A REPORT ON THE GROUND WATER POTENTIAL AND MANAGEMENT IN CENTRAL UNIVERSITY OF KERALA CAMPUS, PERIYE, KASARAGOD

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CHAPTER 1

INTRODUCTION

1.1 Introduction and Objectives of the study

Water is one of the most important natural resource occurring both as surface water and ground water. It is vital for whole life on the earth. We know this precious resource is sometimes scarce sometimes abundant but unevenly distributed both in space and time. Ground water is the resource that supports human health and the ecological diversity saving the storage of ground water and protecting it from contamination and careful in managing its use will ensure its future as an important part of ecosystem and human activity. The rate of ground water flow is controlled by two main properties of the rock: that is porosity and permeability (Todd and Larry, 2011).

The Central university of Kerala campus is presently experiencing the shortage of water especially during the summer. The open wells, bore wells and ponds in the campus are getting dried too quickly as compared to the last 10 years. The campus and the nearby areas including Periye region faces acute water shortage during February, March and April. The water available in open wells dries up during the months of February and March. The availability of water in bore wells also reduces after the month of February. There is a decline in water level as well. In Kanhangad Block, declining water level in the range of 0.015 to 0.206 m/year in pre-monsoon period is observed. In the post-monsoon period the water level shows a decline in many of the wells in the range of 0.010 to 0.059 m/year. (CGWB, 2013). For the construction in work in the campus, huge quantity of laterite (aquifer) has been removed which might have affected the ground water conditions in the area. In this context, the present study is aimed at the assessment of groundwater reserve, identify locations for the development of open and bore wells in future and construction of artificial recharge structures in Central University of Kerala campus, Kasaragod. The proper groundwater management and groundwater recharge must be employed for meeting the ever growing demand for groundwater.

The main objectives of the study are following:

1. To assess the hydrogeological conditions in Central University of Kerala campus and identify ground water potential zones.
2. To identify the suitable sustainable water resource management practices and artificial recharge structures for Central University of Kerala campus.

1.2. Location and setting

The permanent campus of the Central University of Kerala spans an area of 310 acre at Tejasiwni Hills, Periye, Kasaragod, the northernmost district of Kerala state, India (Fig. 1.1). The area is occupied between the north latitudes of 12° 22′51.04” and 12° 23′53.14”, and East longitudes of 75°05’44.69” and 75°05’29.04”. Politically this area included in Periye Pullur Grama Panchayath.

1.3. Physiography

The Central University of Kerala is a part of Midland area of Kasaragod. The study area undulating topography with small hillocks and valleys. The altitude varies from 44 to100 meters above mean sea level. The coastal plain is about 8 km distance from the study area.

1.4. Geology and Hydrogeology

Kasaragod is a part of Precambrian metamorphic shield in which majority of the area is occupied by Archean rocks. Geologically the district can be divided into five belts: southern Charnockitic rocks, Northern Gneiss, Syenite pluton in central, isolated capping of sedimentary rocks (Warkalli Formation) confined to coastal tract, Quaternary sediments of the coastal plain (District Survey Report, 2016). These rocks are extensively lateritised in most part of the district. It covers all the underlying rock formation except Quaternary deposits. Generally it is 5 to 15-metre-thick, hard, ferruginous and bauxitic at places (District Survey Report, 2016). The laterite is the main aquifer of groundwater as well.

The study area is also a lateritic terrain (Fig. 1.1) with thick sequence of laterite with no parent rock visible. Laterite in the area is ferruginous, porous and hard. Due to the porous nature the wells, laterite gets recharged fast and water escapes as subsurface flow.

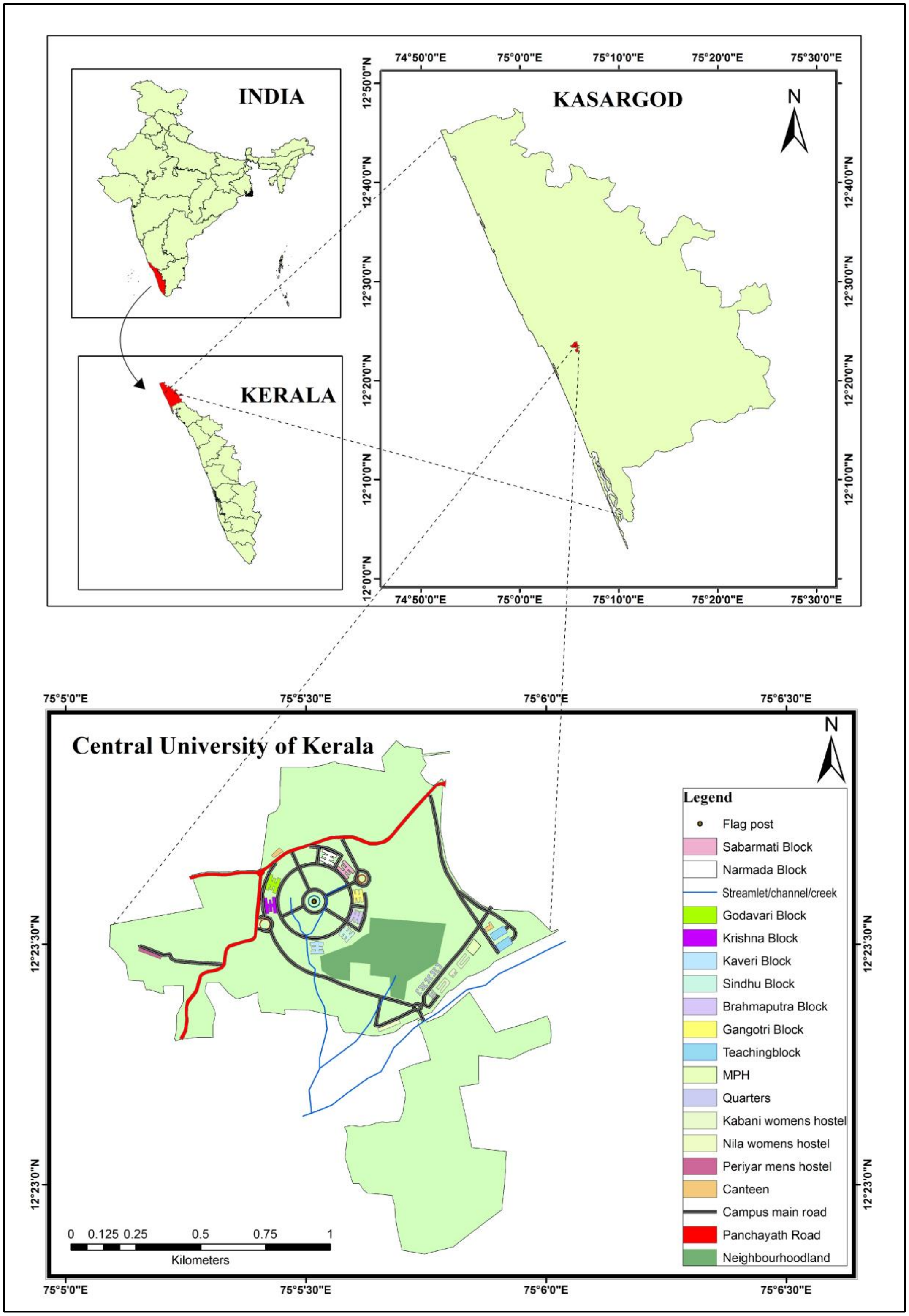


Fig 1.1. The location map of the study area (Central University of Kerala).

1.5. Soil

The laterite is covered by lateritic soil, having thickness of 0.5 to 1 meters. The laterite is generally underlain the lithomarge clay and which is the preliminary laterization front.

1.6. Climate

The district including the study area receives an average of about 3500 mm rainfall annually. The major source of rainfall is southwest monsoon from June to September which is contributing nearly 85.3% of the total rainfall of the year. The north east monsoon contributes only 8.9% and remaining 5.8% is received during the month of January to May as pre monsoon showers. Out of the 106 rainy days in a year, 87 days occur during south west monsoon (CGWB, 2013).

The average mean monthly maximum temperature ranges from 29.2°C to 33.4°C and minimum temperature ranges from 19.7°C to 25°C (CGWB, 2013). The temperature is more during the months of March, April, May and less during December and January.

Relative humidity is more during morning hours and less during evening hours. During the morning hours it ranges from 87.1% to 98.7% and during evening hours it ranges from 54.4% to 86.5%.

The wind speed ranges from 2.1 to 3.3 km/hour. The wind speed is high during the months of March to June and less during the months of September to December. Sunshine ranges from 3.2 to 10.2 hours/day. Maximum sunshine is during the month of February. The months of June to August records the minimum sunshine due to cloudy sky. Good sunshine hours are recorded in the months of November to May.

Chapter 2

MATERIALS AND METHODS

2.1. General

This chapter provides details about the methodology adopted for the preparation of elevation contour map (DEM), electrical resistivity survey, interpretation of resistivity data using IPI2win software, identification of ground water zones and investigations on soil piping.

The electrical resistivity method is mainly employed in the present study which is a form of geophysical survey that aids in imaging the sub-surface. The study was done with Schlumberger array which follows the resistivity potential. The basic setup for a resistivity survey involves a resistivity meter and four electrodes which are placed at equal distance. Resistivity soundings, profiling and mappings provide an image of the subsurface resistivity by non-destructive means. Electrical profiling uses collinear arrays to determine lateral resistivity variations in the shallow subsurface at a more or less fixed depth of investigation. The current and potential electrodes are varied along a profile with constant spacing between the electrodes. There are many array types used for different purposes like Wenner, Schlumberger, and dipole-dipole, pole-dipole with current and potential electrodes.

The common factor in these configurations is a set of current input electrodes usually labeled A and B and a set of voltage measurement electrodes usually labelled M and N. In resistivity method of electrical prospecting, an electric field is artificially created in the ground by means of either galvanic batteries (DC) or low frequency AC generators. The energizing current is sent in to the ground by means of two grounded electrodes, called the current electrodes designated as ‘A’ and ‘B’ placed at two selected points. The potential in the area is measured by another two more grounded electrodes called the potential electrodes designated as ‘M’ and ‘N’. Electrical resistivity is defined as the resistance offered by a unit cube of material for the flow of current through its normal surface. If ‘L’ is the length of the conductor and ‘A’ is its cross-sectional area, then the resistance (R) is defined as

$$\mathbf{R=\rho L/A}$$

In general, electrical investigations particularly vertical electrical soundings and multi-electrode resistivity imaging are conducted to determine the depth to Bedrock, groundwater potential zones and sources of groundwater pollution. Some of the significant applications are lateral differentiation of permeable formations from impermeable or less permeable formations and vertical distribution of various layers.

2.2. Preparation of elevation contour map (Digital Elevation Model) from Google Earth Pro

The 'add path' tool of Google Earth Pro software was used to draw closely spaced path over the study area boundary and saved as Kernel Markup Language (KML) file format. The KML file is loaded in TCX converter (version 2.0.32) and converted to CSV file format. This CSV file was loaded in open source software Q-GIS (version 3.6.0). Using the SAGA Plugin 'Interpolate (Natural Neighbour)', the elevation contour map (Digital Elevation Model) of the Central University of Kerala is prepared based on X, Y and Z values.

2.3. Electrical Resistivity Measurements

SSR-MP1 (by Integrated Geo Instruments & Services Private Limited) is the instrument used for the geophysical electrical resistivity survey in present study (Fig. 2.1). The SSR-MP1 has mainly two parts viz. Current unit and Microprocessor based measuring unit built in a single housing. The current unit sends bipolar signals into the ground at a frequency of about 0.3Hz. The receiver has a 4 ½ digit duel-slope analog to digital converter unit which can measure the ground potential and current with resolution up to 100µV and 100µA respectively. The microprocessor controls the current unit, determines the attenuation level for potential measurements, computes the resistance values, averages and displays the measured values.

The following procedures are adopted for the operation of the instrument.

1. C1 and C2 terminals were connected to current electrodes.

2. P1and P2 terminals were connected to potential electrodes.

3. The battery box was connected to the instrument through the cable and the power switch was switched on.

4. The START switch was pressed to start the measurement.

5. The meter took measurements up to 16 stack displaying the present current and average of stacked resistance values in display.

6. The STOP switch was pressed consistent readings up to the third digit were obtained.

7. The resistance value was noted and proceeded to the next spacing.

Fig. 2.1. Electrical Resistivity Meter (Model: SSR MP1) used for the present study.

2.4. Vertical Electrical Sounding (VES)

In the Vertical Electrical Sounding (VES) technique, the space between the electrodes is increased from a fixed center. The larger spacing cause electricity to enter deeper into the ground and greater depth of investigation is obtained. For sounding, the current and potential electrodes are placed on the ground in a variety of configurations or arrays. This method gives the information about depth and thickness of various subsurface layers and their potential for groundwater exploitation. Since the fraction of total current flows at a depth varies with the current electrodes separations, the field procedure is to use a fixed centre with an expanding spread. The VES measurements were carried out in 11 points using the Schlumberger Array in the Central University of Kerala campus (Fig. 2.2).

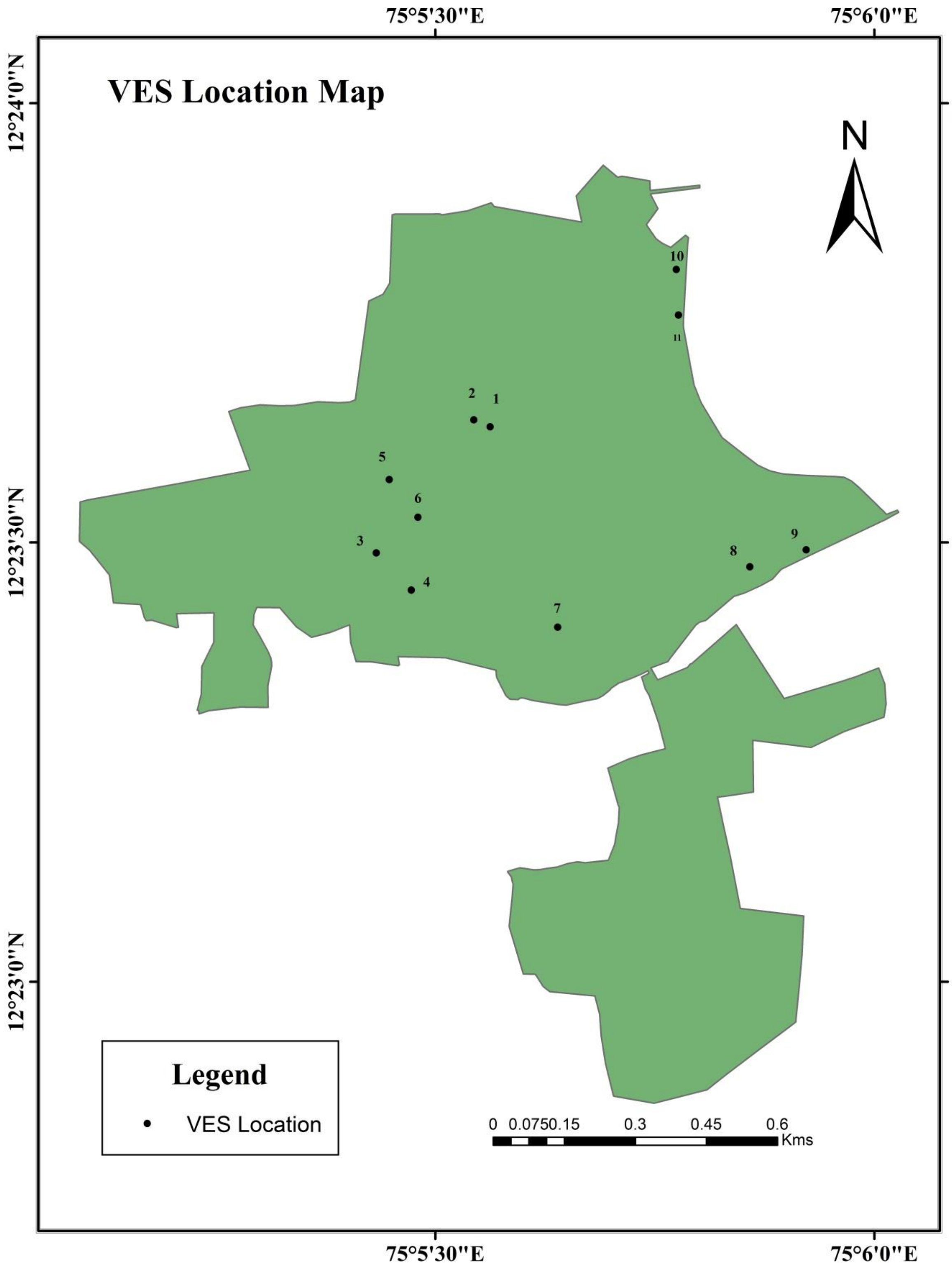


Fig. 2.2. The map showing locations in the Central University of Kerala campus where VES measurements were carried out.

2.4.1. Schlumberger Array

The Schlumberger array consists of four collinear electrodes; the two outer current electrodes and two inner potential electrodes. The potential electrodes are installed at the center of the electrode array with a small separation, typically less than one fifth of the spacing between the current electrodes. The current electrodes are increased to a greater distance during the survey while the potential electrodes remain in the same position until the observed voltage becomes too small to measure.

The advantages of the Schlumberger array are that fewer electrodes need to be moved for each sounding and the cable length for the potential electrodes is shorter. Schlumberger soundings generally have better resolution, greater probing depth, and less time-consuming field deployment than the Wenner array. The disadvantages are that long current electrode cables are required, the recording instrument needs to be very sensitive, and the array may be difficult or confusing to coordinate amongst the field crew. Substantial lengths of cable energized with current at high voltage present a safety hazard. The Schlumberger array is a labor-intensive survey because of the cable lengths required and the movement of the electrodes during the survey.

The Schlumberger arrangement was as such, the potential and current terminals are placed collinearly where potential terminal was spaced a little distance than the current electrode. Mid-point of potential electrode (MN) and current electrodes (AB) coincide (Fig. 2.3). The formula for calculating the apparent resistivity (ρa) is given as:

$$\rho_{a} = \frac{(AB/2)^2 - (MN/2)^2}{MN} \bullet \frac{\pi \Delta V}{I}$$

Where,

AB Current electrode spacing (in meters)

MN Potential electrode spacing (in meters)

I Current (in amps)

V Voltage (in volts)

The Schlumberger array is an array where four electrodes are placed in line around a common midpoint. The two outer electrodes, A and B, are current electrodes, and the two inner electrodes, M and N, are potential electrodes placed close together. With the Schlumberger array, for each measurement the current electrodes A and B are moved outward to a greater separation throughout the survey, while the potential electrodes M and N stay in the same position until the observed voltage becomes too small to measure (source). At this point, the potential electrodes M and N are moved outward to a new spacing. As a rule of the thumb, the reasonable distance between M and N should be equal or less than one-fifth of the distance between A and B at the beginning. This ratio goes about up to one-tenth or one-fifteenth depending on the signal strength.

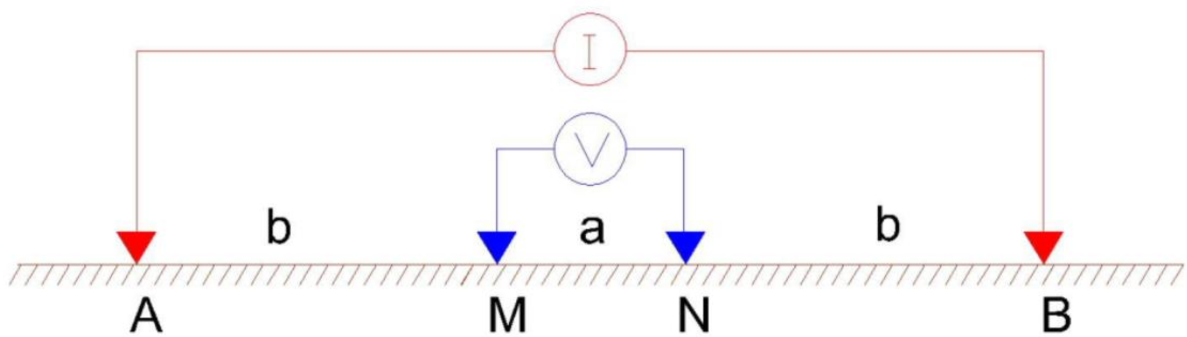


Fig. 2.3. Schlumberger array of electrode spacing.

Thus, in such electrode configuration, the potential difference for a selected value of AB/2 is measured and in turn, the resistivities are obtained. The resistivities are plotted against AB/2 on a double log graph. A log-log plot of the apparent resistivity versus current electrode spacing (AB/2) is commonly referred to as the "sounding curve". The resistivity data is generally interpreted using the "modelling" process.

- **$\rho 1 < \rho 2 < \rho 3$** is defined as A-type
- **$\rho 1 < \rho 2 > \rho 3$** is defined as K-type
- **$\rho 1 > \rho 2 < \rho 3$** is defined as H-type
- **$\rho 1 > \rho 2 > \rho 3$** is defined as Q-type

CHAPTER 3

GROUND WATER POTENTIAL ASSESSMENT OF THE CAMPUS

3.1. VES Curve Interpretation

The VES data of the study area has been interpreted through curve matching technique using IPI2Win software version 3.0.1.a (Moscow State University 1990-2003). The interpreted sounding curves are given in the Fig. 3.1 to 3.3. The layer wise aquifer thickness and resistivity obtained are listed in Table 3.1.

Table 3.1. Resistivity data interpretation and corresponding thickness.

VES NO	Location	Resistivity of 1[st] Layer (ρ1), ohm-m	Resistivity of 2[nd] Layer(ρ2),ohm-m	Resistivity of 3[rd] layer (ρ3), ohm-m	Thickness of 1[st] Layer (h1), m	Thickness of 2[nd] layer (h2), m	Thickness of 3[rd] Layer (h3), m	Depth to basement, m
1	Near Sabarmati Block	2083	136	4394	15.8	5.8	58.4	80
2	Near Sabarmati Block	1742	168	4416	20.2	7.2	52.6	80
3	Between Kaveri and Krishna	1294	150	5252	19.4	43	-	-
4	Between Kaveri and Krishna	1406	211	984	24.5	51.5	24	100
5	Near Krishna Block	1323	187	16.4	13.4	36.6	5.1	60
6	Near Kaveri Block	2958	156	19.8	10.1	15.5	4.8	60
7	Near Nila Hostel	539	7494	44.5	7.5	22.5	5	60
8	Behind MPH	687	55.5	8186	6.4	5	-	-
9	Behind Teaching Block	697	56	1946	7.5	4.5	-	-
10	Near Second gate	2613	74	8441	12.5	14.9	-	-
11	Near new main gate	1679	103	6015	11.2	13.6	-	-

The interpreted true resistivity represented 3 layer H-type curve types in all locations (VES 1, VES 2, VES 3, VES 4, VES 5, VES 6, VES 8, VES 9, VES 10, VES 11; Figs 3.1 and 3.2) except one (VES 7) (Fig. 3.3). This type of curves are obtained generally in hard rock terrains which consists of dry top soil and/or hard laterite of high resistivity as the first layer, water saturated weathered layer of low resistivity as the second layer and compact hard rock of very high resistivity as the last layer.

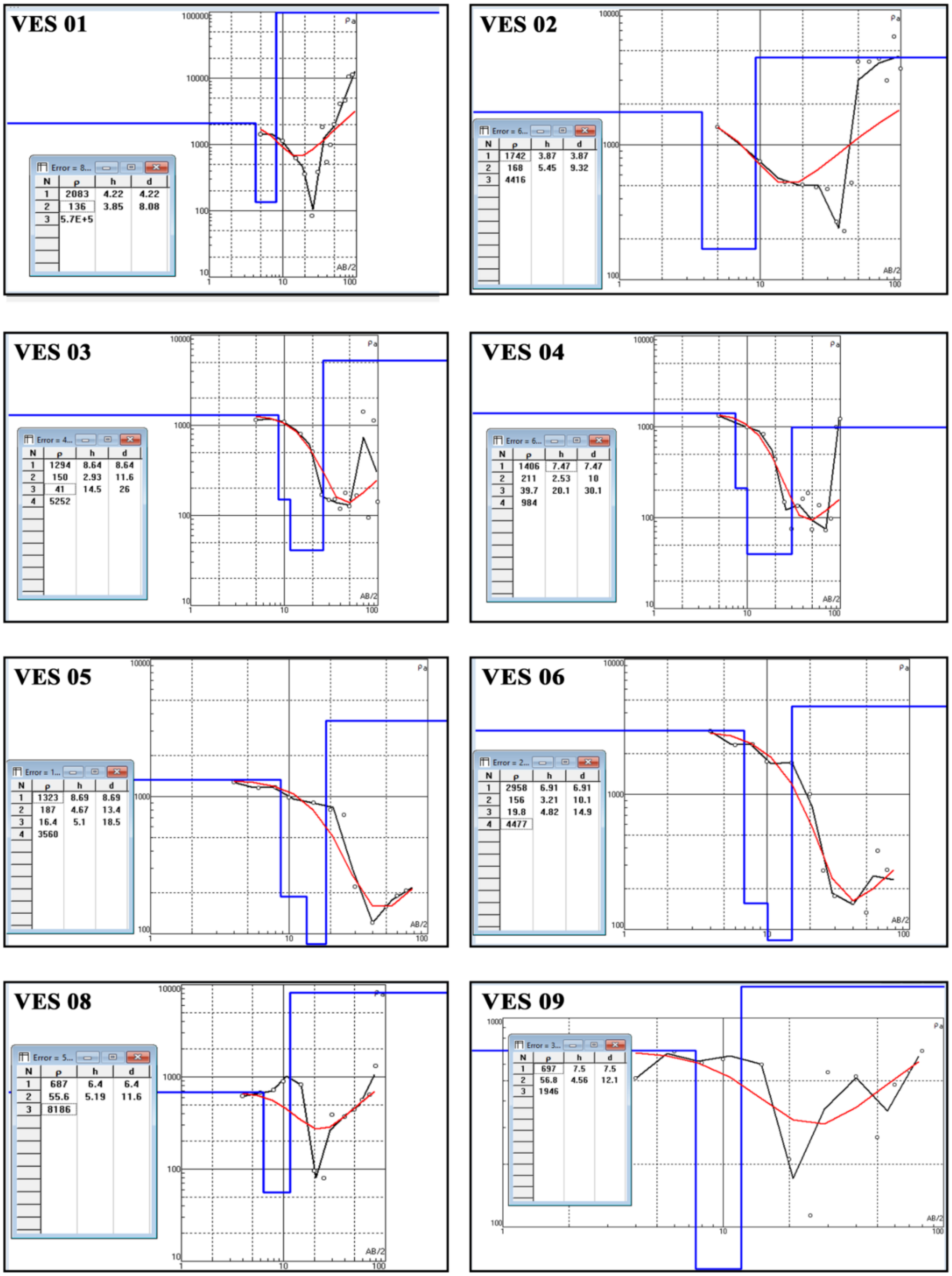


Fig. 3.1. Resistivity sounding curves (H type) of 8 locations (VES 01-06, VES 08-09).

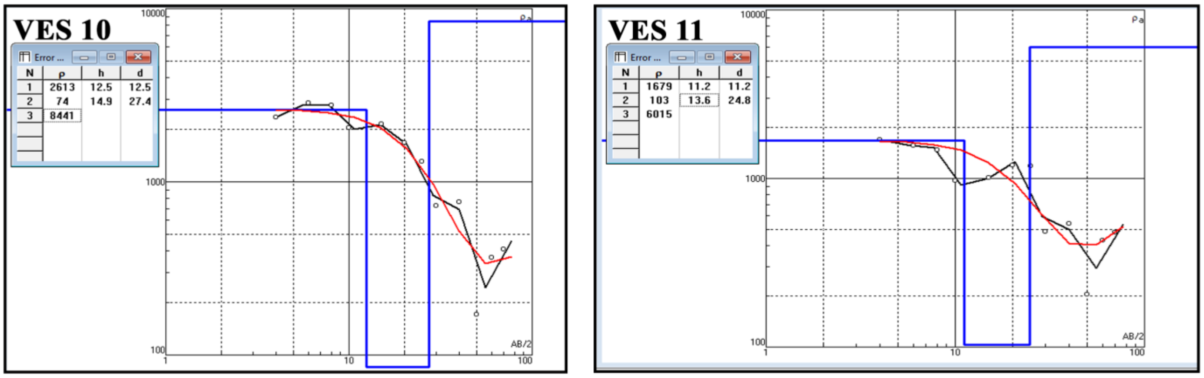


Fig. 3.2. Resistivity sounding curves (H type) of 2 locations (VES 10-11).

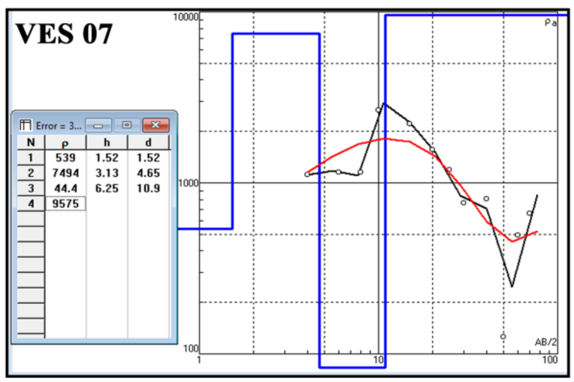


Fig. 3.3. Resistivity sounding curves (KH type) of location VES 07.

From the excavated cross section of lateritic layers in the nearby areas, it's observed that the study area comprised of hard laterite in the top followed by water saturated soft porous aquifer or weathered laterite, below that sometimes lithomarge clay and then followed by bed rock of Charnockite or other massive rocks.

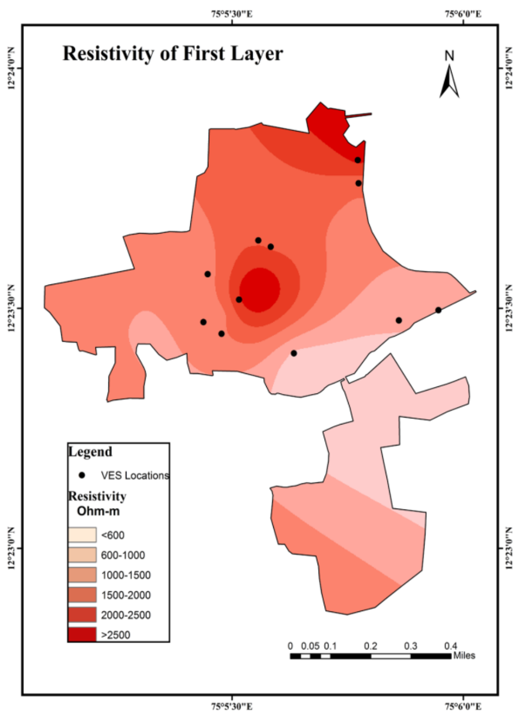
Irrespective of layers, over all resistivity varies from less than 100 Ω-m to > 2500 Ω-m . In order to understand the resistivity and layer thickness variation of the study area, spatial map has been prepared for the same as shown in Figs. 3.4 and 3.5. The first layer resistivity ranged between < 600 to 2958 Ω-m and thickness ranged from 4m to 24 m (Fig. 3.4), where a very low resistivity found in VES location 8 and high resistivity found in VES location 6. In the case of VES 1,2,3,4,5,6,10,11, the first layer the resistivity value ranges from 1294 to 2958

Ω-m, whereas in VES 8 and VES 9 the resistivity value ranges only up to 697 Ω-m. The thickness of the first layer is greater than 15 m in northern and western side of the study area. The low resistivity less than 1000 Ω-m is mainly seen at eastern and central part of valley region of study area which has a thickness of 5-10 m.

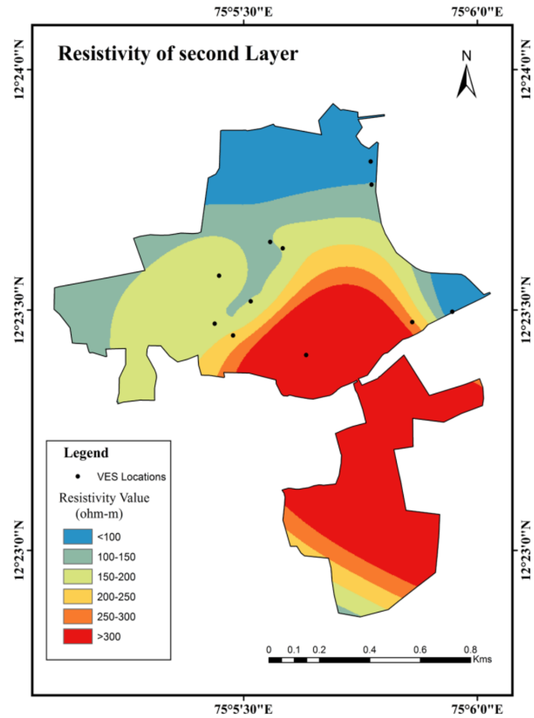
The second layer has resistivity ranging from 55.5 to greater than 300 Ω-m (except in VES 7) (Fig. 3.4) which represents the presence of water saturated soft laterite and weathered zone or the presence of clayey laterite. The thickness ranges from 4.5 to 51.5 m. This layer seems to have high potential for ground water compared to other layers. The zones with resistivity values up to 200 Ω-m indicate the presence of ground water. This range is seen in VES 3, 4,5,6,8 and 9 with varying thickness. The spatial variation of second layer resistivity and thickness is shown in the Fig. 3.4. The thickness of the second layer is low in the northern and eastern sides of the study area. Whereas, it is high (> 25m) in western and central valley region of the study area.

The third layer has resistivity ranging up to 8441 Ω-m, indicating the presence of unweathered/partially weathered massive charnockite/gneiss. At VES 5 and 6, the third layer also shows weathered zone or presence of lateritic/lithomarge clay with comparatively low resistivity. The spatial variation of third layer resistivity and thickness is shown in the Fig. 3.5. The majority of the study area exhibits high resistivity for third layer.

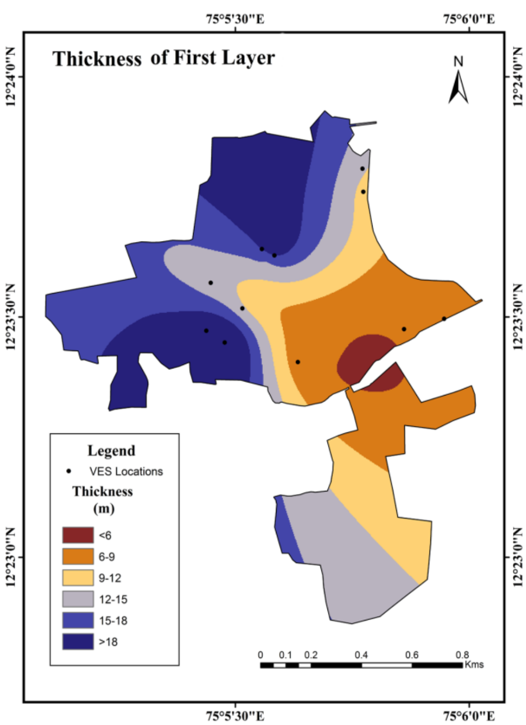
The resistivity sounding curve of VES 7 is different from all other locations and it can be explained by a four layer model ($\rho 1< \rho 2> \rho 3< \rho 4$) with 'KH' type curves (Fig. 3.3). In this case, the first layer exhibits low resistivity up to 7m due to the presence of soft top soil and pebbly laterite. The second layer has high resistance due to the presence of hard laterite followed by low resistivity in the third layer. At higher depths, the presence of hard massive rock is indicated by the high resistivity values of greater than 9000 Ω-m.



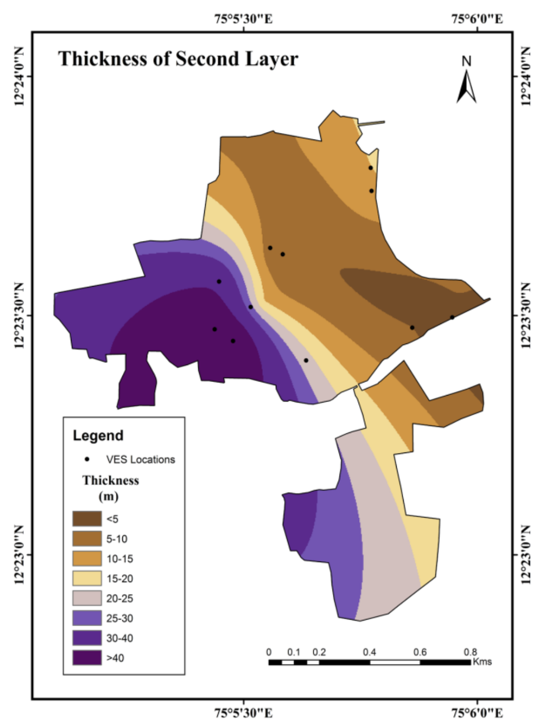
Spatial distribution map of first layer resistivity



Spatial distribution map of second layer resistivity



Spatial distribution map of first layer thickness



Spatial distribution map of second layer thickness

Fig. 3.4. Spatial distribution map of first and second layer resistivity and thickness.

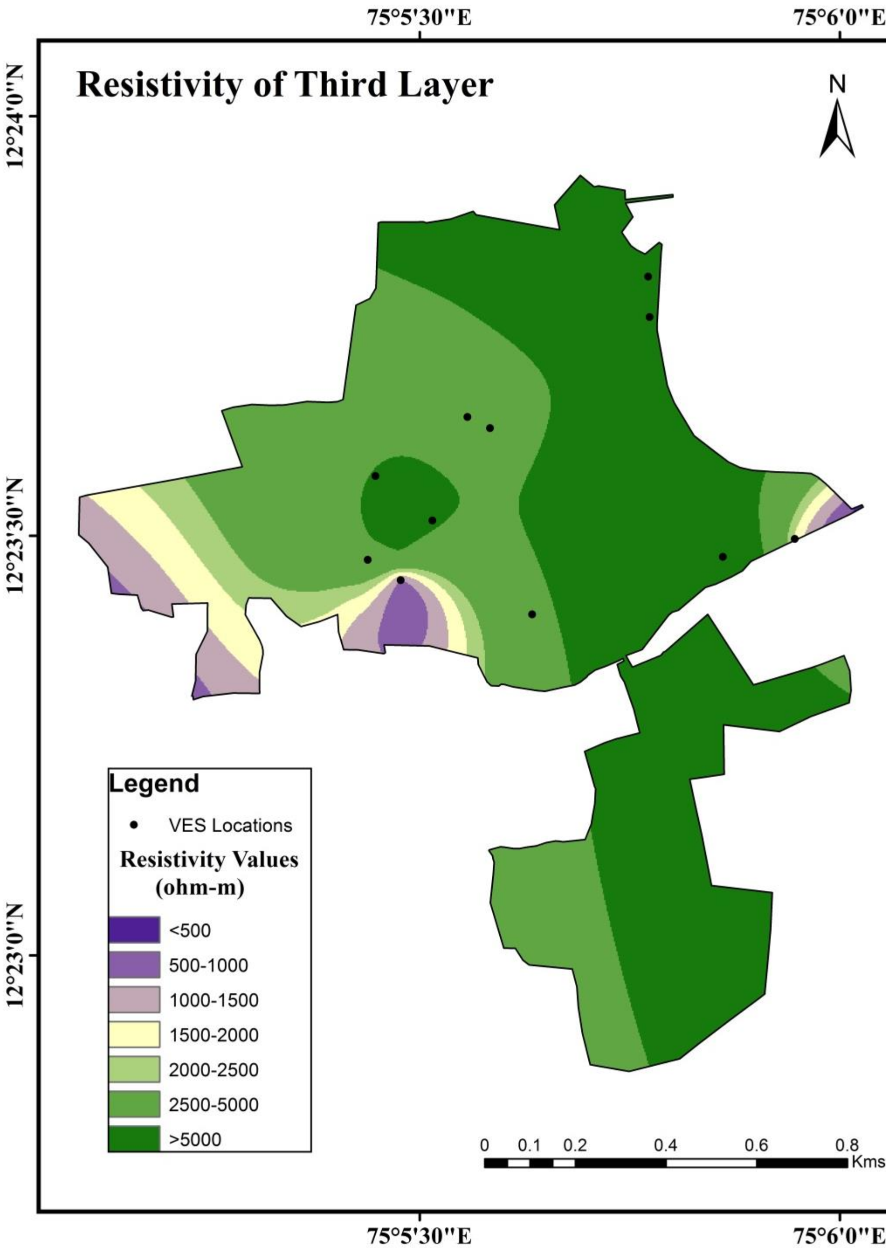


Fig. 3.5. Spatial distribution map of third layer resistivity.

3.2. Ground water potential zones

Most of the Central University of Kerala campus is underlain by three layers which are interpreted as laterite, weathered soft laterite and hard bed rock (charnockite). The resistivity values of 50 to 200 Ω-m are assumed to indicate the presence of ground water in the study area. Hence, the ground water is generally present in the second layer of weathered laterite at a depth ranging from 8-35 m the university campus. The thickness of this saturated layer ranges from 4.5 to 51.5 m. As the ground water indicated by the low resistivity values is present only in the second layer, the spatial distribution map of second layer resistivity can be used for the identification of ground water potential zones in the campus. Hence, the locations where resistivity values are low (50-200 Ω-m), have good ground water potential. The high resistivity values are indicative of moderate to poor ground water potential.

The areas near the buildings Teaching Block- 1 and 2 situated in the eastern part of the north campus area has very good ground water potential as indicated by resistivity values less than 100 Ω-m. The water table may be at a depth of 4-8 m in this area and is suitable for the construction of open wells. An open well near to it shows a water depth of 7.5 m, hence validating the interpretation made based on resistivity data. Near the multi-purpose hall, the ground water availability decreases slightly. However, the ground water potential decreases significantly as traversed to west (near to Nila and Kabani hostels and the area in between new academic buildings and the old buildings) from these two points.

The central valley region, where 8 academic blocks are situated has good ground water potential. The resistivity varies from 100 to 250 Ω-m. The water table may be at a depth of 10-15 m in this area. The shallow depth is found near the academic blocks Krishna and Kaveri, where construction of open wells are feasible. But in other parts, construction of bore wells is more feasible.

In the northern part of the campus, the ground water potential is very high. The resistivity values of < 150 Ω-m is observed in this part. The water table may be at a depth of 25-30 m in this area. Hence, the region is suitable for the development of borewells.

CHAPTER 4

SUSTAINABLE WATER RESOURCE MANAGEMENT AND ARTIFICIAL RECHARGE STRUCTURES FOR CENTRAL UNIVERSITY OF KERALA CAMPUS

4.1. Introduction

Artificial recharge to ground water is defined as the recharge that occurs when the natural pattern of recharge is deliberately modified to increase recharge (ASCE, 2001). The process of recharge itself is not artificial. The same physical laws govern recharge, whether it occurs under natural or artificial conditions. What is artificial is the availability of water supply at a particular location and a particular time. In the broadest sense one can define artificial recharge as "any procedure, which introduces water in a pervious stratum". The term artificial recharge refers to transfer of surface water to the aquifer by human interference. The natural process of recharging the aquifers is accelerated through percolation of stored or flowing surface water, which otherwise does not percolate into the aquifers. Artificial recharge is also defined as the process by which ground water is augmented at a rate exceeding that under natural condition of replenishment. Therefore, any man-made facility that adds water to an aquifer may be considered as artificial recharge (CGWRDM 2007). Artificial recharge aims at augmenting the natural replenishment of ground water storage by some method of construction, spreading of water, or by artificially changing natural conditions. It is useful for reducing overdraft, conserving surface run-off, and increasing available ground water supplies. Recharge may be incidental or deliberate, depending on whether or not it is a by-product of normal water utilization.

Artificial recharge can also be defined as a process of induced replenishment of the ground water reservoir by human activities. The process of supplementing may be either planned such as storing water in pits, tanks etc. for feeding the aquifer or unplanned and incidental to human activities like applied irrigation, leakages from pipes etc. (CGWRDM 2007).

4.2. Need for the artificial recharge and ground water management in CUK campus

Natural replenishment of ground water reservoir is a slow process and is often unable to keep pace with the excessive and continued exploitation of ground water resources. This has resulted in declining ground water levels and depletion of ground water resources. A major part of the precipitation is received during the months of June to September in Kasaragod as in most part of Kerala. The natural recharge to ground water reservoir is restricted to this period in the study area. The rates of potential evapotranspiration (PET) are also exceptionally high in the study area. Even though the rainfall is comparatively high, scarcity of water is often felt in the post-monsoon season, as most of the water available is lost as surface runoff. Because of the highly porous nature of the laterite, it gets recharged fast in the initial stages of monsoon, however this water escapes as sub-surface flow and the water level falls quite fast especially in wells located on topographic high and slopes (CGWRDM 2007). Springs, the major source of water in such terrains, are also depleted during the post monsoon period. In such areas, rainwater harnessing and small surface storages at strategic locations in the recharge areas of the springs can provide sustainable yields to the springs as well as enhance the recharge during and after rainy season (CGWRDM, 2007). The campus and the nearby areas including Periye town faces acute water shortage during the summer months. The water available in open wells dries up during the months of February and March. The availability of water in bore wells also reduces after February. Hence, there is an urgent need for the artificial recharge and proper ground water management in CUK campus.

4.3. Sustainable water resource management plan for CU Kerala campus.

The study area is having rugged topography which is characterized by small hillocks separated by deep-cut-valleys. This region shows a general slope towards the western coast. In this area, the groundwater occurs in the zone of saturation below the water table in weathered laterites as indicated by electrical resistivity studies discussed in Chapter 3, The groundwater may also occur in deeper fractured crystalline rocks, under semi-confined to confined conditions. The main aquifer in this area is laterite. These laterites are generally underlain by thick lithomarge clay, which is the preliminary laterization front. Laterites are seen in the campus are more ferruginous, porous and harder than the other parts of the district. Laterite quarrying and excavation of hill for the construction creates huge impact on groundwater potential of the area. Laterite is the main aquifer in the study area and which is being excavated throughout during the construction work of the campus. Hence, a suitable ground water management plans are necessary for the area. It is clearly evident from the comparison of Google Earth images of the year 2010 and 2018 (Figs. 4.1 and 4.2).

Based on the geology and geomorphology of the campus area, the following water resource management methods suggested:

4.3.1. Rooftop Rainwater harvesting

Rooftop Rain water harvesting can be adopted in the all the buildings in the main campus. Each of the 8 academic buildings has very large area of rooftop which can be utilised effectively to collect the rain water. The rain water falling on the roof top can be channelized through pipes, filtered and collected in underground sumps and storage tanks for future use (Fig. 4.3a). It can also be collected in storage tanks in the ground surface for temporary use after passing the water through a sedimentation tank to remove soils and sediments (Fig. 4.3b). These structures can be built near the buildings where there are no nearby open and borewells and hence no scope for the artificial recharge. These buildings include Narmada and Sabarmati blocks as well as hostel blocks.

4.3.2. Artificial groundwater recharge structures

Many different techniques are available for artificial recharging of aquifers. Projects are varied but usually involve storing surplus water in an aquifer for later use. The following artificial recharge structures are proposed in CUK campus:

- **Recharge pits:** Recharge pits with dimensions (width = 1-2 m and 2-3 m depth) can be constructed which are backfilled with boulders, gravels and coarse sand (Fig. 4.6). The pond or the pits can be part of campus modification which includes gardening (vegetation) within the campus. Lot of excavated portion in the laterite quarry can be used for the construction of recharge pits. The recharge pits can be constructed near the buildings where open and bore wells not available nearby. For example, Near Narmada, Gangotri, Sabarmati blocks and periyar mens hostel block (Fig. 4.11).

Fig. 4.1 Google Earth image of CUK campus in 2010.

Fig. 4.2 Google Earth image of CUK campus in 2018.

Diagrams of rain water harvesting

Fig. 4.3a. Graphical representation of proposed underground RWH structure in CUK academic buildings.

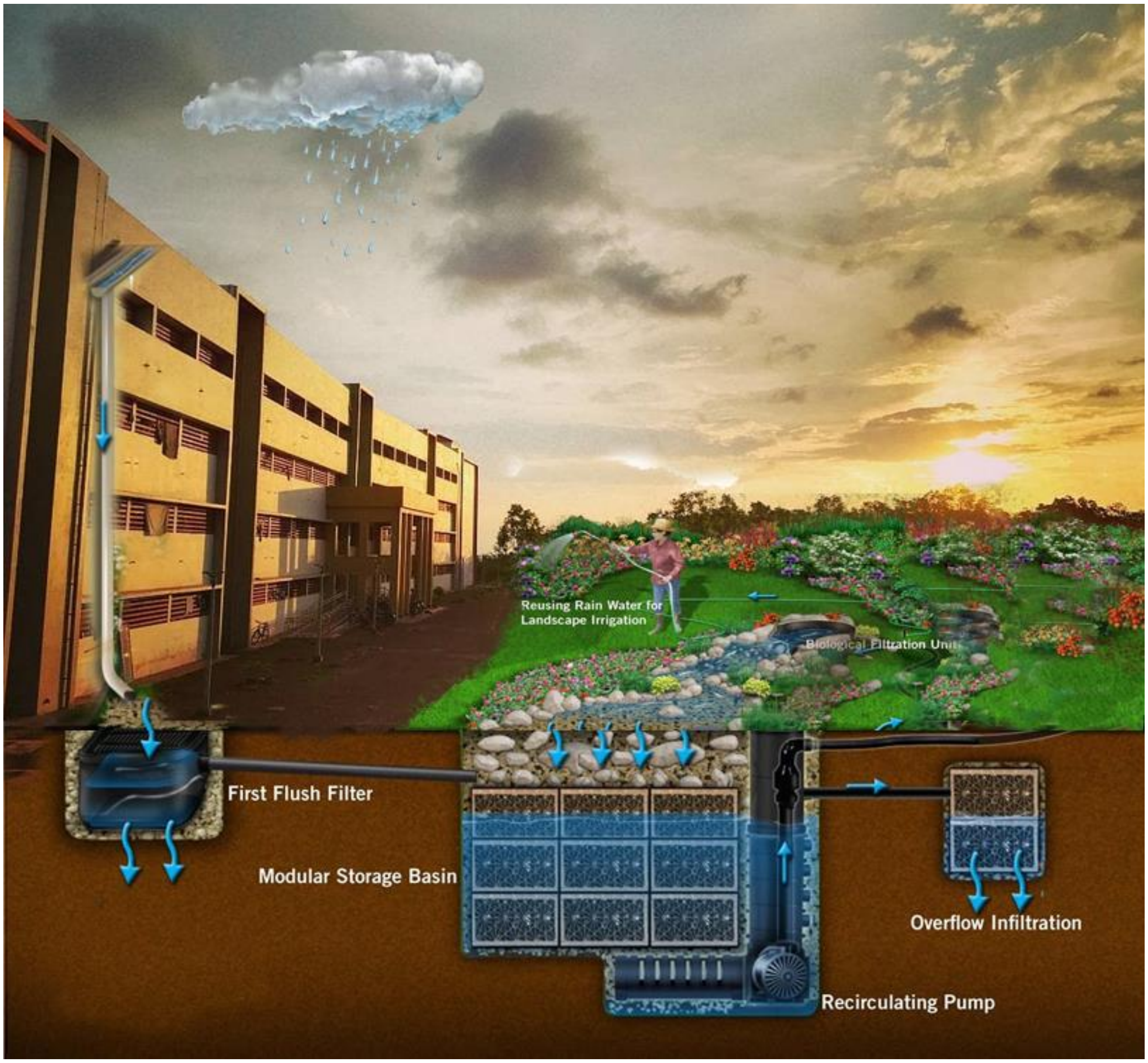


Fig. 4.3b. Graphical representation of proposed underground RWH structure in the CUK hostel buildings.

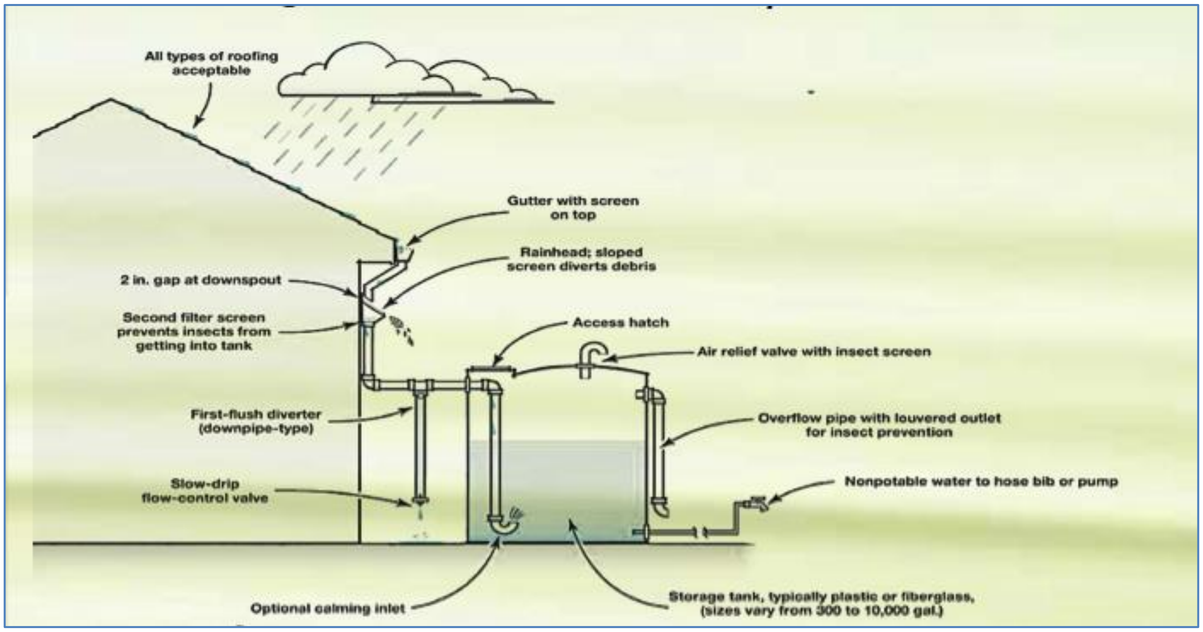


Fig. 4.4 Schematic diagram of proposed surface RWH structure.

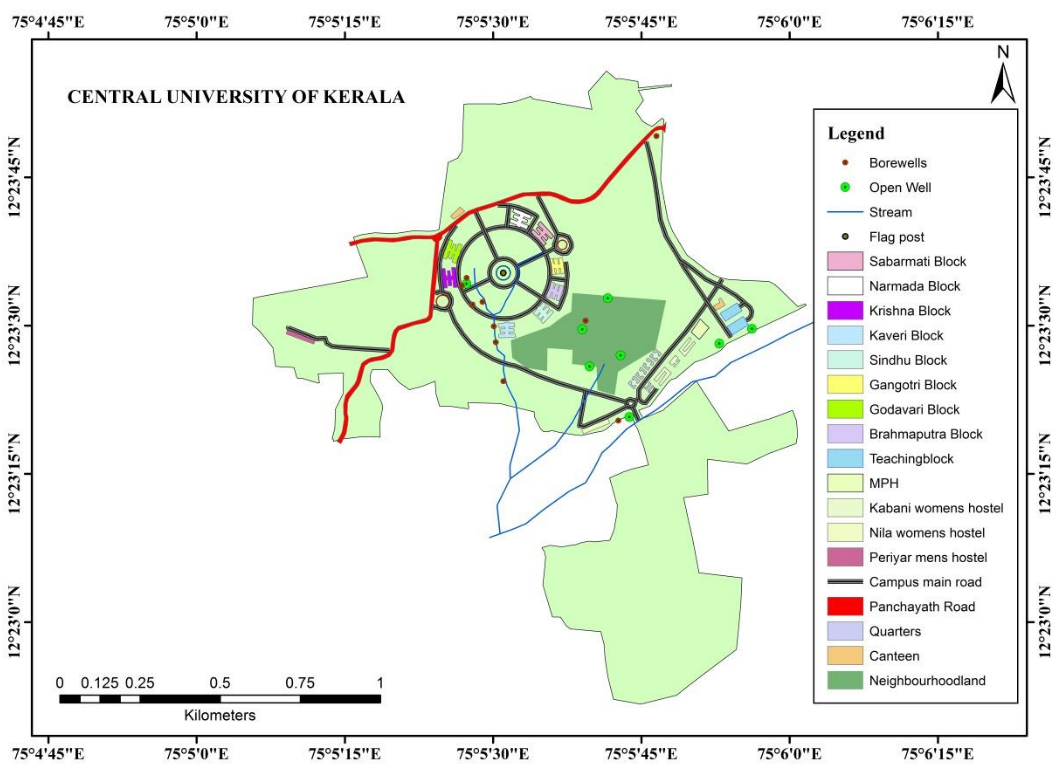


Fig. 4.5. Map showing the location of open wells and bore wells in CU Kerala Campus.

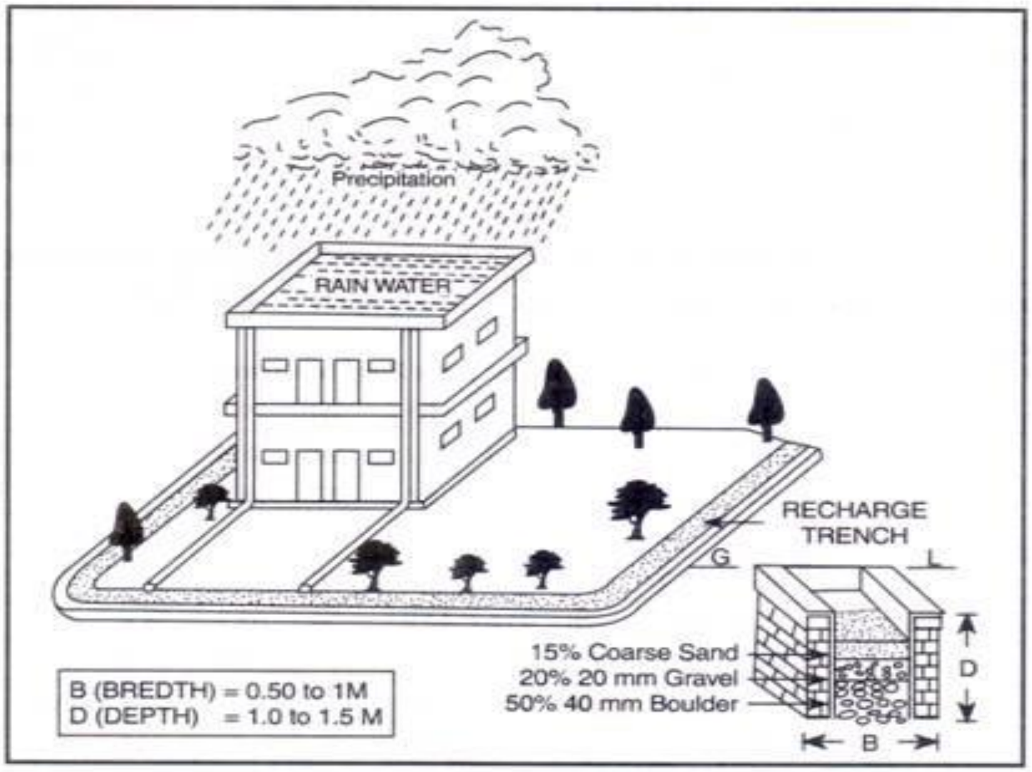


Fig. 4.6. Recharging through pits and trenches.

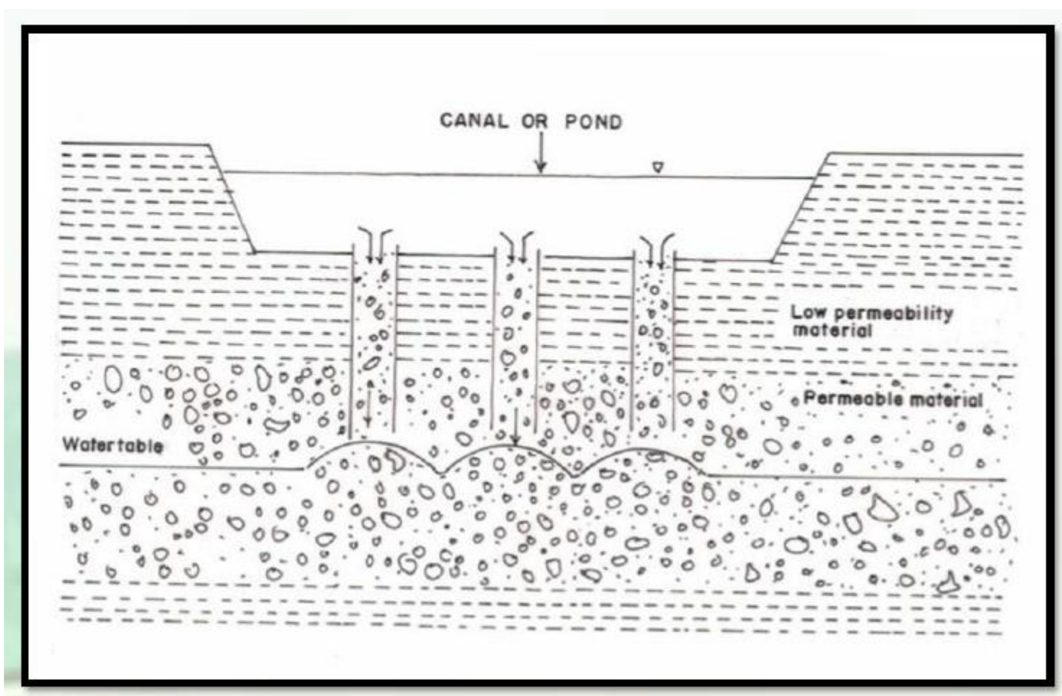


Fig. 4.7. Recharging through shafts within the pits.

- **Recharge trenches:** Recharge pits with dimensions (width = 0.5 to 1 m, 1.5 m depth and 10-20m length) can be constructed near the pits and can be backfilled with filler materials (Fig. 4.6). Recharge trenches can be constructed near the buildings Narmada, Gangotri, Sabarmati blocks and periyar mens hostel block (Fig. 4.11)
- **Recharge shafts:** Recharge shafts can be constructed along the central valley portion of the campus with dimensions 0.5 to 3 m diameter and 10-15 m depth. It can be backfilled with boulders, gravels and coarse sand (Fig. 4.7).
- **Open and bore wells:** The existing open and bore wells found in the topographic highs can be utilised as recharge structures. The water should pass through filter media before entering the wells (Figs. 4.8 and 4.9). The rainwater collected in the rooftop can be diverted to the nearby open and bore wells. It can be constructed near the buildings like Krishna, Godavari, Kaveri, Sindhu, Brahmaputra and hostel blocks (Fig. 4.11).
- **Check dams and sub-surface dykes:** Combination of check dams with the small surface dykes can create a barrier across stream which retards the base flow and stores water upstream below the ground surface. This will help in water level in upstream part of dyke rises. The sub-surface dykes can be constructed mainly in the central valley side of the campus (Fig. 4.11).

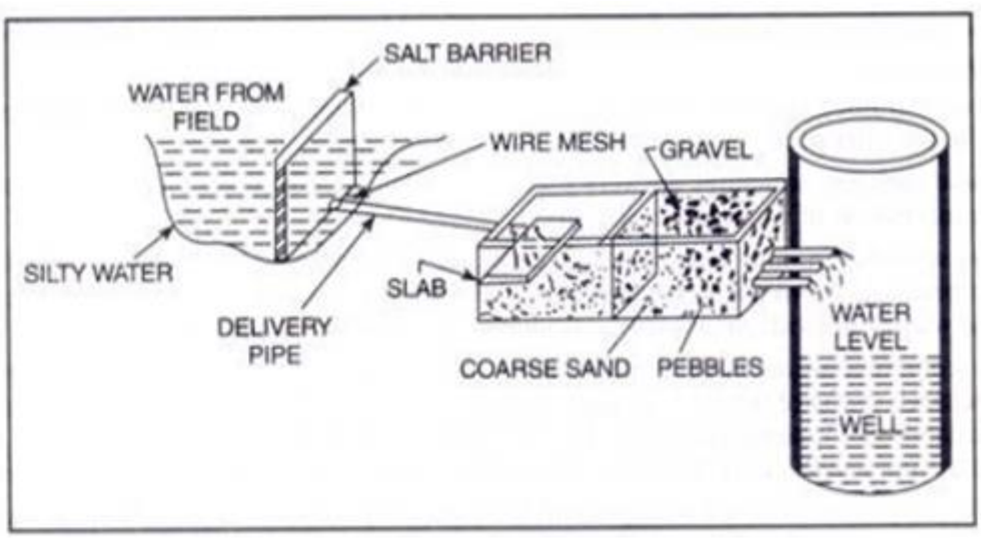


Fig. 4.8. Rain water harvesting through dugwell recharge.

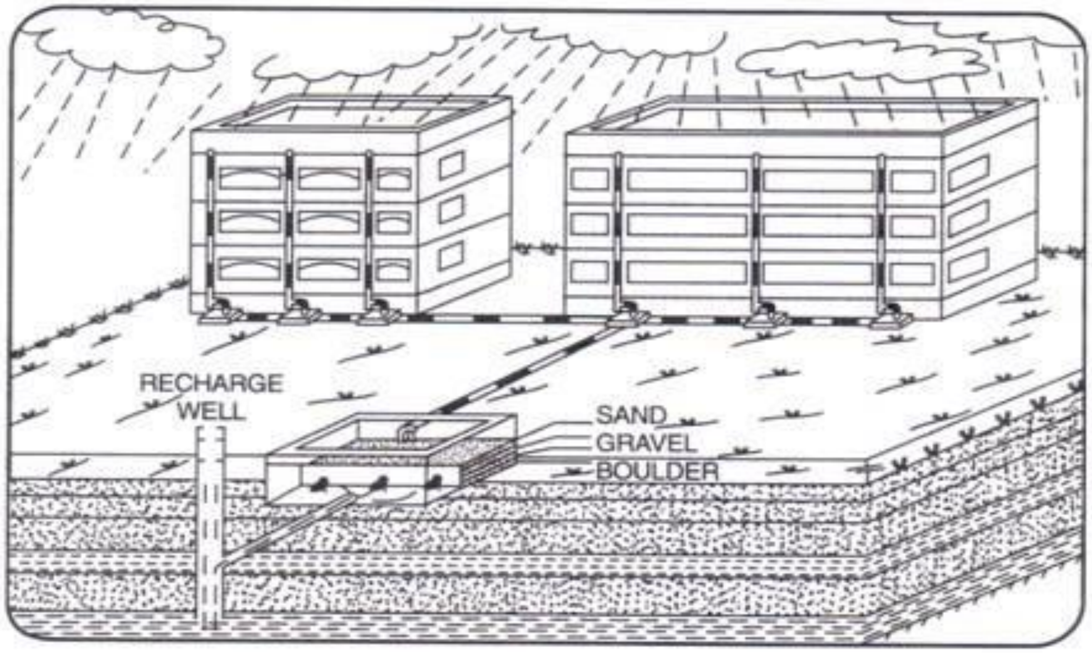


Fig. 4.9. Artificial recharge through existing bore wells in the campus.

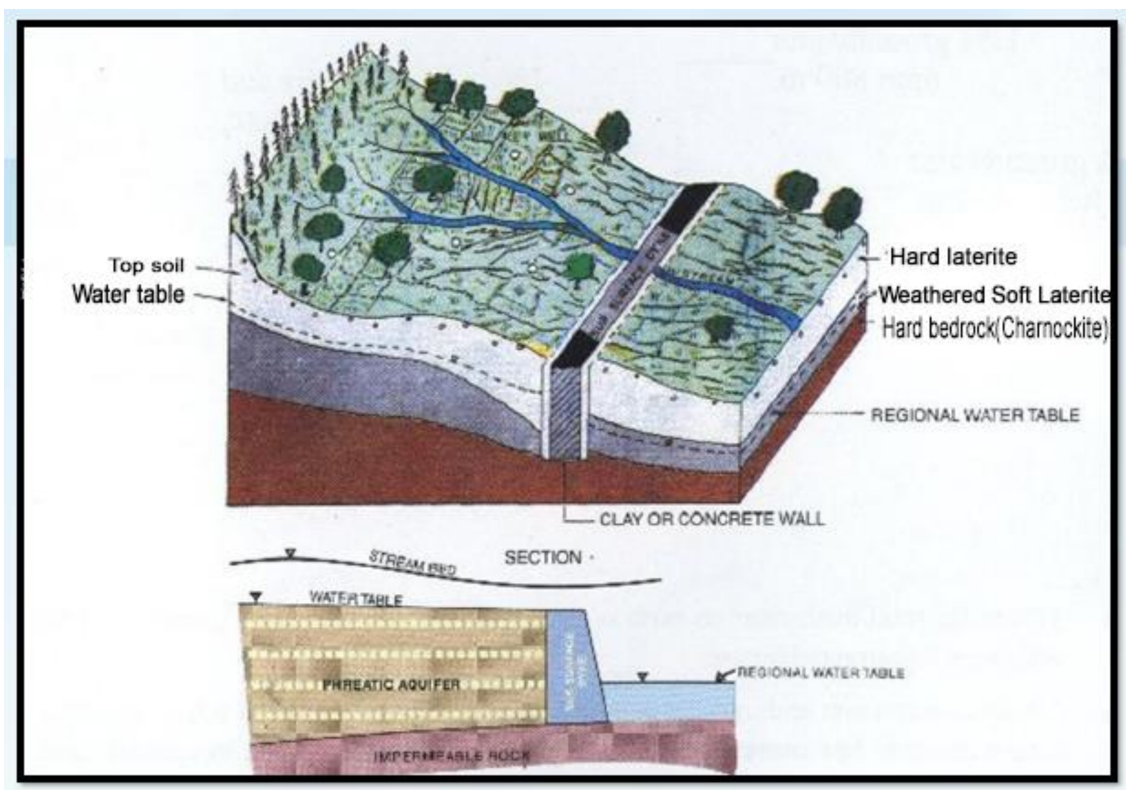


Fig. 4.10. Representation of recharge through Sub surface dykes

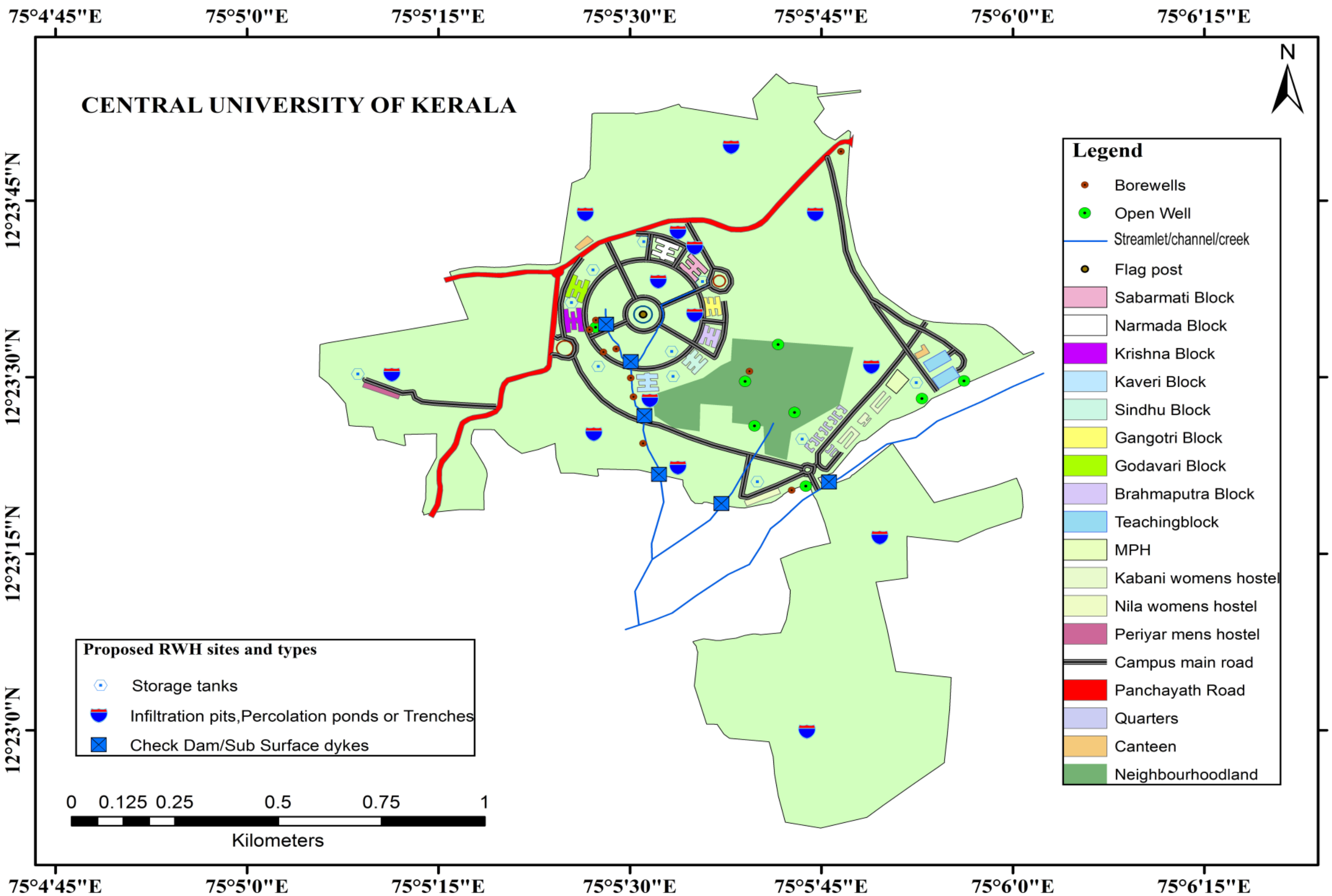


Fig. 4.11. Proposed rain water harvesting sites and types in CUK campus.

CHAPTER 5

SUMMARY AND CONCLUSIONS

The Central university of Kerala campus and surrounding areas are experiencing the decline of water table especially during the summer resulting in acute water shortage. In this context, present study was undertaken to assess the hydrogeological conditions, identify potential zones for the extraction of ground water and propose suitable sustainable water resource management practices and artificial recharge structures for Central University of Kerala campus. The electrical resistivity survey using the Schlumberger array was carried out in 11 locations across the campus using the Resistivity Meter SSR-MP1. The apparent resistivity was interpreted using IPI2Win software to obtain the true resistivity and layer thickness of the sub-surface formation. The VES curves, pseudosections and iso-resistivity maps (of depths 10m, 20m, 30m, 40m and 60m), spatial distribution map of first and second layer resistivity and thickness were prepared. The VES data of the study area has been interpreted through curve matching technique using IPI2Win software. The ground water potential zones for the development of open and bore wells in the campus were delineated based on these data. The suitable sustainable water resource management practices and artificial recharge structures for Central University of Kerala campus is also proposed. The soil piping investigation was carried out during the subsurface study of the area.

The main conclusions of the study are as follows:

- The interpreted true resistivity represented 3 layer H-type curve types in all locations except one. The first layer resistivity ranged between < 600 to 2958 Ω-m and thickness ranged from 4m to 24 m. The second layer has resistivity ranging from 55.5 to greater than 300 Ω-m and the thickness ranges from 4.5 to 51.5 m. The third layer has resistivity ranging up to 8441 Ω-m.
- The 3 layers are interpreted as dry top soil and/or hard laterite of high resistivity, water saturated weathered layer of low resistivity and compact hard rock of very high resistivity with or without fractures.
- The ground water is generally present in the second layer of weathered laterite at a depth ranging from 8-35 m the university campus.

- The region with low resistivity values (50-200 Ω-m), have good ground water potential and the regions with high resistivity values have moderate to poor ground water potential.
- The central valley region and eastern region (parallel to the trend of nearby streamlet) are the high potential zones in the study area. The water depth is this area is 4-8 m. The western part of the campus has very low ground water potential.
- The artificial groundwater recharge structures and rain water harvesting structures such as recharge pits, trenches, percolation ponds, storage tanks, check dams, subsurface dykes can be constructed in the suitable locations for the sustainable management of ground water.

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