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Study of Boreholes' Data from the Eastern Part of Mandara Hill Area of Northeastern Nigeria

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ABSTRACT

Static water level map of boreholes in the study area shows low, medium and deep static water level closures from one part to another. Depth to the static water level increases away from the foot of Mandara hill area due to deepening of the substratum. Low discharge rates from boreholes are attributed to possible concentration of argillaceous materials, while higher discharge rates occur where the aquifer is dominated by sandy materials. High displacement closure values in the central region are enveloped by medium and lower ones on both sides. Lower values depict potential hydrogeological units favourable for groundwater accumulation. Also lower dynamic water level along some communities' boreholes may indicate favourable water well conditions. Production capacities of the wells are higher where the wells stabilized at short intervals of pumping. The presence of fine-grained matrix in coarse-grained fractions conditioned the aquifer around some community boreholes to transmit insufficient amount of water into the wells where continuous withdrawal is interrupted from time to time to enable recovery. Medium storage coefficients values enclosed higher ones along some parts. The hydraulic conductivity values are within those of basement aquifer. Lower hydraulic conductivity values dominated the central region. The presence of fine-grained matrix in coarse-grained sediments conditioned the low conductivity of the aquifer along the north – south direction. Medium hydraulic conductivity zones enveloped higher values at the eastern and southwestern parts. Evaluations of the hydrogeological parameters of boreholes' aquifer indicate favourable conditions that can sustain water supply needs in the area when properly managed.

Key words: Boreholes, Groundwater, Yield, Static water level, Aquifer and Pumping test.

INTRODUCTION

Water is renewable and occurs almost everywhere on the earth's surface and subsurface. Surface water may be absent in certain areas due to geological peculiarities. Pollution and industrial complications on surface water may necessitate the search and exploration of groundwater resources. The availability of groundwater in areas underlain by crystalline basement rocks depends on the development of thick soil overburden or the presence of fractures that are capable of holding water. The storage of groundwater is confined to fractures and fissures in the weathered zone of igneous, metamorphic and volcanic rocks, the thickness of which range from 20 - 30 m in arid areas [10]. The groundwater resources here are usually limited. The aquifer deposits consist of sands, gravels, silts and clays. Quite often the sands and gravels are water bearing, hence they are the main targets for the development of the groundwater.

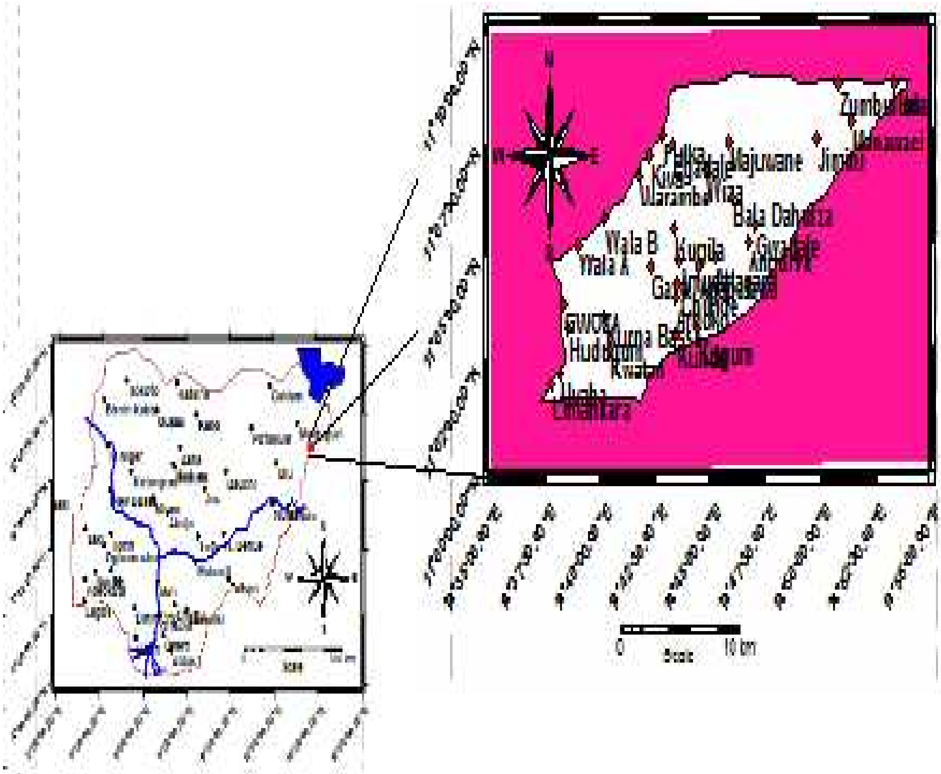


Fig. 1: Location map of the study area

The study area (Fig. 1) is located by latitude 13037’30” N – 14000’00” N and longitudes 10055’00” E – 110 15’00” E. It lies within the tropical continental semi arid region of Nigeria with short rainy season and long dry season. This work examines the hydrogeological parameters of boreholes data from the eastern part of Mandara mountain area with the aim of assessing the viability of future boreholes programmes in the area.

Geology of study area.

Crystalline rocks of the Basement complex are widely spread in Africa. In Nigeria, the Basement complex is the principal and oldest stratigraphic unit and consists mainly of granites, gneisses, migmatites and sub-volcanic schist rocks. It is believed to have undergone through various tectonic events with differing intensities from the Achaean to the Pan African. According to Oluyide [8], fractures in the Basement complex are primarily oriented towards north – south, north northeast – south southwest, northeast – southwest, north northwest – south southeast, etc. These fractures are marked by considerable shearing and brecciation

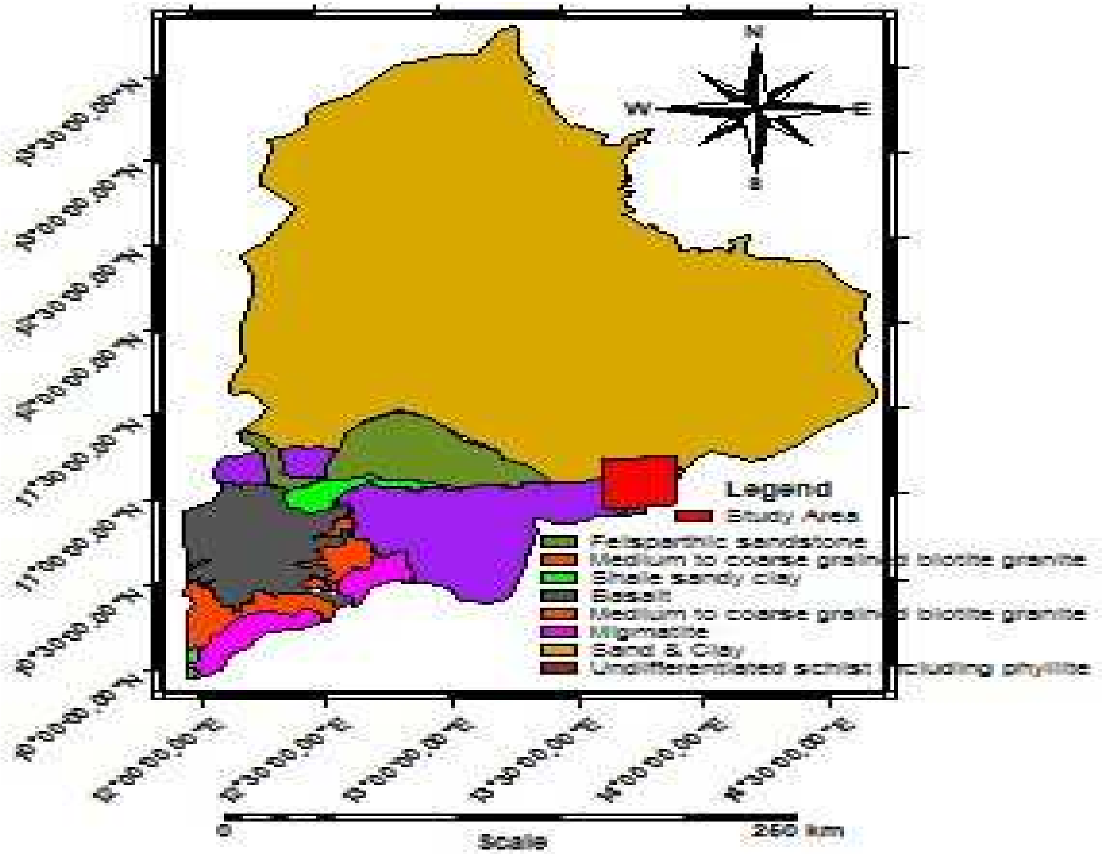


Fig. 2: Geology map of Borno State showing the study area

[3] Considered the northeastern part of the Nigerian Basement complex as consisting mainly of undifferentiated rocks exposed over much of the southeastern part of Borno State (Fig. 2). It is bordered at the north by the Chad Basin; to the west and to the south it is delimited by the graben structure of the Benue Trough and the lateral Yola Trough. Migmatite-gneiss, schists, tectonised granitic rocks and undeformed granites of Older Granite suite underlay Gwoza area [6]. The Older Granite is hill forming, outcropping as batholiths. Low-lying migmatite gneisses, schists and quartzites enveloped the batholiths. The late Tertiary volcanic activity in Nigeria gave rise to the Biu Plateau. Numerous volcanic plugs and dykes characterized by conical hills and calderas occur in the south towards the Benue Trough. Isolated plugs are preserved along the Mandara mountain chain [4]. The geological setting of the rocks is association of volcanic and pyroclastic rocks within a possible ring complex. The superficial deposits formed from weathered rocks of the Basement complex and volcanic rocks are the porous sands, gravels, silts and clays.

MATERIALS AND METHODS

Methodology

Data from fourteen boreholes drilled in the eastern part of the Mandara hill area in Gwoza Local Government area, the data consist of the borehole location (Fig. 3), borehole identification number, depth drilled, yield, static water level and pumping test.

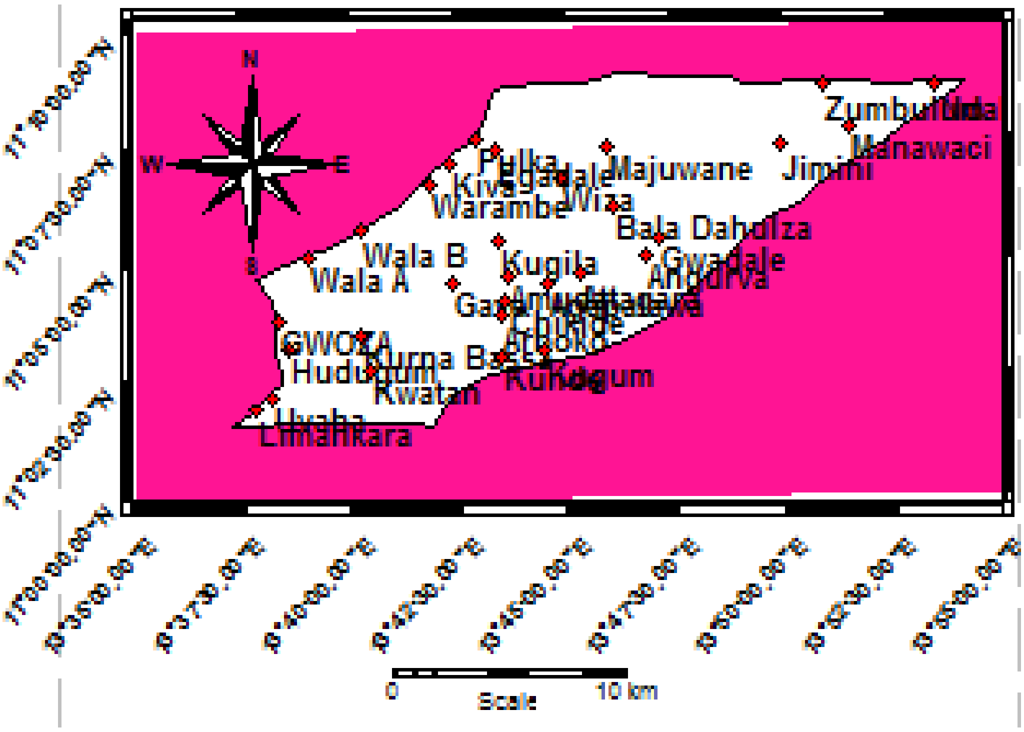
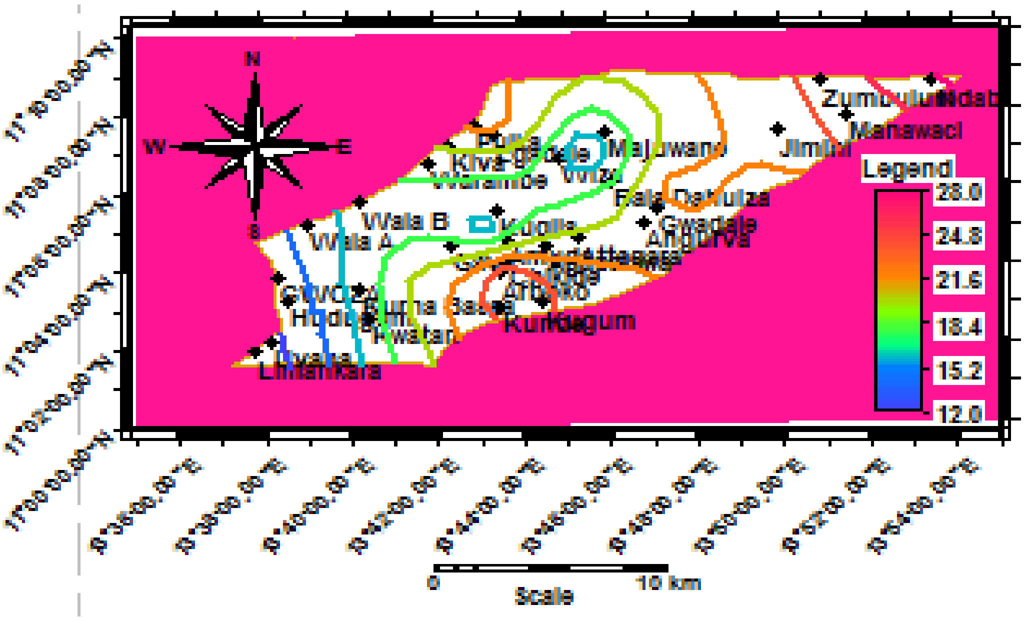


Fig. 3: Borehole locations

Also provided are the depth of the pump, hole size, slot size, surface casing, PVC, and screen thickness. The thickness of the screen, static water level, yield and pumping test were used to compute the borehole drawdown, dynamic water level of the boreholes and transmissivity, storativity and hydraulic conductivity of the aquifer. The results of the analyses are presented in two dimensional maps.

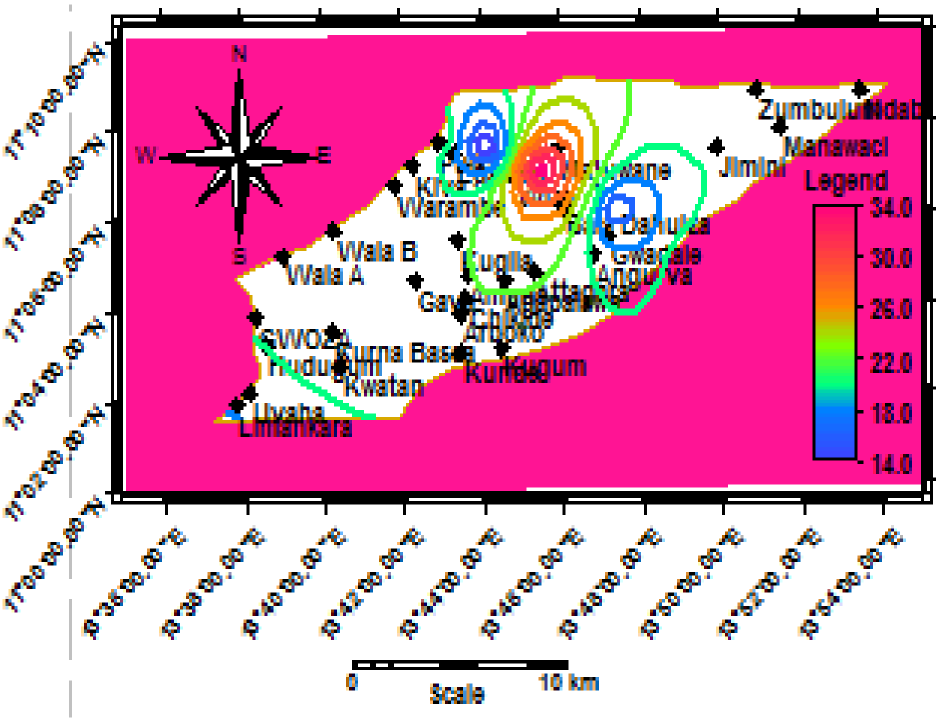
DISCUSSION

In the Basement complex terrain, groundwater occurs in the weathered regoliths and in fractures in the fresh crystalline rocks. Where thick weathered zones or fractures in fresh rocks occur, wells and boreholes tap the groundwater for water supply. Crystalline rocks generally have low porosity and low permeability; however, substantial yields could be obtained from the basement aquifers with effective exploration and exploitation techniques. Pumping test was conducted to determine the performance characteristics of the well and the hydraulic parameters of the aquifer, and information for selection of the pumping equipment. Pumping test also provided data from which the aquifer transmissivity values and storage coefficients were calculated [11]. The aquifer's capability to transmit or store groundwater [2], were determined using response curves of the aquifer drawdown with time. The curves obtained by field measurements made at the wells during the pumping periods were evaluated using AQTESOLV for Windows software developed by [5] using the Neuman analytical solution for unsteady flow to a partially penetrating well in an unconfined aquifer with delayed gravity response.



Contours in metres

Fig. 4: Static water level map

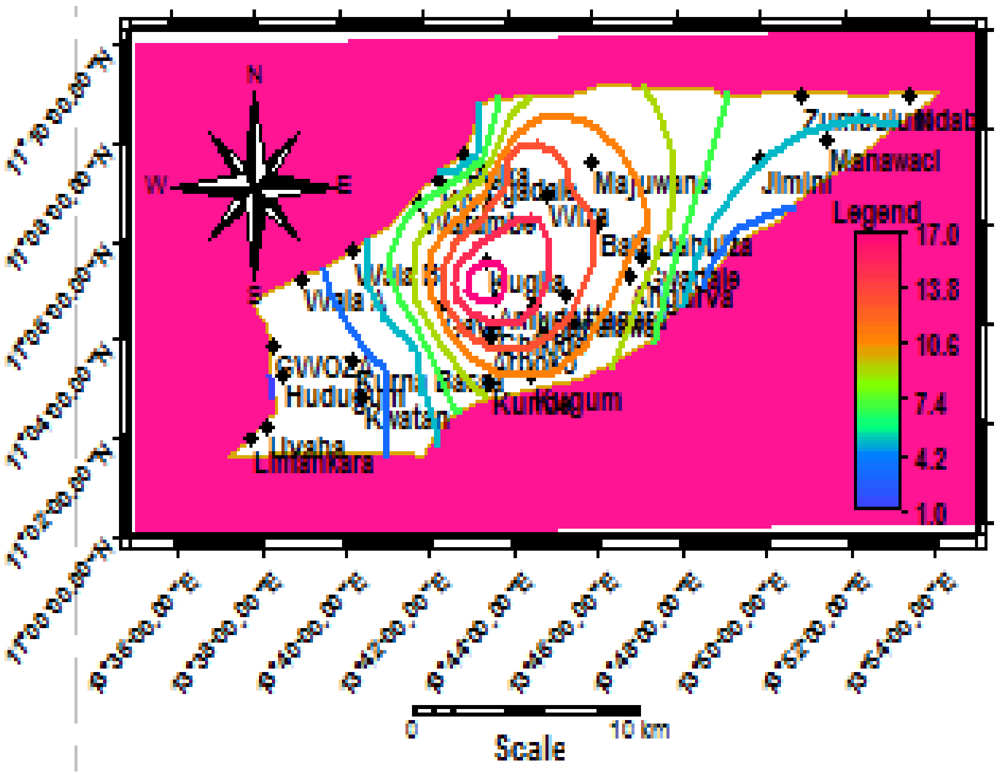


Contours in metre cube per day

Fig. 5: Discharge map

Fig. 4 shows the static water level map measured before the commencement of water withdrawal from the wells. The map consists of lower static water level at the southwest, medium static water level at the central to the southern regions and deep static water level at the northeast and southeastern parts. Variability in the static water levels is a clear indication of discontinuity of the aquifer system [7]. The water moves from where the head is high to where it is low, and in this case water enters from the southeast and moves towards east central area. Also water from the central part converges at the northeastern and northwestern parts. The decrease in the head of the static water level may be attributed to increase in overburden as distance from the Mandara hill area increases.

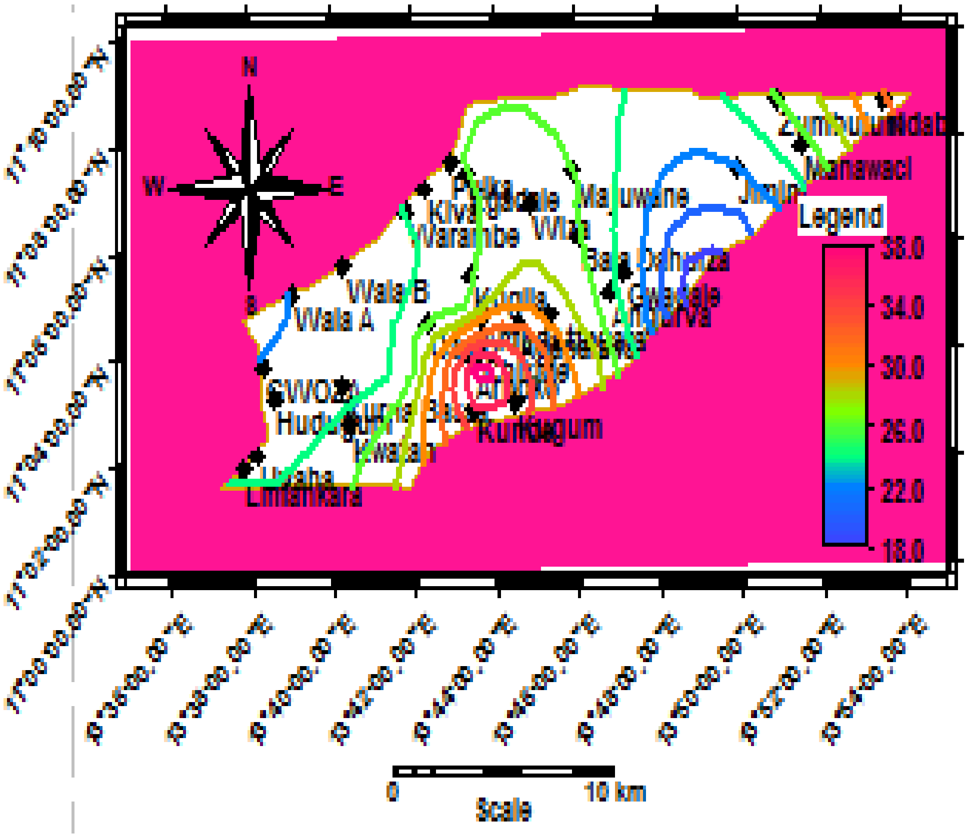
Basement aquifers are of particular importance due to their widespread extent and accessibility as sources of water supply. However, variability of yields is common due to clayey materials. In general specific yield decrease with increase clay contents [1]. Consequently, there is the need for greater understanding of the hydrogeological principles involved. The boreholes tap the weathered and fractured basement aquifer. Three closures trending in the northwest – southeast directions can be seen in Fig. 5. Discharge rate of the aquifer lower than 26 m^3day^{-1} obtained in the northwest and eastern parts indicates possible concentration of argillaceous materials [12]. Productive well are however envisaged around the north central part where sandy materials dominate and discharge rates from the wells are higher.



Contours in metres

Fig. 6: Displacement map

The drawdown, which is a measure of the change in water level relative to the static condition shown by the contour map in Fig. 6 indicates higher displacement values occupying the central region.

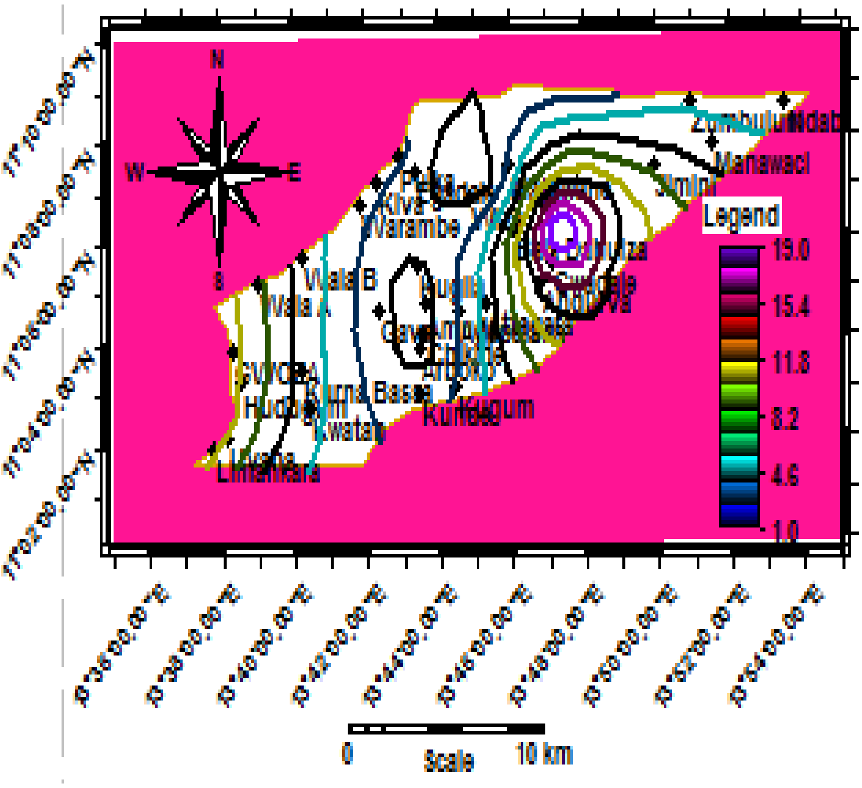


Contours in metres

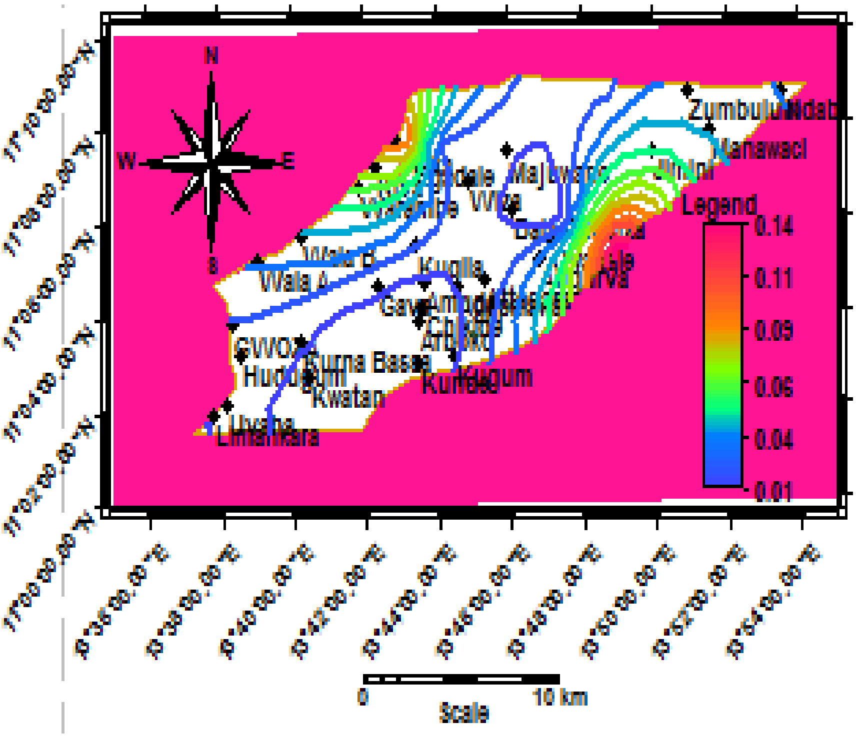
Fig. 7: Dynamic water level map

This closure is enveloped by medium and lower displacement values away from the centre. The lower values at the southeastern and part of the eastern areas may serve as potential hydrogeological units that favour water well development. No matter the length of time spent in pumping water from a well, the water level of a good productive well may not fall below the dynamic water level. In Fig. 7 lower dynamic water level was observed at northeastern and part of the southwestern regions. These regions may house favourable water wells. The northern and southern parts have medium dynamic water levels, while the east central and part of the northeast parts indicate higher dynamic water level.

Production capacities of the wells in Fig. 8 are higher at the northeast where the wells stabilized within short intervals of pumping. The presence of fine-grained matrix in coarse-grained fractions might have conditioned the aquifer in the southwestern and northern parts to transmitting water into the wells in quantities insufficient for economic use. Under this condition continuous pumping water from the wells should be suspended from time to time to enable recovery.

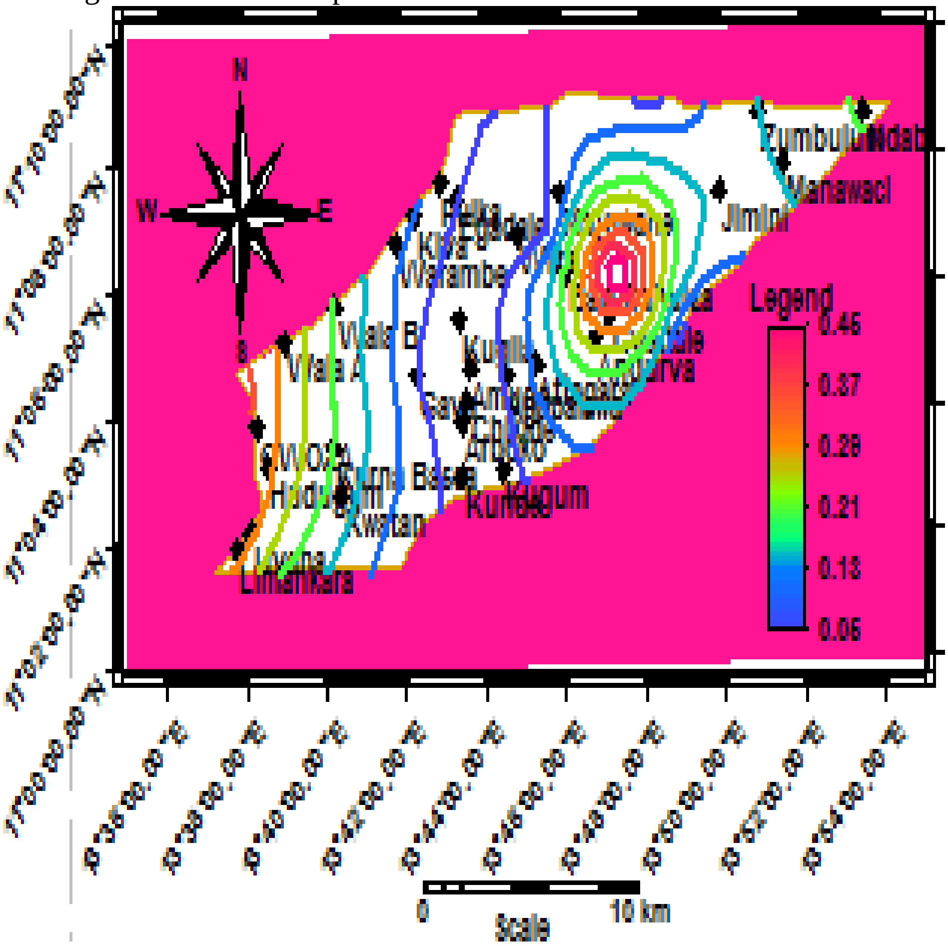


Contours in metre square per day
Fig. 8: Transmissivity map



Contours in metre square per day
Fig. 9: Storativity map

In Fig. 9 lower storage coefficients aligned in the northeast – southwest direction separates medium and higher storage coefficients to the northeast and the eastern parts. The medium values seem to enclose the higher values along these areas. Thus the northwestern and eastern parts may favour groundwater development.



Contours in metre per day

Fig. 10: Hydraulic conductivity map

The hydraulic conductivity values shown by the contour map in Fig. 10 are within the range given by [9]. The pattern of the hydraulic conductivity contour maps is similar to that of the transmissivity map given in Fig. 8 earlier. Lower hydraulic conductivity values run from the north to the south at the central part. The presence of fine-grained matrix in coarse-grained sediments might have conditioned the low hydraulic conductivity of the aquifer in the north – south direction. Enveloping the higher values at the eastern and southwestern parts are the medium hydraulic conductivity zones.

CONCLUSION

Crystalline rocks generally have low porosity and low permeability; however, substantial yield could be obtained from its aquifers with effective exploration and exploitation techniques.

Pumping test conducted on the boreholes gave the productive capacity of the boreholes and provided data from which the aquifers' transmissivity and storage coefficient values were calculated. The static water level map consists of low, medium and deep static water level closures from one place to another. Water moves from the southeast towards the east central area and from the central part it converges at northeastern and northwestern parts. Increase in depth of the static water level as one move away from the Mandara hill area is attributed to increased overburden thickness. Lower discharge rates from some boreholes indicate possible concentration of argillaceous materials, while higher discharge rates were obtained where the aquifer is dominated by sandy materials. High displacement closure values in the central region are enveloped by medium and lower ones on both sides. Lower values depict potential hydrogeological units favourable for groundwater accumulation. Also lower dynamic water level along some communities' boreholes may indicate favourable water well conditions. Production capacities of the wells are higher where the wells stabilized at short intervals of pumping. The presence of fine-grained matrix in coarse-grained fractions conditioned the aquifer within some boreholes to transmit water into the wells in quantities insufficient for economic use. Medium storage coefficients values enclosed higher ones along some parts. Hydraulic conductivity values are within those fine-grained matrix in coarse-grained sediments conditioned the low conductivity of the aquifer along a north – south direction. Medium hydraulic conductivity values enveloped higher ones at the eastern and southwestern parts. Evaluation and assessment of the hydrogeological parameters of the boreholes' aquifer indicate favourable conditions that can sustain water supply needs in the area when properly managed.

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