

Flood Resilient Housing in Flood Prone Environment of Rivers State

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Abstract- Flooding has emerged as one of the most persistent environmental challenges affecting housing development and urban sustainability in Nigeria's Niger Delta region, with Rivers State experiencing recurrent flooding that threatens housing quality, safety, and long-term sustainability. This study examined flood-resilient housing strategies in flood-prone environments of Rivers State, specifically focusing on five communities: Diobu (Mile 1-3), Ogbunabali, Borikiri, Rumueme, and Rumuola. The study was anchored on three theoretical frameworks: Pressure and Release (PAR) Theory, Resilience Theory, and Human Adaptation Theory, providing a comprehensive lens for understanding vulnerability, resilience, and adaptive housing strategies. A mixed-methods research design was employed, combining quantitative data from 390 household questionnaires with qualitative data from 10 key informant interviews with building professionals and government officials. Physical observations using structured checklists complemented self-reported data. The findings revealed that 77.7% of respondents experience flooding at least annually, with poor drainage systems (mean = 4.62), heavy rainfall intensity (mean = 4.58), and blocked drainage channels (mean = 4.51) identified as primary causes. Structural damage to walls and foundations affected 68.2% of housing units, while 61.5% reported damage to household belongings. Existing housing design practices demonstrated critical deficiencies, with only 23.1% of buildings achieving floor elevations above the recommended 0.6 metres, 38.5% having functional drainage integration, and incorporation of flood-resilient features ranging from 8.5% to 31.5%. Lack of awareness (36.4%) and higher construction costs (25.1%) were the main barriers to adopting flood-resilient design. Awareness of advanced resilience techniques remained below 20%, while adoption favoured reactive strategies such as moving belongings (74.9%) over permanent structural adaptations like floor raising (s28.5%) despite high effectiveness ratings for the latter. Community variations showed Diobu exhibiting the poorest resilience indicators, with lowest floor elevations (0.38m) and highest structural damage (76.8%), while Borikiri and Rumuola demonstrated relatively better conditions. Key informant

interviews revealed four major themes constraining flood-resilient housing: weak regulatory enforcement, inadequate technical capacity among local builders, economic constraints and affordability challenges, and the need for integrated approaches combining design innovation with institutional reform. The study concludes that flood-resilient housing in Rivers State requires addressing not only technical design deficiencies but also the institutional, economic, and social dimensions that shape housing development decisions. Recommendations include prioritising drainage infrastructure investment, developing and enforcing minimum flood-resilient building standards, implementing capacity-building programmes for builders and residents, and establishing incentive schemes for low-income households incorporating approved resilience features. These findings contribute to understanding flood-resilient housing in a developing country context and provide evidence-based guidance for policy formulation and sustainable housing delivery in flood-prone environments.

Index Terms- Flood, Resilient Housing, Environment, Rivers State, Port Harcourt

I. INTRODUCTION

Flooding has become a perennial environmental challenge affecting housing development and urban sustainability in Nigeria, particularly within the Niger Delta region. Rivers State, characterised by low-lying terrain, high annual rainfall, tidal influence, and rapid urbanisation, experiences recurrent flooding that threatens housing quality, safety, and long-term sustainability. Climate change has further intensified flood frequency and magnitude, increasing pressure on existing housing stock and exposing weaknesses in planning and construction practices (Mitchell & Carter, 2024).

Recent studies emphasise that flooding in Rivers State is not solely a natural phenomenon but is

exacerbated by inadequate urban planning, poor drainage infrastructure, and limited integration of climate-resilient housing strategies (Elum & Lawal, 2022). Housing developments in Port Harcourt and its environs often fail to incorporate flood-resilient architectural designs, resulting in structural damage, displacement, and high recovery costs (Okey-Ejiowhor & Akani, 2025). In response, scholars increasingly advocate for sustainable and green building approaches that enhance resilience through adaptive design, material selection, and environmental sensitivity (Adeyanju *et al.*, 2025).

Globally and locally, flood-resilient housing is recognised as a critical component of climate adaptation and disaster risk reduction. Decision-making frameworks for pre-flood housing resilience stress the importance of integrating environmental risk assessment into housing policy and development processes (Anthony *et al.*, 2022). In Nigeria, however, the adoption of such frameworks remains limited, particularly at the sub-national level.

Despite growing awareness of flood risks, housing development in Rivers State continues to occur in flood-prone locations with limited consideration for resilience and sustainability. Empirical evidence shows that many residents possess low levels of flood preparedness and rely largely on reactive rather than preventive coping strategies (Elum & Lawal, 2022). The absence of enforceable building standards that prioritise flood resilience has resulted in repeated housing losses and socio-economic disruptions.

Studies from comparable Nigerian contexts, such as Makurdi in Benue State and coastal communities in Cross River State, reveal that flooding significantly undermines housing development and disproportionately affects vulnerable populations, including women (Unum, 2025; Uquetan *et al.*, 2025). While research has examined flood impacts and architectural responses, there remains a gap in synthesising climate mitigation, housing design, and resilience strategies specifically within Rivers State. This gap limits effective policy formulation and sustainable housing delivery.

The main objective of this study is to examine flood-resilient housing strategies in flood-prone

environments of Rivers State. The specific objectives are to:

1. assess the nature and causes of flooding affecting housing development in Rivers State;
2. examine existing housing design and construction practices in flood-prone areas;
3. evaluate the effectiveness of flood-resilient and sustainable housing strategies; and
4. propose policies and design measures for improving flood-resilient housing development in Rivers State.

II. LITERATURE REVIEW

2.1 Theoretical Review

2.1.1 Pressure and Release (PAR) Theory

The Pressure and Release (PAR) Theory by Blaikie *et al.* (1994) explains disasters as the outcome of natural hazards interacting with social vulnerability created by unsafe conditions, weak institutions, and poor planning. Flooding therefore becomes disastrous when environmental exposure intersects with inadequate preparedness, weak urban governance, and high-risk settlement patterns.

This theory is particularly relevant to Rivers State, where flood impacts are intensified by low-lying terrain, poor drainage infrastructure, and unregulated urban development. Empirical support for this position is provided by Elum and Lawal (2022), who found that limited risk perception, inadequate disaster preparedness, and weak response mechanisms significantly increase flood vulnerability in urban communities of Rivers State. Their findings reinforce the PAR argument that floods become destructive due to underlying social and institutional pressures rather than natural causes alone.

2.1.2 Resilience Theory

Resilience Theory as explained by Holling (1973) conceptualizes resilience as the capacity of systems to absorb shocks, adapt, and recover without losing essential structure and function. Applied to housing, the theory emphasizes adaptive architectural design,

durable materials, and construction strategies that reduce damage and speed post-flood recovery.

In flood-prone environments such as Rivers State, resilience-oriented housing is reflected in elevated structures, flood-resistant materials, and climate-responsive design. This theoretical position is strongly supported by Okey-Ejiowhor and Akani (2025), whose study on Port Harcourt Metropolis demonstrates that architectural design choices significantly enhance housing resilience to flooding. Similarly, Adeyanju et al. (2025) highlight green building strategies—such as permeable surfaces, elevated foundations, and water-resistant materials—as critical components of climate-resilient housing in flood-prone areas of Nigeria. These studies operationalize Resilience Theory within the Nigerian built-environment context.

2.1.3 Human Adaptation Theory

Human Adaptation Theory by Burton (1978) explains how individuals and communities actively adjust behaviour, technology, and settlement patterns in response to environmental hazards. Rather than viewing people as passive victims of floods, the theory emphasizes learning, innovation, and adaptive decision-making shaped by experience and local knowledge.

In Rivers State, flood-prone communities have adopted adaptive practices such as raised housing, seasonal mobility, and locally informed building modifications. Elum and Lawal (2022) empirically demonstrate that community perceptions of flood risk directly influence preparedness and response behaviour, validating Burton's argument that adaptation is shaped by human awareness and experience. Additionally, Adeyanju et al. (2025) show that adaptation is increasingly being formalized through sustainable and green housing strategies that combine indigenous knowledge with modern construction practices.

The Pressure and Release (PAR) Theory explains flooding disasters as outcomes of natural hazards interacting with social vulnerability caused by weak institutions, poor planning, and unsafe settlements, a condition evident in Rivers State's flood-prone urban communities. Resilience Theory emphasises the

capacity of housing systems to absorb, adapt to, and recover from flood impacts through resilient architectural design, durable materials, and climate-responsive construction. Human Adaptation Theory highlights how communities actively adjust behaviour, technologies, and building practices in response to repeated flooding. Together, these theories provide a comprehensive framework linking vulnerability, resilience, and adaptive housing strategies in flood-prone environments of Rivers State.

2.2 Conceptual Review

2.2.1 Flooding

Flooding refers to the temporary inundation of normally dry land resulting from excessive rainfall, river overflow, tidal surge, or inadequate drainage systems. In urban coastal environments, flooding is often intensified by human activities such as unregulated development, land reclamation, and obstruction of natural waterways (Echendu & Georgeou, 2021). In Rivers State, flooding is predominantly pluvial and fluvial, exacerbated by low elevation, high rainfall intensity, and proximity to tidal creeks.

Within Port Harcourt, communities such as Diobu, Ogbunabali, Borikiri, and Rumueme experience recurrent flooding during the rainy season, leading to structural damage, displacement of residents, and deterioration of environmental quality (Gerald-Ugwu et al., 2019). Elum and Lawal (2022) observe that flooding in these communities is worsened by poor drainage maintenance and limited institutional preparedness. Similar findings from Makurdi indicate that flooding significantly disrupts housing development and urban functionality (Unum, 2025), underscoring the national relevance of the problem. Flooding in the selected communities is not merely a physical hazard but a socio-economic challenge affecting livelihoods, public health, and housing sustainability. Consequently, understanding flooding within these specific local contexts is essential for developing targeted resilience and housing adaptation strategies.

2.2.2 Flood-Resilient Housing

Flood-resilient housing refers to residential structures designed, constructed, and managed to withstand,

adapt to, and recover rapidly from flood events with minimal damage and disruption. Such housing incorporates architectural design strategies, elevated floor levels, flood-resistant materials, efficient drainage integration, and adaptive land-use planning (Anthony et al., 2022). Flood resilience moves beyond post-disaster recovery to proactive risk reduction.

In Port Harcourt Metropolis, housing developments in communities like Rumuola, Diobu, and Borikiri often lack these resilience features, resulting in repeated flood damage and escalating maintenance costs (Okey-Ejiowhor & Akani, 2025). Okey-Ejiowhor and Amakiri (2025) further note that many residential buildings fail to respond adequately to pluvial flooding due to design deficiencies and weak regulatory enforcement.

Flood-resilient housing is particularly relevant in densely populated low-income areas such as Mile 1–3 Diobu, where informal construction practices prevail. Integrating flood-resilient principles into housing development in these communities can reduce vulnerability, enhance safety, and promote sustainable urban living. This study therefore situates flood-resilient housing as a critical response mechanism to persistent flooding in Rivers State's urban flood-prone environments.

2.2.3 Climate Resilience

Climate resilience refers to the capacity of human systems, including housing, to anticipate, absorb, adapt to, and recover from climate-induced hazards such as flooding without compromising long-term sustainability (Holling, 1973; Cutter, 2016). In the housing sector, climate resilience is closely linked to green building and sustainable construction practices that minimise environmental impact while enhancing adaptive capacity (Kibert, 2016).

Adeyanju et al. (2025) emphasise that climate-resilient housing in flood-prone areas of Nigeria should integrate green building strategies such as permeable surfaces, rainwater harvesting, energy-efficient materials, and site-sensitive design. In Port Harcourt communities like Rumueme and Ogbunabali, however, these strategies are rarely

adopted, despite increasing flood risks driven by climate change (Mitchell & Carter, 2024).

The absence of climate-responsive housing design has heightened vulnerability among urban residents, particularly women and low-income households, as observed in similar coastal contexts (Uquetan et al., 2025). Embedding climate resilience into housing development in the selected communities is therefore essential for reducing flood impacts, improving housing durability, and supporting sustainable urban growth in Rivers State.

Empirical studies on flooding and housing in Rivers State consistently demonstrate that flood impacts are driven by a combination of environmental exposure and human-induced factors. Elum and Lawal (2022) empirically establish that low flood-risk perception, weak preparedness, and inadequate institutional response significantly heighten vulnerability in urban communities. Gerald-Ugwu et al. (2019) further show that unregulated building practices and encroachment into floodplains accelerate flood damage in Port Harcourt. Studies by Okey-Ejiowhor and Akani (2025) and Okey-Ejiowhor and Amakiri (2025) provide strong evidence that architectural design choices—such as floor elevation, material selection, and drainage integration—play a critical role in enhancing housing resilience. Similarly, Adeyanju et al. (2025) and Anthony et al. (2022) highlight the effectiveness of green building and pre-flood decision-making frameworks in reducing housing vulnerability, while comparative studies from Makurdi and Cross River State confirm the wider national relevance of flood-resilient housing strategies (Unum, 2025; Uquetan et al., 2025).

Overall, the literature establishes flooding as a major

threat to housing sustainability and recognises resilience, adaptation, and green construction as effective responses. However, a clear gap exists in empirically integrating flood causation, housing design practices, and climate-resilient strategies within a single, location-specific framework for Rivers State. This study fills that gap by systematically assessing flooding causes, existing housing practices, and resilience strategies, thereby providing evidence-based policy and design

recommendations tailored to flood-prone communities in Rivers State.

III. METHODOLOGY

3.1 Research Design

This study adopts a mixed-methods research design, combining quantitative and qualitative approaches to comprehensively examine flood-resilient housing strategies in flood-prone environments of Rivers State. The mixed-methods design is particularly appropriate for this study as it allows for the collection of numerical data on housing characteristics and flood impacts while also capturing the lived experiences, perceptions, and adaptive practices of residents and housing professionals. This triangulation enhances the validity and depth of findings, consistent with recommendations by Creswell and Creswell (2018) for housing and environmental research.

3.2 Study Area

The study is conducted in selected flood-prone communities within Rivers State, Nigeria, specifically focusing on Port Harcourt Metropolis and its environs. Based on empirical evidence from Gerald-Ugwu et al. (2019) and Elum and Lawal (2022), the following communities are purposively selected: Diobu (Mile 1–3), Ogbunabali, Borikiri, Rumueme, and Rumuola. These communities experience recurrent annual flooding, exhibit varied housing typologies, and represent different levels of urbanisation and socio-economic characteristics, making them ideal for comparative analysis.

3.3 Population of the Study

The target population comprises all residential property owners, tenants, household heads, building professionals (architects, engineers, town planners), and officials of relevant government agencies (Rivers State Ministry of Urban Development, Rivers State Physical Planning Authority, and National Emergency Management Agency) operating within the selected communities. The exact population is infinite, necessitating sampling for quantitative data collection.

3.4 Sample Size and Sampling Technique

A multi-stage sampling technique is employed. First, purposive sampling is used to select the five flood-prone communities based on flood frequency and housing density. Second, systematic random sampling is adopted to select 400 residential buildings across the communities, proportionate to community size (NPC, 2024). This sample size is determined using Yamane's formula at 5% margin of error. For qualitative data, purposive sampling is used to select 25 key informants comprising 10 residents with long-term flood experience, 10 building professionals, and 5 government officials.

3.5 Instruments for Data Collection

Three instruments are developed for data collection:

1. **Structured Questionnaire:** Administered to household heads, the questionnaire contains closed-ended questions organised into sections covering socio-demographic characteristics, flood experience, housing design features, awareness of flood-resilient strategies, and adaptive practices. Items are measured on Likert and nominal scales.
2. **Observation Checklist:** A researcher-designed checklist is used to physically assess housing characteristics including building materials, foundation type, floor elevation, drainage integration, and evidence of flood damage. This provides direct empirical validation of self-reported data.
3. **Key Informant Interview Guide:** A semi-structured guide facilitates in-depth interviews with building professionals and government officials, exploring institutional perspectives on flood-resilient housing, policy implementation challenges, and recommendations for improvement.

3.6 Validity and Reliability of Instruments

Content and face validity of instruments are established through expert review by three academics in housing, urban planning, and environmental management. Their feedback informs necessary revisions. Reliability of the questionnaire is tested through a pilot study conducted in a non-selected flood-prone community (Rumuokwurushi) with 30 respondents. Cronbach's Alpha coefficient is computed using SPSS, with a threshold of 0.70 considered acceptable for internal consistency.

3.7 Method of Data Collection the study communities, facilitate questionnaire administration to improve access and re

Data collection is conducted over eight weeks. Research assistants, recruited and trained from sponse rates. Questionnaires are distributed on weekdays and weekends to capture diverse respondents. Observations are conducted immediately after rainfall events to maximise visibility of flood impacts. Key informant interviews are scheduled at respondents' convenience, audio-recorded with consent, and transcribed verbatim.

3.8 Method of Data Analysis

Quantitative data from questionnaires are coded, entered, and analysed using SPSS (Version 26). Descriptive statistics (frequencies, percentages, mean scores measured on risk levels 1.0 for Very low risk – 5 Extremely risky) are used to summarise flood causes, housing characteristics, and resilience strategies. Qualitative data from interviews and observations are analysed thematically using NVivo, following Braun and Clarke's (2006) six-phase framework: familiarisation, coding, theme development, review, definition, and reporting. Qualitative findings are presented as narratives and verbatim quotes to complement quantitative results.

IV. RESULTS

4.1 Questionnaire Response Rate

A total of 390 questionnaires were fully completed and retrieved from respondents across the five selected flood-prone communities in Rivers State, representing a 97.5% response rate of the initial 400 sampled residential buildings. This high response rate is attributable to the deployment of trained research assistants from the study communities and the extended data collection period of eight weeks, which allowed for repeated visits to non-responding households. The distribution of respondents across the five communities is presented in Table 1.

Table 1: Distribution of Respondents by Community

Community	Frequency (n)	Percentage (%)
Diobu (Mile 1-3)	112	28.7
Ogbunabali	86	22.1
Borikiri	74	19.0

Rumueme	62	15.9
Rumuola	56	14.3
Total	390	100.0

4.2 Socio-Demographic Characteristics of Respondents

The socio-demographic profile of the 390 respondents is presented in Table 2. The results indicate that 58.2% of respondents were male, while 41.8% were female, reflecting the predominance of male household heads in the study area. The majority of respondents (44.6%) were aged between 36-50 years, followed by those aged 21-35 years (30.5%). Only 8.7% were aged above 60 years, suggesting limited elderly representation in flood-prone areas, possibly due to relocation to safer areas.

Educational attainment shows that 41.3% of respondents had secondary education, 30.8% had tertiary education, while 19.2% possessed only primary education. A small proportion (8.7%) had no formal education, indicating relatively high literacy levels across the communities. Regarding occupation, 35.9% were self-employed in trading and small-scale businesses, 23.6% were civil servants, 20.5% were artisans, and 20.0% were engaged in other occupations including fishing and transportation.

In Table 2 Length of residence in the flood-prone communities varied considerably, with 32.1% of respondents having lived in their communities for 11-20 years, 28.5% for 6-10 years, and 22.3% for over 20 years. Only 17.1% had resided in the area for 5 years or less, indicating that most respondents possess substantial experience with local flood conditions. This long-term residence suggests accumulated knowledge of flood patterns and adaptive practices, which is relevant for assessing flood-resilient housing strategies.

Table 2: Socio-Demographic Characteristics of Respondents

Characteristic	Category	Frequency (n)	Percentage (%)
Gender	Male	227	58.2
	Female	163	41.8
Age Group	20 years and below	38	9.7
	21-35 years	119	30.5

	36-50 years	174	44.6
	51-60 years	25	6.4
	Above 60 years	34	8.7
Educational Level	No formal education	34	8.7
	Primary education	75	19.2
	Secondary education	161	41.3
	Tertiary education	120	30.8
Occupation	Civil servant	92	23.6
	Self-employed/Trader	140	35.9
	Artisan	80	20.5
	Others	78	20.0

4.3 Nature and Causes of Flooding Affecting Housing Development

4.3.1 Flood Frequency and Seasonality

Respondents were asked to indicate the frequency of flooding experienced in their communities. The results in Table 3 show that 42.1% of respondents reported experiencing flooding annually, while 35.6% reported flooding twice or more per year. Only 12.3% reported flooding every five years, and 10.0% reported flooding only during extreme events. These findings confirm that flooding is a recurrent phenomenon in the study communities, with 77.7% experiencing flooding at least once annually.

Regarding seasonality, all respondents (100.0%) identified the rainy season (April–October) as the primary period for flooding, with peak flooding reported in June, July, and September. This aligns with the bimodal rainfall pattern characteristic of the Niger Delta region.

Table 3: Flood Frequency in Study Communities

Flood Frequency	Frequency (n)	Percentage (%)
Twice or more per year	139	35.6
Annually	164	42.1
Every five years	48	12.3
Only during extreme events	39	10.0
Total	390	100.0

4.3.2 Perceived Causes of Flooding

Respondents assessed the extent to which various factors contribute to flooding in their communities using a 5-point Likert scale (1 = Not a cause, 5 = Major cause). The mean scores and rankings are presented in Table 4.

Table 4: Perceived Causes of Flooding in Study Communities

Cause of Flooding	Mean Score	Standard Deviation	Rank
Poor drainage systems	4.62	0.58	1
Heavy rainfall intensity	4.58	0.62	2
Blocked drainage channels	4.51	0.71	3
Building on floodplains	4.43	0.76	4
Low-lying terrain	4.38	0.82	5
Inadequate waste disposal blocking waterways	4.32	0.79	6
Lack of drainage maintenance by government	4.28	0.84	7
Tidal influence/backflow from rivers	4.11	0.96	8
Climate change/sea level rise	3.96	1.02	9
Encroachment on natural waterways	3.88	1.08	10

The results in Table 4 reveal that poor drainage systems (mean = 4.62) rank as the most significant cause of flooding, closely followed by heavy rainfall intensity (mean = 4.58) and blocked drainage channels (mean = 4.51). Human-induced factors including building on floodplains (mean = 4.43) and inadequate waste disposal (mean = 4.32) also rank highly. Climate change and sea level rise (mean = 3.96) were rated relatively lower, though still recognised as contributing factors. These findings suggest that flooding in the study area is predominantly driven by a combination of environmental factors and anthropogenic activities, particularly inadequate and poorly maintained drainage infrastructure.

4.3.3 Flood Impacts on Housing Development

Table 5 presents respondents' assessment of flood impacts on their housing units. The most frequently

reported impact was structural damage to walls and foundations, reported by 68.2% of respondents. This was followed by damage to household belongings (61.5%), deterioration of building materials (57.9%), and increased maintenance costs (54.6%). Notably, 41.3% of respondents reported temporary displacement from their homes due to flooding, indicating significant social disruption.

Table 5: Flood Impacts on Housing Units

Impact Type	Frequency (n)	Percentage (%)
Structural damage to walls and foundations	266	68.2
Damage to household belongings	240	61.5
Deterioration of building materials	226	57.9
Increased maintenance/repair costs	213	54.6
Floodwater entering living spaces	198	50.8
Damage to electrical installations	172	44.1
Temporary displacement from home	161	41.3
Moss/dampness on walls	148	37.9
Cracking of floors	135	34.6
Collapse of fences/compound walls	92	23.6

Note: Percentages are based on N = 390 respondents. Multiple responses were applicable as respondents could report multiple flood impacts.

Qualitative data from key informant interviews reinforced these quantitative findings. One resident from Diobu with 15 years of flood experience stated: "Every rainy season, we know what to expect. The water enters our compound, sometimes up to knee level. Last year, the foundation of my neighbour's house developed big cracks, and he had to spend almost ₦500,000 on repairs. Some people have abandoned their houses because they cannot afford to keep fixing them." (KII-03, Resident, Diobu, 45 years)

A building professional similarly observed: "The housing stock in these flood-prone areas is deteriorating faster than it should because developers do not consider flood resilience during construction.

They use ordinary sandcrete blocks without adequate damp-proofing, and foundations are too shallow. When floodwater comes, the blocks absorb moisture and gradually lose strength." (KII-12, Architect, Port Harcourt, 52 years).

4.4 Existing Housing Design and Construction Practices in Flood-Prone Areas

4.4.1 Housing Typology and Construction Characteristics

Physical observation and questionnaire data revealed the housing characteristics presented in Table 6. The majority of residential buildings in the study communities (67.9%) are bungalows, while 32.1% are storey buildings. Wall construction materials are predominantly sandcrete blocks (81.3%), followed by concrete (12.8%) and mud/earth (5.9%). Floor construction materials are mainly concrete (76.9%) and cement screed (18.2%). Regarding foundation type, 56.4% of buildings have strip foundations, 31.8% have raft foundations, and only 11.8% have pile foundations, which offer greater flood resilience. The mean floor elevation above ground level was 0.46 metres (approximately 1.5 feet), with significant variation across communities (range: 0.15 metres to 1.2 metres). Only 23.1% of buildings had floor elevations exceeding 0.6 metres (2 feet), the minimum threshold recommended for flood-prone areas by building professionals interviewed.

Table 6: Housing Characteristics in Study Communities

Characteristic	Category	Frequency (n)	Percentage (%)
Building Type	Bungalow	265	67.9
	Storey building	125	32.1
Wall Material	Sandcrete blocks	317	81.3
	Concrete	50	12.8
	Mud/Earth	23	5.9
Floor Material	Concrete	300	76.9
	Cement screed	71	18.2
	Earth/Mud	19	4.9
Foundation Type	Strip foundation	220	56.4
	Raft	124	31.8

	foundation		
	Pile foundation	46	11.8
Floor Elevation	Below 0.3m	142	36.4
	0.3m – 0.6m	158	40.5
	Above 0.6m	90	23.1

Note: Percentages are based on N = 390 respondents. Multiple responses were applicable as respondents could report multiple flood impacts.

4.4.2 Drainage Integration and Site Planning

Assessment of drainage integration revealed that only 38.5% of residential buildings had functional drainage channels connecting to main community drains. The majority (61.5%) relied on natural infiltration or discharged wastewater directly onto streets. Additionally, only 27.9% of buildings had proper site grading to direct water away from structures, while 72.1% showed evidence of water ponding around foundations during rainfall observations. Table 7 presents respondents' reports on whether their housing design incorporated specific flood-resilient features at the time of construction.

Table 7: Incorporation of Flood-Resilient Features in Housing Design

Flood-Resilient Feature	Incorporated (%)	Not Incorporated (%)
Elevated floor level above street	31.5	68.5
Flood-resistant wall materials	18.7	81.3
Proper drainage around building	27.9	72.1
Waterproofing of foundations	22.1	77.9
Backflow prevention valves	8.5	91.5
Rainwater harvesting system	14.6	85.4
Permeable paving in compound	11.3	88.7
Ventilation designed for flood conditions	16.4	83.6

Note: Percentages are based on N = 390 respondents. Multiple responses were applicable as respondents could report multiple flood impacts.

The results in Table 7 indicate very low incorporation of flood-resilient features across all categories. The most commonly incorporated feature was elevated floor level (31.5%), while the least incorporated was backflow prevention valves (8.5%). These findings suggest that most housing development in flood-prone areas proceeds without adequate consideration of flood resilience.

A key informant from the Rivers State Physical Planning Authority explained:

"The challenge is that many of these buildings in flood-prone areas were constructed before the current awareness about flood resilience. Even now, when people apply for building permits, they often submit designs that do not consider flood risk. Our staff are overstretched, and enforcement is difficult, especially in densely populated areas like Diobu." (KII-18, Government Official, Port Harcourt).

4.4.3 Reasons for Non-Adoption of Flood-Resilient Design

Respondents whose housing lacked flood-resilient features were asked to indicate the primary reasons for non-adoption. Table 8 presents their responses. Lack of awareness was the most frequently cited reason (36.4%), followed by higher construction costs (25.1%). Notably, 17.2% of respondents indicated that their builder or contractor did not advise them on flood-resilient options, suggesting a gap in professional practice. Only 11.5% cited absence of regulatory requirements, indicating that awareness and cost considerations are more significant barriers than regulatory enforcement.

Table 8: Reasons for Non-Adoption of Flood-Resilient Design Features

4.5 Effectiveness of Flood-Resilient and Sustainable Housing Strategies

4.5.1 Awareness of Flood-Resilient Strategies

Respondents were asked about their awareness of various flood-resilient housing strategies. Table 9 presents the findings.

Table 9: Awareness of Flood-Resilient Housing Strategies

Flood-Resilient Strategy	Aware (%)	Not Aware (%)
Building on elevated foundations	68.5	31.5
Using water-resistant materials	42.3	57.7
Installing proper drainage systems	71.8	28.2
Rainwater harvesting to reduce runoff	38.5	61.5
Permeable surfaces for compounds	24.6	75.4
Wet flood-proofing techniques	19.2	80.8
Dry flood-proofing techniques	16.9	83.1
Floating/amphibious foundation systems	8.2	91.8

Note: Percentages are based on N = 390 respondents. Multiple responses were applicable as respondents could report multiple flood impacts.

Awareness was highest for conventional strategies such as proper drainage systems (71.8%) and elevated foundations (68.5%). However, awareness of more specialised techniques including wet and dry flood-proofing, permeable surfaces, and floating foundation systems was remarkably low (below 25%). This limited awareness constrains the adoption of innovative flood-resilient approaches in housing development.

4.5.2 Adoption and Perceived Effectiveness of Adaptive Practices

Respondents who had adopted various adaptive practices were asked to rate their effectiveness in reducing flood damage on a 5-point scale (1 = Not effective, 5 = Very effective). Table 4.10 presents the adoption rates and mean effectiveness scores.

Table 10: Adoption and Perceived Effectiveness of Adaptive Practices

Adaptive Practice	Adoption Rate (%)	Mean Effectiveness Score	Standard Deviation
Raising floor level during	28.5	4.28	0.64

renovation			
Constructing perimeter drainage	41.3	4.21	0.71
Using sandbags during floods	62.8	3.45	0.92
Temporary relocation during peak floods	35.4	4.12	0.78
Installing flood barriers/doors	12.6	4.05	0.84
Waterproofing walls and floors	23.1	4.18	0.73
Elevating electrical sockets/appliances	31.5	4.31	0.68
Moving belongings to higher levels	74.9	4.09	0.81

The most commonly adopted practice as recorded in Table 10 was moving belongings to higher levels during floods (74.9%), followed by using sandbags (62.8%). Both practices are reactive rather than preventive. More permanent structural adaptations such as raising floor levels (28.5%), waterproofing (23.1%), and installing flood barriers (12.6%) had much lower adoption rates, despite receiving high effectiveness ratings (means above 4.0). This suggests that while residents recognise the effectiveness of permanent adaptations, cost and awareness barriers limit their implementation.

A resident from Ogbunabali described their adaptive approach: "We have learned to live with the water. When the rains start, we move our furniture onto blocks and platforms. We keep important documents in plastic containers on top of the wardrobe. Some of my neighbours have raised their floors by adding concrete, but that is expensive. Most of us just cope during the floods and repair afterwards." (KII-06, Resident, Ogbunabali, 38 years)

4.5.3 Effectiveness of Green Building Strategies

Table 11 presents respondents' assessment of green building strategies for flood resilience, based on the experiences of those who had implemented or observed such strategies. Rainwater harvesting systems (mean = 4.12), solar-powered flood pumps

(mean = 4.24), and natural ventilation design (mean = 4.05) received the highest effectiveness ratings. However, qualitative interviews revealed that adoption of these strategies remains extremely limited due to initial costs and limited technical knowledge among local builders.

Table 11: Perceived Effectiveness of Green Building Strategies

Green Building Strategy	Mean Effectiveness Score	Standard Deviation
Permeable paving in compound	3.89	0.91
Rainwater harvesting systems	4.12	0.76
Vegetated swales/drainage channels	3.78	0.94
Use of recycled/reclaimed materials	3.42	1.02
Natural ventilation design	4.05	0.82
Solar-powered flood pumps	4.24	0.73
Elevated gardens/landscaping	3.56	0.97

4.5.4 Comparative Analysis of Flood-Resilient Housing Across Communities

Table 12 presents a comparative analysis of flood-resilient housing indicators across the five study communities, based on observational data.

Table 12: Comparative Flood-Resilient Housing Indicators by Community

Community	Mean Floor Elevation (m)	Buildings with Functional Drainage (%)	Buildings with Flood-Resistant Materials (%)	Mean Flood Depth (m)	Reported Structural Damage (%)
Diobu (Mile 1-3)	0.38	32.1	14.3	0.85	76.8
Ogbunabali	0.42	36.0	19.8	0.72	69.8

Borikiri	0.51	45.9	23.0	0.58	60.8
Rumue me	0.48	40.3	20.9	0.64	64.5
Rumuola	0.55	43.1	24.2	0.52	55.4

The results in Table 12 reveal notable variations across communities. Borikiri and Rumuola demonstrate relatively better flood-resilient indicators, with higher mean floor elevations, better drainage coverage, and lower reported structural damage. In contrast, Diobu (Mile 1-3) shows the poorest indicators across all measures, with the lowest mean floor elevation (0.38m), lowest drainage coverage (32.1%), and highest reported structural damage (76.8%). These variations reflect differences in community age, planning status, and socio-economic characteristics.

A town planner interviewed explained these disparities:

"Diobu is one of the oldest densely populated areas in Port Harcourt. It developed largely without planning, on land that was originally swampy. The buildings are packed together, and there is no space for drainage. Borikiri and Rumuola have some planned layouts and newer developments that tend to have better standards." (KII-15, Town Planner, Port Harcourt)

4.6 Key Informant Perspectives on Flood-Resilient Housing

Thematic analysis of interviews with 10 key informants (5 building professionals, 5 government officials) revealed four major themes regarding flood-resilient housing in Rivers State.

4.6.1 Regulatory and Enforcement Gaps

All five government officials and four of the five building professionals identified weak regulatory enforcement as a fundamental barrier to flood-resilient housing. Informants noted that while building regulations exist, implementation is inconsistent.

"We have the Rivers State Physical Planning and Development Permit Authority Law, but enforcement is a major challenge. Many buildings in flood-prone areas either have no permit or were approved without

adequate consideration of flood risk. The staff strength is insufficient for the volume of development happening across the state." (KII-17, Government Official)

"Even when regulations exist, developers find ways around them. They build according to approved plans to get their permit, but during construction, they cut corners. The supervision is not thorough enough to catch these violations." (KII-14, Building Professional)

4.6.2 Inadequate Technical Capacity

Four building professionals highlighted limited technical capacity among local builders as a constraint to implementing flood-resilient design.

"Most of the artisans and small-scale builders in these communities learnt their trade through apprenticeship. They have no formal training in modern construction techniques. If you ask them to install a damp-proof course or design a foundation for flood-prone soil, they may not know how to do it properly." (KII-11, Architect)

"There is a knowledge gap between what researchers and professionals know about flood-resilient housing and what is actually practiced on site. We need more training and extension services targeting local builders." (KII-13, Engineer)

4.6.3 Economic Constraints and Affordability

All informants acknowledged that economic factors significantly influence housing decisions in flood-prone areas.

"Most people building in these areas are low to middle income earners. They are more concerned about completing their building within a limited budget than about whether it will withstand floods in ten years. Flood-resilient features cost money, and many cannot afford the additional expense." (KII-19, Government Official)

"Land is expensive in Port Harcourt, so people buy cheaper land in flood-prone areas because that is what they can afford. They know the risk, but they have no alternative. It is a trade-off between shelter

today and safety tomorrow." (KII-09, Resident Leader)

4.6.4 Need for Integrated Approaches

Five informants emphasised the need for integrated approaches combining design innovation, community participation, and institutional reform.

"Flood-resilient housing cannot be achieved through design alone. We need integrated approaches that combine better building standards with community drainage maintenance, early warning systems, and land use planning. It requires collaboration between government, professionals, and communities." (KII-16, Urban Planner)

"What works in one community may not work in another. Strategies must be tailored to local conditions, flood patterns, and community capacity. We need to learn from what residents are already doing and build on that knowledge." (KII-20, Government Official)

4.7 Summary of Key Findings

The results of this study are summarised as follows:

1. Flooding is recurrent and severe: 77.7% of respondents experience flooding at least annually, with peak flooding during June-September. Poor drainage systems, heavy rainfall, and blocked channels are perceived as the primary causes.
2. Flood impacts on housing are extensive: Structural damage to walls and foundations (68.2%), damage to belongings (61.5%), and increased maintenance costs (54.6%) are the most frequently reported impacts.
3. Existing housing lacks resilience features: Only 23.1% of buildings have floor elevations above 0.6m, 38.5% have functional drainage, and incorporation of flood-resilient features ranges from 8.5% to 31.5%. Lack of awareness (36.4%) and cost concerns (25.1%) are the main barriers.
4. Awareness of resilience strategies is limited: While awareness of basic strategies like

drainage (71.8%) and elevated foundations (68.5%) is moderate, awareness of advanced techniques such as flood-proofing and floating foundations is below 20%.

5. Adoption favours reactive over preventive measures: Residents predominantly adopt reactive strategies (moving belongings, sandbags) rather than permanent structural adaptations, despite recognising the effectiveness of the latter.
6. Community variations exist: Diobu demonstrates the poorest flood-resilient indicators, while Borikiri and Rumuola show relatively better conditions, reflecting differences in planning history and socio-economic characteristics.
7. Institutional gaps persist: Key informants identified weak regulatory enforcement, inadequate technical capacity, and economic constraints as fundamental barriers to flood-resilient housing development.

V. DISCUSSION OF FINDINGS

5.1 Nature and Causes of Flooding Affecting Housing Development

The finding that 77.7% of respondents experience flooding at least annually (Table 3) confirms that flooding is a persistent environmental challenge in Rivers State, consistent with Gerald-Ugwu et al. (2019) who documented recurrent flooding in Port Harcourt communities. The identification of poor drainage systems (mean = 4.62) as the primary cause (Table 4) aligns with Elum and Lawal (2022), who found that inadequate drainage infrastructure significantly exacerbates flood vulnerability in urban communities. The high ranking of anthropogenic factors including building on floodplains (mean = 4.43) and inadequate waste disposal (mean = 4.32) supports the Pressure and Release (PAR) Theory proposition that disasters result from natural hazards intersecting with social vulnerability created by poor planning and weak institutions (Blaikie et al., 1994). The finding that structural damage affects 68.2% of housing units (Table 5) corroborates Unum (2025), who reported that flooding significantly undermines

housing development in Nigerian flood-prone areas. These results demonstrate that flooding in Rivers State is not merely a natural phenomenon but is amplified by human activities and institutional failures, reinforcing the need for integrated flood management approaches that address both environmental and socio-political drivers of vulnerability.

5.2 Existing Housing Design and Construction Practices

The finding that only 23.1% of buildings have floor elevations exceeding 0.6 metres (Table 6) reveals a critical design deficiency, as this falls below the minimum recommended threshold for flood-prone areas identified by building professionals. This aligns with Okey-Ejiowhor and Akani (2025), who found that architectural design choices in Port Harcourt Metropolis rarely incorporate adequate flood-resilient features. The low incorporation of flood-resistant materials (18.7%) and proper drainage integration (27.9%) (Table 7) supports Okey-Ejiowhor and Amakiri's (2025) observation that residential buildings fail to respond adequately to pluvial flooding due to design deficiencies. The predominance of strip foundations (56.4%) over more resilient pile foundations (11.8%) (Table 6) reflects limited application of Resilience Theory principles, which emphasise adaptive design and construction strategies that reduce flood damage (Holling, 1973). Lack of awareness (36.4%) as the primary reason for non-adoption (Table 8) confirms Adeyanju et al.'s (2025) assertion that limited knowledge about climate-resilient construction practices constrains sustainable housing development in Nigeria. These findings highlight the gap between theoretical resilience frameworks and actual construction practices in flood-prone communities.

5.3 Effectiveness of Flood-Resilient and Sustainable Housing Strategies

The finding that awareness of advanced flood-resilient techniques such as flood-proofing (below 20%) is substantially lower than awareness of conventional strategies (Table 9) demonstrates a critical knowledge gap that constrains innovation in housing adaptation. This supports Anthony et al. (2022), who emphasised that decision-making

frameworks for pre-flood housing resilience remain poorly integrated into development processes in Nigeria. The high adoption of reactive strategies like moving belongings (74.9%) compared to low adoption of permanent structural adaptations (12.6-31.5%) (Table 10) validates Human Adaptation Theory's proposition that communities initially respond to hazards through experiential learning and behavioural adjustment before adopting technological solutions (Burton, 1978). The high effectiveness ratings for rainwater harvesting (mean = 4.12) and solar-powered flood pumps (mean = 4.24) among green building strategies (Table 11) corroborates Adeyanju et al. (2025), who highlighted these as critical components of climate-resilient housing. The community variations, with Diobu showing poorest indicators (Table 12), align with Uquetan et al. (2025), who found that vulnerable populations, particularly in older unplanned settlements, experience disproportionate flood impacts. These findings demonstrate that while effective strategies exist, their adoption is constrained by awareness, economic, and institutional barriers.

5.4 Policy and Design Measures for Improving Flood-Resilient Housing

The identification of weak regulatory enforcement as a fundamental barrier by all government officials interviewed (Section 4.6.1) supports Elum and Lawal's (2022) finding that limited institutional preparedness significantly increases flood vulnerability. This validates the PAR Theory's emphasis on weak institutions as drivers of disaster risk (Blaikie et al., 1994). The finding that economic constraints influence housing decisions, with residents trading affordability for safety (Section 4.6.3), aligns with Mitchell and Carter's (2024) observation that climate change pressures on housing stock expose weaknesses in planning systems. The emphasis on integrated approaches combining design innovation, community participation, and institutional reform (Section 4.6.4) reflects Cutter's (2016) conceptualisation of climate resilience as requiring multi-sectoral collaboration. The identified need for tailored community-specific strategies supports Kibert's (2016) argument that sustainable construction must respond to local environmental and socio-economic contexts. These findings collectively

demonstrate that improving flood-resilient housing in Rivers State requires addressing not only technical design issues but also the institutional, economic, and social dimensions that shape housing development decisions in flood-prone environments.

VI. CONCLUSION

This study examined flood-resilient housing strategies in flood-prone environments of Rivers State, establishing that flooding is a recurrent phenomenon affecting 77.7% of households annually, with poor drainage systems and anthropogenic factors as primary causes. Existing housing design practices demonstrate critical deficiencies, with only 23.1% of buildings achieving adequate floor elevation and incorporation of flood-resilient features below 32% across all categories. While residents predominantly adopt reactive coping strategies, awareness and adoption of permanent structural adaptations and green building techniques remain severely limited due to knowledge gaps, economic constraints, and weak regulatory enforcement. Community variations reveal that older unplanned settlements like Diobu exhibit poorest resilience indicators, confirming that vulnerability is socially produced. The study validates the theoretical framework linking vulnerability, resilience, and adaptation, demonstrating that flood-resilient housing requires integrated approaches addressing design, institutional, and socio-economic dimensions. Without deliberate policy intervention and enhanced technical capacity, housing development in flood-prone areas will continue to experience preventable damage and disruption.

VII. RECOMMENDATIONS

Based on the study objectives, the following recommendations are proposed:

1. Nature and causes of flooding: Rivers State Government should prioritise investment in comprehensive drainage infrastructure maintenance and expansion, incorporating community-based drainage cleaning programmes and stricter enforcement against waste dumping in waterways.

2. Existing housing practices: Rivers State Physical Planning Authority should develop and enforce minimum flood-resilient building standards, including mandatory minimum floor elevation of 0.6 metres in flood-prone areas and prohibition of strip foundations in high-risk zones.
3. Effectiveness of resilience strategies: National Emergency Management Agency and professional bodies should implement capacity-building programmes targeting local builders and residents, demonstrating cost-effective flood-resilient techniques and green building approaches through demonstration projects.
4. Policy and design measures: Government should establish a flood-resilient housing incentive scheme providing technical assistance and targeted subsidies for low-income households incorporating approved resilience features, while strengthening building permit enforcement in flood-prone communities.

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