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Determination Of Groundwater Flow Direction In Ekintae Limestone Quarry Near Mfamosing, South-Eastern, Nigeria

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Abstract: ***Mapping of groundwater flow directions from twenty one (21) exploratory boreholes were undertaken for the Ekintae East proposed limestone quarry phase II sites, near Mfamosing village. The elevations of the borehole sites were accurately measured using GPS (Garmin Oregon 550) and the depths to the static water level were determined using dipmeter. The hydraulic head for each of the boreholes was computed as the difference between the elevation and the static water level. The results indicate that hydraulic heads ranges from 8.98-61.98m, borehole depth ranges from 53.40-100.57m, static water level ranges from 1.01-22.02m. The hydraulic heads, static water levels, borehole depths, and 3D surface elevation data of the study area were contoured using ArcGIS software. The flow directions measured perpendicular to contoured hydraulic heads were noted. The resulted topographical and hydraulic head contoured maps of the area reveal that the flow direction is controlled by the geomorphology and the flow of Ekintae river systems particularly towards the North - Western and South – Eastern parts of the study area. Thus the proposed quarry phase II design and planning should take into cognizance the North – Western and South – Eastern axes of the study area as control points during mines development, groundwater and dumpsites managements should be sited within these regions while domestic boreholes for portable water should be sited at the centre and South – Western parts of the study area***

Keywords: Groundwater flow, limestone quarry, Arc GIS, Mfamosing

1. Introduction

The presence of groundwater in an environment is one of the major causes of erosion, landslides, slope instability, dam failure, inflow into tunnels and excavations and generation of earthquakes [1]. Groundwater is water in the zone of saturation where all the voids within a geologic stratum are permanently filled with water [2], [3]. It is not usually statics but flows through a rock under a suitable hydraulic gradient. The ease with which water can flow throuh a rockmass depends on the combination of the size of the pores and the degree to which they are interconnected [4].

Groundwater also plays an important role on fault movement, generation and prediction of earthquakes, the development of geothermal system, the thermodynamics of plutons, and the genesis of economic minerals deposits. At depth, groundwater flow systems control the migration and accumulation of petroleum, and nearer to the surface it plays a major role in such geomorphollogic processes such as karst formation, natural slope development, stream bed erosion [1].

The primary motivation for the study of groundwater has traditionally been its importance as a resource – water supply for domestic, industrial and agricultural uses. Over dependence on it for many purposes has led to its over-exploitation, assessment and management.

The depth to the water level is critical in ground water flow mapping as it represents the energy level (hydraulic heads) in moving water particles from one point to another. The depth to water level varies according to the local topography and prevailing climate. The depth is generally established by a long term balanced between recharge and discharge despite seasonal climatic fluctuations. The water level is the top of the water surface in the saturated part of an aquifer. It has peaks and valleys that echo the shape of the land above it [5].

Groundwater may flow either towards or away from streams, rivers, lakes, creeks, ponds and boreholes. The flow of groundwater in aquifer may not always reflects the flow of water on the surface. Groundwater usually flows from points of higher hydraulic heads to points of lower hydraulic heads. It is therefore neccessary to know the direction of groundwater flow and take steps to ensure that land use activities in the recharge area will not pose threat to the quality of grounwater [1], [6].

[7] recognised the total driving mechanism of groundwater flow is embodied in Darcy's Law. These Authors showed from Darcy's law that a hydraulic gradient must exist for groundwater to flow.

The economy, safety, design and costruction of all major engieering projects like dams and reservoir, tunnel and highways, open mines etc. are intimately related to the groundwater regime of the area in which projects are located. It is therefore, a matter of importance that the project engineers obtains fullest possible information on ground water conditions of the site [8].

Global positioning system, tape and peizometers have been used in deducing groundwater flow direction in wastedump sites and mines management [9], [10].

Mining operations in the former Calabar Cement Company(CALCEMCO) limestone quarry at Mfamosing village were abandoned because of influx of excessive groundwater into their mine excavation.

Recently, the United Cement Company of Nigeria Limited (UNICEM) has opened a new quarry site at Mfamosing and is currently quarrying limestone there. The company is also facing the challenge of inflow of groundwater from their mine excavation at a depth of about 25m.

The UNICEM is proposed to open a new limestone quarry site at Ekintae East, near Mfamosing covering an area of about $4200m^2$ (Fig.1). Twenty one (21) exploratory boreholes have been drilled for reserve estimation. In order to guide against the threat pose by the problem of groundwater at the proposed quarry, measurement of groundwater levels in each of the boreholes were determined. The information so obtained would be used to map the possible flow direction of groundwater in Ekintae East, proposed limestone quarry phase II sites.

The study area is located at Ekintae East, bounded by Mfamosing to the west, to the East by Ekonganaku, to the North by Mborokp, and to the South by Mbobul. It covers an estimated area of about $4200m^2$and lies between latitude N0452240, N0453420 and longitude E005122, E005062 (Fig 1).

The climate of the study area is that of equitorial belt which is characterized by wet and dry seasons. The wet season starts from April to September with a peak in June and July while the dry season starts from October to March with a break in August, The meteorological parameters records at the study area show a mean annual rainfall of about 2600mm, a mean annual temperature of 32^0F.

2. GEOLOGY AND HYDROGEOLOGY

The dorminant lithologic unit in the study area is limstone called Mfamosing Limestone. It is the Northenmost carbonate deposit in the South Atlantic. Its deposition took place during the initial marine transgression into the South Atlantic in Mid-Albian time [11]. Information from exploration campaigns from 2003 to date by Emmol drilling Limited confirmed Limestone as the dorminant lithologic unit with shale intercalations, dolomite and sandstones at variable depths.

Scanty existing water wells and few boreholes have been drilled in the study area. Water is stored in weathered Limestone and fracture zones. Fracture zones are frequently occured at the boundary between dolomite/sandstones from the depth of 40-60m. The Limestone aquifer recieves direct recharge from precipitation, local surface runoff and Ekintae River system.

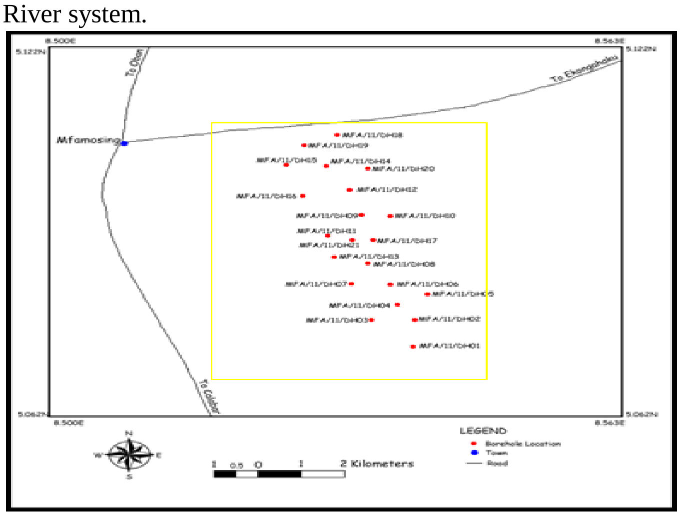

Figure 1: Base map of Ekintae East showing the distribution of exploratory boreholes

3. MATERIALS AND METHODOLOGY

With the aid of dipmeter, metre rule and tape, the depth to the water level in the twenty one boreholes were measured and recorded in the field notebook. The Global positioning system (GPS) Garmin 550 was used for measuring the longitude, latitude and the surface elevation of each of the borehole sites. The hydraulic head at various locations was obtained by subtracting the statiic water level(SWL) from the elevation(E) gotten from the GPS reading with respect to the mean sea level (Fig 2).

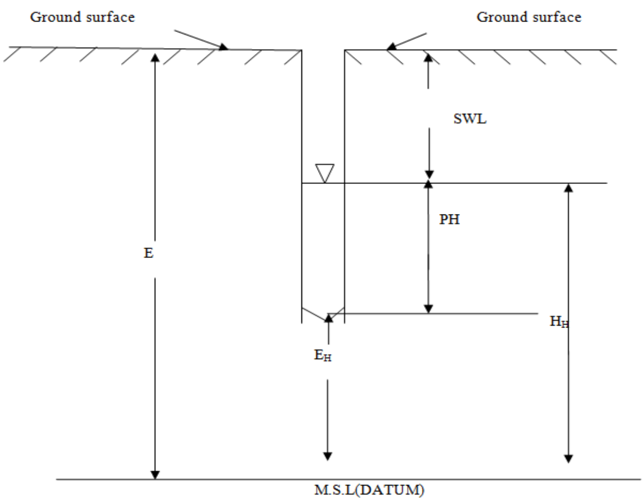

Figure 2: A schematic diagram showing distribution of heads in a borehole.

From Fig. 2, hydraulic head $H_H = P_H + E_H = E - SWL$
where :

H_H= hydraulic head,

P_H= Pressure Head

E = elevation, and

SWL=Static water level .

The distribution of head at various locations were contoured for the entire study area using Arc GIS software (see Fig 3).

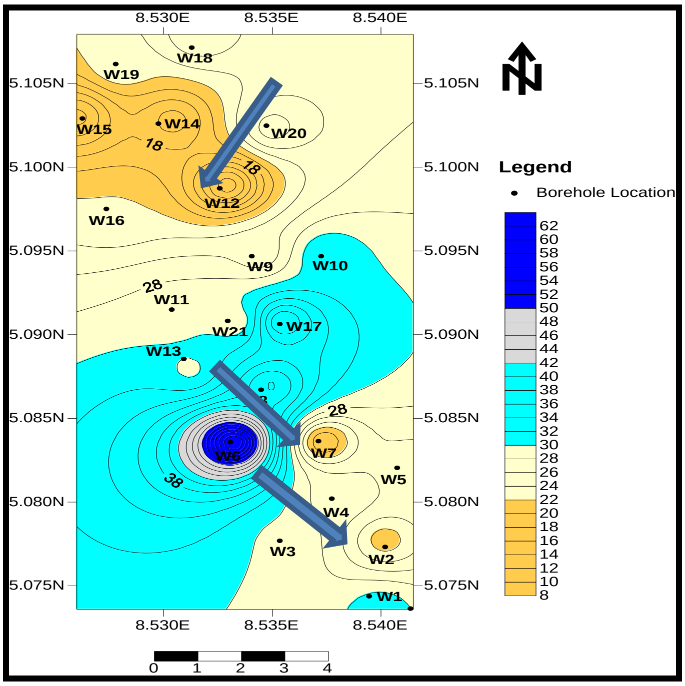

Figure 3: Contour map of Ekintae East Showing ground Water flow direction In 2 - D using Arc GIS suffer 10.

4. RESULTS AND DISCUSSION

Twenty one (21) exploratory borehole locations we re visited and surveyed accurately within Ekintae East, near Mfamosing and its environs(Fig.1). Table 1. indicates the results of the hydraulic heads calculated by subtracting static water level from the elevation values. From Table 1, the elevation ranges from 12-76m, boreholes depth from 53.40-100.57m, static water level from 1.01-22.02m and hydraulic heads from 8.98-61.98m.

Table1indicates that groundwater is likely to be encountered by mine shaft/excavation below a mean depth of 6.0m.The rate of inflow will depend on the amount of water in storage, size and depth of the excavations and the hydrogeological properties of the formations being excavated [1].The occurrence of groundwater in crevices and joints may lead to irregularities of the surface in karst areas and surface and subsurface removal of rock mass by dissolution of limestone or dolomite. Karst topography is caused by precipitation of calcium carbonate by surface water while caves are caused by dissolution of limestone by groundwater flowing through joints. In addition, the presence of high pore water build up in mine excavation leads to geotechnical problems such as landslides, rockfalls, and weathering which may pose threat on mining operations.

The contoured maps for elevation (Fig4a and b) and hydraulic head (Fig. 3) were produced by joining lines of equal elevation and hydraulic head values respectively in such a way that no one overlaps each other.

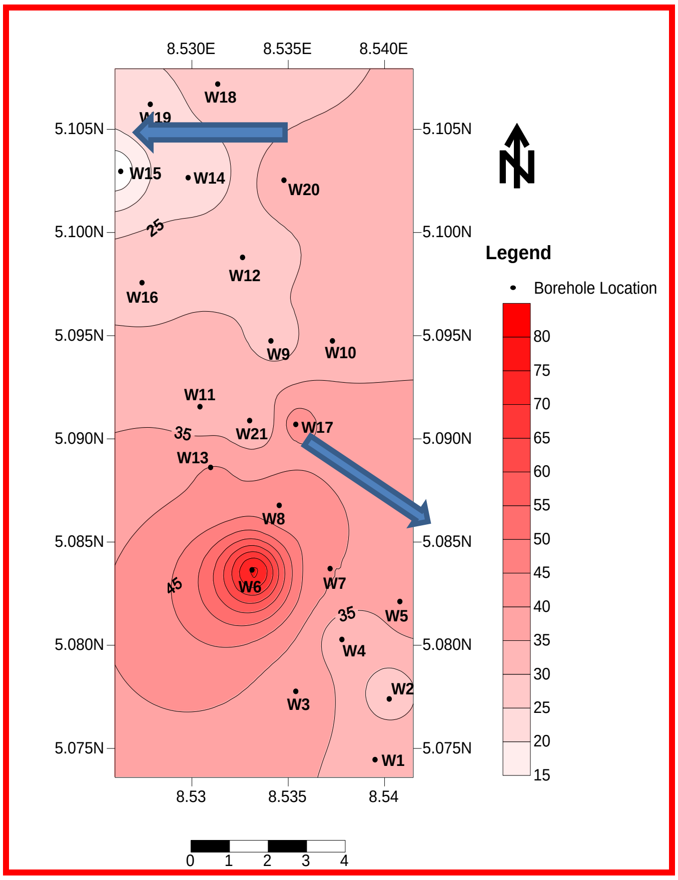

Figure 4a: Contour elevation control map of Ekintae East showing ground water flow direction In 2 - D using Arc GIS suffer 10.

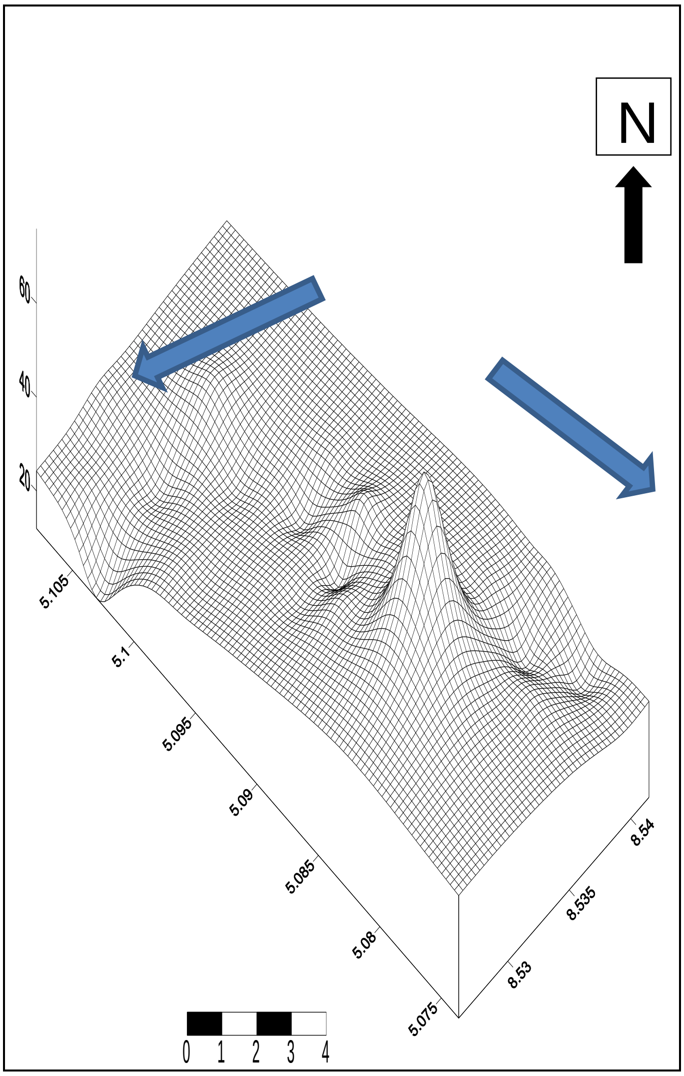

Figure 4b: Contour elevation map of Ekintae East showing ground water flow direction in 3 - D

The elevation map was also modeled in 3D with the help of Arc GIS suffer 10 computer software (Fig. 4b). The result from the static water level, hydraulic head maps, and the elevation maps reveal that the ground water flow direction in Ekintae East (proposed quarry phase II) and its environ is toward the North – Western and South – Eastern axis of the study area. It is therefore recommended that UNICEM quarry phase II design and planning should take into account the North – Western and South – Eastern parts of the study area as control points for mines groundwater management and mines development.

Excessive groundwater influx into quarry pit in the study area could lead to problems such as landslides, rock falls, cutting of quarry phase, slope failure and closure of mining operations.

1.1. Mitigation measures

At sites where the formations have low permeability only small inflows will occur and these can usually be handled easily by pumpage from a sump or collector trench. Formations of high conductivities allow large inflows and can be handled by horizontal drainholes into the slope face, vertical wells drilled behind the slope or with radial drainholes gallery and drainage trenches constructed down or along slope face [1]

Table 1: Borehole data and Static Water Level within the Study area.

S/N	LOCATION NAME	COORDINATES		ELEVATION Z (E)	DEPTH OF BOREHOLE (m)	STATIC WATER LEVEL (m)	HYDRAULIC HEADS (m) E-SWL
		NORTHING X	EASTING Y				
1	**MFA/11/01**	**4,50,240**	**5,59,936**	**32**	**76.75**	**1**	**31**
2	**MFA/11/02**	**4,50,700**	**5,59,958**	**27**	**84.6**	**6.04**	**20.96**
3	**MFA/11/03**	**4,50,703**	**5,59,422**	**39**	**100.05**	**9.26**	**29.74**
4	**MFA/11/04**	**4,50,975**	**5,59,741**	**30**	**66.1**	**3.28**	**26.72**
5	**MFA/11/05**	**4,51,170**	**5,60,104**	**37**	**81.15**	**12.42**	**24.58**
6	**MFA/11/06**	**4,51,341**	**5,59,188**	**76**	**96.34**	**14.02**	**61.98**
7	**MFA/11/07**	**4,51,345**	**5,59,651**	**40**	**99.92**	**22.02**	**17.98**
8	**MFA/11/08**	**4,51,715**	**5,59,378**	**42**	**100.1**	**1.87**	**40.22**
9	**MFA/11/09**	**452, 593**	**5,59,316**	**27**	**90.16**	**2.4**	**24.6**
10	**MFA/11/10**	**4,52,578**	**5,59,659**	**34**	**88.76**	**2.06**	**31.94**
11	**MFA/11/11**	**4,52,217**	**5,58,888**	**33**	**100.08**	**4.24**	**28.76**
12	**MFA/11/12**	**453.04**	**5,59,153**	**26**	**82.05**	**17.02**	**8.98**
13	**MFA/11/13**	**4,51,825**	**5,58,966**	**41**	**100.57**	**11.42**	**29.58**
14	**MFA/11/14**	**4,53,465**	**5,58,874**	**21**	**86.2**	**5.87**	**15.13**
15	**MFA/11/15**	**4,53,490**	**5,58,385**	**12**	**99.78**	**0.6**	**11.4**
16	**MFA/11/16**	**4,52,864**	**5,58,592**	**29**	**99.93**	**6.92**	**22.08**
17	**MFA/11/17**	**4,52,137**	**5,59,441**	**42**	**88.6**	**1.95**	**40.05**
18	**MFA/11/18**	**4,54,035**	**5,59,006**	**28**	**53.4**	**0.07**	**27.93**
19	**MFA/11/19**	**4,53,836**	**5,58,611**	**24**	**87.54**	**0.02**	**23.98**
20	**MFA/11/20**	**4,53,420**	**5,59,383**	**34**	**75.75**	**5.04**	**28.96**
21	**MFA/11/21**	**4,52,141**	**5,59,188**	**30**	**84.15**	**1.52**	**28.48**
Minimum				12	53.4	1	8.98
Maximum				76	100.57	17.02	61.98
Mean				33.52	87.713	5.78	27.387

5. CONCLUSION

Ground water occurs at a mean shallow depth of 6.0m below the ground surface at the proposed limestone quarry at Ekintae near Mfamosing. The static water level and hydraulic head contoured maps of Ekintae East and its environ have revealed that groundwater flows toward the North - Wastern and South – Eastern parts of the study area. It is therefore recommended that UNICEM quarry phase11 design and planning should take into account the North – Western and South – Eastern parts of the study area as control points for Mines development and groundwater management. However, monitoring boreholes should be constructed and piezometers installed for more accurate information on mines groundwater management.

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