar river basin and it is also used to delineate geomorphic units and lineament features. Based on the use of above data, preparation of various maps, analysis of thematic layers and by overlay analysis the favorable groundwater potential zonation map of Malattar water shed was generated.

## 2. Literature Review

Rainfall is the major source of groundwater availability. If the rainfall is more than groundwater is available, if rainfall is less than groundwater will be less. Rainfall may be varying from one region to another region. From that the annual rainfall data is taken from the rain gauge stations for past 39 years and interpolation method has been used to find amount of rainfall has been appeared in the study area. Then zones are classified with equal intervals and weights are assigned to each zone [9].
Water level fluctuation maps are more important for estimation of storage changes in an aquifer [5]. The chemical parameters are effectively used to discuss the area of discharge, recharge and the residence time within the aquifer, suitability of water for domestic irrigation or industry use [10]. The recharge zones in Live Osaka area of Florida were identified with the help of different ion constituents present in the groundwater by using vector analysis [7]. The different features available in land use map are crop land, barren land, hill, medium dense forest, and dense forest. The dense forest mainly covers the plantation. Groundwater recharge is not suitable for these lands due to heavy rainfall. Prioritization is given to barren land and crop land to recharge ground water where the availability of groundwater and surface water is less for domestic and irrigation purpose [4].
Geomorphology is the study of earth structures and landforms. It is mainly depended on geological formation [11]. The map shows five geomorphological features in order to know about the water resources areas. (1) Denudational hills are the area which is covered forest and slope which provides moderate to good recharge of groundwater. (2) Pediment is the area which covered cultivate land and is having well to very good recharge of groundwater prospect. (3) Undulating upland is very steep slope area, having poor groundwater recharge. (4) Pediment Inselberg complex is full of barren land with poor drainage pattern. The ground water prospect is also poor. (5) Peneplain area is of flat rocks with uneven land. The drainage pattern is sub parallel to sub dendritic with poor groundwater prospect [2].
R S based methodology was the best method for the exploration of groundwater [8]. The groundwater level and various geomorphological units. It is observed that, the water level was varying from 3.4 to 6.5 m below ground level in the erosional valley as compared to other landforms [1]. Hydrogeological information such as water level, rainfall data, water quality, irrigation details were collected and brought into GIS platform to generate the composite map of groundwater potential zones. The potential zones of groundwater were divided into five categories such as very poor, poor, moderate, good, excellent [11]. Contouring the geophysical resistivity data is one of the important methods, through which the groundwater potential areas, movement pattern can be easily identified [3]. Some methodology to delineate groundwater potential zones of Marudhaiyar basin. The potential zonation map was prepared with this model was checked by the pump test data to ascertain the goodness of the model developed. The verification showed that the potential zones of groundwater evaluated through this model are in good agreement with the pump test yield data [6].
Keeping the above literatures in mind, the study has been undertaken to identify the potential zones of groundwater in the Malattar watershed.

The main objectives of this study are an integrate approach to identify favorable groundwater potential zones in Malattar watershed.

A. To identify different geomorphologic units using the satellite data IRS P6 LISS III,
B. To find out the land use categories,
C. To analyse the seasonal water level fluctuation with rainfall influence and
D. To Identify favorable zones groundwater potential using R S data and GIS analysis.

**3. Study Area**
The location of Malattar watershed is lies in the north eastern part of the Pennaiyar basin. Malattar watershed is bounded by Lower Pennaiyar and Gadilam watersheds in the east, Lower Pennaiyar in the north and Gadilam watershed in the south and Upper Pennaiyar and Turineli watersheds in the west (Fig.3.1) and the coordinates of watershed is between north latitudes 11° 43’ 30” N to 11° 56’ 15” N and east longitudes 79° 15’ 45” E to 79° 36’ 30”. It is covering mostly (75%) in Villupuram district, and about 25 % in Cuddalore district of Tamil Nadu (Fig.1).

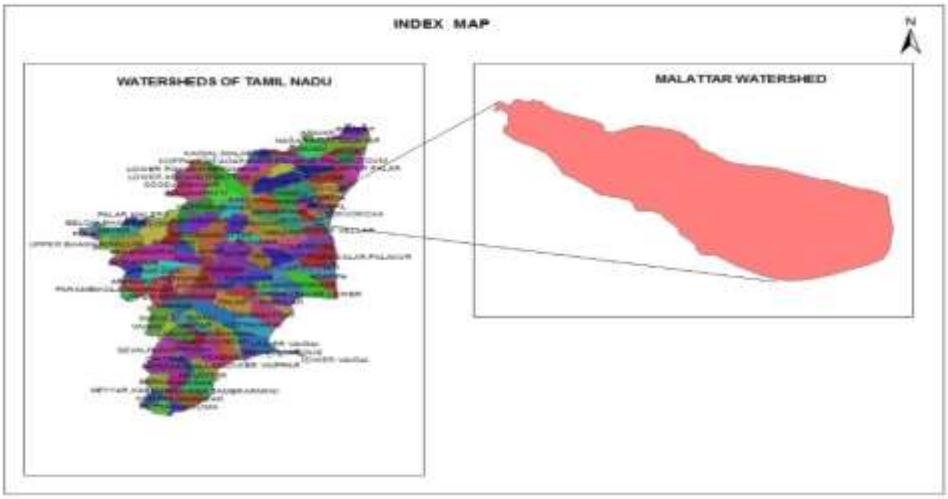


**Figure 1.** Index map

The watershed occupies an aerial extent of 271.82 sq.km covering most of the areas in Panruti, Ulundurpettai and Thirukovilur taluks (Fig.2). The watershed falls in the following Survey of India topo sheets 58M/5 and 58M/9 having 1:50,000 scale. There are 6 blocks covered partially in the watershed. Thiruvennainallur block of Villupuram district covered 68% of the study area and other blocks Thirukovilur, Mugaiyur, Thirunallavur, of Villupuram district covered a small portion in the watershed. Annagaramam and Panruti of Cuddalore district covered in the south eastern part of the watershed. 71 villages in Villupuram district and 41 villages in Cuddalore district (Total 112 villages) covered partially or fully in the study area.


**Figure 2.** Taluk map

Data products

1. Satellite data used: The LISS III data of IRS were used to prepare various thematic maps of Malattar watershed.
2. Physiographic data: District Map, Taluk maps and 1:50,000 scale survey of India toposheets.
3. Hydrogeological data
    a. Groundwater level data
    b. Geophysical resistivity data.
4. Hydrometeorological data

The hydrometeorological characteristics of the Malattar watershed includes analysis of temperature, humidity, wind speed, sunshine hours and rainfall for Malattar watershed.

## 4. Methodology

The general methodology adopted for this research study includes collection of data, data preparation and validation. Selection of satellite data in respective of its spatial resolution and period, Data on water level, water quality, rainfall, climatology and well census are sorted out for the study area for reasonable and comfortable years for analysis. Selection of software and method of analysis is essentially required for the research study. All the above data were collected from public works department, water resources data centre Chennai, India. These spatial and non - spatial data were used to analyse through RS and GIS.

The satellite image of IRS LISS III are shown in the figure 3 were taken into Erdas Imagine system for processing, preprocessing, display and enhancement, and information extraction. Other geomorphology features, landuse categories and lineaments are delineated by visual interpretation techniques.

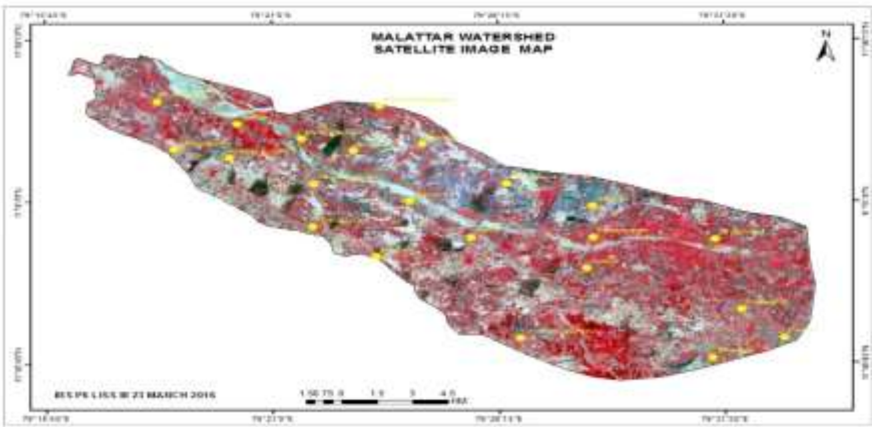


**Figure 3.** Satellite image

All the thematic maps such as base map, drainage map, water level contour, soil map, rainfall map, geology map, geomorphology, land use map, depth to bed rocks is taken into the GIS platform for groundwater potential zonation. The zonation map of groundwater potential was derived according to the ranking as well as weightages assigned in overlay analysis to each thematic map.

### *4.1. Hydometeorology*

The details of the rainfall as well as other hydrometeorological information are essential for planning, development, evaluation and management studies.

A. Climate

Palur and Thirukovilur weather stations have been considered for climatical analysis. The climatological values such as the maximum and minimum monthly average temperature, the relative humidity of air, the monthly average wind velocity, monthly average sunshine hours/day of the watershed are given in table 1.

**Table 1.** Climatological Parameters

| SI. No | Climatological Parameter (Annual Average) | Palur | Thirukoilur |
|---|---|---|---|
| 1 | Average monthly temperature Maximum in $^0$ Celsius | 43.00 (Jun-2003) | 43.50 (May-2003) |
| 2 | Average monthly temperature Minimum in $^0$ Celsius | 14.00 (Jan-2002) | 17.00 (Dec-2007) |
| 4 | Monthly average relative humidity in % | From 89.73% Nov2010 to 51.23% May 2012 | From 99.35% Aug2010 to 51.18% May-2012 |
| 5 | Average wind velocity in km/hour | From 9.50 Km/hr (June2003) to 1.77Km/hr (Oct 2013) | From 14.23 Km/hr (May2006) to 0.81 Km/hr (Dec-2014) |
| 6 | Average Sunshine hours / day | From 10.05 hrs/day (Apr2002) to 3.32 hrs/day (Jul2013) | From 11.70 hrs/day (Aug2008) to 2.39 hrs/day (Dec-2010) |
| 7 | Average Pan Evaporation in mm/month | 163.59 | 161.70 |

B. Rainfall

The recorded rainfall data were collected from Thirukovilur Anicut, Villupuram, Ulundurpet and Cuddalore. Malattar watershed falls in the tropical monsoon zone. The contour map of average annual rainfall for the period 1976 to 2016 was generated using Arc View GIS software. It is observed from the contour map, the minimum rainfall recorded in the upper reach of the watershed whereas the maximum rainfall recorded in the south eastern part of the study area. The average annual rainfall is recorded as 1100 mm

*4.2. Spatial Geometry*

The assessment of the ground water potential with the help of spatial geometry of geomorphology, geology, land use and soil along with information on aquifer characteristics based on geophysical study have become a part of water resource management / planning Studies.

A. Physiography and Drainage

Almost the entire area is a plain terrain and in some areas the elevation is about 10 -100 m. The watershed is sloping towards east and southeasterly directions. Malattar river is a tributary of Pennaiyar which routed from Veeramadai in Thiruvennainallur block of Villupuram district. After running 16.72 km towards south east, the river further divided into two branches near Arasur village carrying the same name. The first bransch of Malattar river join with Gadilam river after travelling 11.86 km towards south east. Another branch of Malattar river run upto 14.12 km towards east and abruptly vanished near Rajapalayamand is shown in fig 4.


**Figure 4.** Drainage Map

B. Geology

This watershed is occupied by mostly alluvium formation in the lower part of the watershed. Alluvium consisting of sand, clay and silt in the lower portion of the watershed. Hard rock formation having Hornblende gneiss is found in the north western part of the watershed (Fig.5).

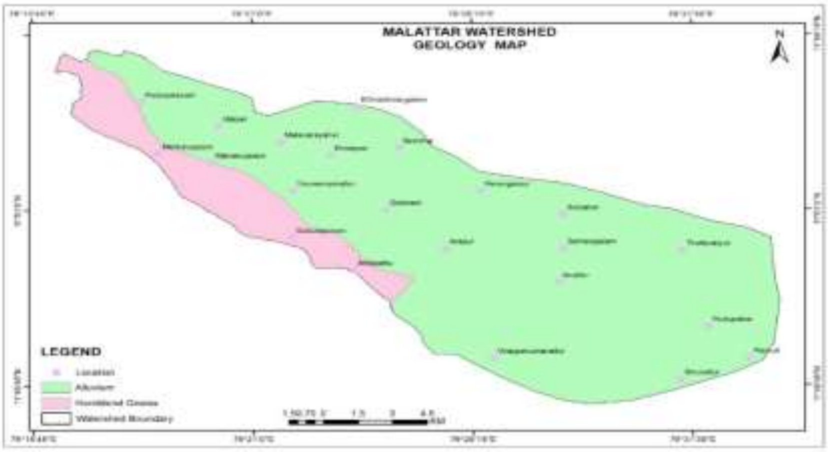


**Figure 5.** Geology map

C. Geomorphology

Geomorphological study is also one of the most important parameters to evaluate water resources both surface and subsurface water The Malattar watershed is mostly covered by flood plain in the north and western portions. Satellite data from IRS P6 LISS III, May 2008 Geocoded FCC on 1: 50,000 scale have been utilized for this study. Based on the geomorphological study the following major landforms have been identified (Fig.6).


**Figure 6.** Geomorphology map

The north-west portion of the watershed covered by a small portion of buried shallow pediment zone. Regularly dry crops like Cholam, Cumbu and some other pulses are raised in this area during the monsoon period only. Generally, the agricultural activities are greater in buried pediment moderate zone and is found in the north western part of the watershed. The dissected/ undissected geomorphic unit are noticed as small patches in the southern part of the watershed

The flood plains are preferable for groundwater recharge. Floodplains have very good potential zones and are very fertile land for agriculture. 60% of the area in northern and eastern parts of the watershed covers the flood plain. Groundwater prospect in this alluvium plain of land form is very good. This type of landform is seen in the south eastern part of the watershed.

D. Lineament

Lineament map was prepared from IRS P6 LISS III data satellite and is shown in (Fig. 7). The movement of groundwater is more along these lineaments. Lineament intersection zone contribute very huge amount of groundwater.


**Figure 7.** Lineament map

E. Land Use

Remote sensing is used to analyze the various categories of land use in the past and comparing the changes with present trends. Land use and land cover analysis is very much useful for planning, development and land management activities in agricultural sector.

Visual interpretation was mainly aimed to derive the relevant land use information of the Malattar watershed from IRS P6 False Colour Composite (FCC) LISS III data of June 2016. Only land use categories of 2nd level were delineated from the remotely sensed data (Fig.8).


**Figure 8.** Land use map

The aerial extent of land use categories is given in table 2.

**Table 2.** Aerial extent of land use category

| Sl No. | Category | Area in Sq.Km | Area in % |
|---|---|---|---|
| 1 | Wet Crop | 107.458 | 39.53 |
| 2 | Dry Crop | 8.336 | 3.07 |
| 3 | Fallow Land | 1.591 | 0.59 |
| 4 | Platation | 102.058 | 37.55 |
| 5 | River | 15.580 | 5.73 |
| 6 | Tank | 22.493 | 8.27 |
| 7 | Land with scrub | 0.127 | 0.05 |
| 8 | Sandy area | 0.252 | 0.09 |
| 9 | Settlement | 13.929 | 5.12 |
| | **Total** | **271.824** | **100.00** |

The area described under settlement (built up land) category has been estimated as 13.93 sq km which 5.12% in the total geographical area of Malattar watershed. The aerial extent of the wet crop is 107.458 sq.km.3.07% of the watershed covered by dry crops. The spatial distribution of dry crop is 8.366 sq.km. The scrub land occupied 0.127 sq.km of area.  The landform occupies an area of 0.252 sq.km. Tanks occupied 22.493 sq.km and it is 8.27% in the watershed. The Malattar river occupies about 15.580 sq.km and it is 5.73% of the watershed area.

F. Soils

Soil is also one of the natural resources which are important in agricultural activities. Clay occupied maximum portion of the watershed followed by sandy clay which is noticed in the lower portion of the watershed. Sandy clay loam is spread over in the south eastern part and some part of the western side of the watershed shown in the fig. 9.

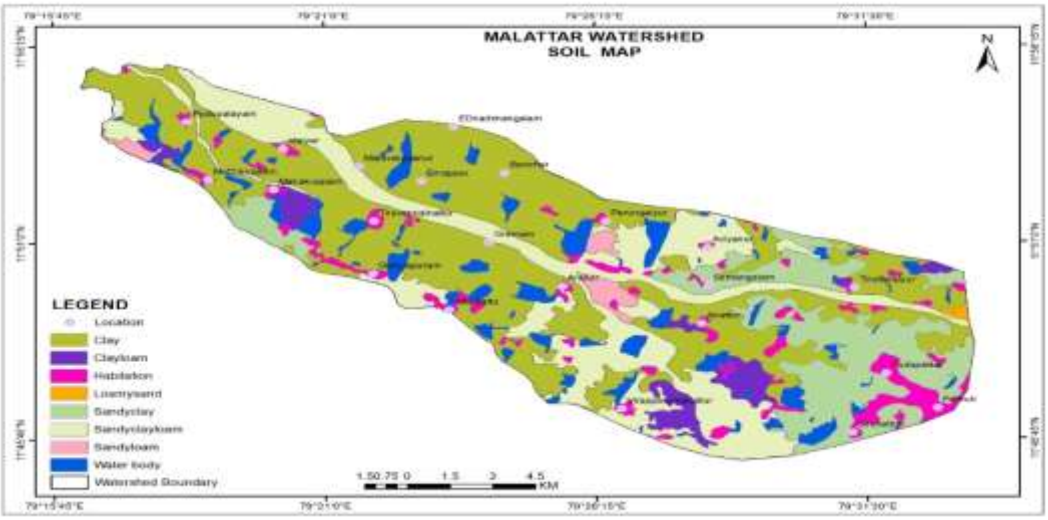


**Figure 9.** Soil map

G. Hydro Geophysics

Electrical resistivity method has been widely used for the practical application in detecting the groundwater. For evaluating the groundwater potential zones of the entire Malattar watershed, vertical electrical sounding data of 7 locations have been used.

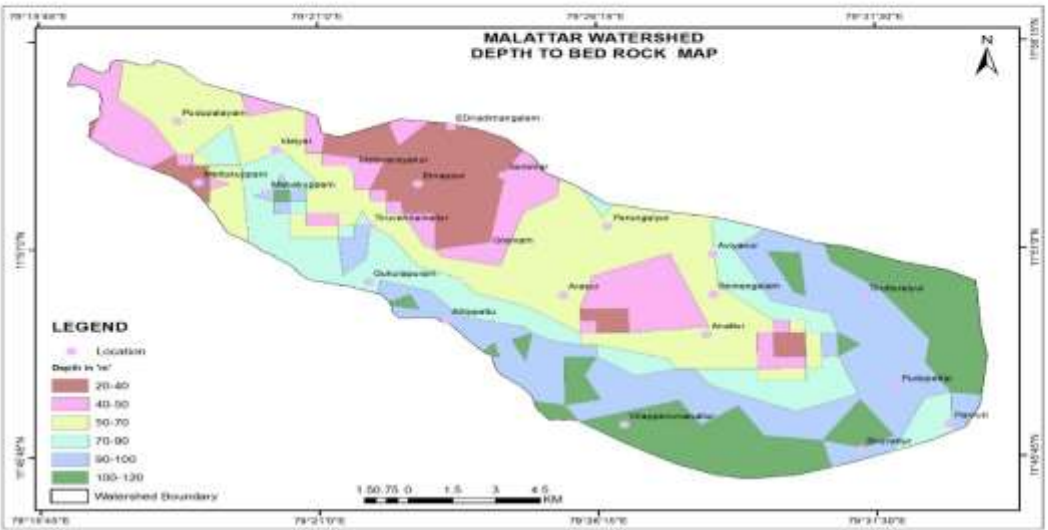


**Figure 10.** Depth to bed rock map of the watershed

The profile of depth to bedrock have been analyzed through interpolating VES data and reveal that the lower part of the watershed the basement rock touches more than 100 m bgl. The south eastern portion shows favourable for groundwater recharge for further development.

From the depth to bed rock contour map (Fig. 10) the basement of rock was observed at a depth of 50 to 70 m in along the river course area and in and around Arasur, Perungaiyur, Pudupalaiyam, Idaiyur and Anathur villages. 70 to 90 m depth of basement was noticed in and around Gokulpuram and Aviyanur villages. In villages Attipattu, Pudupettai and Panrutti 90 to 100 m depth of bed rock is noticed. The maximum depth of basement 100 to 120 m was noticed in and around Manakuppam, Viraperumanallur and Srivattur village.

H. Groundwater level

Details of aquifer geometry and well constructions can be easily recognized in water level contour maps and in the water table maps are systematically studied by taking the water levels in the observation wells. The 46 years (1973-2015) average water levels recorded and contour map prepared during pre- monsoon season are shown in fig. 11.

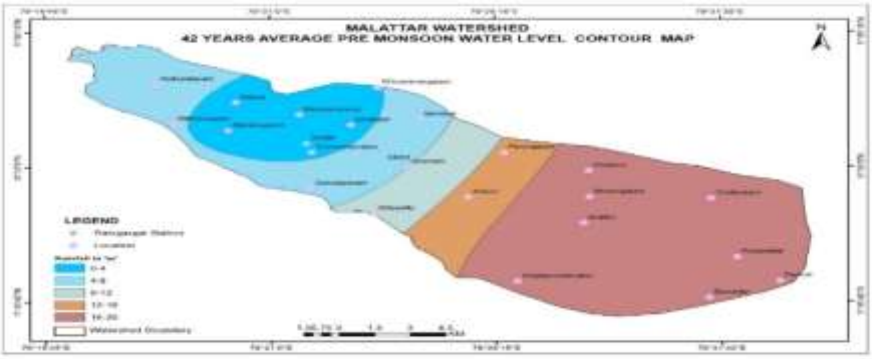


**Figure 11.** Average pre monsoon water level map

The average water level ranges from 4m- 20m during pre- monsoon period, Water levels in a major part of the watershed were in the range of 12 to 20 m bgl during the period. Shallowest water levels were observed in some pockets along the Idaiyar, Manakuppam, Malavarayanur and Emappur villages. Deepest water levels were observed in the southern parts including Arasur, Aviyanur, Anathur, Virapperumanallur, Panruti, Tirutturaiyur and Srivuttur villages.

## 5. Groundwater Potential Evaluation

GIS is an essential tool for delineation of groundwater potential zones which is used to integrate and analyse the spatial and non-spatial information. Arc View GIS were used to generate database for non-spatial and spatial data. TIN model was used for interpolation of data like water level, rainfall for generating the raster output to incorporate in the potential zonation map.

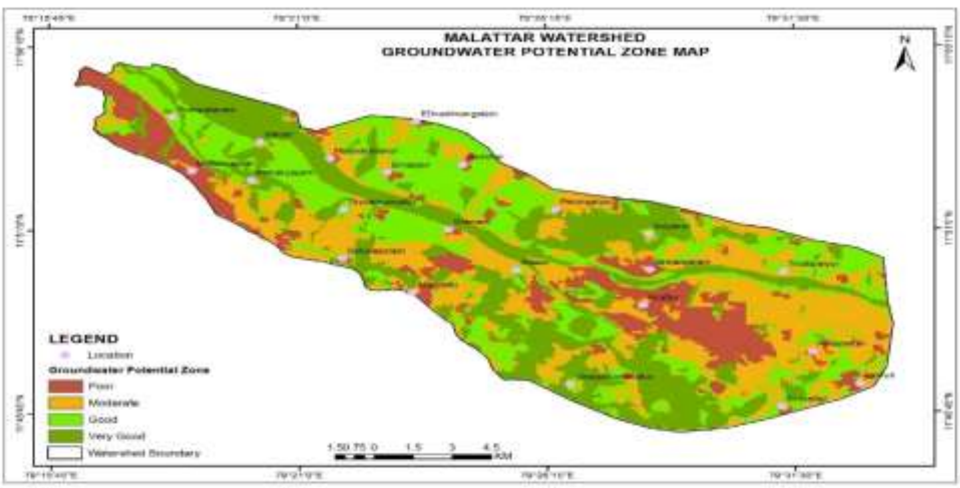


**Figure 12.** Groundwater potential zonation map

The composite map of groundwater potential has been prepared by integrating the information from geomorphology, geology, lineament, annual rainfall, Pre monsoon water level, depth to bed rock, soil and land use by giving appropriate weightages. The rainfall, depth to bed rock and water level map are generated by using Inverse Distance Weighted (IDW) method. The category of good groundwater potential zones is identified and spread over in the upper northern part and central part of the watershed.

## 6. Result and Conclusion

### *6.1. Result*

The following studies were carried out using RS and GIS techniques for identifying favorable zones of groundwater potential in this Malattar watershed.

1. Geological map of the area was generated. The different type of rocks is encountered and favorable geological formations for the groundwater storage were identified.
2. Geomorphological units like buried pediment deep, buried pediment Shallow were identified and their groundwater potential was qualitatively assessed. Groundwater development of these units can help agriculturists to sink or drill a well
3. Hydrological information like rainfall, temperature, soil condition, etc. were collected and analyzed.
4. Hydrogeological data and pre monsoon water level and topsoil thickness, persistence of weathering, depth to bedrock were collected for some locations and GIS data base was created.
5. Integrating geological, geomorphological and hydrological data for Malattar watershed favorable areas for groundwater potential were identified.

### *6.2. Conclusion*

The surface water which is available during rainy season must be recharged to the underground aquifer through recharge wells which can be dug in various places to various aquifer of shallow or deeper nature; of course, care must be taken in sending the surface water directly to the aquifer which may spoil the natural condition of the aquifer. It may fill up the pore spaces with clayey sediments or react with the aquifer materials and giver off precipitation, which may occupy the pore spaces and spoil the aquifer characteristics. To avoid the entry of clayey material into the aquifer, lower portion of recharge well must be filled with fine sand, coarse sand, grit, pebbles and conglomerates in the ascending order so that the recharge water filtrated before it is entering in to the aquifer system.

The following problems also exits in the study area such as groundwater conservation and reclamation, droughts, siltation and encroachment in tanks, socio economic issues and public awareness and participation in water resources management. To overcome the above problems, artificial recharge structures have to be constructed in feasible locations.

Hence the study on **“Evaluation of Groundwater potential in Malattar watershed of Pennaiyar Basin using Remote Sensing and GIS Techniques”** is very much useful for identification of groundwater potential zones.

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