Deformation Monitoring and Geohazards in Nigeria: A Critical Review

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Abstract:- **Geohazards are geological and environmental conditions that involve long-term or short-term geological processes. It occur when artificial structures, such as buildings and natural structures, such as slopes are deformed in various ways. To achieve the aim of this study which is to is to facilitate comprehensive technical understanding and knowledge of the processes of monitoring geological hazards and to better appraise their impacts on engineering structures and the environment with a view to providing mitigation strategy, in order to achieve the stated objective, secondary data sourced from dailies, reports internet and other relevant research works were used. Having studied the state of geohazard and deformation monitoring control Nigeria as well as mitigation approaches to geohazards. The study concluded that the monitoring or control surveys serve not only the purpose of providing information on geometrical deviations at the surface of the investigated object but also become a tool for physical interpretation of the deformation.**

Key Words: **Geohazard, Deformation Monitoring, Geotechnics, Risk, Structures, Tectonic**

I. INTRODUCTION

The term "geohazard" often used by the geologists and engineers to describe the hazards that maybe associated with any potential gravity-related geological or geotechnical problem or failure, such as slope instabilities, landslides, ground settlements and many others (Psarropoulos *et al*, 2012).Simply, geohazard denotes geological hazard, which implies a geological state that may lead to widespread damage or risk. Geohazards are geological and environmental conditions that involve long-term or short-term geological processes. Geohazards can be relatively small features, but they can also attain big magnitudes such as submarine or surface landslide that may to a large extent affect local and regional socio-economy. Evidently, geohazards are the result of a dynamic process of environmental change (Huang, 2012), that can result into huge ecological disasters that threaten human life and property (Chen *et al*, 2017). Similarly, Moore & Davies (2006) also noted that geohazards are geological materials, features or processes that represent commercial and safety risks for development and for the environment.

Hence, geohazards occur when artificial structures, such as buildings and natural structures, such as slopes are deformed in various ways. In actual sense, geohazards such as earthquakes and volcanoes would not happen if there no rupture in geological fault. The theory of continental drift explains more of how the continents have moved over time due to plate tectonics. As noted by Chen *et al* (2017), different types of geological hazards occur through different mechanisms. Even when the same types of hazard occur in different internal geological structures, the causes and characteristics of the environmental external terrain conditions of the hazard can differ. MARI (2017) therefore asserted that geohazards include: earthquakes, volcanic activity, landslides, ground motion, tsunamis, floods, droughts, meteorite impacts and health hazards of geologic materials. Spatial scales can range from local events such as a rock slide or coastal erosion to events that pose threats to humankind such as a great volcano or meteorite impact.

Geological hazards are natural phenomena that cause major problems where they occur. However, the expansion and development of cities may lead to an increase in impact and damage due to geological hazards. Hence, detecting early indications of geohazards and monitoring their changing status are effective ways of managing and abating their impacts. In particular, monitoring the progressive deformation of slopes can be a crucial factor in preventing landslides (MARI, 2017), can help in minimizing their impacts. The objective of this work therefore is to facilitate comprehensive technical understanding and knowledge of the processes of monitoring geological hazards and to better appraise their impacts on engineering structures and the environment. Apart from contributing to public safety. It is projected that, deformation monitoring and hazard assessment will enhance fundamental scientific understanding on the processes involved in the monitoring geological hazards. This paper therefore presents a suggestion to a quantitative model for geohazard data portal with particular reference to the Nigeria situation.

1.1. Background to the Study

Many of the disasters caused by natural hazards originate from geohazards, such as earthquakes, volcano eruptions, landslides, and tsunamis (Marsh & GTT, 2004).Geohazards could cause huge anthropological and economic losses and disruption (Tomás & Li, 2017).Recent earthquakes which then triggered a tsunami in Greece and Turkey which registered a 6.7 magnitude on the richter scale, having over 40 aftershocks from the initial larger earthquake that continued to shake the island of Kos and southwest Turkey (Nace, 2017), painfully reminded the world of the destructive impact of seismic events and the importance of the availability of reliable earthquake risk information. Indeed, most of the African countries are challenged by a multitude of natural and anthropogenic hazards and disasters such as: landslides, volcanic activities, earthquakes, and mining activities among others. These disasters have claimed thousands of lives, devastated homes and destroyed livelihoods. With more than 40% of the population living below the poverty line, Sub-Saharan Africa is also the least equipped and prepared continent to cope with the impacts of these events (ICSU, 2007). As Shlütter(2006) stated, in 24 of the 56 African countries geohazards inventory has not been made.

Deformation studies cover a broad spectrum of applications ranging from the study of crustal deformation or tectonic movements, glacier and shelf ice movements at global or regional scale, to the deformation monitoring of engineered or natural structures such as dams, bridges, tunnels, landslides, etc. at local scale (Caspary 2000).The importance of deformation studies cannot be underestimated. Basically, engineering structures are subject of deformation due to factors such as changes of ground water level, tectonic phenomena and human activities (Ero*et al*, 2005).The monitoring or control surveys serve not only the purpose of providing information on geometrical deviations at the surface of the investigated object but also become a tool for physical interpretation of the deformation. The role of the monitoring surveys extends into the explanation of causes of unexpected deformation and their consequent impacts on the safety and economy as well as environmental effects (Szostak-Chrzanowski *et al*, 2005).The safety of large engineering structures requires monitoring of deformation patterns of these structures such as dams, bridges and high-rise buildings is essential for the development of nation. However, under excessive loading, such as building or structures are subjected to deformation, potentially causing loss of lives and properties (Kalkan*et al*,2010)

Monitoring landslides for example is a crucial task to understand the mechanisms, adopt preventive measures and reduce casualties and infrastructure damage (Angeli *et al*, 2000). However, EGS (2014) noted that based on information available on geohazards analysis it is almost evident that there are not available systematized data portals or data bases. This revealsthe need for data base not just in disaster response but in the monitoring of geohazards. There are therefore needs and expectations in the field of geohazards analysis.There is necessity for reliable interpretation of monitoring data and preparation of hazards assessments. Therefore, the data portalcould thus be subdivided to these main areas of interest:

i. Methodologies: classification of geohazards, recommendations, other methodical support.
ii. Trainings and knowledge: Science is key to understanding hazard, and to reducing damage and loss of life. It was not until the 1960s that scientists could prove that the seismic waves from earthquakes are caused by slip on faults (ODI, 2016). Staff formation and training, radar interferometry training, capacity to forecast earthquake occurrence, skills development in engineering geology, public awareness.
iii. Equipment: vehicles, equipment for field surveying, monitoring and early warning (sensors and accessories, seismic stations)
iv. Mapping: With the knowledge of science, hazard maps can be created to estimate the probability of an earthquake producing a particular level of ground shaking in a particular period of time, and then take steps to mitigate the associated risk (ODI, 2016), products of earth observation (digital elevation models (DEM), laser scanning data (LIDAR)), remote sensing data (SPOT imagery) for a country-wide geohazard mapping, active faults mapping, etc.
v. Inventory: identification of hotspot areas. Comprehensive hazard maps have enabled scientists to assess the earthquake risk.

II. CONCEPTUAL ISSUES

2.1 Risk Management Cycle: Geohazards Mitigation and Geotechnics

Undeniably, risk management of structural projects extends beyond simply setting out systems and procedures. Risk management is not a one-off event and should be seen as an ongoing process that will arise out of monitoring and assessment. The controls identified to mitigate the risks must be capable of implementation, and the implementation should be consciously and appropriately monitored (Kaplan & Mikes, 2012). Risk management procedures must be sufficiently flexible and responsive to ensure that new risks are addressed as they arise. They should also involve periodic checks in order to identify new risks proactively and ensure that the approach to risk management remains fit for purpose. As alluded by Plag *et al* (2010), the concept of the risk management cycle with: mitigation and preparedness, early warning, response and recovery phases captures the steps necessary to reduce the amount and scale of disasters. According to Lucini (2014) risk is a product of four factors: probability, intensity, vulnerability and resilience. Disaster risk reduction is the art and practice of reducing disaster risks through systematic efforts to analyze and manage the causal factors of disasters. Nonetheless, in order to lessen the risk, in many cases the intervention on the exposure value is hardly practicable and modifying the hazard is not possible or is costly in terms of money and time (UNISDR, 2010).

Geohazards mitigation and response aims at providing practical solutions to challenging projects and sites where geohazards are present, including seismic events, landslides, and other geographical and topographical hazards. However, geohazard management varies from one type to another, as well as on a case by case basis (Surinkum *et al*, 2008). It is noted that structures located in the endangered areas where geohazards continually occur should be regularly monitored and maintained. However, the prevention, mitigation and management on geohazard in Nigeria has social, economic and engineering dimensions. Geotechnics is a form of engineering mitigation it embraces the fields of soil mechanics and rock mechanics, and many of the aspects of geology, geophysics, hydrology, and other related fields. Geotechnics is the use of scientific methods and engineering principles to the acquisition, interpretation, and use of knowledge of materials of the Earth's crust and earth materials for the solution of engineering problems and the design of engineering works. It is the applied science of predicting the performance of the Earth, its various materials and processes towards making the Earth more suitable for human activities and development.

2.2 Deformation Survey and Structural Health Monitoring

Deformation monitoring also referred to as deformation survey is the systematic measurement and tracking of the alteration in the shape or dimensions of an object as a result of stresses induced by applied loads. Deformation monitoring is a key element of logging measured values that may be used to for further computation, deformation analysis, predictive maintenance and alarming. Deformation monitoring may be necessary or can be applied in the following: Roads, Tunnels, Bridges and Viaducts, High-rise and historical buildings, Substructures, Construction sites, Dams, Mining, Landslide and Volcanoes Slopes, Settlement areas, Earthquake areas. Many instruments and surveying methods have been used in order to support the control of these structures (González-Aguilera *et al*, 2008).

Deformation monitoring can be made manually or automatically. Measuring devices (or sensors) can be sorted in two main groups, geodetic and geotechnical sensors. Both measuring devices can be seamlessly combined in modern deformation monitoring. Geodetic measuring devices measure geo referenced displacements or movements in one, two or three dimensions. It includes the use of instruments such as total stations, levels and global navigation satellite system receivers. Geotechnical measuring devices measure non-geo referenced displacements or movements and related environmental effects or conditions, this may include the use of instruments such as extensometers, accelerometers piezometers, raingauges, thermometers, barom eters, tilt meters, seismometers etc. Other techniques e.g. radar measuring devices.

Deformation monitoring systems provide a proactive control of a hazard related to possible change or failure of a structure. Policyholders can reduce risk exposure before and during construction and throughout the lifecycle of the structure and hence decrease the insurance premium (Oilfield, 2016).The monitoring regularity and time interval of the measurements must be considered depending on the application and object to be monitored. Objects can undergo both rapid, high frequency movement and slow, gradual movement. For example, a bridge might oscillates with a period of a few seconds due to the influence of traffic and wind and also be shifting gradually due to tectonic changes.

Structural Health Monitoring aims to give, at every moment during the life of a structure, a diagnosis of the state of the constituent materials, of the different parts, and of the full assembly of these parts constituting the structure as a whole. Structural monitoring is carried out to reduce cases of building collapse thereby enhancing safety conditions for the inhabitants. During this survey, the use of measuring techniques which are geodetic are determined considering the type of the structure of which deformations will be monitored, its environmental conditions and expected accuracy from the measurements. Different structural monitoring requires certain kind of techniques. Control survey is key managing risk from building collapse. Around the world, about 75% of earthquake related deaths are caused by building collapse (Daniel *et al*, 2011). Ensuring that buildings and other structures are made to withstand the expected intensity of ground shaking in a given location, therefore, is one of the best ways to save lives in the event of an earthquake.

2.3 Building Deformation Monitoring in Nigeria

Geotechnical instrumentation and monitoring, along with geo-hazard assessments, play a role in safeguarding assets and infrastructure from collapsing. Furthermore, properly planned geotechnical investigations are, along with monitoring programmes, of paramount importance in identifying potential hazards and risks. Geotechnical monitoring provides clients with this information over the course of time, tracking and assessing changes to an asset or the condition of the surface or subsurface where the asset is located (Applus, 2018).Whereas, Kadiri*et al* (2012), noted that for effective and efficient disasters monitoring, installation permanent GPS stations, densification of GPS and seismic stations. Hence, an integrated monitoring system is an effective tool for monitoring faults.

Since, building collapse has become a regular occurrence in Nigeria. The term ‘building collapse’ is different from ‘building demolition’. While building demolition refers to intentional falling of building, building collapse connotes unintended falling of building. Oyedele (2018)defined building collapse as a situation where building which has been completed and occupied, completed but not occupied yet or under construction, collapses on its own due to action or inaction of man or due to natural event like earthquake, storm, flooding, tsunami or wildfire. He further stressed that all(36) states in Nigeria and the Federal Capital Territory (FCT) have witnessed building collapse within the last ten (10) years. This occurrence therefore necessitate control survey. As captured by Olaleye & Sangodina (2001), the following are some of the basic causes of structural movement experienced by completed projects:

- Nature of the type of soil on which the structure is built,
- Nature of the type of materials used in the construction,
- The Design Plan (may be faulty),

- Quality of the personnel that did the setting-out,
- Quality of the personnel that actually constructed the project,
- Earth movement,
- Weather situations,
- Use of the structure e.g. an industrial building, buildings in densely populated areas, and
- Age of the structure.

Since severe deformation can lead to destruction of structures and cause casualty. Therefore, monitoring engineering projects is the practice of keeping a continuous and periodical record of any engineering project. The prime goal of deformation studies is to investigate the spatial and temporal stability or displacements (the geometrical changes) of an object or body (Heunecke & Welsch 2000). Also Olaleye & Sangodina (2001) provided the roles of deformation monitoring are as enumerated as follows:

i. Offers checks on a project,
ii. Provides control of a project, and
iii. Gives cautionary on a project before it collapsed.

Deformation analysis naturally comprises the estimation of a static set of unknown parameters, where each set of measurements is used to obtain a better estimate of the same quantities. In deformation studies, the data acquired from the monitored object or body contains both useful information and the noises (Eyo*et al*, 2014).

III. METHODOLOGY

To achieve the aim of this study which is to is to facilitate comprehensive technical understanding and knowledge of the processes of monitoring geological hazards and to better appraise their impacts on engineering structures and the environment with a view to providing mitigation strategy, in order to achieve the stated objective, secondary data sourced from dailies, reports internet and other relevant research works were used.

3.1 Geohazards Events in Nigeria

Generally, younger geological faults are more prone to endogenous phenomena such as volcanoes, earthquakes and exogenous phenomena, which determine land evolution and natural hazard such as landslides, coastal erosion, floods, slope instabilities, sinkholes. However, the geology of Nigeria is made up of three major litho-petrological components, namely, the Basement Complex, Younger Granites, and Sedimentary Basins. The Basement Complex, which is Precambrian in age, is made up of the Migmatite-Gneiss Complex, the Schist Belts and the Older Granites. The Younger Granites comprise several Jurassic magmatic ring complexes around Jos and other parts of north-central Nigeria. They are structurally and petrologically distinct from the Older Granites. The Sedimentary Basins, containing sediment fill of Cretaceous to Tertiary ages, comprise the Niger Delta, the Anambra Basin, the Lower, Middle and Upper Benue Trough, the Chad Basin, the Sokoto Basin, the Mid-Niger (Bida-Nupe) Basin and the Dahomey Basin (Obaje, 2009).

Accordingly, Nigeria is prone to both endogenous and exogenous geohazards such as the following:

i. Flooding: Flood can be defined as a hydrologic state whereby the river discharge exceeds the storage capacity of the channel and the excess water overflows and inundates part of the valley bottom (Avijit, 2010). Flooding becomes a hazard when the valley flat of a river is utilized for settlements or economic pursuits. In 2012 Nigeria floods began in early July, From the North to the South, East to the West, the adverse effects are very glaring. From Adamawa to Niger, Kogi to Bayelsa, Edo and Delta and indeed all parts of the country, flood has brought untold hardships on millions of Nigerians. A total number of 363 people were killed and displaced over 2.1 million people as of 5 November 2012. According to the National Emergency Management Agency (NEMA), 30 of the Nigeria's 36 states were affected by the floods (The Guardian, 2018). The floods were so severe, termed as the worst in 40 years, and about seven million people were affected. The events caused a whole of damages and losses worth #2.6 trillion.
ii. Gully Erosion and Gully-Induced Landslides: Gully erosion is a keygeohazard in the country, which peculiar to the southern Nigeria. Gully erosion arises as a result but physical and human factors. Akpokodje *et al*(2010) alluded that the most important human activities that either initiate or quicken gully erosion in this part of the country includes, (a) road construction and infrastructural development, (b) quarrying of sand or gravel, (c) farming (d) footpaths, (e) cattle grazing tract and (f) population density.It is noted that landslide events occur as a result of extreme gullying, they are thus referred to as gully-induced landslides. They are often manifest in the form of slumping as a result of toe undercutting from gully erosion. It was established that gully erosion sites were well dispersed around false bedded sandstone geological formation. Slope characteristics of gully sites were found to be greater than 15° which encourages erosion activities.
 Large-scale landslides can seriously threaten human life and infrastructure over extensive areas, by rapidly moving substantial volumes of material and even by causing catastrophic tsunamis. Nonetheless, better understanding their mechanics is key for predicting such events and protecting ourselves from their consequences(Russell Group, 2018). Confirmatively, it has been reported that millions of people have been displaced and evacuated their homes following gully incidences, in Oko

community of Anambra State, gully erosion has formed an extensive crater, destroying the homes of many, about 826 families. Also revealed that 10 houses were lost in a single event of gully erosion in Auchi area of Edo State and over 450 buildings have been lost in Edo State of Nigeria as a result of severe gully erosion. It was also reported that about 23 lives have been lost in the past few years in a single event of gullying activities in some communities of Edo State, Nigeria including: Ibori, Ugbalo, Ewu-Eguare, Idogalo and Oludide.

iii. Earthquakes occur because the tectonic plates that make up the Earth's surface are in constant motion. The National Space Research and Development Agency (NASRDA) has attributed the cause of the recent tremor in Jama'a Local Government Area of Kaduna State to passive sources. The reports have established that the incidents were recorded in Kwoi and surrounding villages of Nok, Sanbah and Chori in Jama'a Local Government Area of Kaduna State on Sunday, Sept. 11 and Mon. Sept. 12. The analysis showed that the first event occurred at 12:28:16.50 seconds GMT on Sept.11 and the event has an epicentre located Latitude 9.825N and Longitude 7.885 E while Local Magnitude was 2.6 and Moment Magnitude was 3.0 and Focal Depth was 10 km. The report further showed that the second event occurred on Sept. 12 at 03:10:48.80 seconds (GMT) with Local Magnitude of 2.6 and Moment Magnitude of 2.9 with Focal Depth of 10km while the epicentre was Latitude 10.879N and Longitude 7.188E. That was followed immediately by another event at 03:11:20.00 seconds (GMT) located at an epicentre of Latitude 9.927N and Longitude 7.297E, Local Magnitude 2.9 and Moment Magnitude 3.0. "The reports showed the time of occurrence of the events and intensities of the locations as reported by inhabitants of the communities, which included cracks on walls of buildings, falling off of ceiling fans and other items (Guardian, 2016)

This report however corresponds with the results of analysis carried out by the team of experts from NASRDA's Centre for Geodesy and Geodynamics. The centre is charged specifically with the mandates of crustal and coastal deformation monitoring, seismic hazard evaluation and monitoring as well as research in natural hazards like earthquakes, volcanoes, landslides and subsistence. NASRDA has successfully carried out several projects and research for national development among which are series of investigations on peculiar geo-hazards in Nigeria.

3.2 Nigeria: National disaster framework

The National Disaster Management Framework (NDMF) provides a mechanism that serves as a regulatory guideline for effective and efficient disaster management in Nigeria. Some of the framework's objectives are:

i. Establish functional disaster management institutions at all levels of governance to prepare for, prevent, mitigate, respond to and recover from disaster events in Nigeria.
ii. Develop capacity of relevant institutions and stakeholders for effective and efficient disaster management in Nigeria.

The Federal Government through the National Emergency Management Agency (NEMA) shall by this policy perform the disaster management functions. Also, National Space Research and Development Agency (NASRDA)in bid to improving seismic data acquisition and encourage more research activities regarding seismicity in Nigeria, particularly in times of natural disasters. NASRDA has established what is globally known as the Nigeria National Network of Seismic Stations located in Abuja, Kaduna, Ile-Ife, Awka, Abakaliki, Minna, Ibadan, Nsukka and Oyo town.

3.3 Nigeria Disaster Data and Risk Profiles

Table 1:Economic Indicators of Disaster and Risk

GDP (Gross Domestic Product)	Million US$	522,637.872
GDP per capita	Per capita US$	3,005.51
Capital stock	Million US$	592,030
GFCF (Gross Fixed Capital Formation)	Million US$	66,581.941
Social Expenditure	Million US$	35,350
Gross Savings	Million US$	154,259.176
Total reserves	Million US$	46,405.237

Source: UNISDR (2010) https://www.preventionweb.net/english/professional/statistics/

GDP (Gross Domestic Product): **GNP** is the value of a country's overall output of goods and services (typically during one fiscal year) at market prices, excluding net income from abroad. It is calculated at purchaser's prices and is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. GDP generally measures the economic capacity or vitality of a country for a given year.

GDP per capita: GDP per capita is gross domestic product divided by midyear population. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. Dividing the GDP by the number of persons gives an indication of the individual's economic well-being in a country for a given year.

Capital stock: Capital stock as referred to in GAR15 in the context of risk assessments is the total value of commercial and residential buildings, schools and hospitals in each country. This excludes infrastructure such as roads, telecommunications and water supply (UNISDR).Capital stock as defined in GAR 15, gives an idea of the value of the exposed assets and can be used to assess a country's average annual loss or probable maximum loss.

GFCF (Gross Fixed Capital Formation): Gross Fixed Capital Formation - formerly gross domestic fixed investment - includes land improvements (fences, ditches, drains, and so on); plant, machinery, and equipment purchases; and the construction of roads, railways, and the like, including schools, offices, hospitals, private residential dwellings, and commercial and industrial buildings. In the context of GAR, GFCF is the total investment of a country in new infrastructure and improvement of existing infrastructure for a given year. This indicator is compared with Average Annual Loss (AAL) giving an idea of how much investment would be needed to cover future losses. GFCF is flow concept of a given year while capital stock is accumulated stock concept.

Social Expenditure: Social Expenditure relates to government spending on education, health and social protection. In the context of GAR, social expenditure is compared with Average Annual Loss (AAL) to provide an idea of the implications of the potential negative impact on the social expenditure and accompanying loss of social welfare of a country.

Total reserves: Total reserves minus gold comprise special drawing rights, reserves of IMF members held by the IMF, and holdings of foreign exchange under the control of monetary authorities. Gold holdings are excluded. Total reserves suggests an element of a countries' capacity and ability to finance disaster recovery and reconstruction.

Table 2:Probabilistic Risk Result: Average Annual Loss (AAL) by Hazard

Hazard	Absolute [Million US$]	Capital stock [%]	GFCF [%]	Social exp [%]	Total Reserves [%]	Gross Savings [%]
Earthquake	20.64	0.003	0.031	0.058	0.044	0.013
Flood	543.42	0.092	0.816	1.537	1.171	0.352
Multi-Hazard	564.06	0.095	0.847	1.596	1.216	0.366

Source: UNISDR (2010) https://www.preventionweb.net/english/professional/statistics/

Probabilistic Risk: Probabilistic risk assessment uses mathematical models to combine any possible future hazard situations, information about the exposed assets and the vulnerability, to provide results of an estimate of probable loss levels in a region of interest. Unlike historical estimates, probabilistic risk assessment takes into account all disasters that can occur in the future, including very intensive losses with long return periods, and does overcomes the limitations associated with estimated derived from historical disaster loss data.

Probabilistic risk assessment gives an overview of estimated losses, which can provide guidance to predict and plan for future losses. This information can be used to plan and prioritize investments and strategies for managing disaster risk.

Average Annual Loss (AAL); The Average Annual Loss is the expected loss per annum associated to the occurrence of future perils assuming a very long observation timeframe. It considers the damage caused on the exposed elements by small, moderate and extreme events and results a useful and robust metric for risk ranking and comparisons.

AAL Flood results are provisional. These results give an overview of the risk associated with river flooding. Factors other than the depth of the water also have a considerable influence on loss, which means that there is greater uncertainty compared with other hazards.

Probable Maximum Loss (PML); The Probable Maximum Loss is a risk metric that represents the maximum loss that could be expected, on average, within a given number of years.PML is widely used to establish limits related to the size of reserves that, for example, insurance companies or a government should have available to buffer losses: the higher the return period, the higher the expected loss. PML always have associated a mean return period. Mean return period of 100, 250, 500, 1000 and 1500 years means the 5%, 2%, 1%, 0.5% and 0.3% probability respectively of exceeding those losses in 5 years.

IV. RECOMMENDATIONS

Having studied the state of geohazard and deformation monitoring control Nigeria as well as mitigation approaches to geohazards, this paper makes the following recommendations:

i. Collaboration of Professionals

Aversion of any form of geohazards ranging from endogenous hazards of regional or local magnitude, to exogenous requires concerted and collaborative efforts of earth and environmental scientists. The will facilitate an integrated view of the nature and likelihood of vulnerability, and thereby throw cautions on the hazardous nature of the material and that of the entire environment.

ii. Prompt Report of Result

The structures located in the endangered areas where geohazards continually occur should be regularly monitored and maintained. The results of geohazard monitoring, research, and hazards assessments must be communicated efficiently and in a timely manner in order to serve intended purpose. Relevant agencies must endeavour to disseminate hazard warnings, forecasts, and other information through several media such official briefings, workshops, published reports and maps, videos, digital databases, internet (Web site), media, and weekly newspaper columns.

iii. Availability of Geohazards Data Portal and Inventory

As Shlütter (2006) stated, in 24 of the 56 African countries geohazards inventory has not been made. However, identification of hazard areas, through inventory map, comprehensive hazard maps have enabled scientists to assess the geohazard risk.

V. CONCLUSION

Deformation studies cover a broad spectrum of applications ranging from the study of crustal deformation or tectonic movements, glacier and shelf ice movements at global or regional scale, to the deformation monitoring of engineered or natural structures such as dams, bridges, tunnels, landslides, etc. at local scale (Caspary 2000).The monitoring or control surveys serve not only the purpose of providing information on geometrical deviations at the surface of the investigated object but also become a tool for physical interpretation of the deformation. The prime goal of deformation studies is to investigate the spatial and temporal stability or displacements (the geometrical changes) of an object or body

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