

# Implications of Basement Inclusion in Buildings in High-Risk Flood Zones in Yenagoa, Nigeria

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**Abstract** Recent and past studies have shown that buildings without cellars or basements are considered to be most appropriate for flood-prone areas. However, a number of buildings constructed with basements have been observed in High-risk flood areas in Nigeria such as Yenagoa. This paper uses a case study approach to examine some of these buildings in the selected areas and the implications or effects of having such subterranean spaces in these locations without the proper waterproofing or basement tanking methods. The study showed that although knowledge of pluvial flooding and fluvial flooding exists in this region and are often taken into consideration during building construction, what seems to be lacking is a knowledge of groundwater or basement flooding and its implications in building design and construction. The study also showed the extent to which policies address flooding issues and the areas they fall short.

**Keywords:** architecture, basements, floods, groundwater, Yenagoa

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## 1. Introduction

Large parts of the location being considered in this study – Yenagoa falls within the high risk flood zones according to previous studies [1]. Besides major floods like the 2012 and 2017 events in Nigeria, Yenagoa is also susceptible to annual floods that lead to inundation of communities and the destruction of buildings and other infrastructure. The main sources of flood risk are Fluvial or River floods, Coastal floods, Surface water or pluvial floods and Groundwater floods [2]. Of these four sources the one most impinging on building basements is the groundwater floods, although any of the other flood systems can also affect subterranean structures but not as much as the groundwater source. As such, for the purpose of this study, the behavior and characteristics of this particular flood system will be briefly examined for purposes of clarity, context and effectual analysis.

This paper draws on data from a survey analysis of three select case studies in Yenagoa that incorporated basements into their various designs. The International Building Code [3] and the New York Department of City planning [4] jointly define a basement as "any floor level below the first story in a building that is partly or completely below the exterior grade plane with at least one-half of its floor-to-ceiling height above curb level or above average natural grade". The British standard BS

8102:2009, 'Code of practice for the protection of below ground structures against water from the ground' [5], defines four grades of basement

- Grade 1: basic utility (car parking, plant rooms (excluding electrical equipment), workshops).
- Grade 2: better utility (workshops and plant rooms requiring drier environments than grade 1).
- Grade 3: habitable (ventilated residential and commercial areas).
- Grade 4: special (archives, requiring controlled environments).

Waterproofing requirements are dependent on the grade or end use of the basement as well as the expected lifetime of the basement [6].

As an underground or subterranean structure, basements have to contend with moisture and groundwater ingress as well as hydrostatic pressure. Groundwater levels need to be identified, including any seasonal variations in levels and artesian pressures because flotation may become an issue [6] amongst other things. With this study set within the context of the Niger Delta regions of Nigeria, it is also necessary to understand the concept from the perspective of the built environment industry in Nigeria. The National Building Code of Nigeria [7] defines a basement as "that portion of a building, which is partly or completely below ground level. This section of the building may be a part of the foundation but shall be specifically different from it, and shall contain humanly useful spaces, set out on one or

more floors, but shall not extend beyond 1.20 metres above ground level to the top of ground floor level”.

With scarcity of valuable real estate spaces in most developed cities of the world, appropriating subterranean as well as air spaces has become common practice to maximize cost benefits in every available square feet of space obtained. As previous studies have shown, in many cities, gaining additional space for a home or commercial property by building outwards may not be possible due to lack of space or existing neighbouring properties, and extending a property upwards may not be permitted by local planning regulations. A popular solution is to extend downwards by constructing a basement [6]. They even stated that in recent years there has been a significant increase in the number of new basements being constructed beneath existing inner-city domestic properties especially in the UK. Thus, while the inclusion of basements as a design feature has transited from the realm of luxury to one of necessity in many cities of the world, basements as a design feature are still quite uncommon in most of sub-Saharan Africa where land is still largely available.

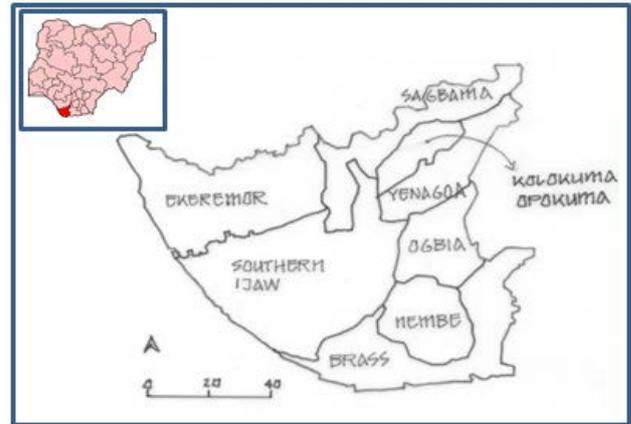
The cities in Africa where inclusions of basements in buildings are likely are often necessitated by their hilly or undulating topography and landforms. As such, it is rare to have excavations for the purpose of basement inclusions on areas with level grounds such as savannahs, places with high groundwater tables or even riverine or coastal communities susceptible to flooding in sub-Saharan Africa. However, this study investigates the rare inclusions of such basement facilities in a high groundwater, flood-prone region of Nigeria's Niger Delta. This is a region where the inclusion of basements is not necessitated by topography of the landforms per se rather; by artificially created levels, by the architect's choice or by client's request. What is certain in the study area is that the inclusion of basements in buildings is an architectural decision, while the protection of such basements is an engineering task. The paper examines two typologies of buildings in Yenagoa where basements have been included; a commercial bank and a large residential development.

## 2. Study Location

Bayelsa State is located in the Niger Delta area which lies in the southern part of Nigeria and is a mixture of tropical rain forests and mangrove swamps. It has a total land area of 9,059 sq. km and the capital city Yenagoa, is one of eight Local government areas that make up its administrative structure. The climatic disposition of this region is tropical. It lies just above the Equator with an annual mean temperature range of 23.9°C – 29.5°C. The mean maximum temperature rarely exceeds 35°C. Relative humidity is high and it increases as progression is made towards the coast.

The terrain is scarred by a network of tributaries, creeks and rivers, depositing their load into the Atlantic Ocean. There are 10 channels from which the waters of the River Niger are emptied into the Atlantic Ocean and 8 of these rivers run through Bayelsa State. The average rainfall experienced in this region is between 2000-2500mm per annum or between 290-360 days of rainfall annually,

culminating in floods. Bayelsa State is made up of eight Local Government Areas, including Yenagoa the State capital which is the study location as shown in Figure 1 below.



**Figure 1.** Map of Bayelsa State showing the eight Local Government Areas (LGAs) and the capital Yenagoa (Source: Author)

The areas within the study location in Yenagoa the Bayelsa State capital where case studies have been identified include; the Central Business District (CBD), Okaka and Kpansia communities. These locations were selected for two reasons. Firstly, they fall within the high-risk flood zones which are areas prone to flooding. Secondly, all three locations are within a kilometer from each other and around the city centre.

After the 2012 floods in Nigeria, The Bayelsa State Government set up a committee (the Post Flood Monitoring Committee, PFMC) to assess the level of damage incurred, the lessons learnt and to make recommendations for the way forward. Some of the conclusions deduced by the PFMC were that the trend of building designs and construction within Yenagoa allowed for the possibility of several openings for ingress and retention of flood waters in buildings. The report revealed that the avenues for flood water ingress into buildings include;

- Backflow of sewage from overflowed septic tanks, soakaway pits and sewers bringing return discharge into buildings through sanitary appliances
- Ingress through cracks in the walls
- Doorways and windows
- Seepage through unrendered external walls
- Capillary action through hollow sandcrete blocks where no damp proof membrane was used.

These avenues for flood water ingress allowed for different types of direct damage to buildings such as:

- Weakened or failed foundations
- Caving-in of ground floors due to erosion of filling material such as mud or sand from under the foundation
- Destruction of most timber based building products from doors to roof members depending on level of inundation or flood depth and duration of flood waters in contact with building
- Damaged wall render and paint due to prolonged contact with floodwater
- Damaged electrical wiring and fittings due to surface wiring technique widely used

- Contamination of property with sewage, drains and chemicals from garages

Because of the widespread inundation due to pluvial and fluvial floods, ingress and possible damage from groundwater floods was not taken into consideration. In a previous study, one of the crucial lessons learnt was that the conventional way buildings in this region have been designed by architects and built over the years makes them vulnerable to damage by flood waters in so many areas [8]. As such, this study investigates the way some structures are being built more recently, with the inclusion of subterranean facilities. The study also seeks to know if lessons have been learnt from building failures experienced during the past floods due to groundwater ingress, hydrostatic pressure or other artesian conditions.

### 3. Groundwater and Basement Floods

Groundwater floods are the least known and least understood of all flood types. This is because its activities are mainly subterranean and as the name implies, it affects basement structures primarily.

To understand groundwater and basement floods, one needs to first understand about groundwater. An estimated 40km<sup>3</sup> of water runs across the surface of the earth per year, some of it gets collected in surface reservoirs like rivers and streams that flow back into the ocean while the rest seep into the ground to recharge groundwater systems or aquifers. There is about 35 times as much water that seeps into the groundwater systems than there is in surface reservoirs [9]. With the increase in frequency and duration of rainfall due to climate change, groundwater aquifers increase in size by absorbing more water. With increased groundwater comes higher groundwater table or artesian conditions. If the groundwater table exists behind a basement wall, then the wall will be subject to hydrostatic pressure which can force large quantities of water through wall cracks or joints and lead to basement flooding.

Other ways basement flooding can occur is by moisture penetration through capillary action where water travels from lower to higher level through porosity of the wall or fine cracks in the masonry; water vapour when there is a difference in vapor pressure between the two areas and; pipe leaks from broken submerged pressurized pipes [10]. Basement floods can also be a consequence of urban floods which arises when precipitation that is heavier than 1-in-10 years overwhelms the drainage system causing raw sewage to back up through drainage lines and flow into basements where it accumulates creating a basement flood [11,12,13]. However, this can occur only in properties where drainage and sewage pipes are combined. In addition, pluvial flooding can also lead to basement flooding if not checked on time [14].

### 4. Basement Flood Damage

In 2015, an entire thesis was done on the risk of basement floods using decision opportunity and choice architecture as study instruments. The study revealed that even with the high risk of basement floods resulting from

the inability of the current urban drainage systems of most countries to handle overwhelming precipitation levels, the proactiveness of property owners to initiate preventive, protective and preparative measures are low as long as they are yet to experience a basement flood [11]. But statistics over the years have shown that during flood disasters, the areas that suffer the most damage in buildings with subterranean facilities are the basements. Studies have also analyzed how private households coped with the pluvial floods of 2005 that affected certain regions of Germany [15]. From the data obtained from three communities; Hersbruck, Lohmar and Osnabruck, respondents reported that majority of the damage to buildings were mainly the basements. In Hersbruck, 80% of the 300 houses reported damages mainly to the basements; Of the 250 houses that suffered damage in Lohmar, 89% of them reported damages to their basements; and of the 1100 households that were affected in Osnabruck 90% of them reported damages mainly to their basements. In 2002, the ICPR stated that buildings designed without cellars or basements helped reduce the flood loss in the residential sector by 3000-6000 EUR in Germany. Kreibich et al summarized the importance of not including basement or any form of cellars in flood prone areas in this statement “that buildings without cellars are recommended in flood prone areas” [16]. The reason is that water seepage from groundwater and floods is the commonest basement problem and the surest way to incur damage to property in flood prone areas.

The most common forms of damage from basement flooding include’

- Damage to wall coverings
- Mildew growth on basement walls
- Musty odours
- Deterioration of walls
- Buildup of salt deposits on inner surfaces of basement walls
- Chemical deterioration of concrete due to dissolved sulfates

These damages come as a result of water seepage and retention in the basement and could ultimately render the basement unusable. The two case studies in Yenagoa analyzed below, show different levels of ponding from water seepage and the current state of the buildings in terms of usage.

#### 4.1. Case Study 1 – Commercial Bank, Sani Abacha Expressway, Yenagoa

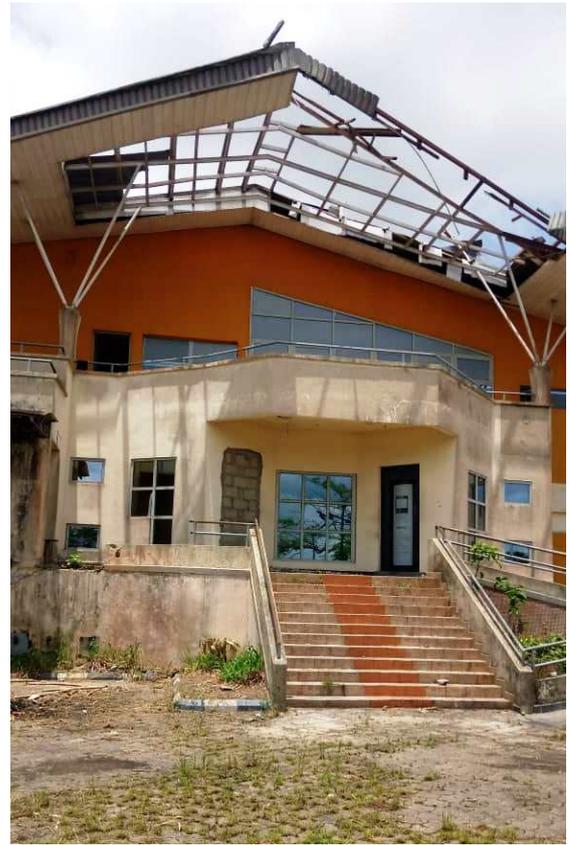
This one-story structure was built in 2006 with banking operations resuming fully in 2007 and its doors were eventually sealed up to discontinue operations less than a decade later in 2016. The main access road –the dual carriage Sani Abacha expressway was raised to address annual flooding issues for which Yenagoa is known for, thereby creating a bit of downward slope into the adjacent lands. Consequently, the site required some filling to attain a level for easy street access. This meant providing a foundation wall of over 1.5 metres, which would be considered a waste of subterranean space if completely backfilled. To avoid the extra expenditure, the design firm

proposed the inclusion of a basement floor to be used as a bulk counting room for large cash deposits as well as extra office spaces. To achieve that, the entrance floor level was elevated by about 1.8 metres from the ground level, which in addition to about 1.2 metres of submerged ground space would provide the required headroom for the basement floor. Prior to commencement of design, soil tests for bearing capacity was carried out but no tests were done to ascertain groundwater levels as this was not a pre-requisite to obtaining plan approvals for the proposed works.

The basement walls were made of reinforced concrete but the details of the type and level of waterproofing used, was not made available to us during fieldwork for this study. However, what was divulged was that a number of contracts had been awarded for post-construction waterproofing and corrective works. These corrective waterproofing works commenced even before banking operations started and continued up until the eventual closure of the building; yet there was continuous ponding of the basement floor. Due to constant groundwater seepage the basement was never put to use as a bulk counting room for which it was designed. The water penetration problems increased with each rainy seasons and subsequent flood season and could reach depths of 15 - 20cm in 24hrs before pumping. The building still remains standing but was eventually closed for business in 2016 when a newly commissioned one was completed on same bank property adjacent to the faulty structure. As lessons learnt, the new banking hall was designed without a basement floor.



**Figure 2.** View of the building from the main access road - Sani Abacha Expressway



**Figure 3.** Elevated ground floor level to create added headroom for basement floor



**Figure 4.** View from the entrance hall bridge to the basement floor below showing a circular water fountain and flower bed



**Figure 5.** View from under the staircase showing one of the decommissioned water fountains (darker water mark below the unpainted area shows height of water usually attained overnight during flood season before pumping)



**Figure 6.** Another view from the entrance hall bridge. (The unpainted wall area and floor were constantly undergoing waterproofing treatment)



**Figure 7.** Flooded basement with water mark on wall



**Figure 8.** Regular state of basement before flood season

#### 4.2. Case Study 2 – Residential Building, Okaka, Yenagoa, Bayelsa State

This case building is located in a low density, high-brow area in Okaka community, close to the central business district (CBD) in Yenagoa. This is one of the few buildings where a basement floor was included deliberately based on client's request and not conditioned by topographical or other environmental factors. This impressive structure is essentially a bungalow with a large footprint, a mezzanine floor and an equally large basement area. The building was at the finishing stage of construction work at the time fieldwork was conducted. Since no form of filling was required for the land, excavation was carried out to create the entire 2.7 metre deep basement.

The basement floor, supporting columns and walls were constructed out of reinforced concrete without any waterproof additives. Data gathered during fieldwork revealed that no specific tests were carried out on the land to ascertain the pre-existing groundwater table and relative permeability of the soil before the decision to include the basement was made. Furthermore, during construction, no steps were taken to ensure basement tanking or any form of water-resistant construction. At the time of fieldwork, the construction crew was still battling with basement floor ponding resulting from water seepage, rising up to 5mm deep on the basement floor. This issue has stalled the final finishing process in the basement area whilst all other parts of the building superstructure have been completed. The assumption was that a monolithically casted concrete basement wall with some waterproofing additives would more than suffice to tackle whatever water seepage or moisture penetrating problem may exist in the sub-terrain. The fact remains that waterproofing

aside, a monolithically casted concrete has not even been achieved and coupled with the lack of waterproofing works the basement has all but failed in its flood resistant capacity.



Figure 9. Water ponding on basement floor



Figure 10. Showing ponding in open plan areas of the basement floor



Figure 11. Ponding extends to basement corridor and room



Figure 12. Entrance and stairwell leading to basement

## 5. Analysis and Discussions

Presumably, it is common fact that one of the ways to achieve a successful dry basement construction is by waterproofing, yet in both case studies attention to such detail appears to be lacking. The building survey conducted during fieldwork revealed that for the commercial bank, attempts at waterproofing came after construction was complete, and a similar route was being taken for the residential building. With basement

inclusions extremely rare in Yenagoa, there were no known previous buildings with subterranean features to serve as a design precedent, hence the inclusion of a basement would have been viewed as a demerit. Building failures in this respect can also be attributed to dearth of flood knowledge amongst building professionals in this region as revealed in a previous study [8]. This is revealed in the conventional way buildings in this region have been designed by architects and built over the years, making them vulnerable to damage by flood waters in so many areas.

As a first step towards averting basement floods in cases where basements have been proposed in buildings in the study region, it is crucial for groundwater tests to be carried out to ascertain the groundwater table. In the course of the study, one of the main issues observed, was that groundwater tests were not conducted on all of the case study sites visited prior to construction. The project engineers in two out of the three projects visited had not as much as heard about groundwater floods or groundwater tests to know the groundwater table. With this crucial step omitted, all other steps employed as flood resilient measures were simply placebos.

In Nigeria, the Federal Ministry of Environment developed the National Erosion and Flood Control Policy aimed at the management of erosion and flood problems [17]. This policy subsumes all flood problems regardless of its source under the same umbrella and proffers similar solutions for all of them. One of the objectives of Section C of the policy which focuses on flood control and water conservation looks at the introduction of flood control procedures as part of contract specifications in construction sites. This would mean that before any building project would be allowed to commence in flood-prone areas, documentations showing flood control measures that have been carried out or put in place would have to be first presented. However, the nature and type of documentations required did not specify tests for groundwater table. Even the National Building Code [7] recommends that project plans approvals should include soil type description as well as drainage plans but also fell short of specifying what other soil type description was required besides the conventional tests for soil bearing capacity of intending structures.

However, the National Environmental Regulations document [18] went a step further to address more direct issues about steps to be taken to curb flooding as it relates to building construction, it states that;

- All new constructions shall be anchored to prevent floatation, collapse, lateral movement of structure due to hydrodynamic forces.

This was the first time hydrodynamic forces were mentioned and acknowledged as potential for flood damage.

- The document also acknowledges flood damage through egress or infiltration of water through sewage and sanitary systems and the need to make attempts to eliminate such.

It however does not state the type of flood as groundwater floods nor give any details on how to go about eliminating them.

Furthermore, although this policy document has some regulations that attempt to address the issues of flooding,

it apparently leaves the design and implementation of more detailed control/ mitigation measures to the various States of the Federation, to be handled on case-specific basis. This was indicated in number 4 of the regulations which states that “applicants are to comply with zoning and building regulations of particular States and Local Governments in which development is to take place” [18]. This is because although in Nigeria the Federal Government establishes Acts, State Governments can also enact laws and bye-laws based on their geographical peculiarities as they see fit. As such, it absolves the Federal Government of the responsibility of actually ensuring the implementation of these regulations and relinquishes the onus to the States [19].

Nonetheless, for Federal projects, the conditions for approval of building plans in flood-prone areas in theory, requires an application made to the National Environmental standards and Regulation Agency (NESREA) with the inclusion of:

- Site Plans
- Detail Plans
- Construction Specifications
- Drainage computations (for run-offs etc)
- Flood proofing details
- Flood proofing certification
- Erosion control plans.

The purpose was to ensure compliance of regulations across flood-prone areas in the country, regardless of what location the project is to be sited. But Brisibe had previously observed that so far, this is only in theory and is yet to be implemented in any flood-prone area in Nigeria [19]. It is worth mentioning that the flood proof details and certification set as part of the building approval documents are those for conventional floods such as fluvial, pluvial and coastal floods. But for groundwater floods resulting in basement flooding, a different set of flood proofing details are required to protect basement walls and floors.

## 6. Research Implications and Recommendations

The study revealed the lack of policies and regulations to carry out groundwater tests prior to construction of buildings in flood-prone areas with or without the inclusions of any subterranean features. It also revealed the lack of any strategies by the regulatory bodies for the enforcement of flood resilient design details as part of approval documents. More importantly it went further to confirm the dearth of flood knowledge amongst professionals in the building industry in such regions as shown in shown in a previous study.

Other implications of the research are the need for separation of flood types under the Flood and Erosion Act and the development of policies to deal with each flood type appropriately. The inclusion of flood proofing details, erosion control plans, drainage computations and flood proofing certifications as part of building approval documentations for States in flood-prone areas should be instituted as planning regulations and building bye-laws. Without these documentations, approval for construction

of buildings especially those with subterranean features should not be given.

A combination of techniques from [9,10,11] on protection of basement walls from moisture and flooding requires the following;

- Inclusion of a sub-drain behind the basement wall to prevent build-up of hydrostatic pressure
- Use of water proofing membrane on basement wall exterior
- Protection board over waterproofing membrane before backfill
- Well-constructed (monolithic) and well-compacted wall with high quality concrete
- Installation of backflow valves

At the last paragraph of the introduction, we stated that the inclusion of basements in buildings within high-risk flood areas is an architectural decision, while the protection of such basements is an engineering task. In all, the best form of mitigation against groundwater floods in high-risk flood zones that can result in basement flooding remains the siting of buildings on higher grounds and without the inclusion of basements. Essentially, a proactive architectural solution where basements are not included in the building design if it can be avoided is highly preferable to proffering protective engineering solutions to ensuring its dryness and continuous resilience. The cost-benefit analysis of the non-inclusion of basements can be seen in the reduced cost of the building in construction; reduced insurance premiums against floods; and elimination of the high probability of basement damage in the ever increasing likely event of flooding in high-risk flood zones.

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