Open Journal of Civil Engineering, 2023, 13, 388-398
https://www.scirp.org/journal/ojce
ISSN Online: 2164-3172
ISSN Print: 2164-3164

Displaying Water Table Levels, Flow Direction for Predicting Construction Techniques Using Geographic Information: Case Study of Kumba (South West, Cameroon)

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How to cite this paper: Bahel, B., Ngwem, B.B., Sigue, C., Ekuka, B., Ndive, M.M., Hyeng, A.C.B., Yamb, E. and Owona, S. (2023) Displaying Water Table Levels, Flow Direction for Predicting Construction Techniques Using Geographic Information: Case Study of Kumba (South West, Cameroon). *Open Journal of Civil Engineering*, **13**, 388-398.
https://doi.org/10.4236/ojce.2023.132029

Received: April 13, 2023
Accepted: June 27, 2023
Published: June 30, 2023

Abstract

The rapid economic growth of the town present the matter of water issue as a problem to human life human life, construction life, agriculture, etc. This study is to predict techniques of foundation construction through the displaying of the water table at the flow direction in the town of Kumba and GIS. It is characterized by a significant research question which is the level of fall and rise in groundwater levels within the town of Kumba and this influence on choice of types of foundation in construction. This study is directed to decision makers, and technicians of the construction field to develop policies facilitating the supervision when building construction foundation by informing about water level depth and its flow direction in the town. To achieve this, depths of static water levels were measured in over 200 randomly selected hand-dug wells in Kumba, after their geolocation and data were collected during the dry season (November and March 2017) and during the rainy season (between April and October 2017). Data were analyzed and treated using Microsoft Excel and GIS software us as Golden Surfer, Global Mapper, and ArcGIS. The results show variations of water level and those areas that may threaten foundation construction. Quarter as Kumba Station, Mile 1, Bulletin Street (Fongong Quarter), and parts of Fiango show that water table is to deep water and proper for the shallow foundation but very hard for water supply through borehole. Groundwater flow direction was revealed to be towards the south and southeastern parts of Kumba. The significant of the study is to propose to the technician the direct application on the field of chosen types of foundations according to the quarter and proposed groundwater supply possibilities.

Keywords

GIS, Prediction, Water Table Level, Kumba, Foundation

1. Introduction

Surface water seems to be the most abundant resources on the planet covering a great potion of the earth surface but the proximity of water table with the world surface is very important for either domestic use or for agricultural use such as irrigation. Equally, just as the land on which construction works is being carried out. The knowledge of the ground water level or water table level beneath the land important and spatial prediction of the water table can be used for many applications related to civil engineering works (foundations, excavations) and other urban and environmental management activities [1]. Seasonal fluctuations such as floods or heavy rainfalls can raise the water table up to or beyond the footing level [2]. The depth of the water table can be measured in existing wells to determine the effects of season, climate, or human impact on groundwater [3]. According to Delleur in his handbook titled "Elementary Groundwater Flow and Transport Processes", the flow of groundwater in aquifer does not always reflect the flow of water on the surface [4]. A number of studies have been conducted to determine the depth to groundwater level in other parts of the world [5].

Quantifying the relationship between groundwater table level and construction works is important in Kumba due to variations in groundwater level and the resulting impacts. This study therefore, is intended to provide information about the water table level in Kumba in order to support construction works such as foundation and borehole construction in the town agriculture and domestic water. This information will be accessed and displayed using GIS and, boreholes and wells. The main objective was to determine the water table level by displaying its flowdirection, establish its database for Kumba area, to predict construction which will entail identifying areas of deep and shallow water table levels, showing water table map of Kumba then proposed civil Engineering works and constructing foundation.

Background of Studies

To support water management, we need to monitor water resources, model hydrological processes, and simulate the effects of public policies. To develop useful hydrological models, we need to consider the uncertainty of the predictions to increase the value of the models in decision-making. Water table depth has significant importance for agricultural, and domestic use potentials [6]. Different construction methods and tools can be adopted depending on the characteristics of the infrastructure and the area in which it is developed [7]. But the presence of groundwater and its interaction with the construction engineering process must be properly considered to avoid accidents and difficulties [8]. The subsurface flow can be much more complex due to heterogeneity of landscape, soil, and hydrogeological environments [9] and [10]. Groundwater does not usually remain stationary, but moves or flows underground according to forces acting on the groundwater [11] and the most direct method of determining the direction of groundwater movement is by measuring the elevation of groundwater at multiple locations over the aerial extent of an aquifer [7] and [3]. Knowledge of water table level in an area where a construction engineering program is to be carried out particularly foundations is very necessary. High water content in ground causes the main foundation materials to wet, dampness, swells [12]. Concrete for instance can absorb some water and eventually break down this increase the weakness of the foundation. Water table in and around a building is measured before construction starts. To balance the needs of economic land use and ecological conservation, knowledge about the spatio-temporal dynamics of the water table is important [2].

In some countries, the water table depth is intensively monitored because of its significance. In the Netherlands, for instance, the seasonal variations of water table depths influence agricultural production because of its shallow depth [12]. Predict the seasonal water table variation in Argentina, presenting a statistical method that aims to mitigate impacts of extreme events (like floods and droughts) [13] present results about aquifer recover in southern Niger. Many times authorities just take actions to understand water table dynamics after some problem has occurred. Studied water table rises after human interventions in the wetlands of northern central Florida. In Brazil, several studies have been conducted in the different ground water systems of the country [1]. Four conceptual models to explain the groundwater flow conditions in the Brazilian Federal District based in hydrogeological information [2]. Solutions for artificial aquifer recharge in areas with problems availability after human intervention in the hydrological system. Previous researches have been carried out in Kumba and its environs [11]. Monitored seasonal geochemical variations and the water quality of groundwater in the aquiferous formations of Kumba [14] and [15]. The saturated hydraulic conductivities of aquifers in Kumba were studied in 2016 [16] and darcy and apparent velocities of groundwater [17]. Their studies were based on water quality and how time taken for contaminants to enter or leave the aquifer. No earlier works have been done relating water table and construction engineering to predict construction system and domestic water used.

2. Materials and Methodology

2.1. Materials

The choice of the materials used were directly related to answering research. A map of Kumba was used during the reconnaissance stage of this work. The GPS (Global Positioning System) was used to collect heights of points in the study area. A 50 m ribbon tape with a plumb bob attached to it was used to measure depth of well water and recorded in a filed notebook. A computer, Microsoft Excel, and some GIS tools such as ArcGIS, Global Mapper, Golden Surfer 12 were equally used to analyse and display spatial information in the form of maps.

2.2. Location of Study Area

Located in and economic capital of the South Western region of Cameroon and headquarter of the Meme Division, Kumba sits on the far shadow of the Mount Cameroon. It lies between longitude E9˚27'00" and E09˚24'15" and Latitude N4˚39'45" and N4˚38'00" (**Figure 1**) Kumba has three Sub-Divisions namely Kumba I, II and III and extends over 286 km^2 with average elevation of 240 m above mean sea level. It has an estimated population of about 400,000 with three quarters of this population being youth (NIS, 2021). It has Flat lands around the Buea Road area with few hills at Government Station, Meta Quarters, New Quarters, Hausa Quarters, as well as downhill quarters in Mbonge Road neighbourhoods like Meboka, Makata, Nkamalekum, Kosala, Malende, Malabo and Saker C. B. C Field being flood prone. As such, Kumba is characterized by a kind of undulating relief. It is one of the largest cocoa cash crop producing areas in the country [14]. Kumba has numerous streams of small discharge (Kumba water, Kake water, Mbanga water), springs (Cold Spring and Mother Spring) and the crater Lake Barombi Mbo [15]. Kumba experiences two seasons; the wet and the dry season and has a hot and humid equatorial climate with annual rainfall 2298 - 3400 mm and annual temperature 27˚C [16]. Though Kumba City Council by "Operation Green City" planted some trees, subsistence farming of food crops in the town is recurrent on the alluvial yellowish red lateritic and sandy soil.

2.3. Methodology

Both quantitative and qualitative methods were used to collect data from the field. Primary data were collected through field observation and monitoring. The research was therefore done in two stages; fieldwork and office work. For the fieldwork, a map of Kumba was used delimit the extent of the research in a way that will represent all the three sections of Kumba. Data collection was done during this stage. It was designed to run between March and August, since 2017. A total of 178 hand-dug wells were selected and measured to determine areas of deep and shallow water tables were collected through a tape of 100 m. At every well point, the GPS was used to obtain the coordinates of that point in X and Y

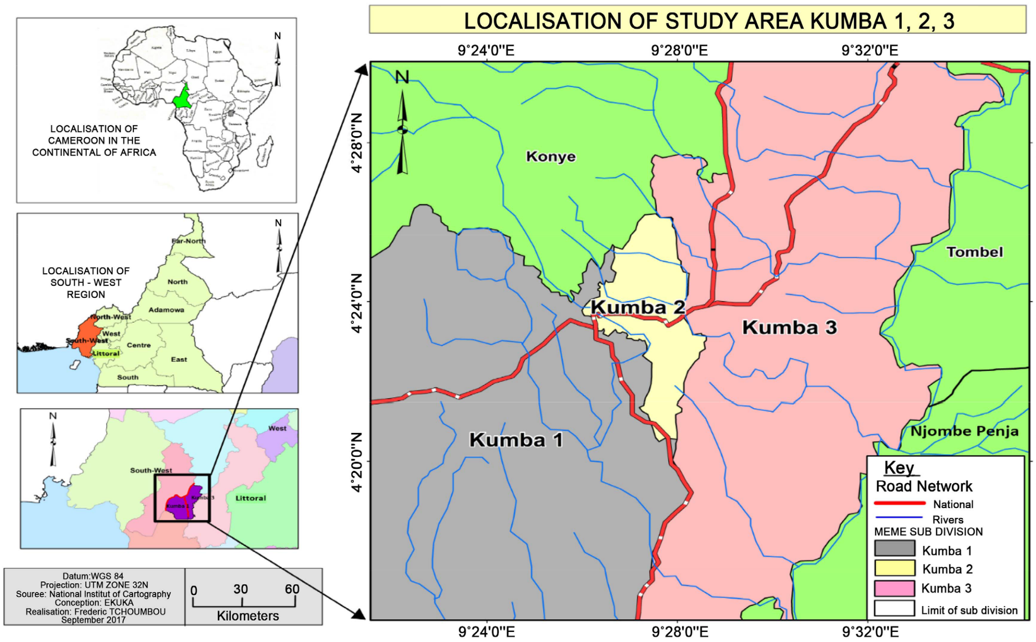

Figure 1. Location map of Kumba in cameroon.

which respectively address the horizontal and vertical and its elevation in Z. Well depths were measured using a weight (plumb bob) attached to the hook of the measuring tape. The weight was lowered down the casing of the well to reach the bottom of the well. It was lifted and dropped several times to feel the well bottom. The tape was lowered down the well casing to touch the water surface known as the water table level then the field note were establish with different variation of water table. The quantity of water in the well can be gotten by subtracting the height at the well depth and that on the water surface. The added length of the plumb bod was removed for accurate measurements. This process was repeated every month. During the office phase, collected data were inputted in Microsoft Excel and converted to readable format such as comma-separated values (CSV) file so that ArcGIS and Golden Surfer will recognize and read them. Global Mapper was used to georeferenced the shapefile map of the study area. Golden Surfer version 12 was used to plot contours and display spatial information in the form of maps such as the water level and groundwater flow direction.

3. Results and Discussion

The parameters analyzed include well depths and depth-to-static water level. Results show there is significant variation in the water table level from one place to another, influenced by seasonal changes. This accounted for by several factors such as; evapotranspiration, temperature change, aquifer recharges. Generally, areas with deep water table include; Mbonge Road/Mile One, Meta Quarter (Dallas), Bakoko Quarter, Government Station, parts of Fiango such Three-corners. While areas of shallow depth include; Buea road (lower Bonakama, Kumba mbeng), Meboka, Nkamalekum (Figure 2 and Figure 3). Most of these areas of shallow depth happens to be at low elevation as most precipitation from high elevation areas discharge in low elevation areas

3.1. Elevation Map

Figure 4 presents the elevation of well points. Areas with high elevations were found to have deeper wells and higher depth-to-static water levels in both seasons. These areas include Kumba Station, Kosala, Fongong Quarters meanwhile low elevation areas were Buea Road and parts of Fiango. High elevation areas form the recharge area where water from precipitation flows downward to the low elevation areas (discharge areas). At higher elevation, water has high gravitational energy that causes groundwater to be driven downhill.

3.2. Depth-to-Static Water Level

Areas of high elevations have deeper water table than areas of low elevation [18]. In the dry season, two-third of the wells are shallow (Figure 2). They are less than 10 m in depths. Deeper water tables are seen in areas such as Mbonge Road/Mile One (Cassava Farm), Bakoko Quarter, Government Station in Kumba I, Meta Quarter (Dallas) in Kumba II with the water table depth ranging between 10 m and 28 m. Buea Road (Lower Bonakama, Kumba-mbeng) in Kumba II, Meboka, Nkamalekum in Kumba I, Barombi Native and Fiango (Gare) in Kumba III show shallow water table ranging between 2 m and 10 m in the dry season. In the rainy season, majority of the wells are less than 16 m. Those deeper than 16 m are seen in Kumba I and II. Kumba III has the majority of shallow wells in this study (Figure 3). These results imply that drilling in these zones needs to go as deep as the depth of the zone or more to supply water sustainably without drying up during dry season. This equally implies drilling in those areas of deep water table level is more costly and time consuming than in those areas of shallow water table level.

3.3. Water Table Depth in Relation to Building Construction

The shallower the depth, the complex and more costly it is to construct a foundation due to the low bearing capacity of the soil in that area. Figure 5 illustrates the spatial variation in water table level in Kumba, particularly between April and August. Areas such as Buea road (Lower Bonakama, Kumba-mbeng) in Kumba II, Meboka, Nkamalekum in Kumba I and Barombi Natives and Gare-Fiango in Kumba III have very shallow (0 m to 4 m). As such, foundations in these areas should be well constructed, raised to withstand and control dampness since buildings in this areas are prone to dampness. On the other hand, the table level rises in areas such as Mbonge Road/Mile One (Cassava Farm), Bakoko Quarter, Government Station in Kumba I, Meta Quarter (Dallas) in Kumba II with water level between 3 m and 20 m deep. This explains that these areas would a more stable foundations than their counterparts above.

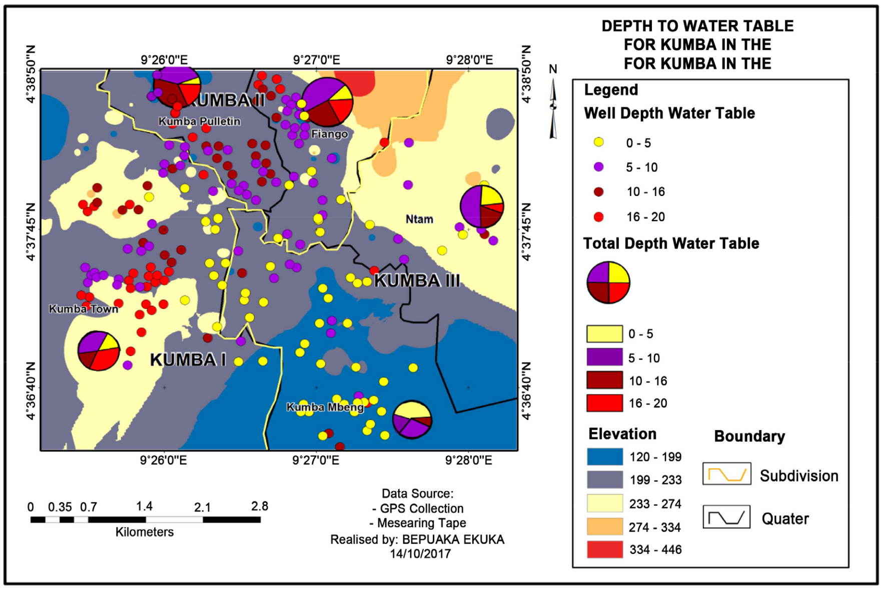

Figure 2. Depth to static water table level map for dry season.

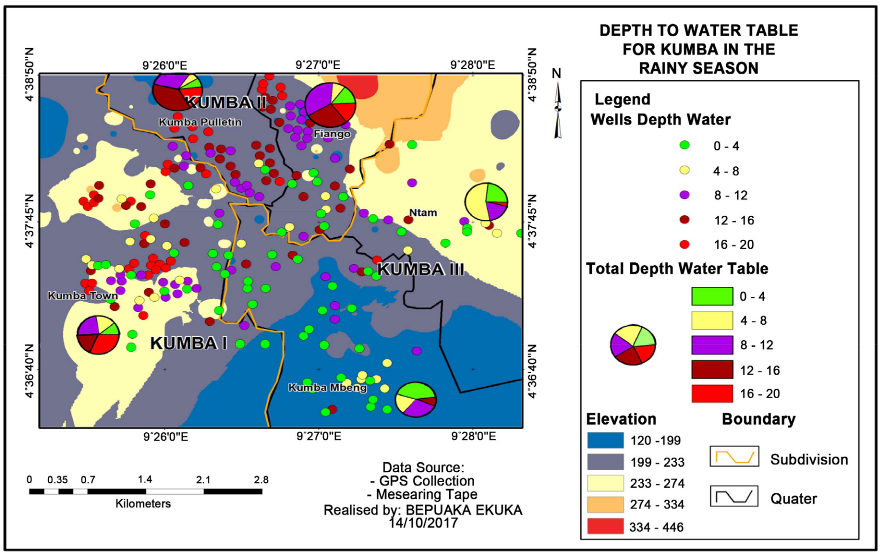

Figure 3. Depth to water table level map for rainy season (April to August).

Details are very critical when constructing a sound bounding foundation as well as drilling boreholes. Since foundations repairs are difficult and expensive, so is important to construct correctly the first time [19]. A sound foundation depends lots on the depth to water table in the site. The shallower the water table depth, the harder it is to build a strong foundation as soil will have low bearing capacity, with bearing capacity being the maximum stress which a soil can withstand without falling. The depth of the foundation depends on the soil type the foundation stands on the ground surface on which the foundation stands is however influenced greatly by, water table depth. In construction and design, water table represents the surface that separates between the saturated and

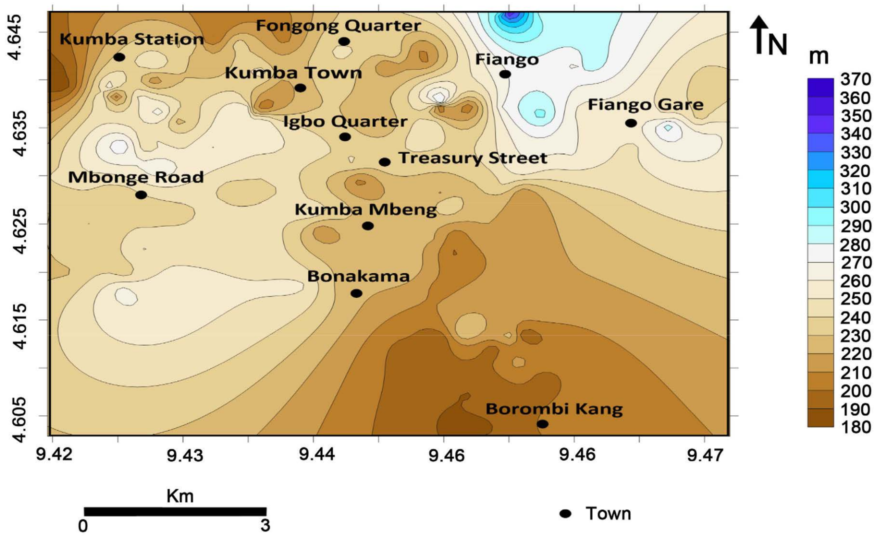

Figure 4. Contour map showing the elevation of well points (above sea level) in the study area.

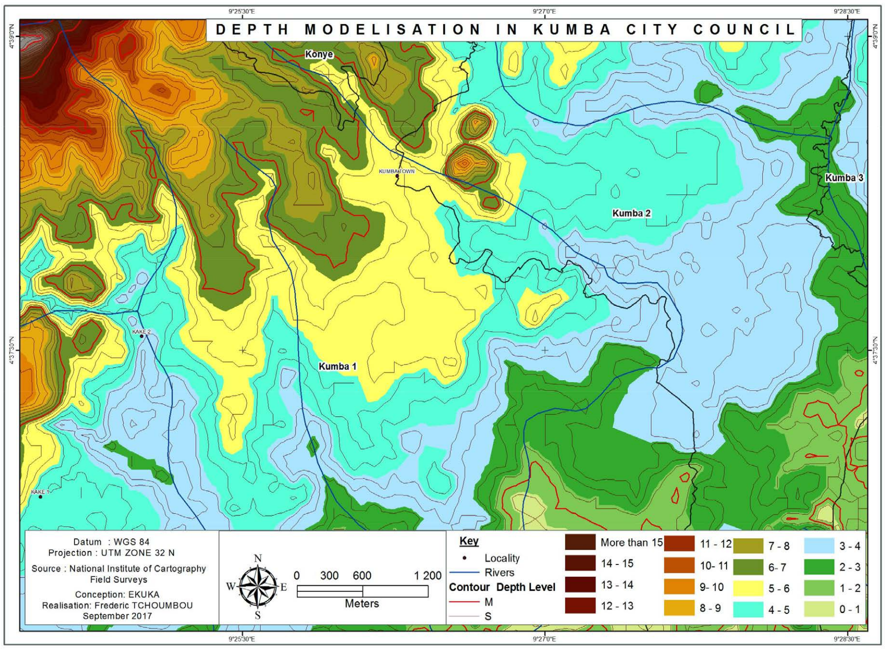

Figure 5. Depth to water table level map of Kumba.

unsaturated ground water zone. The depth to water table at any given time, affects the modeling design especially in the case of the shallow foundation (**Figure 6(a)**). In all cases, the ultimate depth to which one can put utilization of underground space is dependent on the depth of water table. Water table greatly affects bearing capacity of soil. The shallower the water table depth, the softer the soil and the lesser the bearing capacity.

3.4. Groundwater Flow Direction

Groundwater flows towards the Southeastern parts of the study area. This

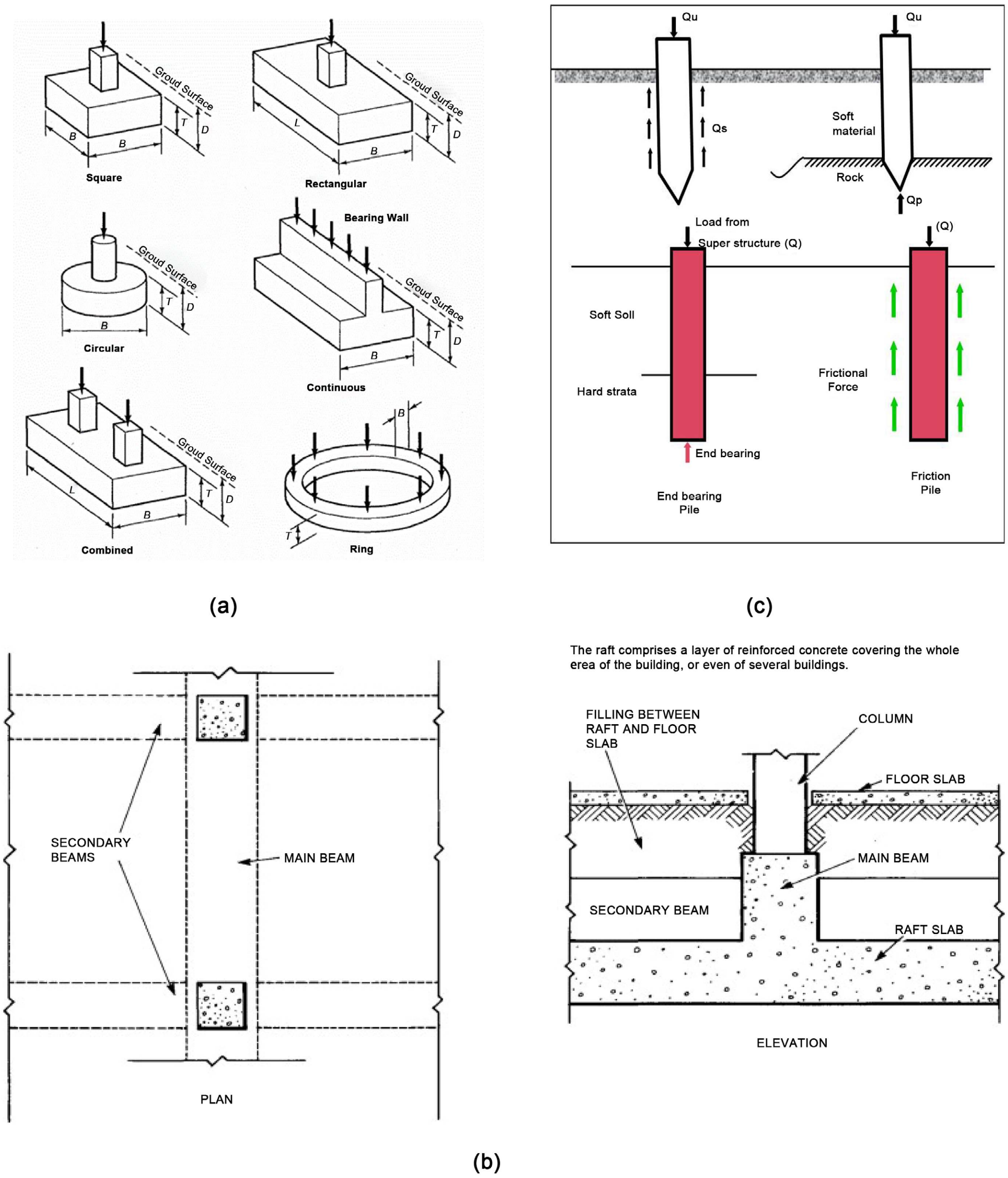

Figure 6. Types of foundations proposed to the fields (a) Spread footing; (b) draft; (c) deep foundation.

contradicts reports of [15]. There is also a scattered radial flow of water from the Northern and Northwestern parts of the study area. This is in line with results gotten in 2018 by [15]. These results explain that water recharges in high elevation areas like Station, Mbonge Road Fongong Quarter and discharges in low elevated areas like Buea Road (**Figure 7**). Topography plays a significant role in the flow of groundwater and the variation of water table in Kumba.

4. Conclusions

The result shows us a radial flow of water from the Northern and Northwestern parts of the study area. It can be deduced that water discharges in high elevation

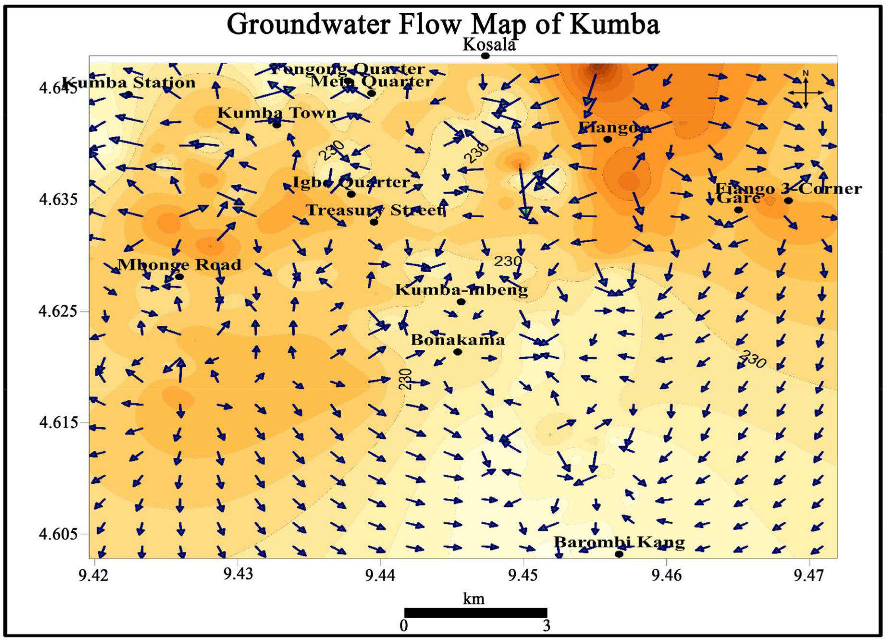

Figure 7. Groundwater flow direction of Kumba.

areas like Station, Mbonge Road Fongong quarter on with shallow foundation is proper and in low elevated areas like Buea Road proper for deep foundation. Topography plays a significant role in the flow of groundwater and the variation of water table in Kumba.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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