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Towards Preventing Possible Earthquake Incedence In Mokwa Nigeria And Mitigating Its Hazards Using Geophysical Method

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Abstract: *The memories of the past earthquakeincidences in Nigeria has recently warranted the warnings from research agencies and the recently predicted2028 large earthquake from researchers in Nigeria. Thus the major forecast from researchers has appeared to be open ended. To this end, this research aimed at the prevention of probabilistic earthquake incidence in Mokwa, Nigeria and the mitigation of its hazards using geophysical method. The Findings of this research established that Mokwa is at the risk of experiencing earthquake. Thisis due to the delineated low resistive subsurface features, overcrowded surface structures and ground punctures in relation to their proximities to the existing rail line.Immediate relocation in addition to Nigerian Government and inclined agenciesto pay rapt attention to predicted earthquakes in Mokwa and Nigeria at large.*

Keywords*: earthquake; geophysical; probabilistic; ground-punctures; low resistive; subsurface features*

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I. Introduction

The incessant increase in population coupled with the growth in economic activities within Nigeria as well as in Mokwa area and its environs has caused unending pressures on the land-use issues. This hasbrought about the insufficiency or inability of government to provide the needed infrastructures that can cater for the greater demands for groundwater and other facilities by the communities. In addition, regional and township master plans has been violated and overlooked by the government. Consequently,this has led tosuch several other activities like indiscriminate location of; bore-holes, locally hand dug wells, dumpsites, railway lines, trunk 'A' roads, residential and other forms of buildings/structures without following the recommended setback distances or standard regional layouts. These unfortunate activities piled up together and gradually translated into natural and human induced Earthquakes occurring at many locations within Nigeria as well as in many other Countries around the world. It has also been reported that Earthquakes can be induced by human activities such as; impoundment of reservoirs, surface and underground mining, withdrawal of fluids and gas from the subsurface, and injection of fluids into underground formations. While most induced earthquakes are small and present little hazards, larger and potentially damaging manmade earthquakes have occurred in the past (Yusuf 2016).

It is worthwhile to note that, it is not the earthquakes which kills the people or damaged the properties, but it is the unsafe or substandard buildings or structures which are responsible for the devastation. The memories of the huge destructions of life and properties in the recent earthquake incidences has led to the adoption of the concept of earthquakes to become a hot topic.Thus globally, a lot of researches are ongoing to discover the various causes of such challenges and learning useful ideason how to mitigate the repetition of such devastation. If in this country, the buildings and structureswere built earthquake resistant at its initialformby effectively utilizing civil engineering professionals in the design and construction of such structures (as practiced in advanced countries like USA, Japan etc), such earthquake disasters would havebeen most effectively mitigated.

The study area majorly is a local residential area (Rural Area) consisting of overcrowded residential houses which were built without following the regional town planning guidelines. As such houses and other structures specifically the hand dug wells are too much and located any how within the area. Also each of the majority of these houses has an indoor locally hand dug well being used as a water source for domestic activities. All these structures were located indiscriminately without considering the hazards or the effects ofnot minding the proximity to each other, subsurface seismic activities or to the existing railway line that cut across the study area.Suchchallenges which can trigger manmade earthquakes and its associated hazards can be mitigated by minimizing or in some cases halting those causative human activities that can induce the occurrence of earthquakes Gaudio, *et al.*, (2017).

Although according to the report from the National Earthquake Prediction Evaluation Council (NEPEC) of Califonia, obtaining high-quality measurements close to a large earthquake is not easy. However, efforts to reduce the societal impact of earthquakes now is highly remindful. Focus should be on developing the next generation of models that can provide better predictions of the strength and location of damaging ground-shaking. (NEPEC 2016).

Also according to (Kadiri, *et al.,* 2011), it is impossible to curb sub-surface tectonic activities, however, with advancement in technologies today, it is now possible to predict earthquake and ground motion with proper understanding of seismic sources and properties of seismic waves. Thus prompting the people in such places prone to the disasters to be in better prepared status for any possible occurrences.

Yusuf, (2016) and Oluwafemi, *et al.,* (2018) ascertain that for about ten decades, the seismic records of Nigeria has shown the occurrence of several magnitudes of earthquakes. This is contrary to the belief of some people in time past that Nigeria is aseismic. Such and many other discoveries has mandated Researchersto commenced warnings and the need for continued researches on some earthquake prone regions within the countryin preparations for the probably devastating earthquakes in years to come.

To that effect, ithas been predicted that natural earthquakes cannot be prevented from occurring in this country, but their effects can be significantly mitigated by continued researching, identifying its hazards, building safer structures, and very importantly providing enlightenment on earthquake & its safety tips. The prediction further hinted that the South-Western region of this country is likely to experience earthquake of magnitude as high as 7.2 in the year 2028 with a probability of 36.79%. Thus the affected communities, government and related agencies need to get prepared fully before the due date. While preparing for the Natural Earthquakes, the risks from the Human Induced Earthquakes can also be reduced by identifying such activities and discouraging them appropriately (Oluwafemi, *et al.,* 2018).

In the light of the above, this Study was therefore, planned to:

i. Create a reference database on the subsurface environment, at the study area which will greatly influence the attraction of attention on earthquake prone areas and sensitization campaigns on its associated risks & hazards with economic convenience.
ii. Protect the agricultural soil, groundwater resources, global communities and environmental lives in general.
iii. Complement the future surveys at the study area.

These would be achieved using Geophysical Method of Electrical Resistivity with the aim of identifying those possible weak/faults zones and the frequency of rock punctures by locally hand dug wells as well as their proximity to the railway line with a view of averting Earthquake and its hazards within the study area. The specific objectives outlined for this survey are:

i Delineation of the subsurface geo-electric formations within the study area.
ii. Delineation and mapping outpossible subsurface structuressuch as weak/faults zones.
iii. Determination of total number of locally hand dug wells in the sampled residential houses within the study area.
iv. Determination of the inter spacing of the sampled wells from each other and the spacing between the wells to the railway line.

II. Methodology

2.1 Site description

Mokwa (Figure 1) is located along Kaduna – Lagos road, specifically at latitudes ($9^o17'$ to $9^o18'$) N and longitudes ($5^o03'$ to $5^o04'$) E. it is the headquarters of Mokwa Local Government of Niger State, Nigeria. It is located within the Bida Basin which is a NW–SE trending intracratonic sedimentary basin extending from Kontagora in Niger State of Nigeria to areas slightly beyond Lokoja in Kogi State. The Bida Sandstone is the basal sediment of the Middle Niger Basin and it consists mainly of fine to coarse grained sandstone, conglomerates, siltstone and claystone (Yusuf, 2016). It has an area of 4,338 km^2 and a population of 244,937 (2006 census). The sandstone which underlie the Mokwa and Kontagora plains are generally angular to sub-angular, well sorted to poorly sorted and very fine to very coarse and pebbly (Olusola, *et al*., 2012). Mokwa is underlain by sedimentary terrain consisting of essentially claystones, sandstones and conglomerates of Campanian to Maastrichtian age and basement complex rocks comprising of migmatites gneiss, quartzite complex, granitoids and minor acid dykes which had different water retaining capacities all year round (Yusuf, *et al.,* 2018).

Legend: ▲ **Study Location**

Figure 1: Study location on the topographical map of Mokwa. (Google map 2019)

2.3 Geophysical Survey

ABEM Terrameter SAS 4000 was used in traversing the four profiles within the study area adopting Vertical Electrical Soundings (VES). Twenty VES points were probed using Schlumberger electrode configuration (Figure 2). The resistance values displayed by the terrameter were recorded in recording sheets which were later used to compute apparent resistivity. The apparent resistivity was computed using equation (1):

$$\rho = \left(\frac{V}{I}\right)\left(\frac{A}{L}\right) = RK \quad (1)$$

Where ρ is the apparent resistivity, $R=\left(\frac{V}{I}\right)$, the earth resistance and $K = \left(\frac{A}{L}\right)$ is the geometrical factor. The apparent resistivity values obtained from equation (1) were plotted against the half current electrode separation spacing using IPI2WIN computer software to generate geoelectric model for which the layer resistivity, depth and thickness were obtained Yusuf, *et al.*, (2018).

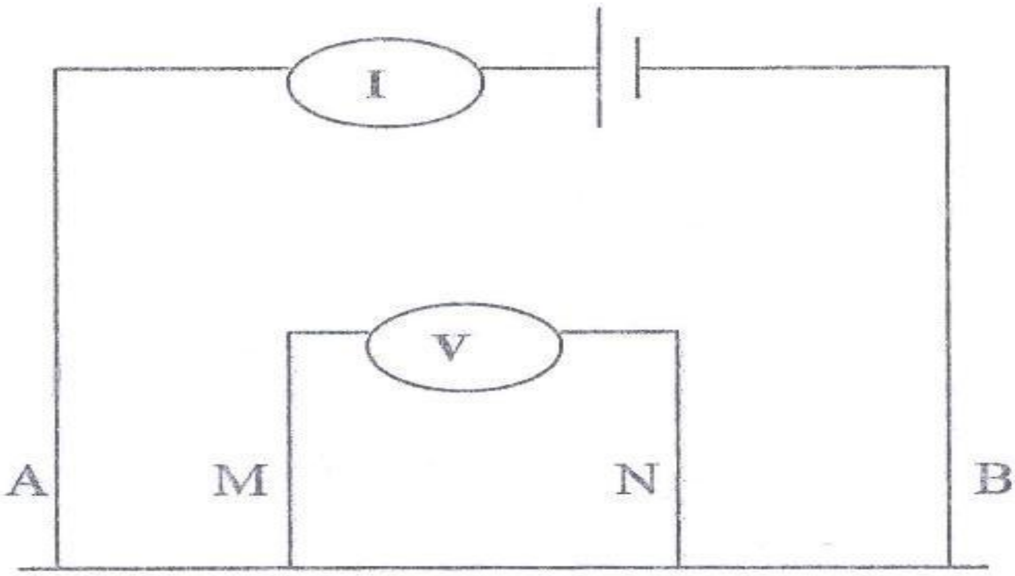


Figure 2: Geometry of current and potential electrodes for schlumbergercon figuration.

2.4 Determination of other Physical Parameters

The study area was divided into four equal profiles with profile length of 1000 m and inter-profile spacing of 250 m covering the total area of 1,000,000 m^2. Total number of 238 residential houses were randomly sampled along the four profiles within the study area (Table 1). Other parameters such as total number of residential houses with or without wells (frequency of rock punctures), proximity of Hand dug wells from each other and to the Railway Line within the Study Area were determined by direct counting and measurement using tape respectively.

III. Results

3.1 Vertical Electrical Sounding (VES) at the Study Area

Figures 3 (a) and (b) showed the pseudo cross sections and resistivity cross sections for VES points 1-5 along Profile 1 which was at the eastern edge of the study area in Mokwa and it runs north-south direction. In the three geologic zones delineated beneath this profile, the first zone exhibited moderately low apparent resistivity values varied (443.9 – 488) Ω-m. The second geologic zone was a moderately higher resistivity zone (varying blue colorations) with apparent resistivity values ranged (478.9 – 523) Ω-m which started from the depths ranged (3.728 to 7.179) m and cut across all the VES point. The third geo-electric zone was a zone of extremely highest resistivity values ranged (950 – 1173) Ω-m which started from the depths ranged (2.863 - 3.728) m and towards the west between VES points 1, 2, 3 and eastwards at VES point 5. This delineated extremely lowest apparent resistivity zone widen in thickness towards the eastern section (VES point 5) and its narrowed up through VES points 1, 2, 3 up to 4 as well as the observed East – West trending was also observed. A weak / fault zone (**A-A'**)was identified by a sudden jump in resistivity values from (523 to 950) Ω-m between the second and third geologic sections.

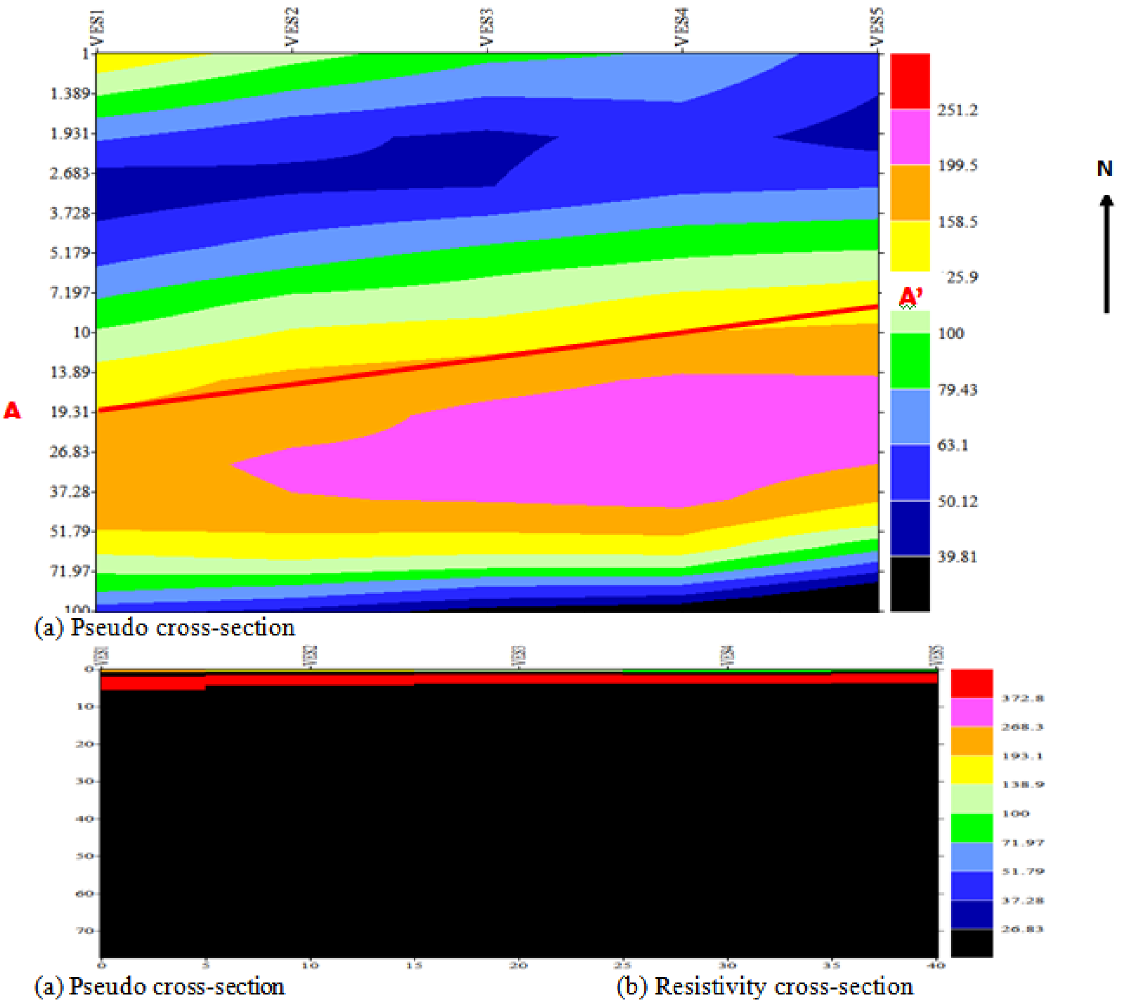
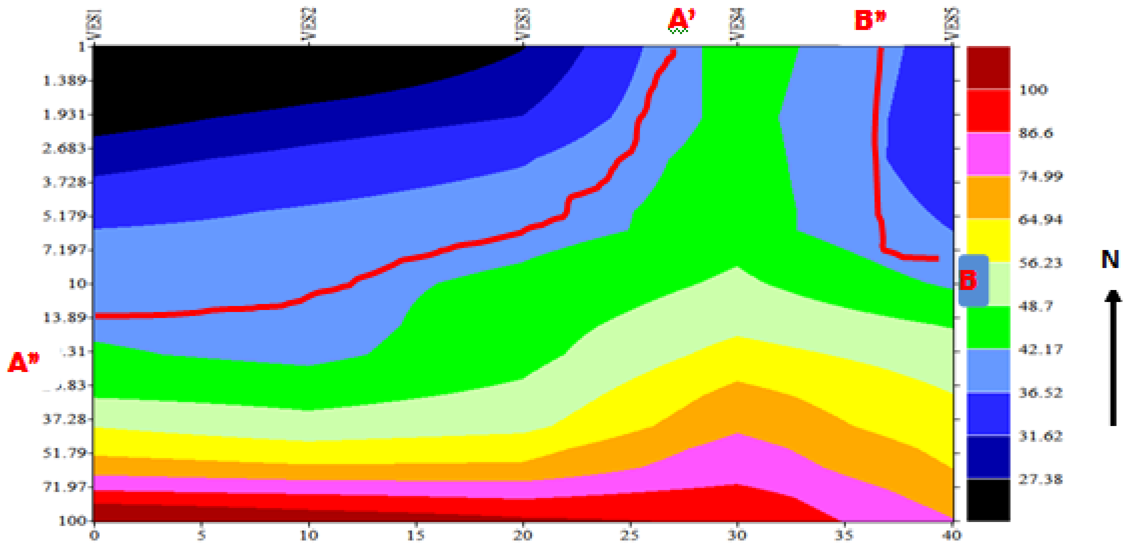
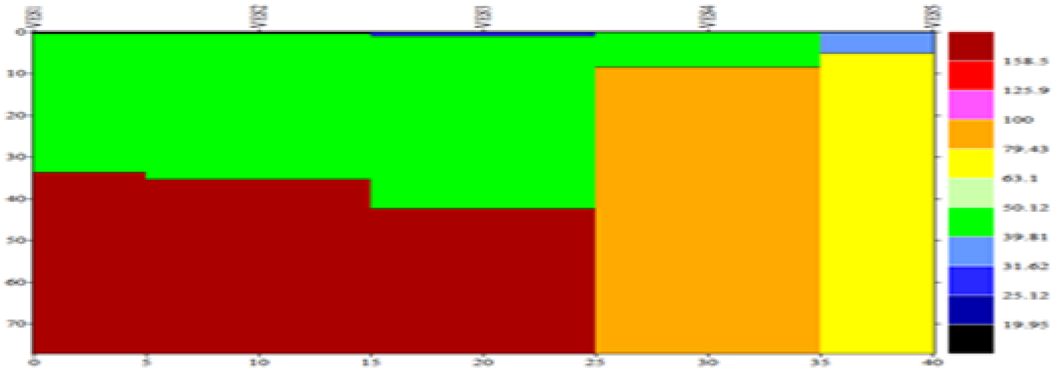


Figure 3: (a) Pseudo cross-section and (b) Resistivity cross-section of VES 1-5 along profile 1 at StudyArea in Mokwa.

The second Profile (Figures 4 (a) and (b)) showed the pseudo cross sections and resistivity cross sections for VES points 1-5 along Profile 2 which was 50 m away from the first profile towards the western edge running through north-south direction. Three geologic zones were delineated beneath this profile also. The first zone exhibited resistivity values ranged (77.56 – 443.9) Ω-m. This zone was observed around VES points 1, 2 and 3. It was very narrower under VES point 3 and progressively increased in thickness towards VES 2 and 1 the depth ranged (0.25 – 2.54) m. Attractively, a very sharp resistivity drop was observed from (443.9 to 112.56) Ω-m between the first and second layers across VES points 1 & 2, and 4 & 5 denoted by (**A-A'** and **B-B'**). This indicated a weak/fault zone which are also probable groundwater reservoir and also are area that can easily influence subsurface seismic activities. The second layer had the lower resistivity values ranged (112.56 – 478.9) Ω-m with thickness ranged (4.63 to 17.29) m and depth ranged (7.02 to 18.11) m. The third zone was a zone of highest apparent resistivity values ranged (1347 – 2085) Ω-m. It occurred to the western section of the profile with thickness ranged (10.21 - 14.20) m and depths ranged (12.05 – 67) m under station VES points 3 and 5.



(a) Pseudo cross-section



(b) Resistivity cross-section

Figure 4: (a) Pseudo cross-section and (b) Resistivity cross-section of VES 1-5 along profile 2 at StudyArea in Mokwa.

Profile 3 (Figures 5 (a) and (b)) which was also 50 m away from profile 2 towards the east of the edge of the study area was probed along north-south direction. Very low resistivity zone (black colour) with apparent resistivity value ranged (29.39 – 78.83) Ω-m was isolated at shallow subsurface with thickness ranged (0.21 – 3.33) m and depths ranged (0.28 – 4.09) m very dense around VES 1 at the edge of the profile and faded towards VES 2, 3 and 4 (represented by the varying blue colorations). The second zone had resistivity values ranged (64.39 – 113.83) Ω-m. This was the aquifer zone (represented by green, grey and yellow). It occurred around VES points 1 - 4 with thickness ranged (6.04 – 13.33) m and depths ranged (7.34 – 13.27) m. The third zone was the zone with resistivity value varied (1239 – 1846) Ω-m with thickness varied (12.01 – 21.15) m and depth ranged (13.08 – 48.02) m between VES point 2, 3, and 4. Also another very attractive sharp jump in resistivity values was observed here (from 113.83 to 1239) Ω-m. This are another weak/fault zones(**A-A'**and **B-B'**) which is just approximately 50 m away from the first identified weak zone and cut across shallow subsurface down to as deep as 100 m. these are faulty areas where seismic activities can easily be influenced with little inducement.

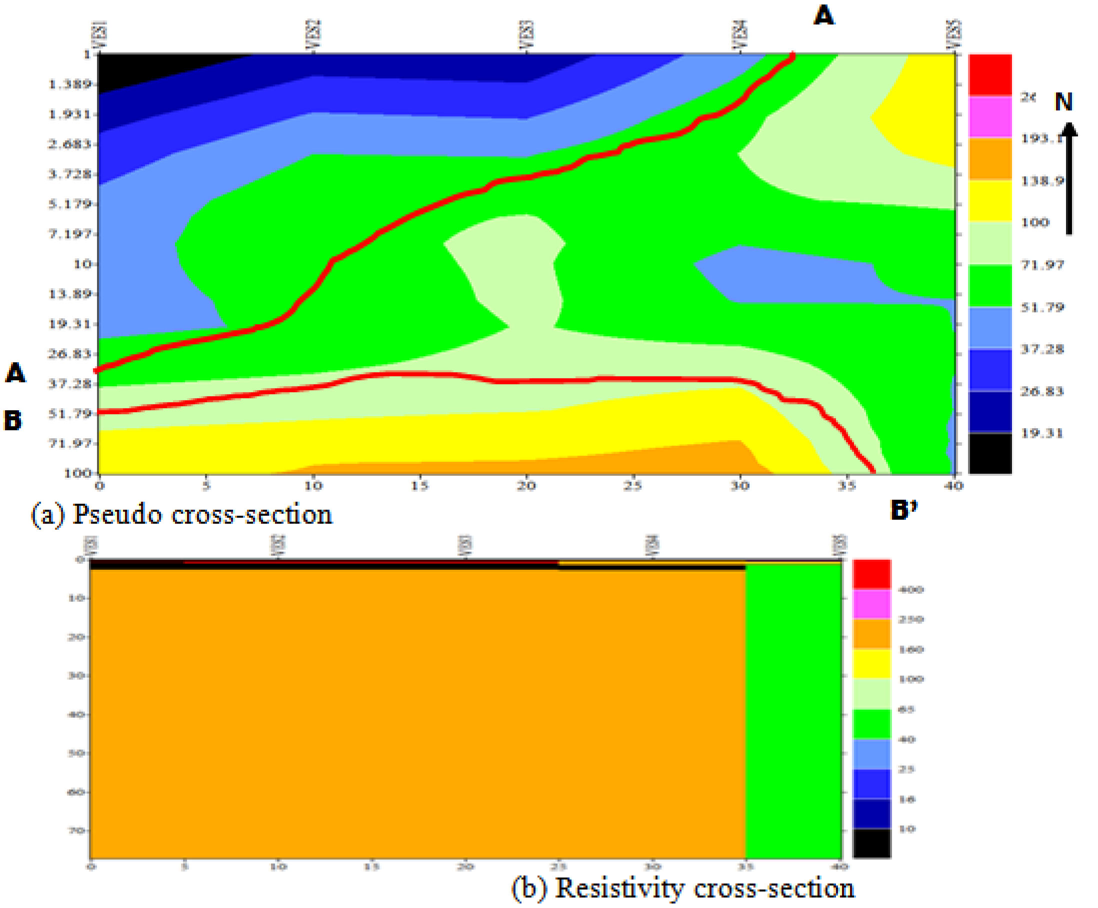
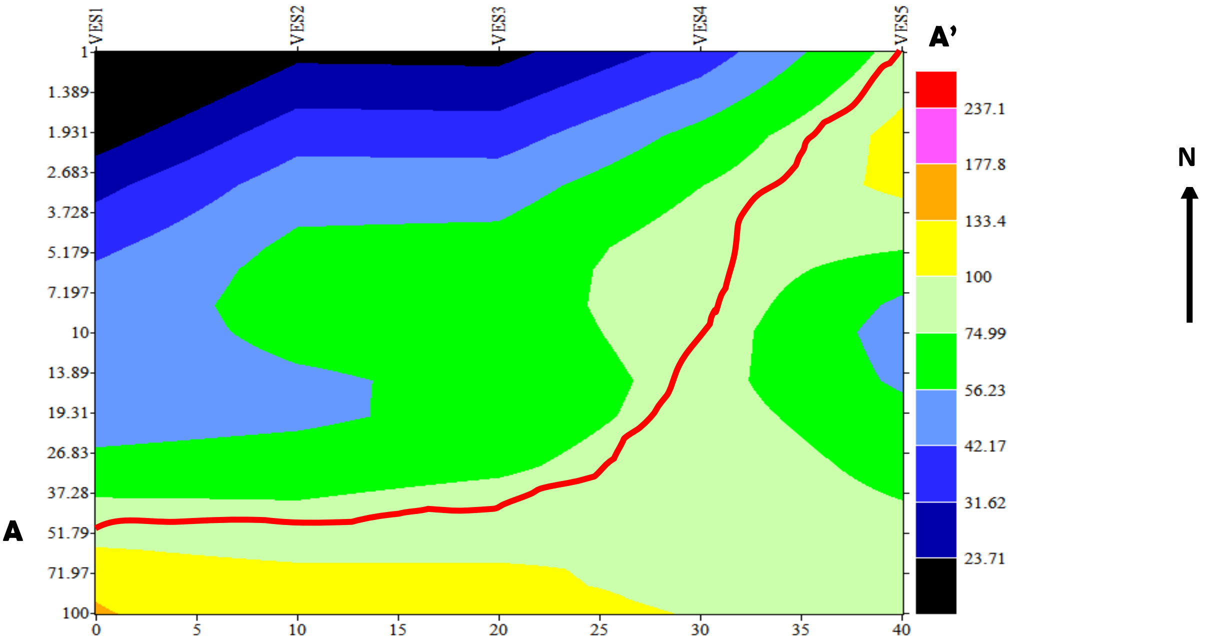
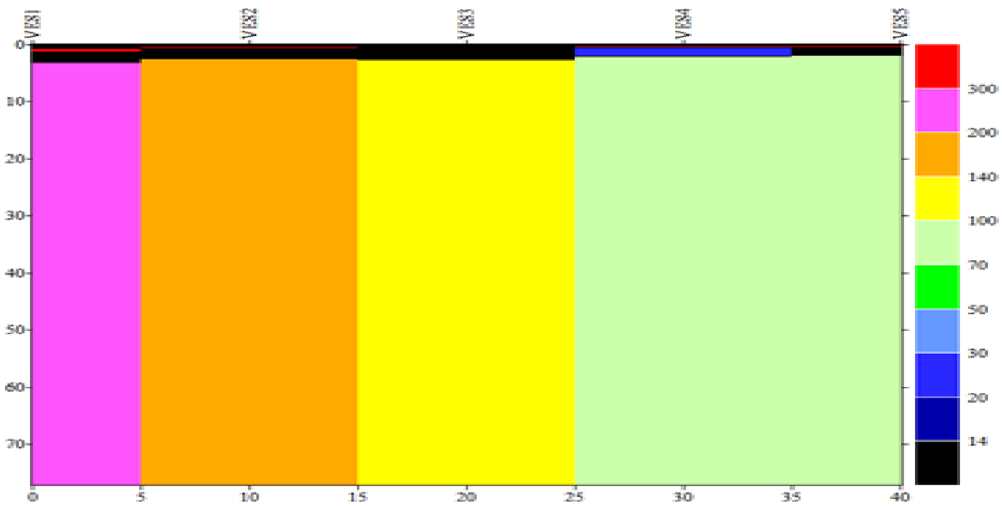


Figure 5: (a) Pseudo cross-section and (b) Resistivity cross-section of VES 1-5 along profile 3 atStudyArea in Mokwa.

Profile 4 (Figure 6 (a) and (b) is also 50 m away from profile 3 towards the eastern edge of the study area. The first layer exhibited an extremely very low resistivity zone (49.75 – 443.9) Ω-m occurred around VES 1, 2 and 3 (black coloration) at relatively shallow topsoil with depth ranged (0.77 – 4.90) m. The second layer was characterized by another delineated very sharp horizontal strange pattern in soil indicated by a sharp fall in resistivity values from (443.9 to 84.75) Ω-m observed between the first and second layers and also from (478.9 Ω-m up to 1135 Ω-m). These are indications of fault zones (**A-A'**) which are unfortunately less than 60 m to hand dug wells and less than 50 m from a railway line which are physical deformations that may influence earthquake. The third layer also was the highest resistive zone with resistivity values ranged (1135 – 1510) Ω-m with thickness ranged (4.66 – 14.40) m and depth ranged (13.00 – 14.05) m.



(a) Pseudo cross-section



(b) Resistivity cross-section

Figure 6: (a) Pseudo cross-section and (b) Resistivity cross-section of VES 1-5 along profile 4 at StudyArea in Mokwa.

3.2 Proximity of Hand dug wells from each other and to the Railway Line within the Study Area

The other physical parameters were determined and presented in (Table 1). The first Profile had a total number of 57 sampled houses, of which each of the 50 houses had one locally hand dug well. These wells are approximately 250 m from each other and are approximately 30 m away from the railway line. This proximity to the railway line is not up to the standard set by the National Building Code (NBC) (152.40 m) and is therefore abnormal (Table 1). In Profile 2 the total number of 68 sampled houses out of which each of the 55 houses had a locally hand dug well approximately 250 m from those along profile 1 and are approximately 80 m away from the railway line which is also below the (NBC) standard. Profile 3 has 53 sampled houses out of which each of the 30 houses bears a locally hand dug well approximately 750 m from those along profile 1 and are abnormally 130 m approximately away from the railway which is also below the standard. However, in Profile 4, out of the 60 sampled houses, each of the 45 houses had a locally hand dug well which are approximately 1000 m from those along profile 1. The location of these houses and the locally hand dug wells in relation to the railway line are approximately 1,030 m and 180 m respectively away from the railway line. The distance here is within the normal standard set by (NBC).

There is tendency of both the residents and all other surface structures located in such weak areas to be exposed to the possibility of induced vibrations, as a result of the heavy pressures caused by the train passing.Such possibility is informed by the frequency of the delineated subsurface weakness/faults zones coupled withthe abnormal proximity of both the residential houses and the locally hand dug wells (ground punctures) to the railway line observed along profiles 1, 2 and 3.

Table 1:The proximity of Residential Houses, Hand dug wells and Railway Line from each other within the Study Area in Mokwa, Nigeria.

Parameter	Profile 1	Profile 2	Profile 3	Profile 4	NBC Standard (m)	TOTAL
Distance b/wwells (m)	250	500	750	1000		
Number of Houses	57	68	53	60		**238**
Total No. of Houses with Wells (Punctures)	50	55	30	45		**180**
Total Number of Houses without Wells	7	13	23	15		**58**
Distance of Houses from Railway line (m)	30	80	130	180	**152.40**	

LEGEND: National Building Code (NBC)

Resistivity models from all the four profiles exhibited very low resistive features from shallow subsurface down to some portions in the third geologic layer indicating pockets of very weak zones which are not conducive for building heavy structures such as residential houses. It also revealed that the study area is generally underlain by three geologic sections which include top soil, Clay-Sandstone, fractured/Weathered basement (Yusuf, *et al.,* 2018). The fractured/weathered basement constitute the aquifer zones within the study location. The number of overcrowded locally hand dug wells increases gradually at the interface of the area alongside with the underlying fractured/weathered basement units, pore-pressure and uplift forces.Consequently, the cohesive force began to be reducing and eventually this situation can lead to instability in the affected area. furthermore, with the increased rainfall, the ground becomes over-saturated and therefore the instability condition continues to be worsening within the affected area. At the end of it all,transmission of mechanical forces of wind into the sloping ground through tree roots and to a more extent, mechanical vibrations from heavy-duty trains passing close to the vicinity, may finally cause the over-saturated materials to flow, leading to a possible land-sliding. (Anthony, *et.al., 2015*) and Awoyera, *et al*., (2016).

IV. Conclusion

None implementation of earthquake resistant measures strictly, miserable violation of earthquake resistant design guidelines, inefficiency and ineffectiveness in system administration in developing countries has been responsible for the huge devastations recorded recently in developing countries such as Nigeria after moderate earthquakes. Therefore, evidences of minimal damage generally without any loss of life when moderate to severe earthquake strikes the developed countries must be emulated. Such can be achieved by utilizing the right available technologies used by the advanced countries and strictly implementing the earthquake resistant design guidelines identified from such technologies to drastically avert the occurrences of earthquakes and mitigate its related disasters in our domains.

Conclusion drone from the findings of this research is that Mokwa town is prone to a possible earthquake based on the following discoveries from this research:

i. Low resistive (very weak/fractured) features characterized the subsurface of the study area.
ii. Overcrowded surface structures such as residential houses (238), locally hand dug wells (180) and railway line proximity (30 to 80) m dominated the study area (1,000,000 m^2).
iii. Possibility ofinducingboth the surface and subsurface structures withmechanical vibrations from the heavy-duty trains passing due to its proximity in addition to thecontinued reduction in cohesive forces andincreasing instability condition which can easily trigger seismic activity.

V. Recommendation

This research has predicted the probable future earthquake in Mokwa North-Central, hence immediate relocation of those affected houses along profiles 1, 2 and 3 at least 152.40 m away from the railway line to safer places and refilling of all those existing hand dug wells are recommended. The Nigerian government and inclined agencies should begin to look into earthquake in this region promptly. There is also need to carefully monitor those activities that have the potential to trigger earthquakes in Mokwa. This can be done through the provision of seismic station in Mokwa to further boost the National densification of seismic stations integrated with spaced-based techniques such as, GPS. The government should ensure that the affected communities are provided with adequate and quality water resources, other descent regional incentives and the implementation of earthquake resistant design guidelines. These can be achieved by employing the roles of Geophysical,Geological, geodynamic and civil engineers'scientist in order to mitigate the sufferings caused by earthquake related disasters.

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