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Prospects of groundwater development in a typical humid tropical watershed – A case study

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Abstract

The Karimpuzha watershed is situated in a typical humid tropical region in the Malappuram district of Kerala State, India. All hydrogeological information has been collected and analyzed to evaluate the groundwater development prospects in the study area. In this watershed groundwater occurs predominantly under phreatic condition. Groundwater is extracted mainly from the lateritic formation through dug wells. The depth to water level below ground level during peak summer ranges between 3.60 and 20.00 metres depending on the topography. The net annual groundwater availability is estimated as 16.6 mcm. Based on the present level of groundwater utilization, the watershed has been categorized as 'Safe' for future groundwater development.

Keywords: Groundwater, Humid Tropics, Development Prospects.

INTRODUCTION

Groundwater is a resource of immense magnitude, but of uneven, though inexhaustible availability. Harnessing groundwater is less expensive compared to surface water irrigation projects. For medium to small-scale consumption like domestic, industrial and agricultural needs, groundwater exploration is much cheaper. The first step in the development, conservation and optimum management of groundwater resources is a regional appraisal of the hydrogeologic condition. Drainage basins or watersheds should be the unit of study area for the better understanding of the hydrologic system and for accurate quantitative estimation of the resources (Tideman, 1996). It is in this context this study has been carried out within a watershed to evaluate the current status of groundwater development, utilization pattern, groundwater draft, etc., and to determine the stage of groundwater development. The study has been carried out in the Karimpuzha watershed, which falls within the Malappuram district of Kerala State, India, and represents the humid tropics.

METHODOLOGY ADOPTED

Topographic and drainage maps were prepared using toposheets of 1:50,000 scale to understand the morphometric characteristics of the watershed. Hydrogeological investigation was made to know the general groundwater occurrence, depth to water level, pattern of groundwater level fluctuation, etc. Water samples were collected and analysed. A hundred percent well-censes was carried in one sq. km area, to know the type of extraction structures, density of wells, persons / well, usage purpose, etc. All the available secondary data on rainfall, surface and sub-surface geology, hydrogeology, etc. were collected from various published reports and agencies. All these information have been analyzed to evaluate the groundwater development prospects in the study area.

BRIEF DETAILS OF KARIMPUZHA WATERSHED

a-General

The Karimpuzha stream is a tributary of Chaliyar River in the Malappuram district of Kerala State. The Karimpuzha watershed lies between north latitude 11°13’48” and 11°24’40”and east longitude 76° 15’ 52” and 76° 34’ 35”. This watershed has an areal extent of 271.55sq.km, with a perimeter is 85 kms.

b-Rainfall

The Karimpuzha watershed represents a typical humid tropical region. The average annual rainfall of this watershed is 2335 mm. About 64.7% of this annual rainfall is received during southwest monsoon (Jun- Aug), 24.8% during northeast monsoon (Sep- Nov) and the remaining 10.5% is received as non-monsoon rainfall during December and January to May. Out of the 10.5% annual non- monsoon rainfall, major portion of the rainfall (79%) is received as pre-monsoon showers during April and May. Average monthly rainfall hydrograph of the study area is shown in Figure1

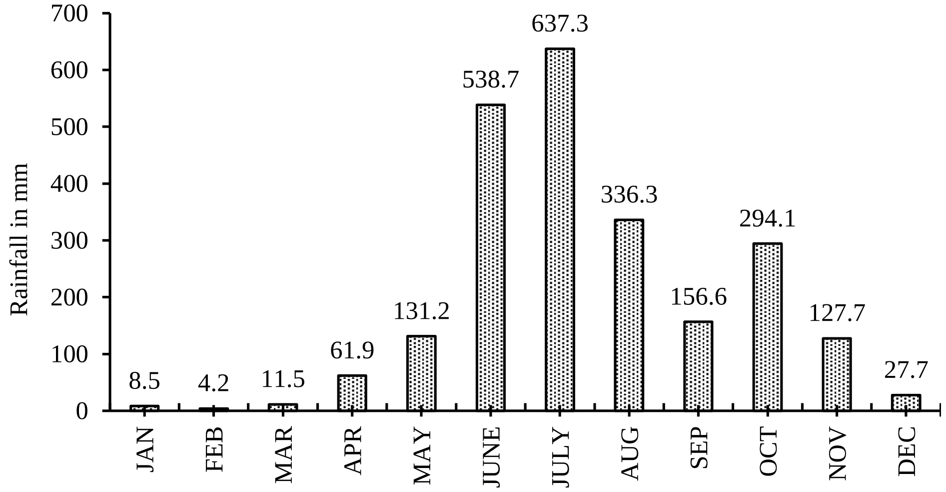

Fig-1. Average monthly rainfall hydrograph (1990-2003)

c-Physiography

Physiographically, the Karimpuzha watershed represents the highland region of Kerala State, India. This watershed is long and narrow, and is elongated in an East-West direction. The maximum length of this watershed is 32.5 km and the average width is 8.0 km. As the watershed is long and narrow, it takes more time for rainwater to leave the watershed as runoff, thereby increasing the scope for rainfall to infiltrate into the soil to recharge ground water. The ground elevation ranges between 40 to 2594 m above mean sea level within the basin length of 32.5 km.

The slope of this watershed is more in the upper reaches and less in the lower reaches. The areas, which are steeply sloping, are categorized by the closeness of the contours. The total area in the watershed having more than 20% slope is found to be 158.74 sq. km. According to the Groundwater Estimation Methodology (CGWB, 1997), areas having ground slope greater than 20% need not be considered as areas suitable for groundwater recharge. This means only 112.81 sq. km area within this watershed is suitable for groundwater recharge, due to rainfall.

d-Drainage Morphometry

This watershed is characterized by dendritic type of drainage pattern with variable density. In the upper reaches, fine drainage texture of dendritic pattern is seen, indicating the hard rock formations of impervious nature. In the lower middle region of this watershed, sub-dendritic drainage of medium texture exists, indicating the presence of rock formations characterized by fractures / joints and moderately permeable in nature. In the lower reaches of the watershed, sub-dendritic drainage of coarse texture exists, indicating permeable sub- surface formations. In this watershed, there are 772 first order, 193 second order, 41 third order, 8 fourth order, 3 fifth order streams and the main stream has been designated as 6th order stream (Strahler, 1952; Horton, 1945). The bifurcation ratio of streams within this watershed is determined as 3.9, indicating that the drainage is not distorted by the geologic structures such as faults, folds, fractures, etc.

GEOLOGY AND SOILS

a-Geology

Geologically, Charnockites and Gneiss of Precambrian age, laterites of Pleistocene age and alluvial formation along the stream course of recent to sub-recent age characterize the area. Charnockite is one of the important rock types in the area. These are dark greenish gray in colour, medium grained, massive or foliated (Soman, 1997). Narrow zones of hornblende – biotite gneiss and gneisses of granitic composition are well exposed in parts of Nilambur region. However these Charnockites and Gneissic rocks are mostly covered by laterites and lateritic soil. Laterite occurs as residual formation formed due to tropical weathering of crystalline rocks. Laterites are found as both primary as well as secondary formation / material. It extends up to 18 metre at depth. At depth this laterite grades in to lithomargic clay, overlying weathered and fractured hard rocks. The recent alluvial formation includes river alluvium and valley fill. These are composed of fine to medium grained sand.

b-Subsurface geology

Already existing data on bore wells and also the observations made in the existing dug wells within the study area have been used to know the sub-surface geologic condition in the area. The lateritic soil of 0.5 to 8.0 metre thickness is overlying the laterites of 2.0 to 18.0 metre thickness followed by lithomargic clay of 0.5-2m thickness, weathered rock and hard rock. In the higher elevations, lateritic soil is directly overlying the weathered and hard rock, without the presence of laterites and lithomargic clay.

c-Soil

The different types of soils, which occur in this watershed are, riverine alluvium along river valleys with surface texture ranging from sandy loam to clay, Lateritic soil as a weathered product derived under humid topical conditions, Brown hygromorphic soil in the valleys between undulating topography, and forest loam developed in the hilly and forest areas.

HYDROGEOLOGICAL CONDITION

In this watershed groundwater occurs predominantly under phreatic condition in laterites, weathered and fractured rocks. In deep-seated fractured rocks, groundwater occurs under phreatic, semi- confined or confined condition.

Groundwater is extracted from the lateritic formation through dug wells of 3-5m diametre. Laterites are highly porous but the permeability depends on the texture and clay content. Specific yield of laterites is 2.5% and the rainfall-recharge factor is 7% (CGWB, 1997). As the laterites are generally stable, no protective lining is usually provided. The depth to water level below ground level during peak summer (April/May) ranges between 3.60 and 20.00 m depending on the topography. A typical groundwater level fluctuation hydrograph of the study area is shown in Figure 2. Wells constructed on the higher slopes or elevated places go dry or have very little water during summer period. Groundwater is also extracted from the hard rocks, which are fractured at deeper horizons, through drilling borewells. The fractures are moderate to highly permeable and are occasionally continuous and locally extensive.

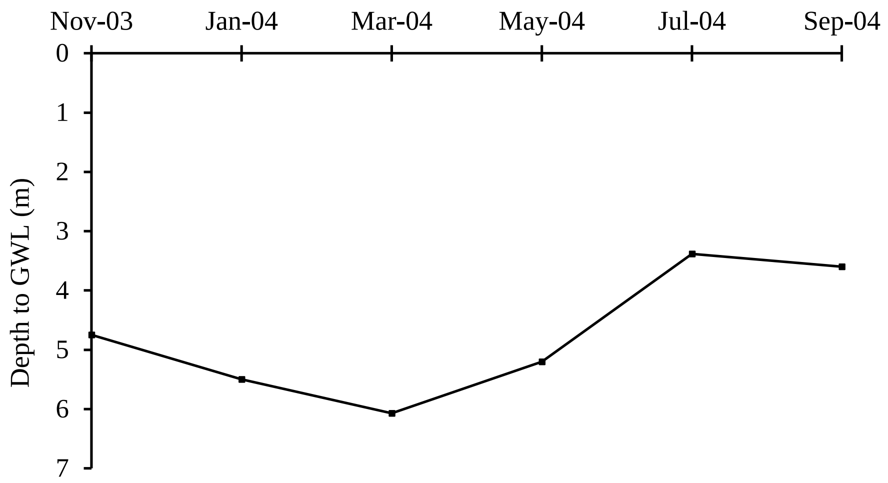

Fig- 2. Bi-monthly groundwater level fluctuation

Groundwater occurs under phreatic, semi-confined or confined condition depending on the thickness and permeability of the overlying lithomargic clay formation. Bore wells of 60 to 80 metres depth are usually drilled to tap groundwater from these fractured rocks in this area. The yield from these borewells ranges between less than 100 litres per hour (lph) to more than 5000 lph. The density of borewells will be only 2-3 bore wells in 1 sq.km area. Most of these borewells are used for domestic purposes and the quality of borewell water is reported to be potable.

GROUNDWATER UTILIZATION PATTERN

A hundred percent well census will give the exact information in terms of well density, groundwater utilization pattern, groundwater draft, etc. This information is very vital in determining the stage of groundwater utilization and scope for future groundwater development. The 100 % well census was carried out in 1 sq.km area within the watershed, which is almost representative of the entire area. Groundwater is extracted mainly through large diametre dugwells for domestic purposes. Very rarely borewells are used to extract groundwater for community water supply, which is done through hand pumps or electric pumps. The details of the most common and widely used dugwells are as follows.

a-Dugwells-General Details

There are 204 dug wells in 1.0 sq. km area in, with almost each family having its own well. The number of dugwells is increasing every year, due to increasing population and influence of urbanization (Fig.3). The density of dugwells in this watershed is 204 wells / sq.km. The depth of these wells range between 3.50 metre and 20.0 metre below ground level depending on the ground elevation. The diametre of the dugwells varies from 1.0m to 3.07m, with majority of the wells having less than 2.0m diametre. These open wells are mostly constructed using cement rings or lateritic bricks. The height of this lining of well wall is dependent on the thickness and stability of the overburden, such as soil, laterite, lithomargic clay and weathered rock.

b-Usage pattern

75% of the dugwells are used for domestic purposes. Only 2 out of 204 wells are exclusively used for irrigation purpose. About 25 %of the wells are used for domestic purposes and irrigating plants within the house compound. Mostly people depend on groundwater for domestic purposes. Number of persons using a single well varies between 2 and 43.

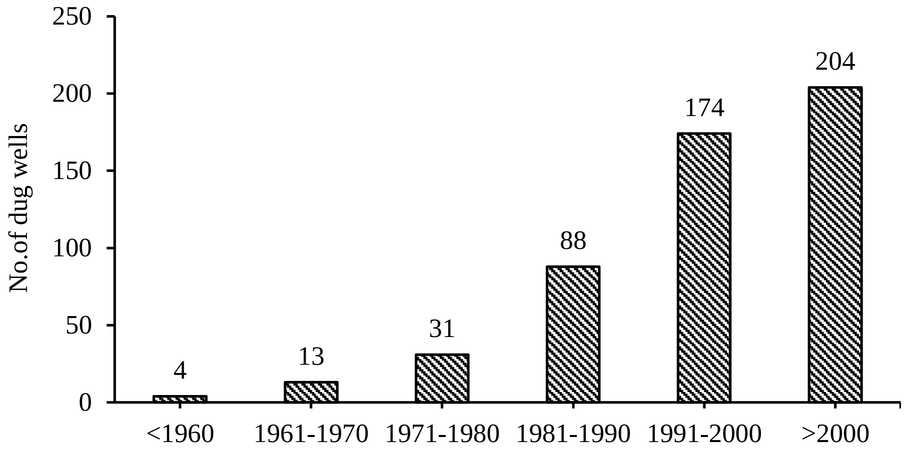

Fig- 3. Decadal growth of dug wells

c-Type of lifting devices

Groundwater withdrawal from the wells is made using pulley with rope and bucket or by using energized pump. Out of the 204 dugwells, 92 wells are fitted with pulley (45%) and the remaining 112 wells are fitted with energized pump (55%). 82% of these pumping wells are fitted with pumps less than 1.5 HP capacity. These wells are generally pumped for 20-30 minutes in a day.

GROUNDWATER QUALITY

It is observed that the quality of groundwater is within the permissible limits of drinking water quality standards. However the iron content in the bore well is very high and this may be due to the use of iron (Mild steel) casing pipe or due to the overlying iron rich lateritic formation. The overall groundwater quality is good. The results of the Physico-chemical analysis for the summer period are given in Table 1.

No major groundwater quality related problem has been reported during the well census. However the water quality problem due to man-made causes such as wells very close to leach pit, washing of cloths near the wells, disposal of waste from rubber sheet production, etc, do exist. The major man-made quality problem is the construction of leach pits / septic tanks close to dugwells. This problem is severe because majority of these are not septic tanks. It can be seen from Figure 4 that about 40% of the wells are within a distance of 10m from the leach pits

Table1. Typical physico-chemical quality of groundwater within the study area

Parameters	Well Type	
	Dug well	Bore well
PH	6.2	6.9
EC	430	310
Total Alkalinity	34	16
Total Hardness	52	120
Chloride (Cl)	62	20
Nitrates	2.5	0.1
Phosphate	Non detectable level	0.01
Iron	Non detectable level	8.4
Sodium	77	21
Potassium	6	6
Calcium	16.8	32
Magnesium	2.5	9.8

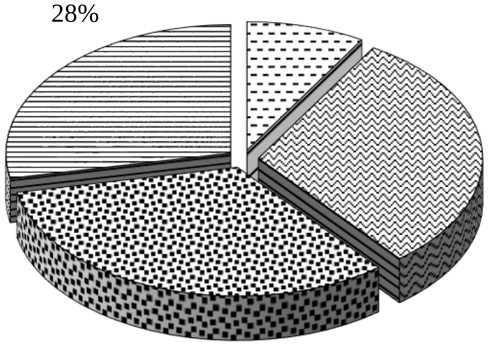

Fig- 4. Dug well proximity to leach pit

STAGE OF GROUNDWATER DEVELOPMENT

a-Groundwater Potential

The effective area for recharge has been considered as 112.81 sq Km2 (excluding areas having slope greater than 20 %). Groundwater estimation methodology-1997 of Ministry of Water Resources, Government of India, (CGWB, 1997), has recommended a maximum rainfall infiltration factor of 7 % for the laterites. Considering the average annual rainfall of 2335 mm, the annual groundwater recharge in this watershed will be 18.44 Million Cubic Metres (MCM). Considering 10 % of this annual recharge as unaccounted losses due to natural discharge, etc, (CGWB, op cit), the net annual groundwater availability is 16.6 MCM.

b-Groundwater Draft

Based on the results of the well inventory, the ground water draft for different purposes has been estimated. Considering an average of 5 persons / well using 100 litres of water each per day through out the year, the total groundwater draft per well used exclusively for domestic purpose will be about 180 m^3/ year. Considering about 1500 litres of water is extracted per day from each well for irrigating garden and plantation crops within the house compound during 180 non-rainy days, the total groundwater draft per well used exclusively for irrigation purpose will be 270 m^3/ year. Considering about 180 m^3/ year / well for domestic purpose and 110m^3/ year/ well for irrigation purpose, the total draft per well used for both domestic and irrigation purposes will be 290 m^3/ year.

Considering a well density of about 200 wells / sq. km in areas having slope less than 20%; absence of wells in areas greater than 20% slope due to reserved forest; and the proportion of wells for different uses is same as that of the sample area, the total groundwater draft within this watershed can be estimated as 4.74 MCM / yr. This draft is only 28% of the annual available groundwater in this watershed.

c-Scope for Groundwater Development

Though the density of dug wells is high and most of these wells are energized, the average draft per well per day will be less than 1000 litres per day. Groundwater assessment made following the Groundwater Estimation Methodology (CGWB, op cit), shows that the stage of groundwater development is only 28 %. Based on this present level of groundwater utilization, the Karimpuzha watershed can be categorized as 'SAFE' for future groundwater development.

SUMMARY AND CONCLUSIONS

The Karimpuzha watershed represents a typical humid tropical region of Kerala State. This watershed is characterized by charnockite and gneissic rocks and dendritic to sub-dendritic drainage pattern. Groundwater is the main source of drinking water and dugwell is the main groundwater extraction structure in this watershed. The net annual groundwater availability is estimated as 16.6 MCM and the total annual groundwater draft for domestic purposes is estimated as 4.74 MCM. This draft is only 28% of the annual available groundwater in this watershed. There are no industries in the study area and the agricultural operations are mainly rain fed. Considering the present level of groundwater utilization, the Karimpuzha watershed can be categorized as 'SAFE' for future groundwater developmental activities.

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