

STUDIES OF GROUNDWATER EXPLORATION IN CHAMARAJANAGAR TALUK, USING ELECTRICAL RESISTIVITY TECHNIQUES, CHAMARAJANAGAR DISTRICT, KARNATAKA, SOUTH INDIA

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ABSTRACT

The geophysical methods has been used for a number of applications particularly groundwater potential zone. There are four important techniques like gravity, magnetic, seismic, and geoelectrical prospecting methods are available. Electrical resistivity (Geoelectrical) methods are the most popular among them and its highest resolving power and economical viability. Electrical resistivity techniques to investigate the different lithological formations, bed rock dispositions, the depth to water table or zone of saturated formations, thickness of weathered zones, detection of fissures, fractures, fault zones, establishment of their depths, thickness and lateral extent of aquifers, groundwater flow directions, valley fills, depth to basement in hard rocks, fresh and salt water intrusions, groundwater prospective zones, for locating ore deposits and archaeological studies. In this area, electrical resistivity method has been worked to analyse geoelectrical parameter identification.

Keywords: *Electrical, Lithological, Thickness, Basement, Valley Fills, Groundwater Flow*

INTRODUCTION

Electrical resistivity method is the most suitable for foundation studies of groundwater exploration. It is easy to employ and the equipment is convenient to transport from place to place. Information about aquifers, water tables, salinities, impermeable formations, bedrock, etc can be obtained from resistivity surveys. Electrical conductivity is the proportionality factor relating to the current that flows in a medium to the electrical force field that is applied. It is a measure of the ability of the material to conduct an electrical current to move through the material. Resistivity is the reciprocal of conductivity. The units of conductivity are Siemens per meter (S/m). The practical unit is milli Siemens per meter (mS/m). Because Siemen, the unit of conductance, is the reciprocal of the Ohm, the unit resistance. The units of conductivity are sometimes given as mhos/meter or millimhos/meter. Resistivity is the inverse of conductivity ($\rho=1/\sigma$). The units of resistivity are ohm meters (Ωm). The direct electric resistivity method uses a man-made source of electrical current that is injected into the earth through grounded electrodes. The resulting potential field is measured along the ground using a second pair of electrodes. The transmitting and receiving electrode pairs are referred to as dipoles. By varying the unit length of the dipoles as well as the distance between them, the horizontal and vertical distribution of electrical properties can be recorded.

MATERIALS AND MEHTODS

Chamarajanagar taluk, Chamarajanagar district of Karnataka comes under the semi-arid region. It lies between $11^{\circ}40'N-12^{\circ}15'N$ Longitude and $76^{\circ}40'E-77^{\circ}15'E$ Latitude with geographical area extent of 1235.9 sq. kms covering 190 villages coming under the Survey of India (SOI) Toposheet nos..57D/12, 57D/16, 57H/4, 58A/9, 58A/13, 58A/14, 58E/1, 58E/2, 58E/5, on a scale of 1:50,000. The study area fall in southern dry –agro-climatic zone. The study area is accessible by good motor able road and is very well connected by Mysore to Chamarajanagar broad gauge southern railway line length of 60 Km (From Bangalore 157 KM) which is observed in location map of the Study Area (Figure1).

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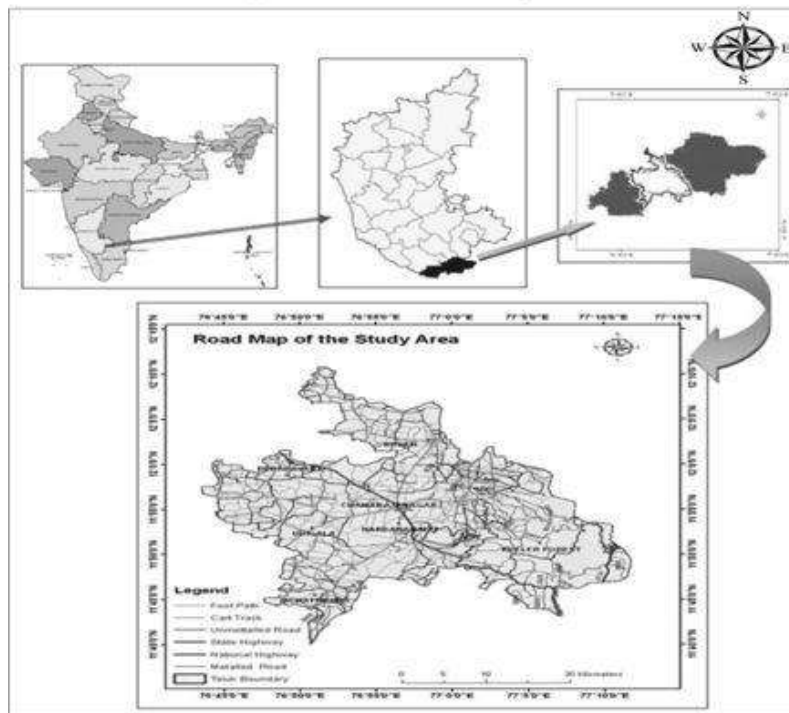


Figure 1: Location map of the study area

RESULTS AND DISCUSSION

All methods of exploration geophysics are based on some physical property. Due to the differences in lithological and chemical composition, different rock types and ore deposits have different physical properties. It is electrical resistivity or its reciprocal electrical conductivity that is used as the physical property in the electrical methods. The physical property has a wide variation. One of the highest resistive rocks is the granite with resistivity values that run into several hundreds and thousands of ohm meters where as one of the lowest geological units is clay with values ranging from no more than one ohm meter (Chistensen & Sorensen 1998, Sorensen *et al.*, 2005). Most of the rock formations conduct electricity because of mineralized water flowing through their pores, fractured zones and fissures. Dry rocks and soils are highly resistant. Resistivity of a geological formation, therefore, is a function of porosity, saturation and salinity of the water. Resistivity of water decreases with increasing salt content.

Vertical Electrical Sounding (VES)

The electrical resistivity methods used in Hydrogeological investigations (Figure 2). In this area, using the vertical electrical sounding, during resistivity surveys, current is injected into the earth through a pair of current electrodes and the potential difference is measured between a pair of potential electrodes. The current and potential electrodes are generally arranged in a linear array. Common arrays include the dipole-dipole array, pole-pole array, Schlumberger array and Wenner array. The apparent resistivity is the bulk average resistivity of all geological influence the current (Zohdy *et al.*, Op.cit). It is calculated by dividing the measured potential difference by the input current and multiplying by a geometric factor specific to the array being used and electrode spacing. In a resistivity sounding, the potential electrodes remain fixed and the current electrodes are expanded simultaneously about the center of the spread. The distance between the electrodes gets too large, it then mandatory to increase the distance between the potential electrodes to have a measurable potential difference and electrode configuration are arranged in the number of ways of setting up of current and potential electrodes, in the groundwater investigation by electrical resistivity methods. In general, the electrode configurations may be classified into two types. First type is one in which all four electrodes are placed along a straight line as in Schlumberger and

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Wenner array. Second type is one in which the pairs of current and potential electrodes are separately placed and they are not supposed to be in a straight line as in dipole-dipole array. The first type is being widely employed for groundwater studies the variation of resistivity with depth is modeled using forward and inverse modeling computer software IPI2WIN.

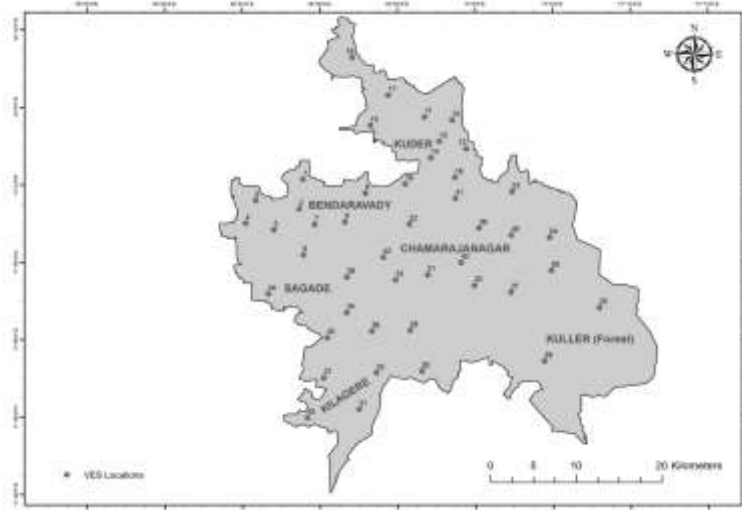


Figure 2: VES Location map of ChamaraJanagar taluk

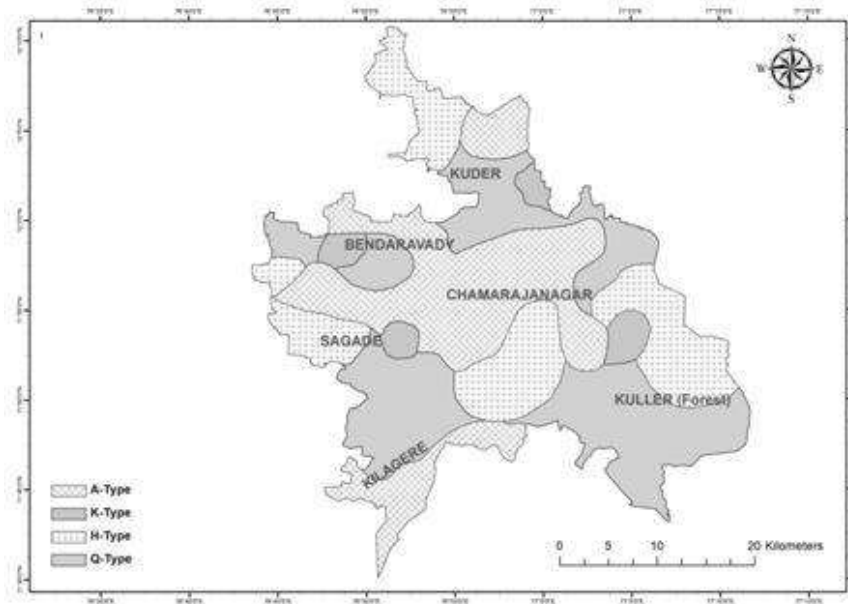


Figure 3: Types of Curves map of ChamaraJanagar taluk

‘A’-type curves are indicates that it is in the hard rocks with conductive top soil and the resistivity of the layers will be continuously increasing ($\rho_1 < \rho_2 < \rho_3$). K-types sounding curves indicates that it is have maximum peak and occupied by low resistivity values ($\rho_1 < \rho_2 > \rho_3$) and such curves result from different geological. H-type sounding curves indicates that it is not normally in hard rock formations and its consists of dry top soil of high resistivity as first layer, minimum resistivity of as second layer and compact hard with very high resistivity as the third layer denoted ($\rho_1 > \rho_2 < \rho_3$). Q-types curve indicates that it is in continuously decreasing resistivity ($\rho_1 > \rho_2 > \rho_3$) and commonly obtained in coastal region because of

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the saline water. Based on the above results interpretation of the Chamarajanagar taluk, the following types of curves are noticed (Figure 3).

Computer Inversion Programme:

Several numerical computer programs for automated fit of resistivity data have been developed. The computer inversion program IPI2WIN has been used to compute the geoelectrical parameters of the study area. The input data given for execution include the field measurement as spacings and apparent resistivities, the type of electrode arrangement used (Wenner, Schlumberger or Dipole), the number of layers and assumed layer of resistivities (ρ) and thickness (h). This is an iterative procedure of utilizing a set of guessed model parameters to compute a sequence of apparent resistivity values. The computed ' ρ_a ' values are compared at each iteration with the observed field ' ρ_a ' values and subsequent attempts are made in refining the layer parameters. When the error between the observed and computed value is less, the resultant model is produced as an output. Instead of an arbitrary initial guess, the parameters derived through curve matching have been utilized for inversion and the best fit results were obtained. It has been found that this strategy produced a very good automated fit and reduced the number of iterations, and compute processing time. Figure 4 Shows the automated fit of matched curves obtained through this computed inversion program for three locations. The resistivity and thickness of different layers obtained through manual curve matching and compute inversion have been compared for all the vertical electrical sounding stations of the study area.

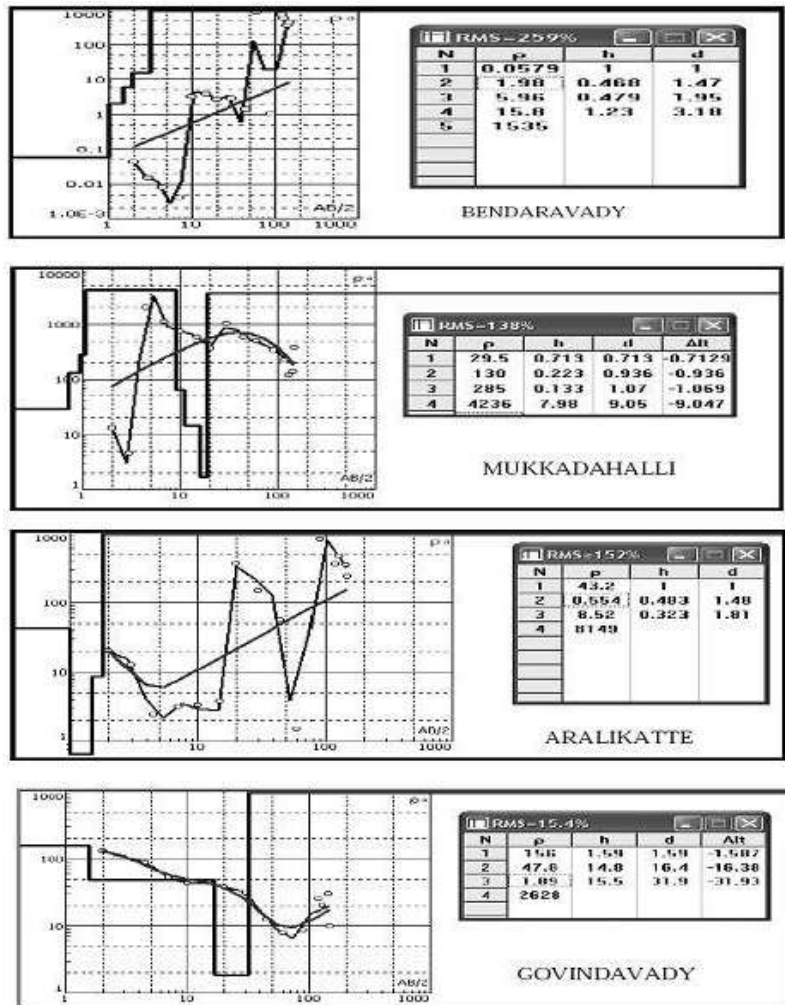


Figure 4: Automated fit of VES curves of Chamarajanagar Taluk

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Arallikate



Munachanahalli Village



Uthuvalli Village



Mudnakoda

Figure 5: Geophysical survey of Chamaranagar taluk

Field Data:

For evaluating the groundwater exploration in the investigated of the study area, the Vertical Electrical Sounding [VES] data of 45 (Figure-2) locations conducted with the help of CRM-20 [Computerized Resistivity Meter-20] was adopted. The maximum depth of investigation was 150 meter. The spread was commonly in steps of half meter interval up to 10 meter, 2 meter interval up to 20 metres, 5 metres interval up to 45 metres and 10 metres interval up to 150 metres.

The geophysical parameter of the aquifers of the Chamarajanagar taluk (curve type, resistivity of the layers and the thickness of the first two layers) has been tabulated for 45 villages (Table 2). From this data the following points are emerge. The four types of resistivity curves for the 3-layered geo-electrical sections (A, K, H and Q) do exist in this (Table 1) Chamarajanagar taluk.

Table 1: Number of curves types in Chamarajanagar Taluk

| Curve types | Number of Sites |
|--------------|-----------------|
| A | 17 |
| K | 04 |
| H | 10 |
| Q | 14 |
| Total | 45 |

Locations with ‘K’ type curves predominate in the Chamarajanagar taluk followed by ‘H’, ‘A’ and ‘Q’ type. Location with ‘A’ and ‘H’ curves are in general suitable for shallow wells, where as location K type could be exploited by deep bore wells or dug cum bore wells. Figure 3 gives the observed field

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curves as well as computed field model curves using the IPI2WIN program along with the geoelectrical model. These diagrams show clearly that the IPI2WIN model exactly coincides with the field data and could clearly be used for the interpretation of resistivity data of hard rock areas. Water saturated horizons at AB/2 equal to 20, 45, 60, 90, 120, and 150 meters has been separately prepared and shown as six figures' (Figure-6 to 11). It was very clearly shown that areas with 20-60 Ohm-meters resistivity is ideal for potable water well sites and areas with > 60 Ohm-meters resistivity are mostly dry in the hard rock areas and Karnataka (Sharma, 1982; Prasad, 1984; Balasubramanian, 1986; Venugopal, 1988; Chandrashekar, 1988; Indira, 1988; Siddaraju, 1996; Nagaraju, 1996; and Rao, 1998).

From the figure's 7 to 12, it could be observed that the area of water saturated horizon increases with depth upto 45 m AB/2 and then decreases slowly depth wise and drastically by the time AB/2 reaches 150 m indicating that dug, dug-cum bore and moderate depth bore wells will be more successful than shallow dug-wells or deep bore wells in this area (Table 2).

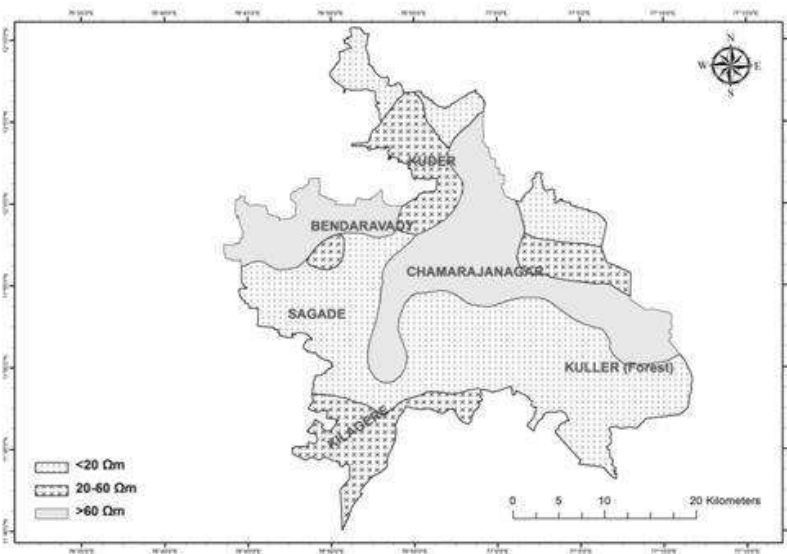


Figure 6: Aquifers isoapparent-resistivity at 20m spacing map of ChamaraJanagar taluk

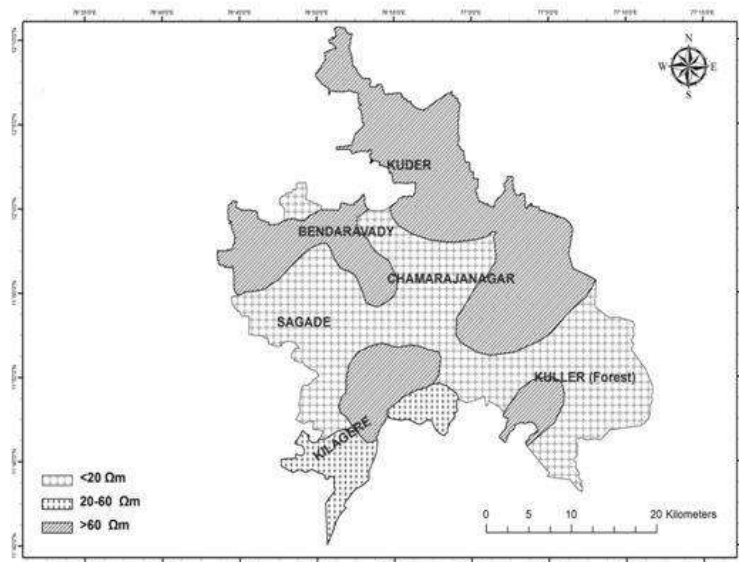


Figure 7: Aquifers isoapparent-resistivity at 45m spacing map of ChamaraJanagar taluk

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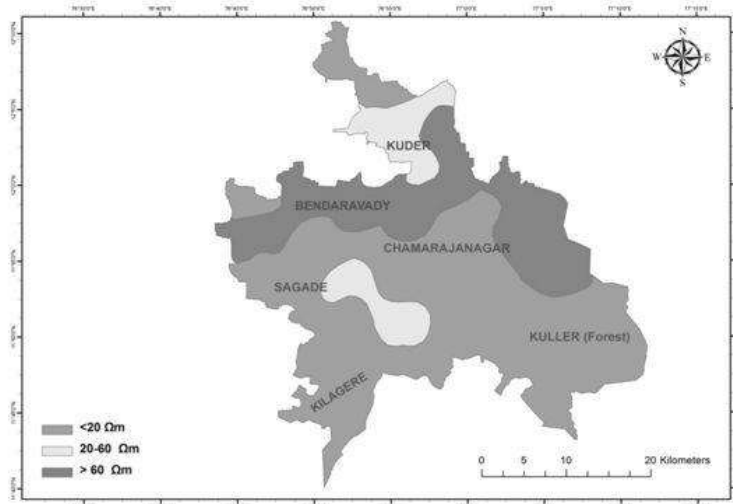


Figure 8: Aquifers isoapparent-resistivity at 60m spacing map of ChamaraJanagar taluk

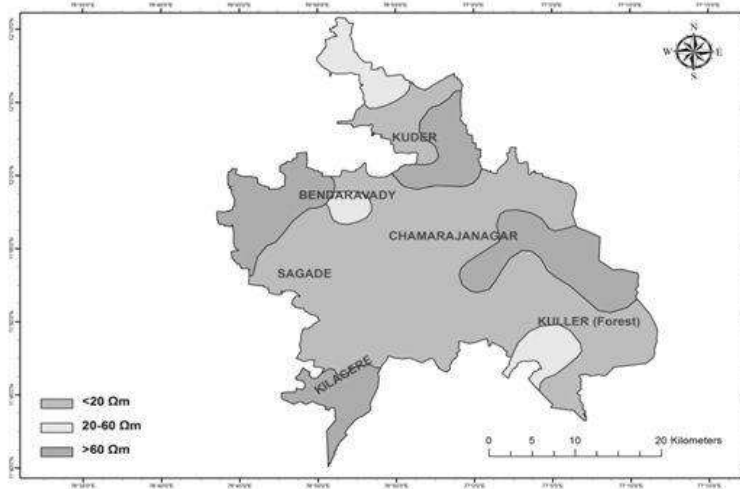


Figure 9: Aquifers isoapparent-resistivity at 90m spacing map of ChamaraJanagar taluk

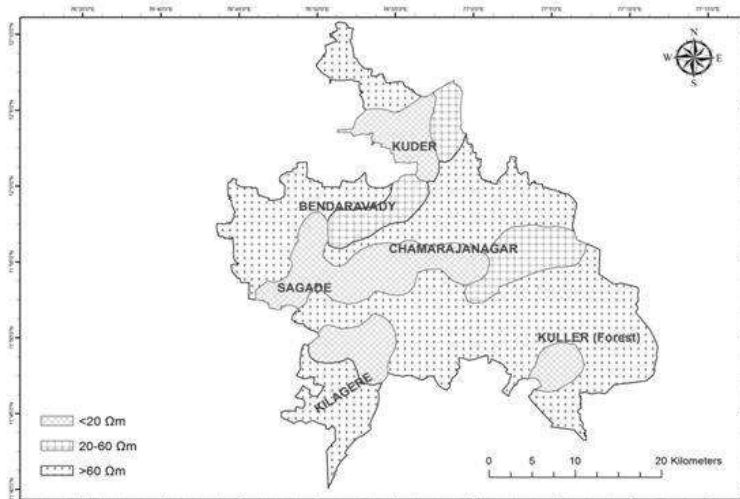


Figure 10: Aquifers isoapparent resistivity at 120m spacing map of ChamaraJanagar taluk

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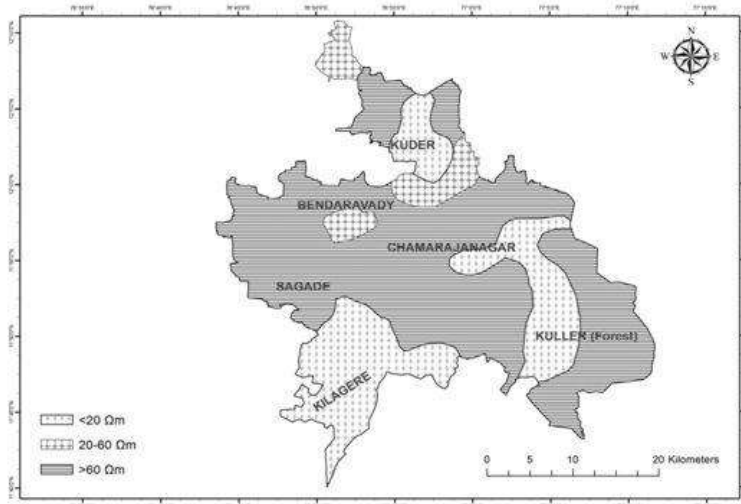


Figure 11: Aquifers isoapparent resistivity at 150m spacing map of ChamaraJanagar taluk

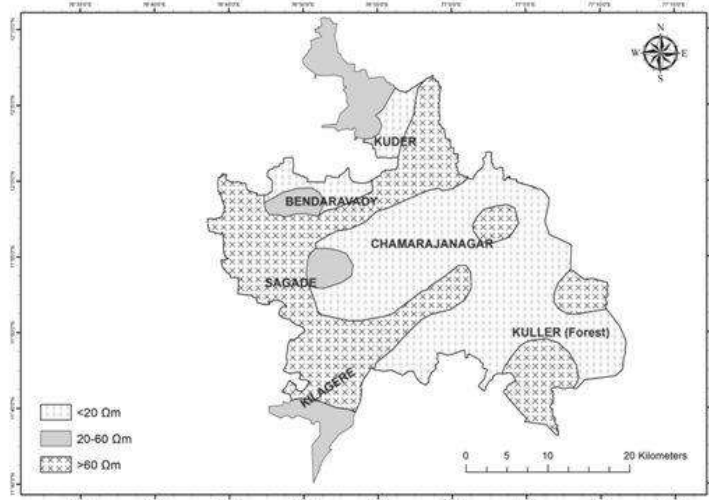


Figure 12: Aquifers resistivity of first layers map of ChamaraJanagar taluk

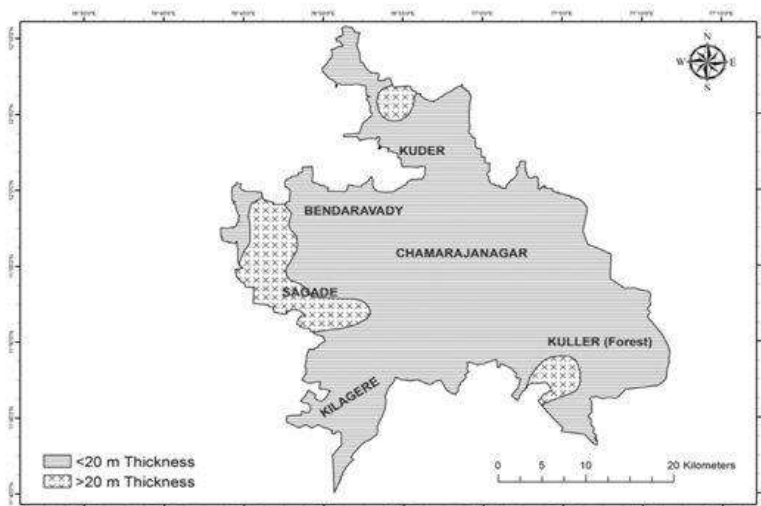


Figure 13: Aquifers resistivity of first layers thickness map of ChamaraJanagar taluk

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Figure 12 and 15 give the iso-resistivity contours of 20 and 60-Ohm meters respectively for the first and second layers. This has been particularly chosen due to the fact that potable groundwater exists in the resistivity areas falling between 20-60 ohm meters, water quality deteriorates when resistivity is < 20 Ohm meters and the formations will be dry if resistivity escalates beyond 45 meters. Thus both these maps have shown three horizons namely non-potable groundwater (< 20 Ohm meters) potable groundwater (20-60 Ohm meters) and dry rocks (>60 Ohm meters).

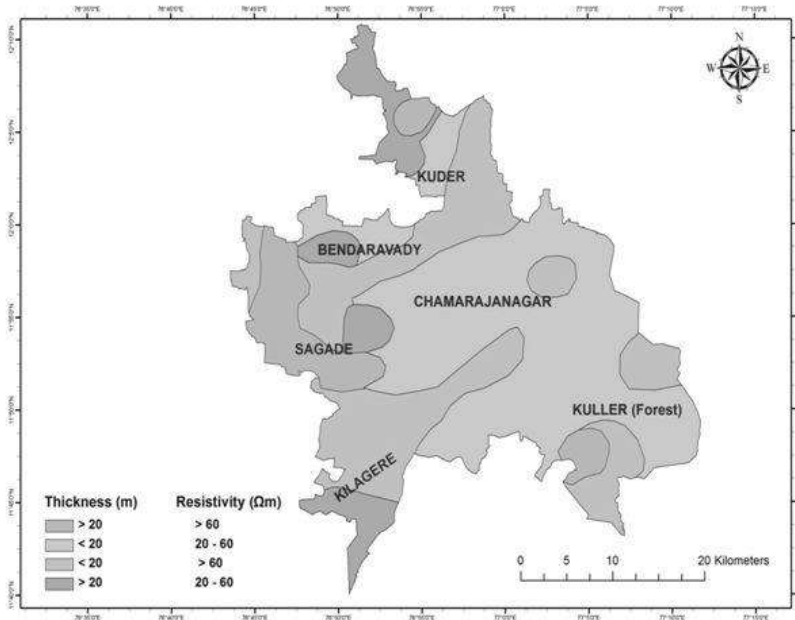


Figure 14: First layer geophysical groundwater potential zones map of Chamarajanagar taluk

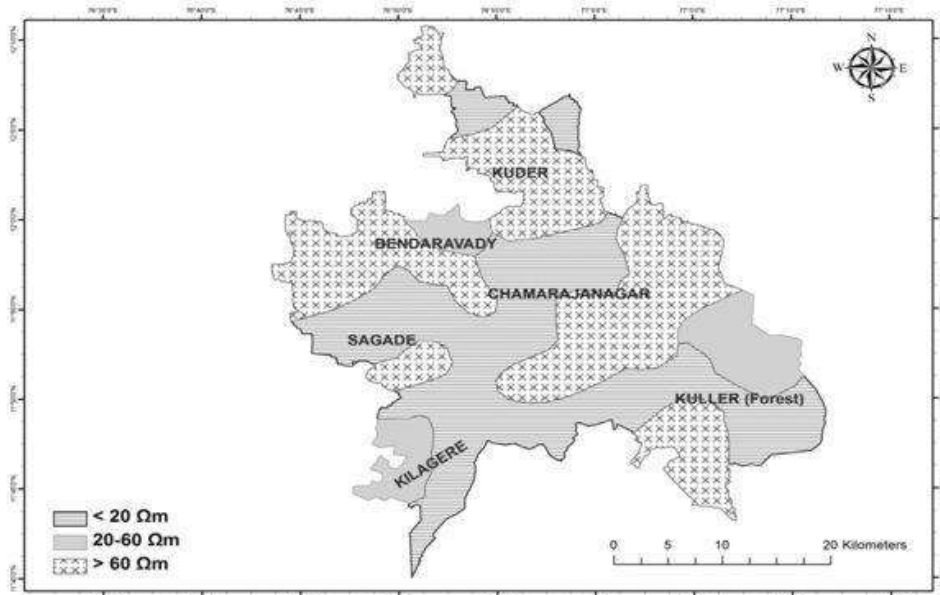


Figure 15: Aquifers resistivity second layer map of Chamarajanagar taluk

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Table 2: Geoelectrical Parameters of VES Locations of Chamarajanagar taluk

| SI No | Name of the location | Thickness layers | | | Resistivity | | | Curve types | Others parameters | | |
|-------|----------------------|------------------|-------|-------|-------------|----------|----------|-------------|-------------------|---------|-----------|
| | | h_1 | h_2 | h_3 | ρ_1 | ρ_2 | ρ_3 | | S | T | λ |
| 1 | Bendaravady | 1.00 | 0.46 | 0.47 | 0.05 | 1.98 | 5.96 | A | 20.26 | 3.17 | 8.90 |
| 2 | Mukkadahally | 0.71 | 0.22 | 0.13 | 29.5 | 130 | 285 | K | 0.026 | 87.89 | 1.42 |
| 3 | Aralikatte | 1.00 | 0.48 | 0.32 | 43.2 | 0.55 | 8.52 | H | 0.14 | 46.16 | 1.40 |
| 4 | Kulugana | 1.00 | 1.1 | 6.05 | 271.0 | 75.4 | 198.0 | H | 0.04 | 1551.84 | 1.05 |
| 5 | Mudankud | 6.74 | 7.7 | 0.00 | 14.30 | 76.35 | 997.0 | A | 0.57 | 684.27 | 1.36 |
| 6 | Harve | 1.00 | 1.8 | 23.7 | 292.0 | 5.31 | 222.3 | A | 0.44 | 5570.0 | 1.84 |
| 7 | Govindavady | 1.59 | 14.8 | 15.5 | 156.0 | 47.8 | 1.89 | Q | 8.51 | 984.73 | 2.87 |
| 8 | Badanaguppe | 1.00 | 9.3 | 29.9 | 0.048 | 76.30 | 135.0 | A | 21.17 | 4746.14 | 7.80 |
| 9 | Bedarapur | 1.00 | 0.8 | 21.3 | 73.40 | 72.60 | 3.92 | Q | 5.45 | 214.97 | 1.48 |
| 10 | Kamaravady | 1.54 | 1.6 | 4.45 | 4.49 | 73.12 | 888.1 | A | 0.36 | 4075.94 | 5.07 |
| 11 | Demahalli | 1.00 | 2.7 | 6.27 | 1.059 | 14.44 | 169.3 | A | 1.17 | 1101.55 | 3.60 |
| 12 | Santhemarahalli | 1.00 | 1.2 | 38.8 | 70.0 | 280.0 | 73.9.0 | K | 0.54 | 3273.32 | 1.02 |
| 13 | Heggavady | 1.00 | 0.9 | 5.07 | 406 | 287.4 | 166.0 | Q | 0.03 | 1506.00 | 7.77 |
| 14 | Kuder | 1.13 | 6.0 | 4.27 | 73.17 | 20.48 | 4.62 | Q | 1.22 | 225.28 | 4.61 |
| 15 | Ummathur | 1.00 | 1.6 | 9.95 | 41.60 | 22.34 | 60.1 | H | 0.25 | 675.33 | 1.03 |
| 16 | Navilur | 1.00 | 1.5 | 13.3 | 58.70 | 0.12 | 15.14 | H | 13.39 | 260.24 | 3.73 |
| 17 | Bagali | 1.06 | 1.0 | 0.00 | 48.20 | 0.333 | 271.2 | H | 3.02 | 51.42 | 6.04 |
| 18 | Yelkkur | 1.00 | 0.5 | 31.6 | 538.0 | 477.0 | 277.0 | Q | 0.11 | 9529.00 | 1.00 |
| 19 | Kastur | 1.00 | 1.9 | 18.2 | 891.7 | 750.8 | 120.5 | Q | 0.15 | 4511.30 | 1.25 |
| 20 | Basavanapur | 1.00 | 1.2 | 9.90 | 71.10 | 7.02 | 61.41 | H | 0.34 | 687.47 | 1.27 |
| 21 | Chamarajanaga | 1.00 | 2.2 | 6.92 | 0.037 | 6.77 | 20.1 | A | 27.6 | 154.00 | 6.44 |
| 22 | Madapura | 1.00 | 2.2 | 9.34 | 0.009 | 5.14 | 23.0 | A | 111.94 | 226.03 | 12.7 |
| 23 | Masanapura | 1.00 | 9.1 | 9.90 | 0.423 | 205.0 | 410.9 | A | 2.42 | 5933.83 | 5.99 |
| 24 | Nanjarajanapura | 1.00 | 2.6 | 2.75 | 131.0 | 54.61 | 557.0 | H | 0.06 | 1804.73 | 1.62 |
| 25 | Bellathum | 1.00 | 10.0 | 15.7 | 218.0 | 77.30 | 491.0 | H | 0.16 | 8699.70 | 1.41 |
| 26 | Nallur | 1.00 | 2.4 | 15.5 | 5.87 | 36.54 | 10.80 | K | 1.67 | 260.96 | 1.11 |
| 27 | Malledevanahall | 1.00 | 4.9 | 41.9 | 1.38 | 458.0 | 20.50 | K | 2.77 | 3104.53 | 1.93 |
| 28 | Haradanahalli | 1.00 | 1.3 | 2.01 | 116.0 | 77.40 | 101.0 | H | 0.04 | 419.63 | 0.98 |
| 29 | Kullur | 1.50 | 2.4 | 9.59 | 785.2 | 776.0 | 2.38 | Q | 4.03 | 3063.02 | 8.23 |
| 30 | Bisalavady | 1.00 | 0.6 | 6.60 | 0.25 | 13.50 | 19.60 | A | 4.37 | 137.71 | 2.99 |
| 31 | Arakalavady | 1.00 | 1.0 | 3.60 | 2.83 | 19.20 | 95.3 | A | 0.44 | 365.11 | 2.26 |
| 32 | Vadagalpura | 1.00 | 0.8 | 6.30 | 495.6 | 180.0 | 172.2 | Q | 0.04 | 1724.46 | 1.00 |
| 33 | Uttuvally | 1.00 | 3.4 | 5.70 | 1.72 | 33.0 | 54.40 | A | 0.78 | 424.00 | 1.80 |
| 34 | Udigala | 1.0 | 0.9 | 7.5 | 90.6 | 16.90 | 9.49 | Q | 0.85 | 176.98 | 1.30 |
| 35 | Katnavady | 1.00 | 0.7 | 4.20 | 94.30 | 0.91 | 94.30 | H | 0.81 | 397.70 | 3.38 |
| 36 | Badagalapura | 1.00 | 27 | 27 | 15.0 | 12.7 | 0.619 | Q | 45.79 | 374.61 | 2.38 |
| 37 | k.k.hundi | 1.00 | 8.7 | 85.0 | 54.7 | 23.4 | 5.96 | Q | 14.64 | 764.88 | 1.11 |
| 38 | Shivapura | 1.80 | 7.3 | 6.10 | 7.59 | 57.9 | 1.38 | K | 4.77 | 444.74 | 3.02 |
| 39 | Alur | 1.10 | 2.1 | 2.9 | 0.04 | 7.42 | 16.10 | A | 27.96 | 62.31 | 6.80 |
| 40 | Kagalvady | 1.00 | 0.3 | 34.0 | 133.2 | 77.1 | 24.30 | Q | 1.41 | 982.53 | 1.05 |
| 41 | Mangala | 1.00 | 0.6 | 11.0 | 0.69 | 2.34 | 19.66 | A | 2.24 | 218.35 | 1.75 |
| 42 | Kudlur | 1.00 | 0.4 | 3.5 | 5.31 | 0.81 | 98.30 | H | 0.70 | 349.68 | 3.20 |
| 43 | Munachanahalli | 1.00 | 9.1 | 22.0 | 0.80 | 4.32 | 85.0 | A | 3.60 | 1910.11 | 2.50 |
| 44 | Sagade | 3.10 | 1.2 | 35.0 | 73.6 | 2.27 | 11.70 | H | 3.55 | 640.38 | 1.21 |
| 45 | Kilagere | 1.00 | 1.3 | 16.0 | 30.4 | 56.1 | 456.0 | A | 0.08 | 7399.30 | 1.32 |

Potential Zones of Groundwater:

The thickness of the first, second, and third layer h_1 , h_2 and h_3 is given in Figure's 13, 16 and 19 resistivity of first, second, and third layer ρ_1 , ρ_2 , and ρ_3 is Figures 12, 15, and 18. A large area of the Chamarajanagar taluk with less than 20 meters thickness and considerably small areas with thickness greater than 20 meters is shown by Figure 13 thus, groundwater potential has to be done with shallow wells. In contrast

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to this Figure 15 the area of the falling is less than 20 meters thickness is lowest, 20-60 Ω meters is larger and greater than 60 Ω meters is in between the first two. This clearly shows that the shallow wells are of no use when deeper aquifers are to be exploited. Super position of Figure 12 and 13 results is Figure 14, which gives the groundwater potential zones of the first layer.

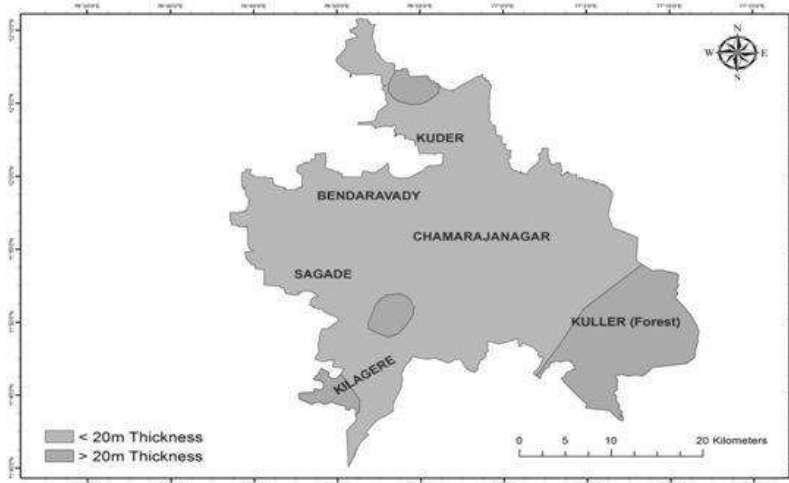


Figure 16: Aquifers resistivity second layer thickness map of ChamaraJanagar taluk

The entire area could be divided into six resistivity thickness horizons as follows.

| Thickness (M) | Resistivity (Ohm meters) | Groundwater Development by / Quality |
|---------------|--------------------------|---------------------------------------|
| < 20 | < 20 | Dug wells, Non-potable water |
| < 20 | 20-60 | Dug wells, potable water |
| < 20 | > 60 | Not feasible |
| > 20 | < 20 | Shallow bore wells, Non-potable water |
| > 20 | 20-60 | Shallow bore wells, potable water |
| >20 | > 60 | Not feasible |

The third column in the above table gives the type of wells for groundwater development and the quality of water, which will be encountered in the area. Larger areas of the ChamaraJanagar Taluk could be served by dug wells development with potable water area.

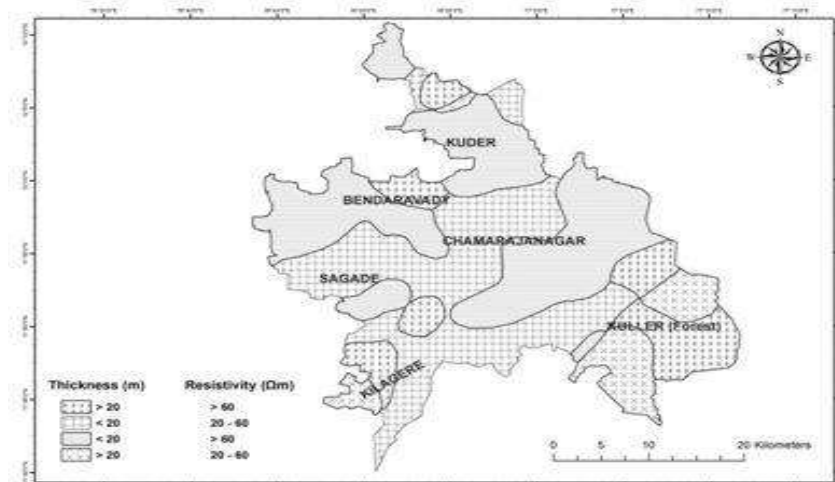


Figure 17: Second layers geophysical groundwater potential zones map of ChamaraJanagar taluk

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For deeper groundwater exploitation and identification of groundwater potential zones Figures 15 and 16 are superimposed over each other and Figure 17 gives the groundwater potential zones second layer and the groundwater potential zones third layer maps are decipher on Figure 18, 19 and 20.

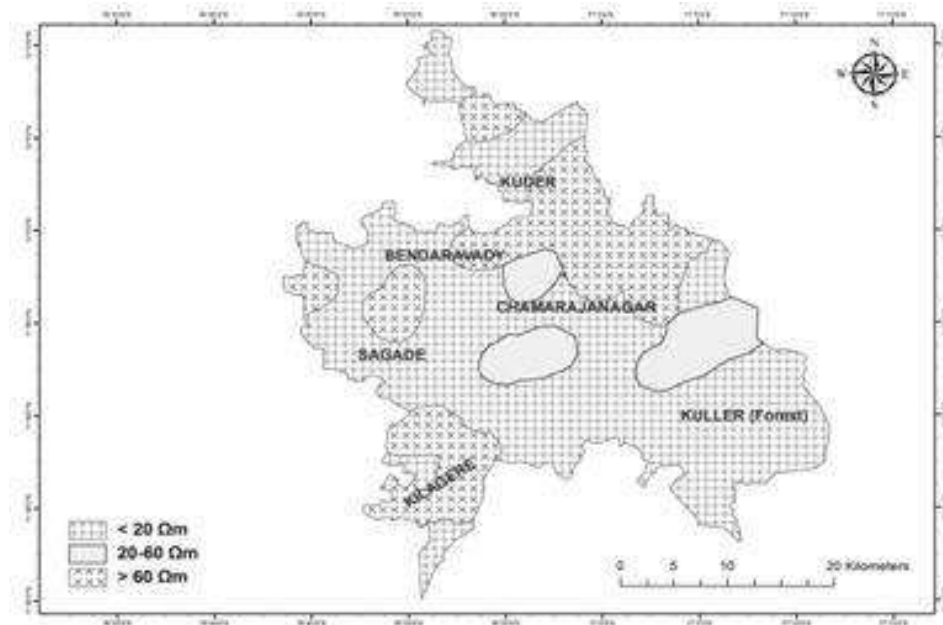


Figure 18: Aquifers resistivity of third layers map of ChamaraJanagar taluk

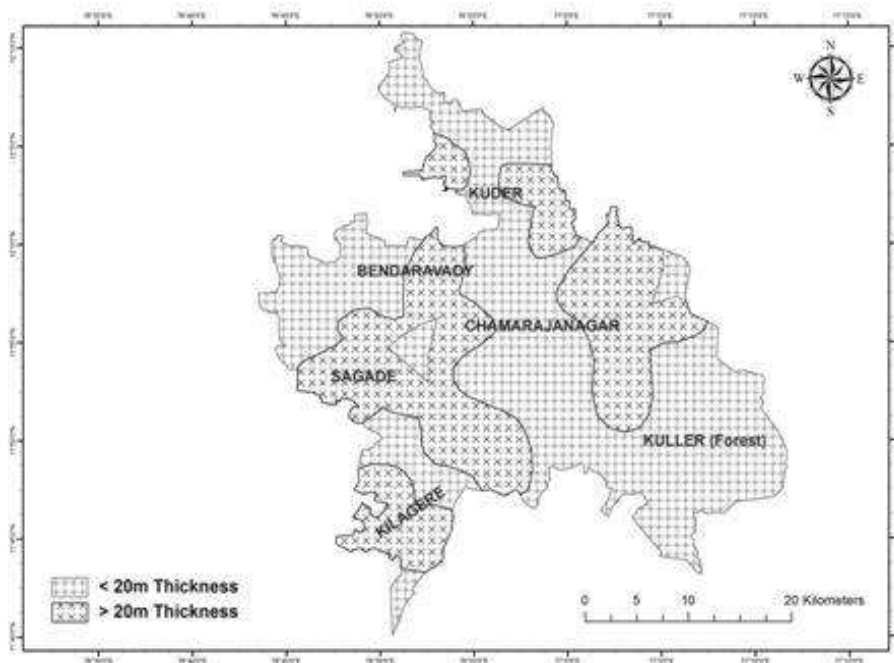


Figure 19: Aquifers resistivity of third layer thickness map of ChamaraJanagar taluk

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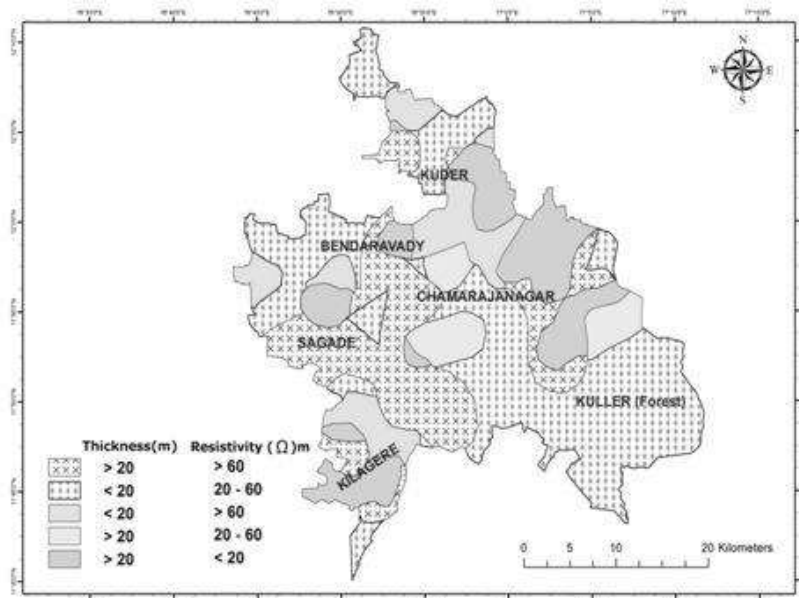


Figure 20: Third layer geophysical groundwater potential zones map of Chamarajanagar taluk

Table

| Thickness (m) | Resistivity (Ohm meters) | Groundwater Development by / Quality |
|---------------|--------------------------|---------------------------------------|
| < 20 | < 20 | Dug wells Non-potable water |
| < 20 | 20-60 | Dug wells potable water |
| < 20 | > 60 | Not feasible |
| 20-60 | < 20 | Shallow bore wells Non- potable water |
| 20-60 | 20-60 | Shallow bore wells potable water |
| 20-60 | > 60 | Not feasible |
| > 60 | < 20 | Deep bore wells, Non potable water |
| > 60 | 20-60 | Deep bore wells, potable water |
| > 60 | > 60 | Not feasible |

The above table shows 9 horizons with the types of wells for development (dug, shallow bore wells, deep bore wells) quality of water (potable, non potable) and not feasible areas. It is interesting to note that a large area could be served by shallow bore wells followed by deep bore wells both yielding potable water.

Conclusion

Geophysical techniques have emerged as important tools in prospecting for groundwater potential zone. In spite of the manifestation of surficial features of any terrain. Actual potable groundwater in areas of hard rock has resistivity's ranges from 30 to 150 ohm- meters where as in the sedimentary formations resistivity values may reach as low as 1 –ohm-m. In general hard rock's groundwater could be tapped in the weathered, fissured and fractured zones are commonly found at comparatively very shallow depth, such zone and pockets have less resistivity values and were correlated to the high compact and fresh rocks and could be simply located by resistivity surveys. Water holds in joints and fissures of the under composed rocks may also be found may be depending on the low resistivity values and suggested the application of integrated geophysical methods in groundwater exploration and protection.

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