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Aquatecture, a Climate-Responsive Building Innovative Strategy for the categories of floods affecting Buildings in Bayelsa State, Nigeria

Inivie Richard Abraham [1], Burabari Akpe Nwako [2], Warebi Gabriel Brisibe [3].

[1]Department of Architecture, Niger Delta University, Wilberforce Island, Bayelsa State.
[2]Department of Architecture, Bamidele Olumilua University of Education, Science and Technology, Ikere-Ekiti.
[3]Department of Architecture, Rivers State University.
Corresponding Author E-mail: burabarinwako@gmail.com

Abstract: ***As climate change keeps aggravating the nature and frequency of flood occurrences, Aquatecture, a water-centred innovative architectural design solution, seems to be a suitable solution for buildings in flood-prone areas, as conventional flood mitigation strategies have been observed not to yield the desired results in Bayelsa State. Floods are categorised internationally into minor, moderate, and major, based on their coverage, depth, and other characteristics such as duration and frequency, which have a direct relationship to the level of destruction they cause to buildings. Thus, this study seeks to examine the nature of the floods in Bayelsa State, using 2012 and 2018 as case studies, to determine their categorisation and in order to recommend suitable climate-responsive Aquatecture design strategies for the flood types in Bayelsa State. Secondary data enumerated the five standard Aquatecture strategies, which are: Flood Avoidance, Flood-resistant buildings, Flood-resilient buildings, Floating Architecture, and Ambitious Architecture. The study adopted a cross-sectional survey method to obtain primary data from a sample of 399 flood-affected residents in the selected 12 communities, within the six affected local government areas. The results of the study reveal that the 2012 and 2018 floods were both major floods, covering almost the entire affected local government areas, having an average depth of 2.7m and 2.4m, respectively, lasting for long periods of 3 months in 2012 and 6 weeks in 2018, and flowing at a slow velocity. The study found that Flood Avoidance (Stilted / Elevated Buildings), Floating Architecture, and Amphibious buildings as the most suitable Aquatecture approaches for the major floods in Bayelsa State. The study recommends, amongst others, that new buildings to be built should adopt the Stilted / Elevated Buildings design option. Also, Architects and building owners should explore the floating architecture and amphibious building Aquatecture design option for new residential buildings to be built on the river banks.***

Keywords: *Aquatecture,* Climate-responsive building, Flood categories, Flood-nature, Bayelsa State

1. Introduction

As the climate keeps changing over the years, generating more environmental issues, building designs are meant to respond to this ever-changing climate to survive in the flood (Irwin et al., 2015). Floods, known to be the main natural environmental issue in Bayelsa State, have become aggravated by climate change over the years, creating different categories of floods, causing damage to buildings and the built environment consistently (Abraham, Ojo, & Wokoro-Kosipre, 2025). Several conventional engineering solutions and structural mitigation strategies intended to resist the floods have not brought lasting solutions, as the floods keep exceeding them (Abraham and Odubo, 2024). The IPCC has recommended that rather than fighting the floods, communities should design buildings to live with the floods (IPCC, 2022). This idea also aligns with the United Nations Sustainable Development Goals (SDG 11), which aims at achieving sustainable cities and sustainable communities, and SDG 13, which focuses on combating climate change and its impacts (United Nations, 2015). Thus, buildings in flood-prone communities need to be designed and modified to adapt to the different types of floods and the damage they cause to buildings in the State. This is

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where Aquatecture, the collective term for architecture of buildings on water, offers the needed solutions (Baker and Coutts, 2016). Since buildings are the last line of defence for floods, designing them to thrive with the floods in areas like Bayelsa State, where flood defences have failed to provide an adequate solution, will reduce the flood risk to buildings and their occupants in the area.

Studies have shown that the nature of floods in Nigeria is fluvial floods (caused by rivers exceeding their capacity due to torrential rainfall), coastal (caused by severe storms forcing seawater to surge and affect the coastal regions), and Pluvial (relating to unanticipated flash floods which flow in rapidly) (Nkwunonwo, 2020). Rural dwellers and some urban dwellers, residing close to the rivers, are always affected by fluvial floods, while most of the urban dwellers frequently experience pluvial flash floods creating run-off into the rivers, which later return as fluvial floods on low-lying land. It has also been observed that most of the severe floods are caused by the release of excess water from the Lagdo Dam in Cameroon, affecting communities along the River Niger and River Benue path, and flowing down to the major rivers in the southern States of Delta, Bayelsa and Rivers, which are the major tributaries through which the flood water exits into the Atlantic Ocean (PDNA 2013; Olanrewaju & Louw, 2019). These floods generate different categories of damage to residential buildings in Bayelsa State, causing more than 50% of the residential buildings to experience minor and major damage in the 2012 and 2018 floods (Abraham et al., 2025).

Over the years, efforts have been put in place to reduce the damage of buildings by floods, but the impact has not been remarkable. According to Abraham and Odubo (2024), government and building occupants in flood-prone areas in Bayelsa State have implemented some structural mitigation strategies after the unprecedented 2012 flood, but the strategies were found to be insufficient and too elementary to mitigate the recurring floods. When the floods occur, dry lands turn into flood plains overnight, while the built environment turns into inter-city waterways, causing a devastating impact on the community (PDNA, 2013). Older buildings experience more major and severe damage in the affected communities, while traditional/indigenous buildings suffered near total damage (Abraham et al., 2025). There are records of the 2012 floods being so high in some areas that they inundate some buildings completely, while some buildings experience total collapse during the peak of the floods, which is usually in the months of October and November in any flood year (Abraham & Odubo, 2024). This relentless damage to buildings has created the need to search for more alternative strategies of coping with the nature of floods in Bayelsa State.

Consequently, the aim of this study is to assess the nature and categorisation of the 2012 and 2018 floods in Bayelsa State, and recommend, based on specific case studies from recent literature, suitable climate-responsive Aquatecture strategies for buildings in the region. The 2012 and 2015 floods are preferred for this study because both have been well documented, and the author collected authentic primary data for the analysis. To accomplish the aim, this present research seeks to investigate two primary objectives:

1. Determine the categorisation of the 2012 and 2018 floods into minor, moderate, and major floods in Bayelsa State.
2. Determine a suitable Aquatecture approach for the category of 2012 and 2018 floods in Bayelsa State.

2. Literature Review

2.1 Flood Size Categorisation

Floods are categorised in terms of their size in relation to the water level and based on impact, not universal numerical depth. (Bureau of Meteorology, [BoM] n.d.). These are major floods, moderate floods, and minor floods. Major floods are those that inundate very wide areas such as entire villages, towns, or cities, causing major devastation to the built environment and destabilizing economic activities for the city (Queensland Government, 2018). This kind of flood covers large areas of farmland, destroying farmsteads, crops, and wildlife, and may require large-scale evacuation. These kinds of floods are mostly generated by tidal storms and torrential rainfall, creating coastal floods, river floods, and dam and levee failures (Hirabayashi et al., 2013;

FEMA, n.d.; NOAA, n.d). Moderate floods, on the other hand, are floods that only inundate lowlands and cause moderate disruption of economic activities, such as blockage of roads and bridges (Queensland Government, 2018). They are caused by torrential rainfall, generating flash floods and overflowing of catchment areas. They may also require the moderate evacuation of people and properties. Some river floods and flash floods fall into this category. Minor floods are those that cause minor disruption of activities, inundation of small areas, and fewer roads. These floods submerge mostly low-lying areas and watersheds (Queensland Government, 2018). Table 1 clearly outlines the differences based on BoM (n.d.).

Table 1: Flood categorisation based on the Bureau of Meteorology

Flood Category	*Description (Adapted from BoM)*	*River Depths (BoM Standard)*
Minor Flood	*Flooding of low-lying areas, minor roads, and small infrastructure; minimal community disruption. These floods submerge mostly low-lying areas and watersheds.*	*Depths vary by river gauge; minor flooding begins at each river's defined "minor flood level."*
Moderate Flood	*Flooding affects homes, businesses, and transport routes; some evacuations and moderate disruption are required. Inundate lowlands and cause moderate disruption of economic activities, such as blockage of roads and bridges.*	*No universal depth; each river has an assigned "moderate flood level" set by local hydrological records.*
Major Flood	*Extensive flooding of towns, major infrastructure, and roads; widespread evacuations and major disruption. These kinds of floods are mostly generated by tidal storms and torrential rainfall, creating coastal floods, river floods, and dam and levee failures.*	*No universal depth; "major flood level" differs between rivers and is determined by historical impact benchmarks.*

Source: Generated from the categorisation of the Bureau of Meteorology (n.d.)

2.1 Flood Categorisation and Nature in Bayelsa State

The available studies, like Berezi et al. (2019), categorised the floods into high vulnerability zones, moderate vulnerability zones, and low vulnerability zones, using a Geographical information system for the study. Horsfall et al. (2023) also used a geospatial basis to categorise the State into high and very high flood susceptibility areas. Oladimeji and Ohwo (2022) also categorised the capital city of Bayelsa State, Yenagoa, into low, moderate, and high flood risk zones, using flood-risk mapping. The State is further classified as moderate flood risk and high flood areas according to Eteh et al. (2019). Collectively, these studies demonstrate that although Bayelsa has well-documented flood-risk or vulnerability classifications, there is no officially adopted system that categorises actual flood events into minor, moderate, or major floods. Even though available studies have not definitely categorised floods in Bayelsa State into major, moderate and minor floods, they have shown that floods have occurred every year in Bayelsa State since the 2012 floods (Nkwunonwo et al., 2020, 2021; UNDP, 2022), affecting most areas previously hit by the 2012 flood (Arokoyu, Amama & Obafemi, 2021; UNDP, 2022; International Organisation for Migration, 2024). From the data obtained from the report and cited studies, Table 2 was generated by combining all the information from the studies, in order to fit the flood depths of the floods in Bayelsa State and the Niger Delta region into the flood categorisation of the Bureau of Meteorology standard of flood categorisation.

Table 2: Characteristics for Categorisation and typical depths of floods in the Niger Delta

Flood Category	Description / Typical Impact	Depths Range (Niger Delta Context)
Minor Flood	*Inundation of low-lying farmland, footpaths, and minor roads. Residential buildings are largely unaffected. Minimal displacement.*	*0.1–0.5 m; shallow overland flow; early-stage seasonal floods (Berezi, Obafemi, & Nwankwoala, 2019; Oladimeji & Ohwo, 2022).*
Moderate Flood	*Partial inundation of residential areas, shops, and public spaces. Roads impassable; temporary evacuations common.*	*0.5–1.5 m; observed in most communities during 2018 & 2020 floods (Horsfall, Obafemi, & Ogoro, 2023; NEMA, 2018).*
Major Flood	*Widespread inundation; homes submerged to window or roof level. Large-scale displacement; boat-only movement; major disruption of services.*	*1.5–3.0 m+; documented in severe floods (2012 & 2022) in Bayelsa and surrounding states (Eteh, Egobueze, & Omonefe, 2019; NEMA, 2022).*

2.2 Aquatecture

Aquatecture is defined as 'A water-centric approach to design in which flood-risk management, development pressure and adaptation to climate change are simultaneously reconciled to allow buildings and cities to live and work with water' (Baker and Coutts, 2016, p. 10). It refers to the design of buildings and cities to live and work with water. The word, Aquatecture, was formed by the combination of the Latin word, Aqua, meaning water, and Architecture. It is a concept that has gained prominence in the world, focusing on architecture and urban designs that can thrive in water without being destroyed, by incorporating water as part of its design element (Baker and Coutts, 2016). Since water has been a vital part of human existence, it has shaped civilisation and fostered innovations; thus, Aquatecture aims to exclude water as a threat, but views it as a hydrosite – a water site for building construction (Baker and Coutts, 2016).

Buildings in flood-prone areas are bound to encounter residual risk of flooding when the floods exceed the available mitigation and defence systems (Baker and Coutts, 2016). Over the years, several strategies have been adopted to tackle the risk of flooding, but five Aquatecture approaches have been identified to effectively control flooding in flood-prone areas, these are: Flood avoidance, Flood resistance, Flood resilience, floating architecture, and amphibious buildings (Baker and Coutts, 2016).

2.2.1 Flood Avoidance

This approach involves locating the building away from the floodwater by raising it up using stilts or props (Baker and Coutts, 2016). Elevated stilt buildings are also known as permanent static elevation (English et al., 2016) are building that have been raised on vertical stilt supports above a certain flood level, most times above the predicted 100-year flood level (see Figure 1) Although, the stilts which is the foundation, still sits in the river bed, but the living space and properties are elevated permanently above the known flood level. This approach also encompasses buildings raised on filled or recalled ground intentionally raised above the floods. Baker and Coutts (2016) further stated that these buildings are elevated on concrete, steel, or bamboo, and these stilt materials must be able to withstand the water pressure, the weight of the floods, and the impact from debris floating in the flood. This approach is considered the best option, and has been in existence in many places in the world, including most riverine areas in Nigeria, and in most fishing camps in Bayelsa State (Brisibe, 2014). This approach is suitable for newer buildings to be built in flood-prone areas for different depths of water, where the maximum depths of previous floods are known (Baker and Coutts, 2016).

Figure 1.0: Elevated buildings in Kompong Phluk, Cambodia.
Source: My Ticklefeet, n.d

Figure 2.0: Elevated buildings in Galveston, Texas, United States of America
Source: English et al. (2016)

Figures 3.0: Abgada ware, which refers to 'house on stilts.'
Source: Brisibe (2014).

2.2.2 Flood Resistance (Dry-proofing)

This strategy seeks to exclude and restrict the water from entering the building's interior space. It is also known as dry proofing methods (Baker and Coutts, 2016). It involves totally keeping the flood water from entering the building through any means, making the building water-tight. This approach involves raising the building's floor level (plinth depths) above the known flood depths, installing automated flood barriers, and adding non-return valves and backflow blockages to drainages (Baker and Coutts, 2016). This method is recommended for floods that last just for hours, less than 0.6m, because studies have shown that water still enters the building for persistent floods that last for days and weeks (Baker and Coutts, 2016). Thus, the methods work better when combined with other methods. A typical case study of this method is the Flood-resistant homes in Stratford-upon-Avon (Figure 3.0) and a neighbourhood of homes using dry proofing in Dordrecht, Netherlands (Baker and Coutts, 2016).

Figure 4.0: Flood-resistant homes that employ a host of innovative features to keep their residents dry have been built on a flood plain in Stratford-upon-Avon.
Source: Construction Management (2020).

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Figure 5.0: Flood-resistant homes during a flood
Source: CBS Renovation (2025).

2.2.3 Flood Resilience (Wet Proofing)

This approach permits the flood water into the building in a controlled way (Baker and Coutts, 2016). It is also known as a wet proofing method, where the building materials are water-resistant enough not to be damaged by the flood, and recover easily. In this method, the water pressure inside the building balances with the water pressure outside the building, making the building able to withstand greater floods without structural failures in the case of dry proofing (Baker and Coutts, 2016). This method is recommended for buildings constructed with solid non-cavity blocks and floors, to prevent water from entering the cavities, which causes prolonged damage to the building fabric. The building should have water-resistant doors and windows, raised electrical sockets, water-tolerant wall and floor finish material. This method is more suitable for flood depths in excess of 0.6m, for existing single-story buildings, compared to dry proofing, as it helps to prevent the risk of structural failure (Baker and Coutts, 2016).

2.2.4 Floating Architecture

This approach involves the permanent floating of the building on the water, but anchoring it at a position so it only rises and descends with the level of the flood, without entering into the interior spaces to cause damage (Baker and Coutts, 2016). These buildings are lightweight buildings that are anchored to a post, which is used to prevent them from being washed away, but allows them to rise and decrease with the flood waters. The floatation works based on Archimedes' principle of floatation.

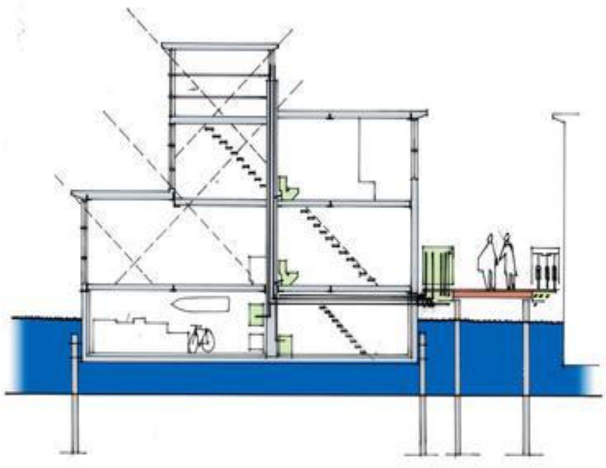

Figure 6.0: A cross-section of a floating house by Ahlqvist & Almqvist
Source: Rubin (2021)

Light-weight building materials such as bamboo and wood, fibre glass, polystyrene, and concrete rafts, waterproof concrete hulls (Baker and Coutts, 2016).

Figure 7.0: Floating homes development in Amsterdam.
Source: Rubin (2021)

It is recommended for areas where the flood water is relatively static, because high velocity floods can force them to break from their guides and drift away, causing damage to the building and properties along their path. Proper planning and building code should be followed to ensure controlled development of floating buildings (Baker and Coutts, 2016).

2.2.5 Amphibious Buildings

Amphibious buildings are similar to floating buildings; the difference is that amphibious buildings are fixed to a buoyant floatable base that sits on the ground, but floats when the flood water rises (Baker and Coutts, 2016). This method seems to be derived from the lifestyle of the amphibious animals that survive on land and in water. Amphibious buildings are suitable in areas where the flood water exceeds 1m in depth, to have sufficient buoyant force to float the building. They are also constructed of lightweight materials, similar to floating buildings (Baker and Coutts, 2016). As with floating buildings, amphibious buildings need to be stable to overcome the flowing flood water without tipping over. They are suitable for mature rivers, which are not characterised by hurricanes, storm surges, or tsunamis, having very devastating wave actions (Baker and Coutts, 2016). Some materials that can be used for construction include a plastic floating base, a steel base, and even a waterproof concrete base. Examples of amphibious buildings have been used in the Netherlands.

Figure 8.0: Floating homes in Maasbommel, Netherlands
Source: Aerial view of Maasbommel, Netherlands [Photograph] (n.d.)

Figure 9.0: BACA Architects' Amphibious House – normal position (left) and flooded position (right)
Source: Aquatecture – Blue Water Thinking (2012)

Furthermore, Table 3 below shows the Aquatecture flood-proof options in relation to the flood characteristics, to identify the effective approach for each flood type.

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Table 3: flood-proof options in relation to the flood characteristics

Aquatecture		Elevated property on structural walls	Elevated property supported on posts or columns	Dry flood-proofing/ resistance	Wet flood-proofing/ resilience	Floating construction	Amphibious construction
Flood characteristics							
Depth	Shallow (<0.3m)	✓	✓	✓	✓	✗	✗
	Fairly shallow (0.3–0.6m)	✓	✓	✓*	✓	✗	✗
	Moderate (0.6–2m)	✓	✓	✗**	✓	✗	✓*
	Deep (>2m)	✓	✓	✗	✗	✓*	✓
Velocity	Slow (<1m/s)	✓	✓	✓	✓	✓	✓
	Moderate (1–2m/s)	✓	✓	✗	✗	✗	✗
	Fast (>2m/s)	✗	✓	✗	✗	✗	✗
Character	Subject to rapid/flash flooding	✓	✓	✗	✗	✗	✗
	Subject to ice and debris flow	✓	✓	✗	✗	✗	✗
Site characteristics							
Location	Coastal floodplain	✓	✓	✓	✓	***	***
	Riverine floodplain	✓	✓	✓	✓	•	•
Soil type	Permeable	✓	✓	✗	✓	✗	✓
	Impermeable	✓	✓	✓	✓	✓	✓

Note:
** Subject to site conditions/details*
*** Flood depths above 0.6m can damage the structural integrity of buildings*
**** Only in protected areas where sudden fluctuations in levels are controlled*

Source: Generated by Author (2022)

3.0 Methodology

This study adopted the mixed method approach, combining interview and cross-sectional survey methods, to gather primary data from the residents of the flood-affected buildings. This study focused on 12 communities in the 6 affected local government areas that were affected by the 2012 and 2018 floods. The sample size for the study area is a percentage of the residential buildings affected by the 2012 and 2018 floods in the study area. According to the data provided by the PDNA (2013) as shown in Table 3.1, the total number of flood-affected houses in Bayelsa State was 132,888.

Table 3.1: Number of totally and partially destroyed houses by 2012 flood in affected states.

States	Traditional Totally Destroyed	Traditional Partially Damaged	Traditional Total Affected	Sandcrete Totally Destroyed	Sandcrete Partially Damaged	Sandcrete Total Affected	Overall Total Affected
Adamawa	117,829	36,134	153,963	23,401	23,401		177,364
Anambra	16,186	6,719	22,905	95,394	95,394		118,299
Bayelsa	79,730	26,577	106,307	26,577	26,577		132,884
Delta	84,834	4,465	89,299				89,299
Edo	13,153	14,249	27,402				27,402
Jigawa	11,623	5,230	16,853	282	282		17,135
Kebbi	103,048	52,555	155,603				155,603
Kogi	124,085	3,102	127,187	16,259	16,259		143,446
Nasarawa	16,326	136,049	152,375	5,759	5,759		158,134
Rivers	36,999	4,111	41,110	10,121	192,290	202,411	243,521
Taraba	81,688	32,675	114,363				114,363
TOTAL	685,501	321,866	1,007,367	10,121	359,962	370,083	1,377,450

Source: PDNA, 2013.

These 132,884 houses spread across the (2012 flood) affected local government areas in the state. Therefore to determine the sample size (number of residential buildings) affected by the 2012 floods in the study area with a population of flood affected houses of 132,884 at 95% confidence level, the Yemane's formula (1967) was used as follows:

n = N/ [1 + N(e)2]

Where:

n = sample size to be determined

1 = constant

N = Population size

e = sampling error (5%)

N = 132,884; e = 0.05

Therefore,

n = 132,884/ [1 + 132,884 (0.0025)]

n = 132,884/333.215
n = 398.919 approximated to 399

The expected sample was approximated to be 399 buildings to be randomly sampled by administering questionnaires to the occupants of such buildings. Thus, the sample size of 399 was obtained from the total number of 132,884 flood-affected houses in Bayelsa State (PDNA, 2013), using the Yamane (1967) formula for sample size determination.

The questionnaire was further proportionately distributed amongst the 12 flood-affected communities, in 6 flood-affected Local Government Areas, based on their population, to determine the number of respondents to be sampled for each community, as shown in Table 4.0 below.

Table 4.0 Respondents to be sampled for each community

S/No.	*Local government areas and Communities to be sampled*	*Number of questionnaires for sampled communities*	*Total number of questionnaires for each sampled Local government areas*
1	Ekeremor		72
	Aleibiri	51	
	Isampou	21	
2	Kolo//Opokuma		64
	Kaiama	27	
	Odi	37	
3	Ogbia		43
	Otueke	9	
	Otuokpoti	34	
4	Sagbama		35
	Toru Orua	9	
	Sagbama Town	26	
5	Southern Ijaw		139
	Amassoma	114	
	Angiama	25	
6	Yenagoa		46
	Yenagoa	27	
	Okolobiri	19	
	Total	399	399

Source: Generated by Author (2022)

4. Data Presentation and Discussion

4.1 Nature of the Flood in the 2012 and 2018 Floods

The nature of the floods can be understood by the depths of the floods in the environment, within the buildings, and outside the buildings. The velocity of the flood was characterised by the time it took to inundate the community, inside the buildings, and the time it took to recede from the buildings. This was achieved by determining the depths of the flood in the community, within and outside the buildings, and also obtaining the records of the time and days taken for the flood to leave the building and the community.

Maximum depths 2012 and 2018 floods inside the building

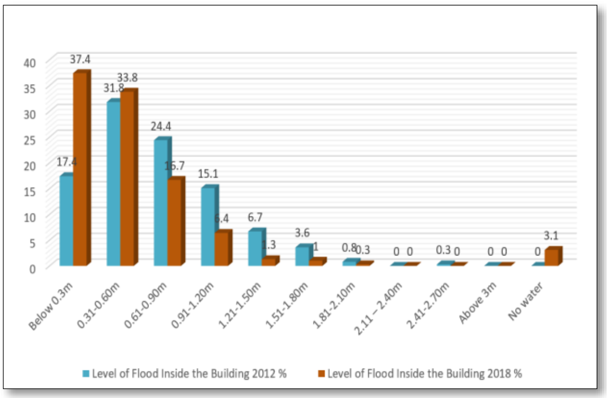

Figure 10.0: 2012 and 2018 flood levels inside the building
Source: Author (2022)

Figure 3.0 shows the percentage distribution of the maximum flood levels inside the buildings in 2012 and 2018, respectively, as indicated by the building occupants. As clearly represented by the histogram, 17.4 % (N=68) indicated the flood was below 0.3m in 2012, as compared to 37.4% in 2018. Also flood level between 0.31-0.6m was indicated by 31.85% (N=124) in 2012, while 33.8% (N=132) indicated that level in 2018. The next level of 0.61-0.90m was indicated by 24.4% in 2012, but indicated by 15.7% in 2018. Also, the flood level of 0.91-1.2m was indicated by 15.1% in 2012, but was indicated by 6.4% in 2018. Next level was 1.21-1.5m, indicated by 6.7% in 2012, while in 2018 it was indicated by 1.3%. The other level of 1.51-1.8m was indicated by 3.6% in 2012, but was indicated by just 1% in 2018. The 1.81-2.1m flood levels were indicated by 0.8% of the respondents in 2012, but just 0.3 indicated such in 2018. Furthermore, all respondents in 2012 indicated that the water entered their buildings, but in 2018, 3.1% indicated that no water entered their buildings. This indicates that the flood had a wide coverage in the State, which is a key characteristic of major floods as stated by BoM (n.d) and other studies in the Niger Delta (Berezi, Obafemi, & Nwankwoala, 2019; Oladimeji & Ohwo, 2022; Horsfall, Obafemi, & Ogoro, 2023; NEMA, 2018, 2022; Eteh, Egobueze, & Omonefe, 2019).

The study also revealed that the highest level of flood within the building in 2012 was between 2.41-2.7m, as indicated by 0.8% of the respondents, and the lowest level was below 0.3m, indicated by 17.4% of the respondents. Some buildings were inundated with flood depths from 1.51-2.7m (indicated by a total of 4.7% of the respondents), although fewer buildings were totally inundated with floods, as indicated by 0.8%. Also findings of the study shows that the highest level of flood within the buildings in 2018 was between 1.81 - 2.10m (indicated by 0.8% of the respondents), the lowest level was below 0.3m (indicated by 37.4% of the respondents) and most of the buildings (with a combined percentage of 87.9%) had flood levels of 0.31-0.9m. This indicated that the floods category in 2012 and 2018 was major flood, since the highest level of both floods were above the 1.5m threshold as indicated by most of the literatures on flood types in the Niger Delta shown in Table 2 (Horsfall, Obafemi, & Ogoro, 2023; NEMA, 2018, 2022; Eteh, Egobueze, & Omonefe, 2019).

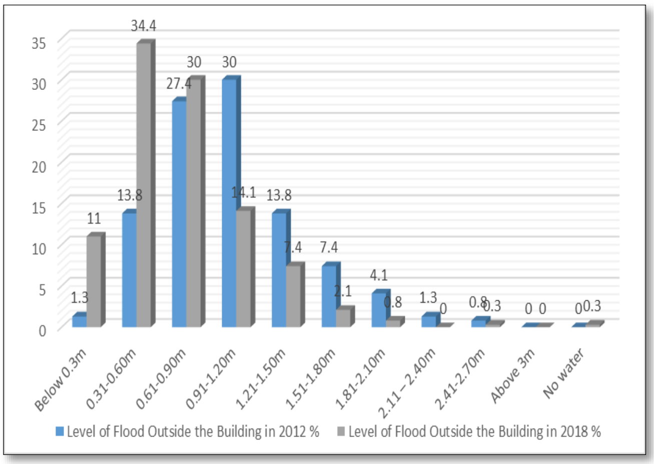

Figure 11.0: 2012 and 2018 flood levels outside the building
Source: Author (2022)

Figure 11.0 shows the percentage distribution of the maximum flood levels outside the buildings in 2012 and 2018, respectively, as indicated by the building occupants. As shown by the histogram, 1.3 % of the respondents indicated the flood was below 0.3 meters in 2012, as compared to 11% in 2018. Also flood level between 0.31-0.6m was indicated by 13.8% in 2012 compared to 34.4% in 2018. The next level of 0.61-0.90m was indicated by 27.4% in 2012, compared to 30% in 2018. Also, the flood level of 0.91-1.2m was indicated by 30% in 2012 compared to 14.1% in 2018. The next level was 1.21-1.5m, indicated by 13.8% in 2012, while in 2018 compared to 1.4% in 2018. The other level of 1.51-1.8m was indicated by 7.4% in 2012, but compared to just 2.1% in 2018. The flood level of 1.81-2.1m flood levels was indicated by 4.1% of the respondents in 2012, as compared to just 0.8 indicated such in 2018. The flood level of 2.11-2.4m was indicated by 1.3% in 2012, but no respondent indicated such in 2018. Finally, for flood levels above 3m, no respondent indicated such depths for both 2012 and 2018. Furthermore, all respondents in 2012 indicated that the water entered their buildings, but in 2018, 0.3% of the respondents indicated that the flood water did not enter their buildings. This is a further confirmation that the 2012 flood was a major flood, since it affected all the respondents in 2012, a total of 399 buildings.

Also, the highest level of the flood outside of the building in 2012 was between 2.41-2.7m, as indicated by 0.8% of the respondents, and the lowest level was below 0.3m, as indicated by 1.3% of the respondents. But a majority of the respondents (with a combined percentage of 71.3%) had outside buildings' flood level between 0.31-1.2m. A few of the buildings had a very high flood level of 2.7m both inside and outside the buildings, exposing a large portion of the building to severe structural damage that affected most of the buildings, including most building components, elements, and services below 2.7m. This accounted for the higher rate of major, severe, total/washed-away damages recorded in 2012 (Abraham et al., 2025). These findings agree with the report of the PDNA (2013), which indicated that Bayelsa State was the worst affected in terms of damage to housing, with 39% of the proportion of houses damaged in the housing sector, the second highest amongst the most affected States. This further supports the point that the 2012 flood was a major flood, causing widespread destruction of buildings and infrastructure.

The findings from the study imply that the levels in 2018 were slightly lower when compared to 2012, as clearly shown with the highest level outside the building in 2012 being between 2.41-2.7m (as indicated by 0.8% of the respondents), and in 2018 it was between 2.11-2.4m (indicated by 0.3 % of the respondents). This agrees with the outcome of the report of NEMA (2018), which stated that both floods were national disasters, which is a vital characteristic of major floods. The results of the study, which show that all the respondents in 2012 were affected by the floods, agree with the drone photographs of the flood incidents covering a vast area and almost inundating the buildings, as shown in Table 5.

Table 5.0: Flood Depth inside the building and outside the building for 2012 and 2018 floods

Year	Highest Depth Inside Buildings	Highest Depth Outside Buildings	Flood Character
2012	2.41–2.7 m	2.41–2.7 m	Major flood; widespread severe damage.
2018	1.81–2.10 m	2.11–2.4 m	Major flood, with several minor damages

Source: Author (2022)

Figure 12: Aerial view of the widespread impact of the 2012 flood in Bayelsa State
Source: Olaide, et al. (2014).

4.3 Duration of time for the flood to inundate the community, inside the buildings, and completely recede from the buildings.

The nature of floods in terms of their surge is determined by the time it takes to inundate the communities and the buildings, and also the time it takes to recede from the buildings. The graph below shows the duration of time it took the 2012 and 2018 floods to inundate the community, the building, and the time taken to recede from the buildings, as indicated by the building occupants.

Figures 13.0, 14.0, and 15.0 show the time taken for the floods to get to maximum height level in the communities, the buildings, and also the time to completely recede from the buildings, respectively. As represented in Figure 13.0, it took the flood 3 weeks to reach maximum height in the community in 2012, as indicated by 34.9% of the respondents, but took from 1-2 weeks to reach maximum height in 2018, represented by 31% of the respondents. Similarly, as seen in figure 4.8, the duration to get to maximum height in the buildings in 2012 was from 3 weeks, as indicated by 39% of the respondents, but took 1-2weeks, as indicated by 25.6% of the respondents. Also, as represented in Figure 4.9, most of the building occupants indicated that it took 2-3months for the floods to completely recede from all the buildings in 2012, as indicated by 35.6% of the respondents. But in 2018, most of the building occupants, making 41.5% indicated that it took 2-6 weeks for the floods to completely recede from the building.

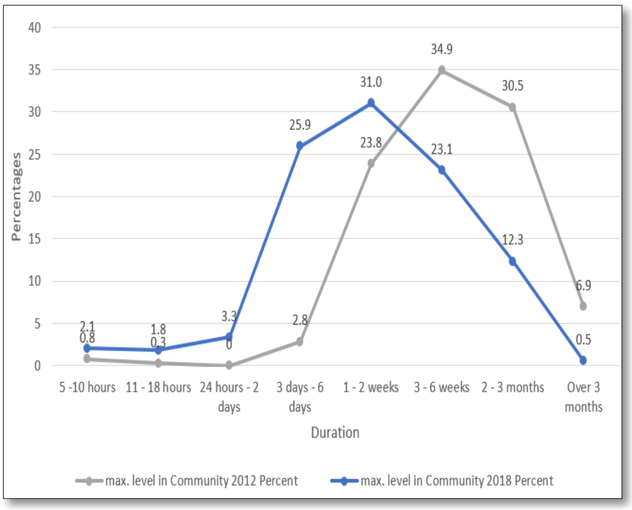

Figure 13.0: Time taken for the 2012 and 2018 floods to inundate the community
Source: Author (2022).

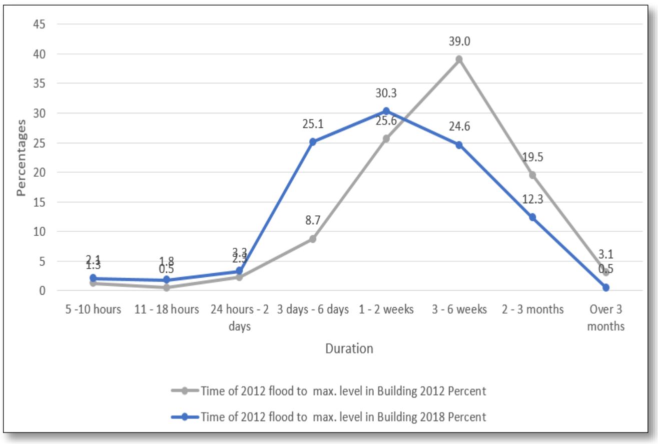

Figure 14.0: Time taken for the 2012 and 2018 floods to inundate the buildings
Source: Author (2022).

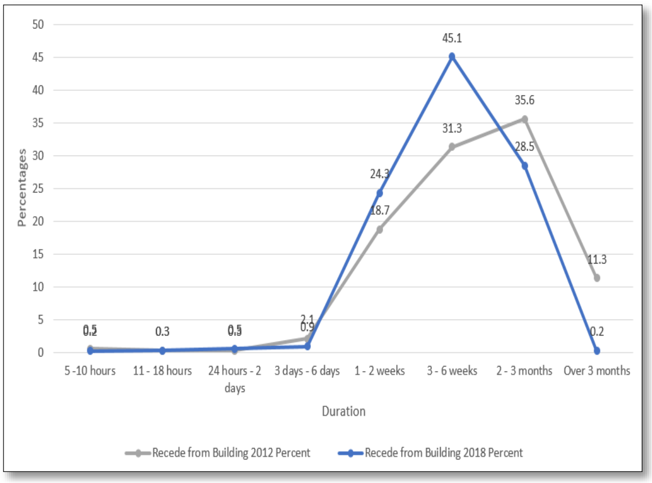

Figure 15.0: Time taken for the 2012 and 2018 floods to completely recede from the buildings
Source: Author (2022).

The analysed result also revealed that it took a longer time (3 - 6 weeks) for the 2012 flood to reach its maximum height in the communities and within the buildings, compared to the 2018 floods, which took just 1-2 weeks. The analysis of the data also revealed that most of the respondents affirmed that the flood of 2012 took up to 2-3 months to completely recede from the buildings, as compared to a 3-6week span indicated by a majority of the respondents for the 2018 floods to completely recede from the buildings. This long period of inundation experienced in the 2012 floods accounts for the many minor, major, severe, and total building damages in 2012 compared to the 2018 floods. This agrees with the statement of Blanco and Schanze (2014), who stated that the level of damage buildings incur during a flood is determined by the height of the flood water and the duration of the stay. This implies that the longer the duration of the floods, the more damage to buildings. This also aligns with the reason both floods were declared as national disasters in 2012 and 2018, respectively. The result of the analysis shows that the 2012 and 2018 floods spanned over two to three months (from early September to late November), spreading beyond the river banks into the communities, and built-up areas in most communities, even in Yenagoa, the State capital. Furthermore, the data revealed that the floods took over 3 months to recede from the buildings and the community, indicating that the floods are relatively slow in nature, making them easier to adapt to. Figure 16.0 and 17.0, also shows the magnitude of the flood waters and the mark on residential buildings, indicating that it will require some considerable amout of days for such inundation to recede. Based on the height and the duration of the flood, and that it affected six local government areas, this study concluded that the nature of the 2012 and 2018 floods was that of major floods, as categorised by Queensland Government (2018) flood categorisation.

Figure 16.0: Flood affected residential buildings in Bayelsa State
Source: Oyadongha (2012)

Figure 17.0: Flood mark on Residential Building in 2018 flood level mark in Otiokpoti, Ogbia Local Government Area.
Source: Author's Fieldwork (2022)

4.2 Determining the suitable Aquatecture strategy for the 2012 and 2018 major floods

According to Baker and Coutts (2016), the different Aquatecture approaches have specific flood inundation depths at which each approach can effectively handle. For the 2012 and 2018 floods, which, based on their characteristics, are found to be major floods in Bayelsa State, were assessed with the five Aquatecture approaches in Table 8 below. With the highest inundation depths of 2.7m in 2012 and 2.4m in 2018, a very high flood depth, it follows that Flood Avoidance (Stilted / Elevated Buildings), Floating Architecture, and amphibious buildings are the most suitable for the major floods in Bayelsa State. This is so because these 3 approaches are suitable for floods with high depths exceeding 1.0m – 1.5m, covering wide areas, and slow-moving, as stated by Baker and Coutts (2016). Other methods, such as Flood Resistance (Dry-proofing), and Flood Resilience (Wet-proofing), are not suitable for the 2012 and 2018 floods, because of the large inundation depth, which exceeds the safe height of 0.6m -1.5m for the safe dry proof, and also the appropriate height for building materials tolerance for wet proofing limits.

Table 4.0: Suitability table of Aquatecture approaches with the 2012 and 2018 major floods in Bayelsa State.

Aquatecture Approach	Description / Recommended Conditions	Suitability for 2012 Flood (2.4–2.7 m)	Suitability for 2018 Flood (1.8–2.4 m)	Reasoning Based on Depth & Characteristics
1. Flood Avoidance (Stilted / Elevated Buildings)	Should be elevated above the known flood level; effective for any depth if elevation is adequate (Baker & Coutts, 2016).	Highly Suitable	Highly Suitable	Can be elevated above the maximum recorded flood levels; already used in Bayelsa fishing settlements (Brisibe, 2014). Most effective for both major floods.

Aquatecture Approach	Description / Recommended Conditions	Suitability for 2012 Flood (2.4–2.7 m)	Suitability for 2018 Flood (1.8–2.4 m)	Reasoning Based on Depth & Characteristics
2. Flood Resistance (Dry-proofing)	Effective only for shallow floods <0.6 m; not suitable for long-lasting or high floods (>0.6 m).	Not Suitable	Not Suitable	2012 and 2018 floods reached 1.8–2.7 m—far above safe dry-proof limits. High hydrostatic pressure likely causes failure (Baker & Coutts, 2016).
3. Flood Resilience (Wet-proofing)	Suitable for >0.6 m; allows controlled inundation; recommended for single-storey solid-wall buildings.	Moderately Suitable	Moderately Suitable	It can withstand high water levels by balancing internal/external pressure. However, 2012 levels (up to 2.7 m) may exceed material tolerance, but 2018 slightly lower depths improve suitability.
4. Floating Architecture	Suitable where water is static; floats permanently; vulnerable to high-velocity floods; needs anchorage.	Possibly Suitable (Conditional)	Suitable (Conditional)	Bayelsa floods are riverine and slow-moving, not high-velocity like storm surges. Depths >1 m provide adequate flotation, but anchoring is essential. Best for planned developments.
5. Amphibious Buildings	Sits on ground but floats when water rises; best for >1 m flood depth (Baker & Coutts, 2016).	Highly Suitable	Highly Suitable	Both the 2012 and 2018 floods exceeded 1 m, providing enough buoyant force. Works well in mature rivers with no violent wave action—matching Niger Delta conditions.

5.0 Conclusion

This paper has examined the characteristics of the 2012 and 2018 floods in Bayelsa State, to determine that these floods were major floods, with inundation depths exceeding 2.7m in 2012 and 2.4m in 2018, covering a wide area (six local government areas), lasting for 2-3 months in 2012 and 3-6 weeks in 2018, and having a slow flowing velocity. It has also assessed the criteria for the application of the five world-renowned Aquatecture flood-proof approaches: Flood avoidance, Flood resistance, Flood resilience, Floating architecture, and Amphibious buildings (Baker and Coutts, 2016). It successfully found Flood Avoidance (Stilted / Elevated Buildings), Floating Architecture, and Amphibious buildings as the most suitable Aquatecture strategies to apply to safely live, thrive, and adapt with the major floods of 2012 and 2018, and similar floods of the same nature in Bayelsa State.

6.0 Recommendations

Based on the above conclusions, the following recommendations are proffered for Bayelsa State:

1. The government should enforce that new buildings built should follow the Flood Avoidance (Stilted / Elevated Buildings) approach, elevating the main living spaces and making the ground floor wet-proof and flood-tolerant spaces, such as using it for outdoor activities like car parks, games space, or family sit-out space.
2. Architects, as the originators of building designs, should start designing contemporary and sustainable Stilt, Floating, and Amphibious buildings for residential living in flood-prone areas of Bayelsa State.
3. Building owners and occupants should have elevated platforms and safe elevated buildings to preserve their valuable property from the floods, due to the unpredictable but slow nature of the floods in Bayelsa State.
4. Older buildings that cannot be modified to elevated buildings should apply the flood resilient approach by retrofitting the buildings with water-resistant and water-friendly materials, elevated electrical systems, and mechanical services above the

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