EVALUATION OF FLOOD RESILIENT STRATEGIES IN THE DESIGN OF RESIDENTIAL BUILDINGS IN LEKKI, LAGOS STATE.

BY

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M.Tech**/SET/2019/9647**

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A THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGER STATE, NIGERIA IN PARTIAL FULFILMENT OF THE REQUIRMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF TECHNOLOGY IN ARCHITECTURE

AUGUST, 2023.

DECLARATION

I hereby declare that this thesis titled **"Evaluation of Flood Resilient Strategies in the Design of Residential Buildings in Lekki, Lagos State"** is a collection of my original research work and has not been presented for any other qualification anywhere, for the purpose of awarding a degree. Information gotten from other sources and publications have been duly acknowledge.

BARDE, Daniel Joseph	………………………………
M.Tech/SET/2019/9647	Signature & Date

CERTIFICATION

The thesis titled **"Evaluation of Flood Resilient Strategies in the Design of Residential Buildings in Lekki, Lagos State"** by BARDE, Daniel Joseph**,** a postgraduate student of the Department of Architecture, Federal University of Technology, Main Campus, Gidan Kwano, Minna, Nigeria, with matriculation number M.Tech/SET/2019/9647 fulfils the requirements for the award of the degree of Masters in Technology (M.Tech) in Architecture and it is approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

This thesis is dedicated to God almighty, My Parents, Mr and Mrs Joseph Barde, My Siblings, Friends, the entire community of Architects and my dear country, Nigeria.

ACKNOWLEDGEMENT

With great appreciation to God, I would like to specially appreciate my academic supervisor Dr. A. D. Isah for his Mentorship and guidance. My friends and colleagues who have been tolerant and abundantly helpful. To my Parents, Mr and Mrs Joseph Barde for their inspiration and support and siblings for their encouragement I Pray for Gods Unending Blessings. Lastly to My Fiancé, Mercy Yerima Kaka for her Love and Support, Thank You.

ABSTRACT

The impact of flooding in recent times on housing are increasing with rapid urban expansion in both developed and developing countries. Various studies have shown the relationship between high flood levels in coastal regions and climate change which causes an increase in sea levels and ocean degradation. The rising flood frequency affects the residents of Lekki peninsula, destroys an array of urban infrastructure, disrupts economic activities and becomes a threat to sustainable development. This study aims at evaluating flood resilience strategies as response to the increasing flood vulnerabilities in residential properties in Lekki, Lagos state. Due to the empirical evidences the variables employed to evaluate Flood resilience and climate adaptation include: the elevation of land, building strategies for resilience and the water levels in Lekki, Lagos state. A quantitative research approach was used where questionnaire survey was administered to the residents of Lekki, Lagos state. The data collected were analysed using both descriptive and inferential statistical tools. It was discovered that residential properties were affected by the increased flood risk with major damages to the structural stability, building façade, life and properties of the occupants of these residential properties. The findings showed that the residents applied flood resilient strategies that were inadequate to control flood. The research advanced the use of water inclusion and water entry technologies as the strategies adopted in designing residential properties that are adaptable to the flood and climate conditions. The study recommends the construction of proper drainage channels to enable efficient draining of flood water, water proofing of the building structure to keep the structural stability in check and the adaptation of amphibious technology water front design, elevated buildings and floating structures to adapt to the costal environment. In conclusion, the type of flood, the environment and Informed historical data affect the choice of strategy employed in resisting flood risk and adapting to climate change and this is the new climate reality.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to Study

Structures should adjust to the reality of climate change, the rise in ocean level and ocean degradation causes flooding in prone regions. Water brought about by weighty precipitation temporarily cover places it typically should not. This influences the livelihood of individuals, achieves enduring suffering and impacts the economy negatively. The world is affected by Natural disasters on a yearly basis with flooding having the greatest damage potential of them all. Low-lying areas along the coast are likely to be at risk of floods, flood damage, and erosion as sea levels rise due to global warming (Obiefuna *et al.*, 2021). Excess water from prolonged rainfall builds up and occupy dry land, this causes a rise in water levels which encroach into built areas.

Flooding in Nigeria can likewise be ascribed to human nature interactions like absence of drainages, blockage of water way, poor garbage removal, deforestation due to rapid urban development which has prompted expansion in flooding rate (Echendu, 2020). In 2012, many communities went through untold hardship in Nigeria as Flood affected an estimated number of seven million people, 363 persons lost their lives and over 618,000 houses were destroyed (Bahago *et al.,* 2019). This led to a psychological disruption causing people to flee from their residents, others prepare for the unknown as they are made to live with the fear of reoccurrence. Human interactions with its environment affects the natural order of things such as water ways forming with the terrain of the area. The recent accelerations in population growth and changes in land use patterns have increased human vulnerability to floods (Doocy *et al.,* 2016). High-risk flood zones in Prone areas are adversely affected with considerable damage to buildings and infrastructure. (Warebi, 2018). This in turn is harmful to man's settlements and their livelihood which are affected in the event of flooding.

Flood monitoring, mitigation, and good communication with civil authorities and vulnerable populations have the potential to reduce the number of people killed in future floods (Doocy *et al.*, 2016). Communities in flood prone areas are faced with finding a way to prepare for the incomming floods in future times. Warebi, (2018) gathered that the ability of a system to absorb disturbance and reorganize while experiencing change and maintaining essentially the same function, structure, identity, and feedbacks is known as resilience. He futher stressed that the capacity of a system, community, or society potentially exposed to risks to adapt by resisting or modifying in order to reach and maintain an acceptable degree of functionality and structure, according to the International Strategy for Disaster Reduction (ISDR) (Warebi, 2018). This is determined by the degree to which the social system is capable of arranging itself. As a result, the goal of this research is to evaluate flood resilience strategies as a response to the increasing flood vulnerabilities and bring adaptive solutions to improve the capacity to adapt, maintain functionality and vitality and also minimize the vulnerability of flood prone areas in Lekki, Lagos State. The objectives towards achieved by establishing the flood resilient strategies of existing households in Lekki, assessing the flood levels in the community, identifying the impact of flooding on the residential houses and to propose a design of residential buildings with the integration of adequate flood resilient strategies.

1.2 Statement of the Research Problem

Floods are the most common and recurring disaster in Lagos State, particularly in the littoral communities. Areas vulnerable to flooding are usually coastal communities because of their proximity to water bodies, location in low-lying areas, population growth and irregular urban development, wetland loss and sea-level rise (Ojolowo and Wahab, 2017).

Floods have a wide range of negative consequences for human health, food security, economic activity, physical infrastructure, natural resources, and the environment (Eze, *et al.*, 2018). The ability for residents of Lekki to adapt to the flood situation and still maintain maximum functionality during flooding has been a great problem. To create a resilient design for adaptation, the approach should prioritize resilient strategies that improve functionality and living conditions during this flood times. Flood protection, prevention, and preparedness are all priorities for resilient strategies, both now and in the future. (Zevenbergen *et al.,* 2019). This paper addreseses the vunerabilities of flood prone areas, evaluate strategies that could encourage construction of physical infastructure and enable maximum adaptability of these buildings to flood disaster.

1.3 Aim and Objectives of the Study

1.3.1 Aim of the study

The aim of this study is to evaluate flood resilience strategies as a response to the increasing flood vulnerabilities and bring adaptive solutions to improve the capacity to adapt, maintain functionality and vitality and also minimize the vulnerability of flood prone areas in Lekki, Lagos State.

1.3.2 Objectives of the study

The objectives towards achieving this aim includes;

1. To establish the flood resilient strategies of existing households in Lekki, Lagos State.
2. To assess the flood levels in Lekki, Lagos State

3. To identify the impact of flooding on the residential houses.
4. To design residential buildings with the adequate flood resilient strategies.

1.4 Justification of Study

This research can be justified by answering the question: what are the flood resilient strategies employed to reduce flood vulnerablities in affected area. The people of lagos has been ridden with flood waters annualy causing a loss of live and properties. This has caused life to be difficult for residients in the flood prone area with focus on lekki penisula. This disrupts the normalcy of livelyhood causeing disruptions in liiving conditions and even economic instaility as flood waters causes damages to physical properties and even restrict movement of goods and services. Bako and Ojolowo, (2021) explains that the Preparedness for disasters should go beyond methods that speed up emergency response, rehabilitation, and recovery, resulting in quick, focused support. This can be achieved through community-based approaches and activities that build peoples abilities to cope with and minimise the effects of a disaster on their lives.

This brings the need to Evaluate strategies that improves the capacity to adapt, maintain functionality, and bounce back after disruptions such as flooding. If properly implemented, adaptive solutions could minimize the vulnerability of flood-prone areas while also providing potential for rapid expansion and development in the region. Zhao *et al.*, (2018). This means that the vulnerability of flood-prone areas exposes the region to conditions that could test its need adapt. People have the chance to adapt to the changing environment by adjusting to the new climate conditions and adapt to the new conditions.

1.5 Limitations of the Study

The non-existence of proper knowledge Designed flood control goes back hundreds of years, for example, in China around 400 BCE, when steps were taken to protect the farming populace from flooding brought about by the Yellow River. This study seeks to focus on physical infrastructure and the vulnerabilities brought about by flood disaster. Flood protection, prevention, and preparedness are all priorities for resilient strategies, both now and in the future. (Zevenbergen *et al.,* 2019).

1.6 Scope of Study

The emphasis of this research is on the design of flood resistant structure using adaptive design solutions to manage flood risk and improve the quality of life in these vulnerable communities. This research focuses particularly on the Lekki, peninsula of Lagos state. Lagos has been a hub for economic activities with lots of land reclamation done to extend liveable areas around the coastal region. This study seeks to focus on physical infrastructure and the vulnerabilities brought about by flood disaster.

1.7 Area Of Study

Lagos, state, south-western Nigeria, on the coast of the Bight of Benin is the area of study. Lagos state is bounded by the state of Ogun to the north and east, by the Bight of Benin to the south, and by the Republic of Benin to the west. The topography of Lagos is dominated by its system of islands, sandbars, and lagoons. All the territory is low-lying, the highest point on Lagos Island being only 22 feet (7 metres) above sea level. Lagos state has a total Area of 3,577 square km sitting on 351,861 Hectares of land. According to National Population Census of 2006, Lagos state houses approximately 9,013,534 people with 20 Local Governments and 37 Local Council Development Areas.

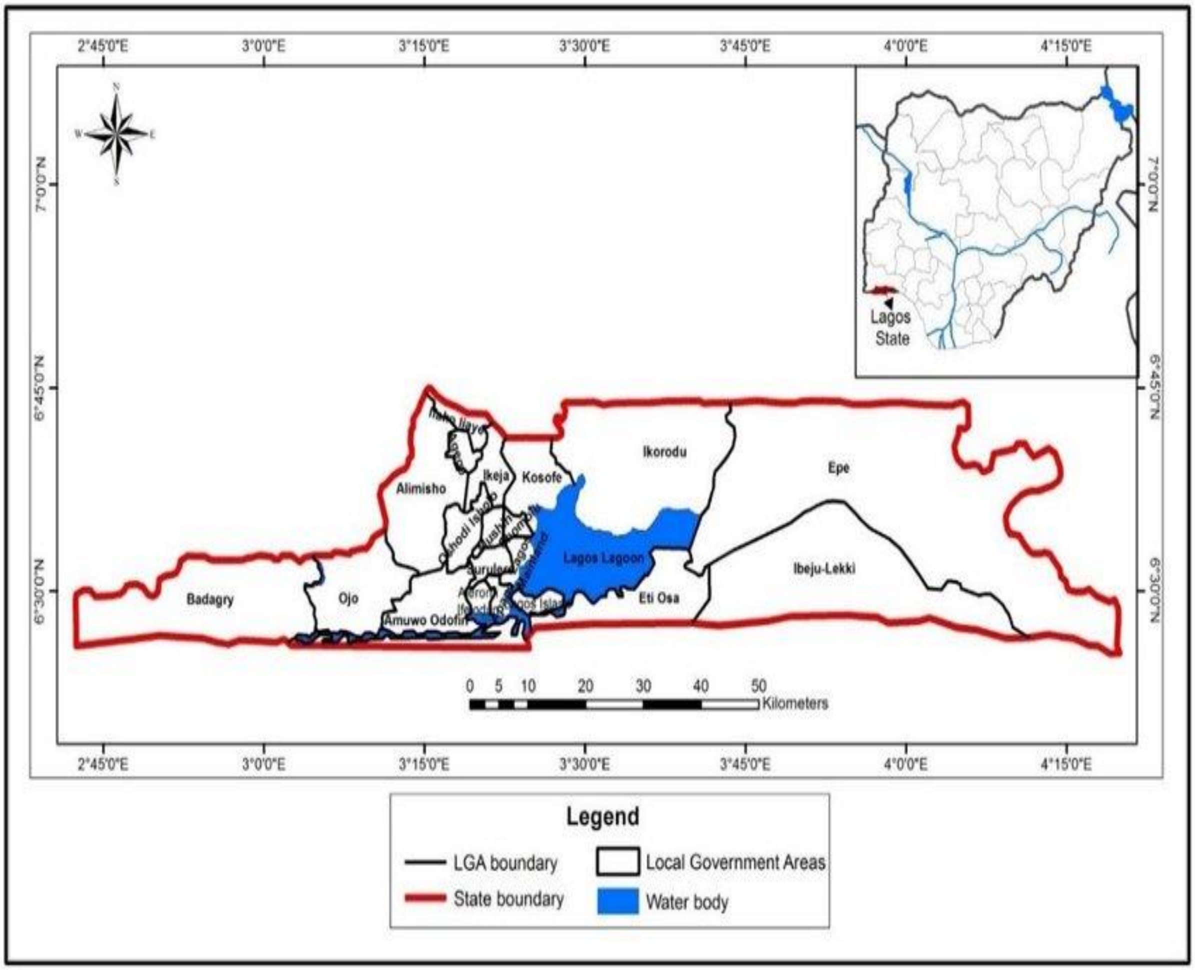

Figure 1.1: Showing administrative map of lagos state with various local government areas

Source: Adapted and Modified from Lamata, 2015.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Flood Vulnerability in Nigeria

Adetunji and Oyeleye (2018) opined that potential victims of flood disasters are often times affected by limitations which force them to live within flood plains characterized by an absence of zoning regulations, flood control, emergency response infrastructure and early warning systems. In the year 2012, flooding accounted for a total of 363 deaths with 597,476 destroyed houses and up to 2.3 million people displaced in Nigeria. Incidents like this are a normal occurrence in states like Lagos State as it is prone to frequent and excessive flooding. Lagos State and some surrounding areas of Ogun State reported rainwater depth of up to 5m in July 2021 with as many as 300 houses being damaged by flooding in Jalingo, the capital of Taraba state, all in July, 2021. The massive rainfalls of 2012 within the entirety of Nigeria claimed 363 lives and displaced 2,157,419 people between July and October of 2012 (Some experts warn that as a result of this, some parts of Lagos might become unliveable; forcing residents to relocate to higher ground (Nkwunonwo *et al.*, 2016). Strangely, the closeness to water that has generated prosperity for many human civilizations have also led to settlement patterns that leave urban agglomerations exposed to regular or occasional flooding (Lamond *et al.*, 2012). In 2015 alone, incremental flood events accounted for 42% of all natural events and tens of thousands of fatalities (MunichRe, 2016).

Floods are caused either by natural or human causes (Nwigwe and Emberga, 2014). Natural causes could be in the form of heavy or torrential rains while human causes are usually implemented via broken water pipes, dam failure or leakages. According to Akande *et al.*, (2023), humans play a part in complicating naturally occuring floods via activities such as illegal structures on drainage channels, land reclaimation/encroachment and poor physical planning amongst others. Industrialization, technology development, urbanization, deforestation, burning fossil and agricultural activities are notable causes as well. Climate change on the other hand has caused a level of unpredictability to the weather (Agbonkhese *et al.*, 2014) resulting in extended periods of rainfall especially in coastal regions such as Rivers, Niger, Kogi, Benue, Sokoto, Katsina, Lagos, Ondo, Bayelsa, Delta, Akwa Ibom, Anambra, and Cross River states.

Plate I: Showing flooded streets in Lekki, Lagos States.

Source: https://punchng.com/videos-floods-sack-lekki-road-as-lagos-is-drenched-by-rains/

Plate II: Showing Residents cramped up in top floor to avoid rain waters

Source: https://www.ifrc.org/emergency/nigeria-floods

Plate III: showing a Resident describing flood levels in kogi state

Source: https://www.icirnigeria.org/2018-kogi-flood-disaster-worse-than-that-of-2012-says-yahaya-bello/

In the United Kingdom, flooding from both tidal and fluvial sources have since been known as one of the most damaging and costly natural hazards (Brown and Damery, 2002). For example, the storm floods from the end of December, 2013 to February, 2014 resulted in about US$ 1,500 million worth of losses (MunichRe, 2015). Further, the winter storm floods of 4th to 10th December 2015 were one of the costliest floods in terms of insured losses (MunichRe, 2016). The damage economically was estimated as Four Hundred to five hundred million euros (£400m - £500m) with the insurance industry paying out between Two hundred and fifty to three hundred and twenty-five million euros (£250m and £325m) – twice compared to the 2009 floods (PWC, 2015). In spite of the acknowledgment of flood impacts, desperate relief techniques remain the norm of the day, regularly missing opportunities to incorporate integrated solutions that can assist with planning out friendly building and infrastructural vulnerabilities. Without change, the total population exposed to flooding could triple to around One hundred and fifty million dollars (150m) by the 2070s due to continuous sea-level rise and increased storminess, subsidence, population growth and urbanisation. Asset exposure could grow dramatically, reaching US $35 billion in the same period (roughly 9% of projected annual GDP). This estimation can however be avoided, as exposure does not eventually translate into impact when resilience is “designed in” through coping and adaptive mechanisms (Nicholls *et al.*, 2008).

2.2 Integrated Design for Resilience

Urban resilience is the capacity of urban systems to prepare and respond to the risks and impacts of natural hazards, climate variability, and climate change (Gigio, 2015). A resilient built environment is designed, located, built, operated and maintained in a way that maximises the ability of built assets, associated support systems (physical and institutional) and the people that utilises built assets, to withstand, recover from, and mitigate for the impacts of extreme natural and human-induced hazards (Dainty and Bosher, 2008).

Godschalk (2003) also proposes the following for resilience: new developments are guided away from known high hazard areas, and where possible, vulnerable existing improvement is moved to safe regions; structures are built or retro-fitted to satisfy code guidelines dependent on risk dangers; regular natural defensive frameworks are monitored to keep up with significant risk relief capacities; at long last, their legislative, nongovernmental, and private area associations are ready with state-of-the-art data about risk weakness and catastrophe assets, are connected with viable correspondence organizations, and are knowledgeable about cooperating.

In essence, a collaborative, communicative and integrated approach to deliver resilient buildings through accept/recover, resist/avoid, and mitigate/adapt strategies. Living with water requires innovative architectural and planning solutions, a significant part of which is a culture shift by professionals as well as members of the public. Therefore, building professionals will also need to work with the government and the public to deliver solutions that are sensitive to nature for Example, living with nature, and not against it. Architecturally, resilience design gives particular reference to external effects and context. Design of physical systems should both include new and retrofit building design and planning, tectonics and use of appropriate materials. An integrated resilient design and practice approach will also utilize resources, reduce waste and further cause the wellbeing, security, wellbeing, and prosperity of lives and jobs in or around structures. Flood in urban region cannot be managed in isolation at the city scale and responses to potential flood impacts are complicated by interlinked political, socio-economic and environmental changes. So, there is a need for approaches that are integrated addressing differing spatial scales, ranging from catchments to neighbourhoods (Zevenbergen *et al.*, 2008). This integrated approach of policy, process, product and people can help deliver resilience before, during and after a natural event, especially if anticipatory actions are taken. Integrated design for resilience interlinks: Governance; Planning and landscaping; Design: Space, form, materials and tectonics; Infrastructure, and other technological innovation; and People – social engagement, participation and action.

2.3 Resilient Construction for Residential Buildings

Resilient construction has been in place for centuries, yet, just moderately as of late has it been utilized as a methodical part of an integrated flood risk management strategy. Resilient buildings are constructed and designed to prevent, reduce, or avoid the damage caused when flooding takes place. They mainly play a very important part in flood risk management strategy by reducing damage and, importantly, speeding up the recovery process. This begins by charting the historical development of the concepts of resilient construction, the use of engineered flood control systems leading to current thinking around living with water, and the acceptance that flooding is unavoidable. The importance of structures and the wider built environment within flood risk management is depicted. A detailed description of the developments in the use of construction technologies and materials follows, including the recognition of the need for more scientific research. The developments of this technology and the understanding of property level measures then follows. This leads to an account of the research and advancements in practice around the reinstatement and repair of flood-damaged buildings.

Moving toward the state of the art, utmost attention is given to the future and current directions around the science of resilient construction, highlighting recent research trends and discoveries. Current developments in the construction, adaptation and design of flood affected buildings are described. The discussion highlights the development of hybrid approaches to property level resilience combining water exclusion measures with water entry measures. Recent research around water resistant and resilient materials is highlighted, as well as developments in considerate reinstatement practices. This leads to a section on future developments in flood resilient construction before presenting conclusions.

2.3.1 Amphibious buildings as a resilient strategy

An amphibious house is a building that rests on the ground but rises up whenever it floods, (Baca Architects, 2014). The Amphibious homes relaxes on concrete foundation and also floats when the level of water rises and also during flooding. They are similar to normal homes with parking space, a garden and access from road. The inhabitant only feels that the house is floating only during flood conditions. (Tejas *et al*., 2019). The buoyancy system beneath the building oust water to allow flotation as needed, ‘and a vertical guidance system allows the rising and falling house to return exactly the same place upon descent. It works based on Archimedes principle: The mass and the volume of the house is less than that of water, and what determined its buoyancy’ (Adithya and Manoj, 2021)

Amphibious architecture is a sustainable flood mitigation strategy that allows an ordinary structure to float on the surface of rising floodwater rather than succumb to flood. Amphibious architecture is a strategy that works in conjunction with a flood prone region’s natural cycles of flooding (that is in a place with reguarly occurance of flooding), rather than attempting to obstruct them it refer to one of several hybrid conditions where the weight of a structure is partially supported by both land and water simultaneous.

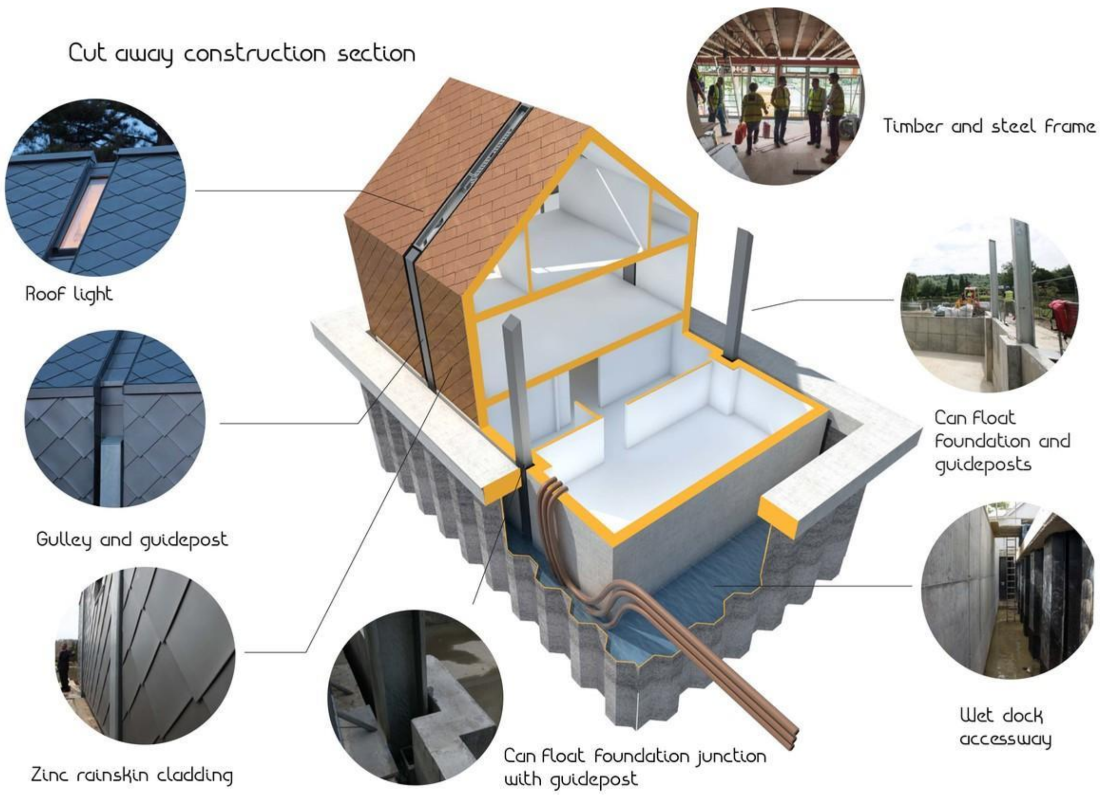

Figure 2.1: Showing Cut out section of The Thames Amphibious House

Source: https://www.construction21.org/case-studies/h/the-thames-amphibious-house.html

Amphibious construction, is not a new concept, but over a decade has had gained ground. The implementation of buoyant foundations as both retrofit and new construction could provide benefit to communities at high risk of chronic flooding, from applications in New Orleans' Lower Ninth Ward to slums in Bangladesh. Amphibious construction is a low-impact hurricane mitigation strategy that provides flood protection without increasing exposure to strong winds. It is an innovative approach that is rapidly gaining acceptance and finding application around the globe (Tejas *et al.*, 2019).

2.3.2 Floating building as a resilient strategy

These are permanently anchored floating building built on a flotation system which is not for, navigation. A floating building must have a floatation system which maintains an acceptable level of stability appropriate to the use. (Okeke *et al.,* 2019). Unlike amphibious buildings, floating buildings is always in the water, i.e., in a floating condition, while amphibious buildings are in the water only in a case of flooding. Floating homes are connected to the mainland by a jetty and are subject to greater variety. The floating houses are entirely prefabricated before transported to the site, sometimes directly by water (Rosso *et al.,* 2020). Just like the amphibious buildings, floating buildings are not new building concepts but have been in used for a long time now. In his "Study on the Floating Building as a New Paradigm of Architecture", Chang-Ho Moo realized that floating buildings could contribute to the development of major new paradigm features such as the various concept of renewable energy and green building concepts. Especially, the use of hydrothermal energy and modular construction would be expanded more, considering the location of the building. This was emphazised by his findings of floating buildings in Germany, Dubai, Hong Kong, and Prague. The IBA dock, in Hamburg, Germany is one of such examples Completed in 2009 and has a Story & floor area of 3 story and 1,623㎡.

This building was the headquarters of the IBA (international building exhibition) Hamburg GmbH as well as an information and event center for the IBA. Now the building is being used for Urban and Architecture information center in Hamburg. This floating building is a steel-construction on concretesubstructure pontoon. The superstructure of building was made in a prefabricated modular construction, and it also used a ready-made heating and cooling ceiling elements in the entire building (Moon, 2013)

Plate IV: Floating Villas in Dordrecht. The Netherlands

Source: https://www.nytimes.com/2018/05/24/arts/design/architecture-floating-houses.html

2.3.3 Elevated buildings as a resilient strategy

These are buildings risen above the flood elevation on some support which is sufficiently strong to carry and hold the load of the building the force of the water acting on the building (Khan and Ahmad, 2017). Elevated building means a non-basement building built to have the top of the elevated floor elevated above the ground level by means of pilings, columns (posts and piers), or shear walls parallel to the flow of the water and adequately anchored so as not to impair the structural integrity of the building during a flood (Law Insider, 2021).

Plate V: Showing Beach Pavilion Elevated Structure

Source: https://www.mdpi.com/2071-1050/12/22/9725

2.3.4 Waterfront design as a resilient strategy

The waterfront area is the confluence area of water and land. It is not only the edge of land but also the edge of water, and the land should cover some areas. Most of the waterfront lands are like belts along the coastlines. Since people use of these areas, proper planning needs to be done so as not allow the water flood the land, connect traffic, establish different functions, and how to communicate with inner cities (Hou, 2009). It is a part of a town that is next to an area of water such as a river or the sea. Waterfronts are actually complex and demand a fair share of planning and strategic thinking.

The proximity to the river, lake, or sea, has always been of great consideration in the choice of a community because of territories on the border between the settlements and water were inhabited because of their geomorphological characteristics: their rich resources for life, freshwater and food; for logistical reasons, as they offer access points to marine trade and transport; for recreational or cultural activities; or simply because of their special sense of place (Dal Cin *et al.*, 2021). Today, there is the need to adapt the coast lines urban settlements to the increased risk of flooding in floodplains areas- to build resilient cities. Indeed, the continuing urbanization process in flood prone areas has led to a large increase in capital and population in vulnerable areas. In future climate scenarios, threshold urban areas, between the city and the water body, will become more vulnerable to flooding, due to rising average sea levels, and the reduction of permeable soil due to urbanization processes (Dal Cin *et al.*, 2021) so a need for more well planned waterfront areas in flood prone location.

2.4 Historic Development in Flood Risk Management and The Built Environment

The wider built environment properties and buildings that shape this, play an integral role in flood risk management. Whenever structures are built nearby flood fields, there is a characteristic need to secure these resources, which prompts the improvement of flood safeguard plans or instruments to alleviate the harm and interruption that is caused. Flooding can make a scope of harm metropolitan settlements, including the danger to individual wellbeing when typically, dry regions are lowered, prompting the need to escape from structures. High-speed floods can clear individuals away before crisis administrations can contact them. Harm to structures and their substance is another significant effect, prompting significant misfortunes and now and again serious expenses for people, organizations, back up plans, and government reserves. Furthermore, social impacts, such as the importance to shutdown hospitals, schools and places of worship and also the loss of important services such as electricity, water, and gas supplies, explains the important need to protect the number of physical assets that make up the built environment.

Engineered flood control goes as far back centuries for example to China in 400 BCE, where measures are put in place to protect the farming community from the flooding of the Yellow River were undertaken and included in the construction of levees, fluvial channels, and natural channels. This approach, while effective, did not protect the built environment. Notwithstanding, these floods brought significant supplements and minerals into the ripe soil, making it rich for cultivating since antiquated occasions. Lately, the way to deal with flood hazard the board has advanced to a way of thinking of living with water (Fleming, 2001). The idea of blue-green urban communities where flooding is acknowledged and embraced (Lawson *et al.*, 2014), and the requirement for recharged comprehension of flood versatility at a property level.

2.5 Developments in Construction and Building Technologies

The scientific investigation of development and building advances that are vigorous to the activities of flooding is a somewhat fresher field than the investigation of measures to anticipate and forestall flooding. There are a few hidden causes First, the relative perceived success of flood control measures in the developed world and the framing of property level interventions as "residual risk" with only a small contribution to integrated risk management. Second, the need to accept that floods cannot be prevented and ultimately that flooding may destroy homes despite the great investment in flood prevention, whereby in developing countries, where flood control has been little or no existence. Developments were later raised by individual houses without earthworks, for example traditional stilt housing in Thailand, the Queenslander style in Australia, and raised housing in the United States and Nigeria.

Progress often has been driven by the reality of experiencing flood events and the process of reconstruction after flooding, as after hurricanes Katrina (Coulbourne, 2012). Some research has been roused by the need to give better direction to help arranging limitations in floodplains, to empower continuation of protection, and to keep up with existing networks, perceiving that they face expanded flood hazard because of environmental change and environmental degradation. As will be shown in the segment on State of the Art, the exploration created in the late twentieth and mid-21st century is being shared universally, and a developing number of studies are arising that are explicitly pointed toward understanding the activity of flooding on various structure types and planning further developed innovation to lessen future harm to structures.

The approaches to manage avoid hurt at a solitary property level are distinctively depicted at this point basically requested into three philosophies: revulsion by picking sensible regions or by arranging regions or lifting constructions to go without flooding; water dismissal, in any case called dry fixing and resistance where water is held back from entering the design by limits and other "safe" development; and water entry, in any case called wet fixing and strength, where it is seen that water will enter a design and the fact is to confine the damage and break from flooding.

2.6 Avoidance Technology as a Resilient Strategy

Out of the three approaches to property level measures (avoidance, water exclusion, water acceptance), the approach of avoidance is mostly preferred. Elevation and landscaping is often advocated as a first recourse by most guidance and research (Bowker *et al.*, 2007). In building plot, aversion can be accomplished through arranging, waste, and maintenance provisions and unattached constructions or hindrances to forestall water arriving at the structure. Quite a bit of this may be viewed as standard development innovation or straightforwardly adaptable from huge scope water designing.

Aversion can likewise be accomplished by rise of the actual structure through raising on columns, broadened establishment dividers or raised earth designs, or buoyancy. In the United Kingdom, raising through broadened establishment is well known now and then with garaging under. This trend for developments in the floodplain to be raised has been in existence for a while but has been speed up and supported by recent planning guidance. The advantages of elevation are seen as self-evident if safe access and escape can be ensured, leaving questions only around suitability in structures and performance during a flood.

Where wood framed construction is common, for example in the Australia and US, raising on pillars is more viable structurally. Riverfront/foreshore construction across the world has often been needed to be built on piles for stability on shifting soils and subject to powerful currents. US Army Corps of Engineers (USACE, 1972) looked into the performance of flood proofing, including learning and elevation, in the United States continued after Hurricane Katrina. Alternatively, another avoidance technique is to create structures that rise and fall with the water, either designed to float in flood conditions or permanently floating. Avoidance Arguably via floating reduces the vulnerability of properties to windstorm destructions, as they are not totally raised and exposed to increased wind loading. Customarily, houseboats have been a component of waterway and beach front living—for instance, in the Netherlands and the United States—and in light of innovation related with boats. Nonetheless, houses intended to drift intermittently are a later turn of events, requiring examines into dependability during and after flood occasions (English *et al.*, 2017). Quite a bit of this supporting examination is situated in the Netherlands and the United States.

2.7 Water Exclusion Technology as a Resilient Strategy

Water exclusion strategies, also known as dry flood proofing and resistance, are made to keep water out of a property. Temporary measures are as often as possible turned to barricades and natively constructed flood sheets are normally utilized by networks to avoid water during a crisis. Blockades and brief measures, while they might slow entrance and harm, are neither satisfactory nor economical. In the United States, flood occasions, specifically the 1927 Mississippi flooding prompting the 1945 Flood Act giving liability to USACE, the 1961 Kansas and Missouri flooding, and the development of the National Flood Insurance Program (NFIP), provoked interest in exploration to decrease the leftover effect of floods on structures (Perkes, 2011). This can be seen in Figure 2.2 below which shows the development of regulation and guidance materials for resilient construction in the united states.

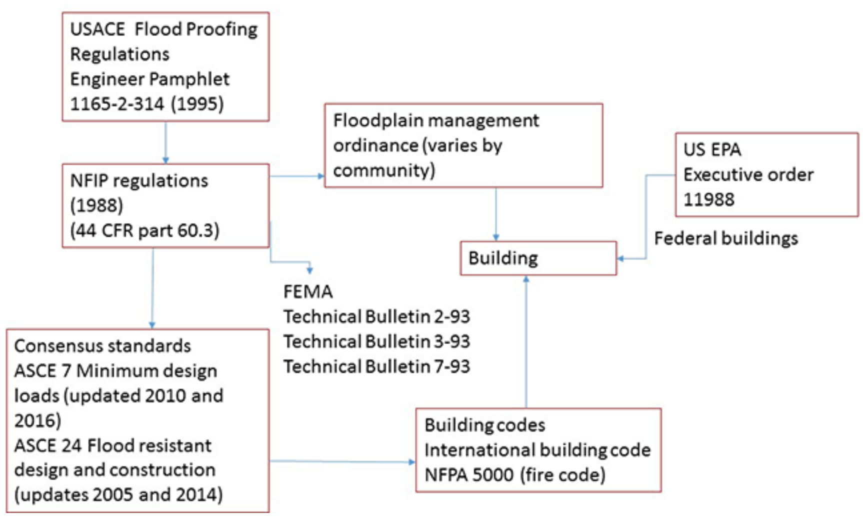

Figure 2.2: Regulation and guidance materials for resilient construction

Source: Authors research work, (2023)

A significant part of the early examination on obstruction items was led in-house and is too various to even think about remembering for this section. In any case, kite mark testing has been completed in planned offices in the United Kingdom since 2004 (BSI, 2016). A new

EU-supported venture likewise tended to the exhibition of flood obstructions (Schinke *et al.*, 2013). In the United States, Aglan *et al.*, (2004) tried entire structure development for wood outlined homegrown structures, and later examinations by Perkes (2011) and Uddin *et al.* (2013) for more contemporary types of development. Entrance through brick work dividers has likewise been examined in the United Kingdom (Beddoes and Booth, 2015). Work supported by CLG in the United Kingdom additionally analyzed floor development innovation (Escarameia *et al.* 2006) and thought about the properties of protection. Water-safe properties of protection have additionally been analyzed by the Smartest undertaking (Schinke *et al.,* 2013). The consideration of tanking technology has been led in the UK by the knowledge derived from waterproofing basements, although in general the difference in hydrostatic pressure between normal flood and groundwater conditions has not been studied.

2.8 Water Entry Technology

This is additionally differently known as wet sealing, flood versatility, or water acknowledgment and includes strategies and innovation intended to restrict the harm whenever water has avoided the structure envelope and entered the consumed space. This is the region least explored, explicitly in the flood situation, a large part of the information about strength has risen up out of the examinations on water rejection as a side issue, maybe on the grounds that water passage has been viewed as totally the final hotel by the danger the executives and property security local area. Around here, logical review is limited and compelled by passionate hindrances, and misinterpretations and tasteful and wellbeing contemplations can outclass building innovation. By and large, this is the space of flood innovation generally educated by native practice and flood insight. Declarations reveal to us that previously, water was just acknowledged and afterward cleared out of structures

(Rogers-Wright, 2013). For instance, directs were given in the floor to work with this in the Netherlands. Be that as it may, with the expanded abundance and innovation housed in structures, in building administrations, and in delicate goods, the "antiquated" strategies presently don't get the job done. There is a huge cross-over with the exploration on restoration, particularly in aversion and speed of reoccupation draws near.

There is additionally an enthusiastic discussion in this field around the reasonableness of retrofitting present day waterproof structure materials in existing (now and then legacy or character) properties (Fidler *et al.*, 2004).

The exploration explicitly on flood strong materials and strategies has typically been a more modest part and has run close by research on water section under the catch-all title "flood sealing." There is a different part of related examination on building material properties which has been drawn on (in some cases improperly) that has likewise educated the flood-explicit investigations. Hence, the resulting trial research in the United States, the United Kingdom, and Europe has advanced in corresponding with Aglan's review (Aglan *et al.*, 2004) dovetailing with Escarameia *et al.*, (2006) work and some lab concentrate.

2.9 Repair and Reinstatement of Flood-Damaged Property

Examination into the recuperation and recreation of property that has endured flood obliteration connects to the subject of strong development through the basic truth that, especially in the created world with expanding limitation on growing new structures in regions in danger, numerous development exercises in regions in danger from flooding emerge because of harm and reproduction exercises. Similarly, it has been seen that those probably going to focus on versatility in structures are those with experience of the misfortune and harms flood occasions can bring. Recreation, which is the destruction of harmed constructions and revamping, can frequently follow plan standards for beginning development as depicted in Jha *et al.,* (2012).

In any case, there might be strain to keep up with social legacy that prompts a comparative style of structures being developed or even direct duplicates of past structures. In a huge extent of flood occasions, nonetheless, the recuperation includes restoration of existing constructions that have been somewhat harmed and don't should be obliterated. This is especially the situation in the United Kingdom, where underlying disappointment because of flooding is an uncommon occasion and most of flood harm fix falls under the classification fix or restoration. Under such conditions, the property remains significantly unblemished, and the inclination to supplant like with like paying little mind to the danger of future flooding is solid.

A large part of the writing in the United States concerns natural and defilement issues related with overflowed structures, like the clinical risks from form. Curtis *et al.,* (2000) showed that parasite and microbes were not essentially higher in recently overflowed houses. Significant work was done in the outcome of Katrina where form was more common (Chew *et al.,* 2006).

2.10 Current State of the Art

Current idea on flood resilient construction starts from the premise that new construction on the floodplain should be avoided where possible, following the principles of “making space for water.” The evidence is underpinned by knowledge of the potential impact of flooding on buildings as outlined in Kelman and Spence (2004), an understanding of limitations and properties of, structural engineering principles, the science of water transport and flood characteristics and construction materials. Nadal *et al.,* (2006) summarizes the state of knowledge based on a combination of and empirical and theoretical evidence. It is evident that construction elements, furnishings, and occupants really need to be looked into from the substructure to provisions. As Kelman and Spence (2004) observed, the main flood actions on building components are:

1. Hydrostatic (lateral pressure and capillary rise)
2. Hydrodynamic (velocity, waves, turbulence)
3. Erosion (scour under buildings, building fabric)
4. Buoyancy (lifting the building)
5. Debris (items in the water colliding with the building)
6. Nonphysical actions (chemical, nuclear, biological)

Flood resilient construction tries to limit the effect of these activities on individuals and property in case of a flood utilizing the standards of evasion, water rejection, and flexibility. The expected activities of flood rely upon the logical source, profundity, and speed of flooding inside a given region; effects of high-speed flooding might be overwhelmed by hydrodynamic and trash activities, though groundwater flooding might be overwhelmed by hydrostatic and lightness activities, and subsequently configuration ought to consistently consider the possible flood ascribes.

2.11 Avoidance of Flood

The latest guidance on raised construction in the United States following learnings from Katrina was issued by the USACE (ASCE, 2015). A serious design factor is the needed elevation of structures to limit the chance that flooding will exceed the designed protection. Over elevation makes superfluous cost and openness wind stacking, while under height expands the likelihood of exceedance. Height is typically prescribed to over a probabilistic pattern flood (for instance 1 out of 100 years + environmental change in the United Kingdom, 1 out of 100 years in the FEMA rules) as addressed by flood danger assessment by government offices. There is plainly the likelihood that these levels will be surpassed and properties may flood, especially if flooding turns out to be more serious later on. UK research under the Technology Strategy Board's "plan for environment" project inspected the momentum and future prerequisites for flood aversion (Baca Architects *et al.*, 2013), inferring those vulnerabilities around future flood hazard might deliver raised properties more powerless than flow gauges recommend. The utilization of the sub-floor space is additionally a matter for banter. Where this space might be utilized for garaging or capacity, the potential for resources for be annihilated remaining parts. Safety net providers pay out on loss of engine vehicles because of flooding rather than substance. Besides, the things put away may become harming trash, and underlying harm to the raised height might result.

Deftly skimming houses enjoy the at first sight benefit of transcending the most extreme flood with minimal expanded expense and no expanded breeze openness. Practically speaking, in any case, there will be restrictions set by the direction and tying instruments just as from appended administrations. Worries around admittance to raised lodging during a flood occasion for crisis administrations has prompted guideline in the United Kingdom that guarantees access is given (Baca Architects *et al.*, 2013).

2.12 Property Level Flood Resilience Technology and Design

Moving away from the water exclusion/water entry dichotomy, the concept of property level flood resilience joins the means to reduce the amount of water entering a building (where necessary) and approaches that limit damage where water does enter the building envelope. This is an idea gaining acceptance in the UK in recognition that a hybrid approach is often the most pragmatic one. As many United Kingdom floods are slow in onset, reasonably shallow and of relatively short duration, water exclusion is often possible and water flow can be controlled.

The decision about whether to try and exclude water from a building is informed by the likely structural consequences in creating higher hydrostatic load due to differences in level of water inside and outside a building. This has been studied In the UK by Kelman (Kelman, 2002) for masonry structures and in the US for wooden construction (Aglan *et al.,* 2004). Such research has led to recommended limits to the water exclusion approach, depending on construction type, varying from 0.3 m to 1 m. Nonetheless, the examination doesn't cover adequate kinds of development, and further testing of development solidness is justified. Assuming water is to be permitted in for underlying dependability reasons, an arrangement to permit or control stream to guarantee fast adjustment of levels might be required; insufficient examination or direction exists on this methodology.

Different conditions that might lessen the adequacy of the water prohibition approach include: groundwater flooding, despite the fact that it could be feasible to make a water safe deck framework that avoids it, but primary contemplations might make this unwanted (Bowker *et al.,* 2007); quick beginning flooding, which might restrict the ideal opportunity for measures to be conveyed; high-speed flooding, where hydrodynamic powers might cause underlying issues at lower profundities; long-length flooding, since most dividers will permit water through ultimately except if steps are taken to treat the divider surface (Beddoes and Booth, 2015); joined property, where a bordering structure that has an alternate way to deal with restricting harm is of various development or is at an alternate rise; notable/character properties, where there might be imperatives on the kind of measures ok for use ; inhabitant contemplations, where both the limit and inclinations are significant; nonstandard development; low quality/permeable block and inadequately kept up with structures.

Barring water requires the thought of various section focuses: windows and entryways, floor voids (especially suspended floors), breaks or holes in dividers, air vents or air blocks (intended for ventilation), administration pipes and pipes, latrines and channels, or leakage through floors (especially earth or stone floors where there is no moist evidence film). Also, the nature of building parts is basic, as disappointment of any one component can think twice about entire plan.

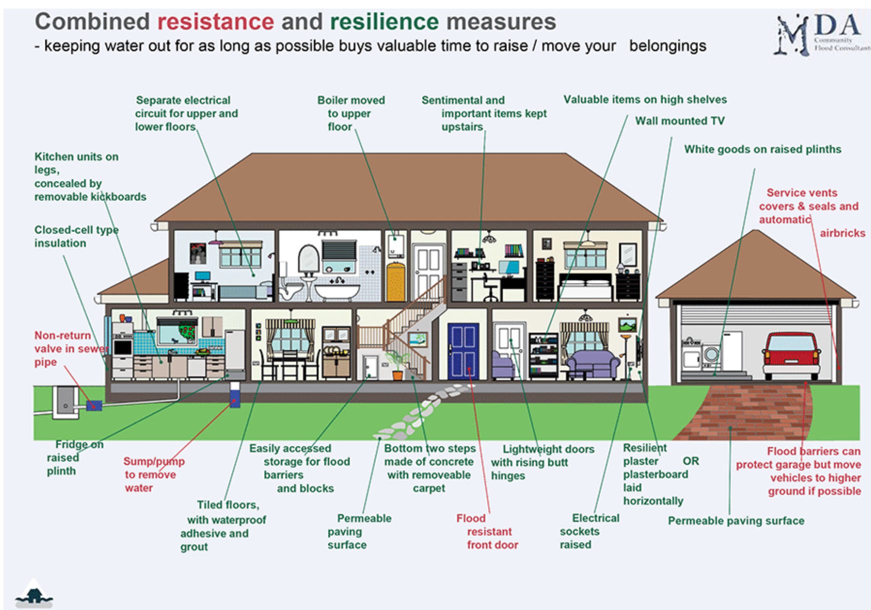

Figure 2.3: Graphic illustrating combined resistance and resilience measures

Source: Dhonau & Rose, (2016).

Aperture technology has emerged from simple wooden boards held up by sandbags to an industry creating innovative, ready-made door guards, smart air bricks, non-return valves, etc. These products have been subjected to laboratory testing, particularly in the Uk as a result of the establishment of kite mark standards defining the acceptable leakage rates of barriers (BSI, 2016).

In brief term flooding, obstructing gaps might be adequate, however in long-span flooding water will possibly pervade through the structure texture itself. This has prompted the expanded utilization of "failing" innovation to build the water snugness of dividers, driven in the United Kingdom by the information got from waterproofing cellars. Layers and collections to further develop water-snugness of dividers have additionally been tried in the United Kingdom by Escarameia and Tagg (Escarameia *et al.*, 2006) and in the United States, showing that mixes including splashed and sheet-applied water-safe layers, protected cement formwork, and metal primary protected boards were appropriate to reject water up to 1 m (Perkes, 2011). Work has likewise been completed by CSIRO in Australia and by Branz in New Zealand. Further examination in the United Kingdom on Silone-based items show that covering dividers and rerouting with advertisement blend grout can decrease entrance to levels that can be controlled and removed by siphons (Beddoes and Booth, 2015).

When water enters the structure, a wide scope of building components, installations, and fittings become defenseless against harm. Ways to deal with limit harm (as delineated in Figure 2.3) inside a structure reflect building-level methodologies, aversion, water-safe materials, water-strong materials, and quick recuperation (Lamond *et al.*, 2012). The viability of aversion measures is plainly obvious, subject to the stature to which building components, installations, and substance might be raised. Things might be forever raised over the stature of anticipated flooding—for instance, electrical attachments, divider mounted cupboards, meters, control boards and boilers, and so on Dropping electrical administrations from a higher place and detaching circuits liable to be influenced from the remainder of the wiring are in accordance with flow electrical practice, and current cabling and funneling inside dividers and floors are typically all around ensured. (Lamond *et al.*, 2015).

On the other hand, things, for example, rugs and sensibly lightweight furniture might be moved fully expecting an approaching flood, if a reasonably high extra room is accessible or one that can be raised briefly on supports. In these conditions, development ought to take into consideration simplicity of evacuation for example simple eliminate pivots for entryways and bureau entryways and furthermore permit simple admittance to upper levels for expulsion (keeping away from steep, tight, and winding flights of stairs).

2.13 Research on Water Resistant and Resilient Materials

Exhortation on the properties of materials according to flooding is given in some direction; for instance, the Hawkesbury-Nepean direction contains tables of material retentiveness and of reasonableness of materials for 96-hour drenching. This data depends on research completed during the 1990s by Cole for CSIRO. This data is additionally given by UK distributions (Bowker *et al.*, 2007) in view of work completed for CLG in 2003–2005.

Examination on materials subject to hydrostatic strain, which may be capable during profound flooding, shows that the porosity of development materials can influence both entrance and drying properties. Properties can be built of materials, for example, designed blocks with an end goal to restrict water entrance into and through dividers (Escarameia *et al.*, 2006). Various sorts of mortar and plasterboard have additionally been contemplated. The insecurity of gypsum-based mortars is all around archived, as they ingest huge amounts of water and are defenseless against weakening and salt vehicle (Drdácký, 2010). Hence, lime-based or concrete based choices are regularly suggested. Nonetheless, gypsum rushes to dry out and might be reasonable in conditions where brief length floods are normal.

Strong mortar straightforwardly applied to dividers or on secures on top of workmanship addresses an illustration of a conventional development technique that is progressively being supplanted by options, for example, "dry covering" with pre-arranged sheets made of gypsum and a light layer of skimming mortar. Standard gypsum sheets experience the ill effects of comparative issues to gypsum mortar (Escarameia *et al.,* 2007). Nonetheless, an expanding scope of dampness and water-safe sheets are accessible, and some have been tried for execution under flood conditions. Aglan *et al.,* (2014) found that water-safe sheets (Fiberock) were reasonable for surges of as long as three days' length. "Sprinkle evidence" board (Fermacell) was found to oppose water entrance by Escarameia *et al.,* (2006), in spite of the fact that it was mutilated because of hydrostatic strain.

The job of protection materials in property level strength is muddled, in light of the fact that it is frequently out of reach, being arranged inside the cavity, under floor structure, or behind different completions. In this manner, insulation must hold trustworthiness when overflowed and not droop inside a pit, dry rapidly and hold warm execution, and not obstruct drying of adjoining materials. Test proof and experience recommend that fiberglass, mineral fiber (also known as mineral fleece/rock fleece/stone fleece), and blown-in mica can droop and corrupt during wetting (Escarameia *et al.,* 2006). Albeit ongoing tests on mineral batt protection shows that it can dry out without debasement when adequately upheld and depleted (Sanders, 2014), it is delayed to dry out, especially inside a cavity. Shut cell protection is more unbending and is in this way regularly suggested, yet there are not many tests that exhibit the post-flood warm execution.

Waterproof protection materials have been tried, and as they can be exhibited to oppose entrance by floodwater, their warm respectability is held, Contemplations of protection and drying are shrouded in the part on fix and restoration. Timber is another widely used building material that under some circumstances can be regarded as highly resilient. Solid, dense, and well-seasoned wood building elements, fittings, and furniture can survive inundation (Lamond *et al.,* 2012). But more modern, lighter-density, and fast-treated wood is less resilient; such wood can be made more resilient by surface treatment with varnish and paints on all surfaces and renewed as necessary. Composite wood products, for example paneling and veneers and MDF/particleboard, are not regarded as resilient, with the exception of highest-grade marine ply The type of timber framing used in modern United Kingdom buildings requires specialist treatment, and panels will usually need to be removed for restoration after a flood.

Table 2.1 below shows an example of guidance helpful in selecting suitable materials for long-duration flooding (over 96 hours' immersion). This demonstrates how the research can be made highly relevant in assisting competent building professionals in selecting materials and assemblages. However, it needs to be considered in a whole-building context and also in the light of occupant capacity and preference, availability, and cost of materials and skilled workers and the reinstatement protocols that may be followed in the event of a flood.

Table 2.1: An example of selection of materials for long duration of flooding

Component	Suitable*	Mild Effects*	Marked Effects*	Severe Effects*
FLOOR, SUB-FLOOR STRUCTURE	slab-on-ground	timber T&G (with ends only epoxy sealed and provision	standard grade plywood	timber floor close to the ground and

	suspended concrete	of side clearance for board swelling) or plywood		particleboard flooring close to the ground
WALLS SUPPORT STRUCTURE	reinforced or mass concrete	full brick/block masonry cavity brick	brick/block veneer with venting (stud frame)	Inaccessible openings large windows low to the ground
WALL AND CEILING LININGS	fiber cement sheet	common bricks	exterior-grade particleboard	particleboard
	face brick or blockwork	solid wood, fully sealed	Hardboard	fiberboard or strawboard
	cement render	exterior grade plywood	solid wood with allowance for swelling	wallpaper
	ceramic wall tiles	fully sealed	exterior grade plywood	cloth wall coverings
	galvanized steel sheet	nonferrous metals	Plasterboard	standard plywood
	glass and glass blocks			gypsum plaster
	stone, solid or veneer			
	plastic sheeting or tiles with waterproof adhesive			
INSULATION	plastic/ polystyrene boards	reflective foil perforated with holes to drain water if used under timber floors	materials which store water and delay drying	open-celled insulation (batts etc.)

	closed cell solid insulation	

KEY

1. **Suitable:** These materials or products are relatively unaffected by submersion and flood exposure and are the best available for the particular application.
2. **Mild Effects:** These materials or products suffer only mild effects from flooding and are the next best choice if the most suitable materials or products are too expensive or unavailable.
3. **Marked Effects:** These materials or products are more liable to damage under flood than the above category.
4. **Severe Effects**: These materials or products are seriously affected by floodwaters and have to be replaced if inundated.

2.14 Resilient Repair and Considerate Reinstatement

As an alternative or as a complement to designing a property to be resilient, it has to be recognized that when a flood event occurs there will be a need to dry, clean, and perhaps repair the affected buildings as quickly and sympathetically as possible. The trauma faced by flood-affected occupants is well documented (Whittle and Medd, 2011), and the desire to return quickly after a flood is widespread (Soetanto *et al.*, 2008). Faster recovery can even limit psycho-social symptoms from flooding (Lamond *et al.*, 2015). Considerate reinstatement as advocated by Woodhead (2011) and the sensitive and professional handling of the recovery process. Fast and effective drying of flooded buildings is therefore a key criterion in recovery, and the avoidance of trapped water, slow-drying material, or water vapor between building layers and behind finishes is desirable. The potential exists for secondary damage to occur if drying is delayed or badly controlled, and therefore the choice of resilience approaches should be contextualized within a recovery/reinstatement plan.

Resilient materials that are slow to dry out—for example, lime can slow recovery, even though they can be retained. Another consideration in the retention of resilient materials is the need to decontaminate them. There is very little evidence available on the scale of the contamination issue in a post-flood situation.

Nonetheless, experts by and large ought to give drying and disinfecting authentications, and biocidal cleaning specialists are broadly accessible for tenants to utilize in case experts are not needed for different purposes. Warmth helped and speed-drying procedures can speed up the restoration of property, and there is a wide assortment of specific instruments to help cleaning and drying and to get to voids where water might be caught. In arranging a versatile property plot, it very well might be imperative to choose materials that won't be harmed by the cleaning and drying measures. Notwithstanding, there is next to no investigation into the effects of cleaning and drying that can direct structure tenants in these decisions.

2.15 Future Developments in Flood Resilient Construction and Adaptation

It is clear from the above that the materials and technology to create and retrofit properties that are more resilient to flooding already exist. However, the adoption of such measures is limited by a number of factors, underlying which are important limitations that indicate the need for future developments in resilient technologies and construction (Proverbs and Lamond, 2008). Recommended adaptations are often rejected on aesthetic or familiarization grounds because they make properties look different (Thurston *et al.*, 2008) or are designed to be functional without adequate consideration of good design. In the United Kingdom, recently developed flood doors are designed to look more conventional and potentially enhance the appearance of homes. Further development of flood resilience technology that enhances the aesthetic appeal of adapted property would support uptake of measures.

Cost of adaptation is also a consideration (Thurston *et al.*, 2008). Future developments that reduce cost or that offer other aesthetic or functional advantages may also reduce the barriers to uptake (Lamond *et al.*, 2015).

For instance, better comprehension of the connection between strong protection and warm snugness may prompt the improvement of multi-reason flood versatility items or conventions. Execution principles for opposition items exist, basically in the United Kingdom, yet execution guidelines for tough materials and planned plans are not accessible. Absence of trust in the exhibition of measures is a boundary to take-up, and in this way future improvements should plan to build up norms or execution markers to upgrade conviction that actions will restrict harm and decrease interruption. Breathability is additionally a significant thought that restricts the determination of measures by experts concerned not to make dampness issues inside properties. Further improvements in innovation might have to expand on the fume penetrable coatings previously existing (Beddoes and Booth, 2015). Shape restraint through biocides or gatherings that can be handily destroyed for cleaning and drying are elective courses to evade dampness trap issues.

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

3.1 Research Method

Research used both qualitative and quantitative analysis methods to gather information about resilient strategies for flood management. Using descriptive analysis to evaluate resilient strategies in buildings situated in flood prone areas. The choice of descriptive research of survey type was based on the fact that it has the potential to provide information about the characteristics within a particular field of study with the purpose of providing a picture of situations, as they naturally exist. Asika (2009) noted that descriptive research is concerned with the collection and analysis of data for the purpose of describing, evaluating or comparing current events or prevailing practices, event or occurrences. The descriptive survey method has the advantage of covering a wide scope since a great deal of information can be obtained from a large population. Also, in a descriptive survey, the characteristics of a defined population can also be inferred from sample drawn from such population.

3.2 Data Collection

In order to attract a sufficient number of respondents, a questionnaire survey was deemed fit for this research. It was also used to gain critical views on the topics under investigation. In their analysis of the respondent's views of public building projects in Nigeria, Akande *et al.*, (2018) took a similar approach. Before it was deemed necessary to gather the required data to verify that the respondents could easily grasp the questionnaire, it was piloted using the intended, structured questionnaire. The survey sample was primarily drawn from residential properties, with respondents selected using random sampling techniques. A total of 200 questionnaires were distributed and 172 responses were obtained for data analysis. The questionnaires were printed and distributed to respondents and subsequently the survey instrument was fully employed.

3.2.1 Method of research data collection

The descriptive analysis approach was used to conduct this study, the primary sources of information used in this analysis were primary and secondary data. The facts obtained are qualitative, and the variable used to obtain the principal data was obtained through secondary data analysis. The researcher gathered the primary data for this analysis in the region. Surveys, observations, and case studies are examples of sources that collect relevant features that help to clarify the variable being evaluated. The research design that was used for the study is the descriptive research of the survey type.

3.2.1.1 Secondary data collection

The data was gathered from printed and unpublished articles, symposium papers, textbooks, and other publications. The data gathered was used to advance the study's interconnected expertise. Relevant evidence from previous studies and documents about flood vulnerabilities and resilient strategies were examined. The following items were considered in the literature review: archives, articles, journals, and magazines on topics related to the research.

3.2.1.2 Primary data collection

A survey, conducted via the administration of questionnaires to residents in Lekki was used to obtain primary data. Also, an observation schedule was used to collect primary data, this was done by examining the condition existing residential structures in Lekki, Lagos State.

The instruments used in this research were tailored towards achieving the research objectives of this study.

3.3 The Survey Instrument

An image of the main issues and situations influencing flood resilient strategies in this studies were obtained first from the literature reviewed, observations and preliminary conversations with residents and built environment professionals, from which a questionnaire was built in line with the need for flood risk management. Closed questions with yes/no answer choices, as well as questions with pre-defined answer categories and the potential for multiple answers in some questions, were included in the questionnaire. The most appropriate method was stated as using a questionnaire for obtaining the most cost-effective, accurate, and widely used method of gathering the required information from the respondents.

3.3.1 Sample selection

The survey's sample was primarily drawn from the residents of Lekki, Lagos State, Nigeria. Random sampling techniques were used to select respondents from among the students interested in the study field. To eradicate bias, the data used was primary data collected by the use of a questionnaire. Research assistants were used to distribute the questionnaires. The sampling procedure for selecting respondents for this study were multi-stage sampling technique(s) consisting of proportionate sampling and convenience sampling. Daramola (2006) defined a sample as a fair representative group selected from the target population.

3.3.2 Data analysis

In order to accomplish the study's objective, the relative importance index for ranking was used to calculate the responses obtained from the questionnaire using descriptive statistics. The socio-demographic data was summarized using descriptive analysis, and the problems identified in this study were analysed using statistical analysis. Because the reading needs investigation, examination for the case study, qualitative data analysis approach was used in the research. Related points of view were analysed and itemized as a result, and this served as the foundation for making decisions. The variables and parameters used in this study were gotten from relevant literature

which were reviewed and studied to retrieve vital and useful information for this study. These variables gotten from relevant literature were used in the observation schedule and the questionnaire. Thus, the observation schedule was used to check the conditions and evaluate the food resilient strategies in Lekki, Lagos state. These features are specific landscape properties are manipulated through management and design. Other variables measured in this study were gotten from works done by various researchers. As such, a study conducted by the criteria for case study selection were purposely selected based on; Building's Strategies to adapt to flood, materials employed, functionality and flexibility of design.

3.4 Reliability Test

The data was analysed and reliability tests were performed to assess the reliability of the measurement scales used in this study. The instruments' reliability was determined using Cronbach's uniform alpha to ensure un-dimensionality between the test scales. Cronbach's alpha was calculated for each test, and it was discovered that the reliability scales had acceptable values of 0.59. This means that the data is reliable and has a Moderate level of reliability.

3.5 Method of Data Analysis and Presentation

The data obtained from the distribution of questionnaires were thereby analysed using the SPSS statistical analytic tool. Correlation analyses were used in order to find similarities between various variables and parameters adopted by this study. Also, frequencies were used as well to gain understanding on percentages and hierarchy-based data from variables and parameters. Pearson's chi-square test was also used to gain insight and to find statistical relationships between variables. This sheds light on potential areas of research that need to be investigated. Hence, from the analyses, results were highlighted and presented in tables, charts and graphs which were done using the Microsoft excel tool. The significance level was determined using arithmetic mean value scores from the questionnaire created for this study, which mainly used on a scale of 1 to 5, Likert scales are used. The lower the mean value, the less significant the element is in the analysis. The case studies have been analysed on the following characteristics; Architectural description, Architectural Style, Strategies Employed.

3.6 Summary of Research Method

The research method adopted by this study is mixed due to the fact that both quantitative and qualitative data were obtained based on the research instruments used. Both primary and secondary data were used for this study. Analyses were done using SPSS and Microsoft Excel as a tool. Results and inferences were presented in tables, graphs and charts.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Empirical Findings (Quantitative)

Primary data was collected through the use of questionnaire. The data was examined and test for reliability was conducted and it was discovered that the reliability was 0.59. This imply that the reliability was high therefore other analysis can be conducted. Relative Important Index (RII) was calculated and each observation was ranged and the most important ones was identified and interpreted. Ranks of 5 were employed. With scales ranging from Very Ofen to Not often for question 3, a scale of Least effective to Higly effective for questions 15 to 18 and a scale of Not damaged to very Serious Damage for questions 21 to 25

4.1.1 Reliability test

In order to verify the reliability of the measurement scales employed in this study's analysis, the data was analyzed and reliability tests were carried out. Using Cronbach's standardized alpha (Table 4.1), the reliability of the instruments was obtained to ensure unidimensionality between the test scales.

Table 4.1: Summary of the reliability for the questionnaire survey

Cronbach's Alpha	Number of questions	Conclusion
0.59	26	Moderately reliable

Source: Author's Work (2023)

From the data set, 26 variables were observed because these are the variables with numeric values and the reliability coefficient of all 26 parameters is 0.26. This implies moderate reliability of the data.

4.1.2 Respondents' socio-demographic characteristics

In view of the projected population of 401,272 residents in Lekki, Lagos state, a total of 172 respondents were recorded from 200 questionaires administered. This shows a response rate of 86%. Based on gender, females have a greater outcome with a frequency of 102 respondents which makes up 58.6% and 65 male respondents which makes up 37.45%. 5 of the respondents failed to indicate gender which makes up 2.9% of the total respondents Table 4.2. This is hoped to offer the nacessary foundation for comprehension of the data collected.

Table 4.2: Respondents Background Characteristics

Gender	Frequency	Percentage
Male	65	37.4
Female	102	58.6
Others	5	2.9
Total	172	100

Source: Aurthors Research Work (2023)

4.1.3 Respondents duration of stay in the study area

From Table 4.3 below 62.3% or the respondents have resided in the study are for up to 5 years while 25% of the respondents has stayed within 6 to 10 years in the study area. 19 respondents have stayed in the study area within 11 to 20years which accounts for 11% while just 3 people have stayed for 20 years and above which takes 1.7 percent of the total respondents

Table 4.3: Respondents Duration of Stay in the study area

Characteristics	Frequency	Percentage
0-5 years	107	62.3
6-10 years	43	25
11-20 years	19	11
20 years above	3	1.7

Source: Aurthors Research Work (2023)

4.1.4 Frequency of flood events

From the survey, 98 respondents asscertain that floods barely happens in a rain cycle while 27 respondents agree that flooding happens quite often. 18 Respondents said the event of flooding happens while not often. 1 respondent however always experiences flood every rain cycle while 8 respondent agreen o not highly often as seend in Figure 1 below

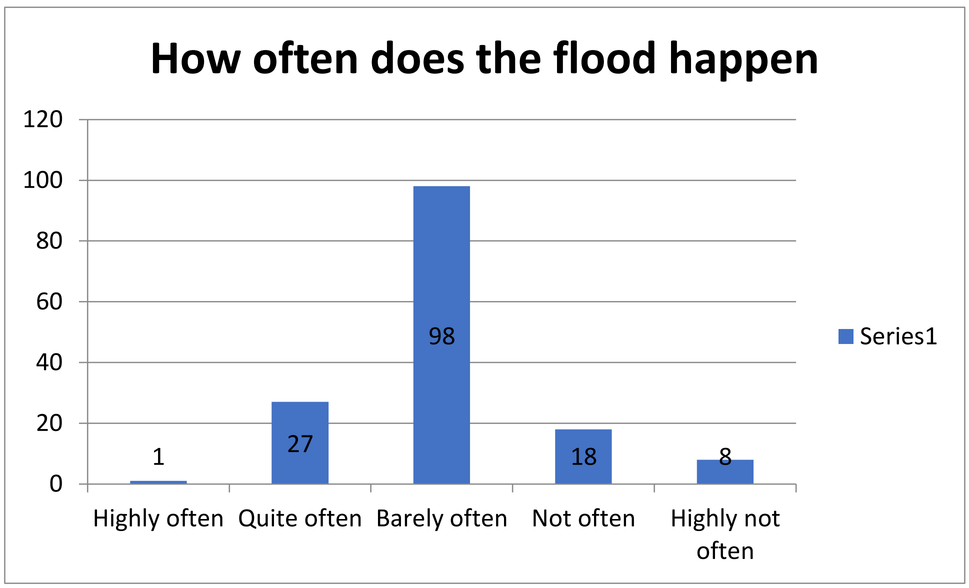

Figure 4.1: How often does flood happen

Source:Aurthors Research Work (2023)

4.1.5 Respondents knowledge on the types of flood

From the survey, respondents asscertain that flash floods and river floods are most common causes of floods in the study area as 77 and 69 respondents says respectively, 4 building occupants suguest costal floods are the causes as they think that there buildings are on natural flood plain, while 2 repondents had no idea of the cause of the flood.

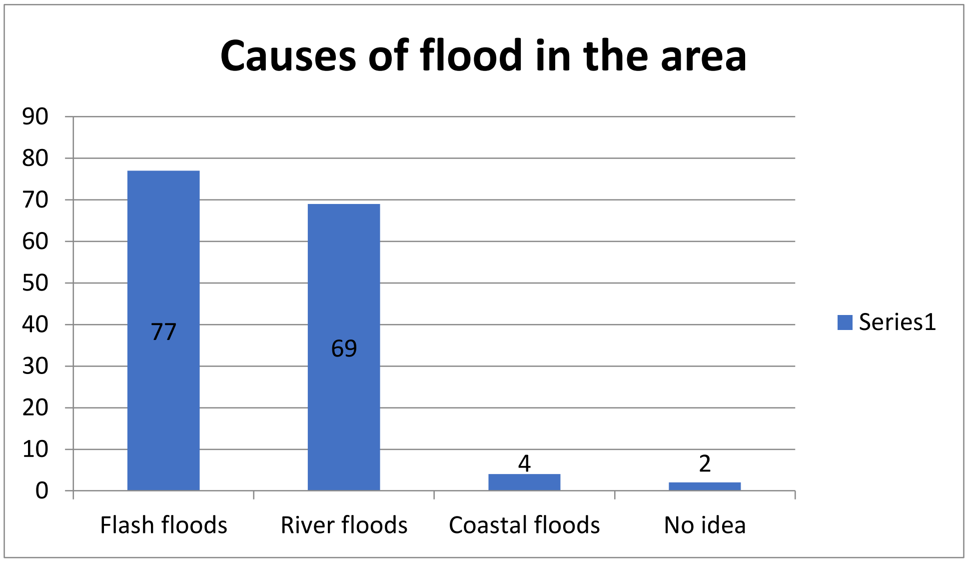

Figure 4.2: Causes of flood in the area

Source:Aurthors Research Work (2023)

4.1.6 Presence of flood strategies

From Table 4.4 below, 61 respondents actively use flood resilient strategies to manage flood vulnerabilities while 85 respondents do not use any flood resilient strategies. 21 respondents are not sure if the employ any strategies while 7 respondents do not find the situation applicable to them.

Table 4.4: Presence of flood resilience strategies in sample

Characteristics		**Frequency**	**Percentage**
Valid	Not applicable	7	4.0
	Yes	61	35.1
	No	85	48.9
	Not Sure	21	12.0
	Total	172	100.0

Source:Aurthors Research Work (2023)

4.1.7 Building strategies employed

Table 4.5 below also shows building materials employed in the residential buildings in lekki, lagos. It reports Sandcrete blocks as a dominating building material in the study are with 65.1% Ranking 1st with steel, wood, burnt clay, Thatch and mud ranking 2nd, 3rd,4th,5th and 6th respectfully.

Table 4.5: Building materials employed

Materials Specified	Frequency	Percentage	Rank
Sandcrete Block	112	65.1	1st
Mud	1	0.6	6th
Thatch	3	1.7	5th
Burnt Clay	2	1.2	4th
Wood	7	4.1	3rd
Steel	47	27.3	2nd

Source: Aurthors Research Work (2023)

4.1.8 Structural systems employed in the buildings substructure

Table 4.6 Highlights structural system and employed in the substructure of residential buildings. Mixed Method (Reinforced cement concrete + Masonry) ranking 1st with 45.3% and Steel structures, Reinforced cement concrete (RCC) and Timber structure comes in 2nd, 3rd and 4th respectfully. Mixed (Steel + Masonry) Structure and Load bearing structure were void with 0%.

Table 4.6: Structural systems employed in the building

Materials Specified	Frequency	Percentage	Rank
Reinforced cement concrete (RCC)	42	24.4	3rd
Mixed (Reinforced Cement Concrete + Masonry)	78	45.3	1st
Load Bearing Structure	-	-	-
Timber structure	7	4.1	4th
Steel Structure	45	26.2	2nd

Mixed (steel + Masonry) Structure	-	-	-

Source:Aurthors Research Work (2023)

4.1.9 Problems encountered due to flood in the building

The results shows that 12% of the respondent experience negative health outcomes, 11% of the building collapse due to flooding, while 29% of the respondents experience moisture and 15% of the respondents' material deteriorating due to flood and only 2% of the respondent were confirmed dead due to flooding.

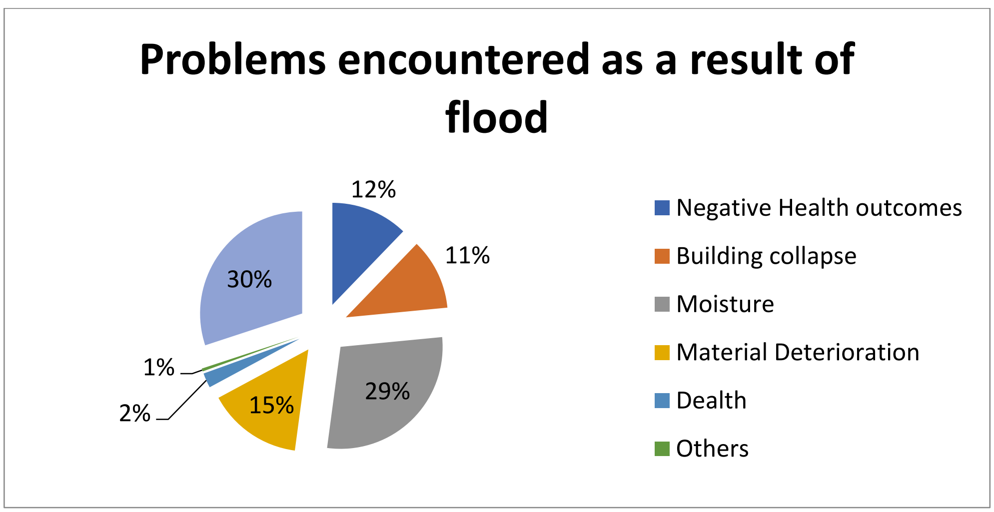

Figure 4.3: Problems Encountered as a result of flood

Source:Aurthors Research Work (2023)

4.1.10 Measures taken to prevent the building from flood

From figure II Below, which illustrates how 31 of the respondent applied temporary barriers to control flood, 54 of the respondents control flooding by channelling the water away from the building, 33 of the respondents uses elevated or raised floors and lastly, 66 of the respondent uses water proofing as a measure to prevent the building from flood.

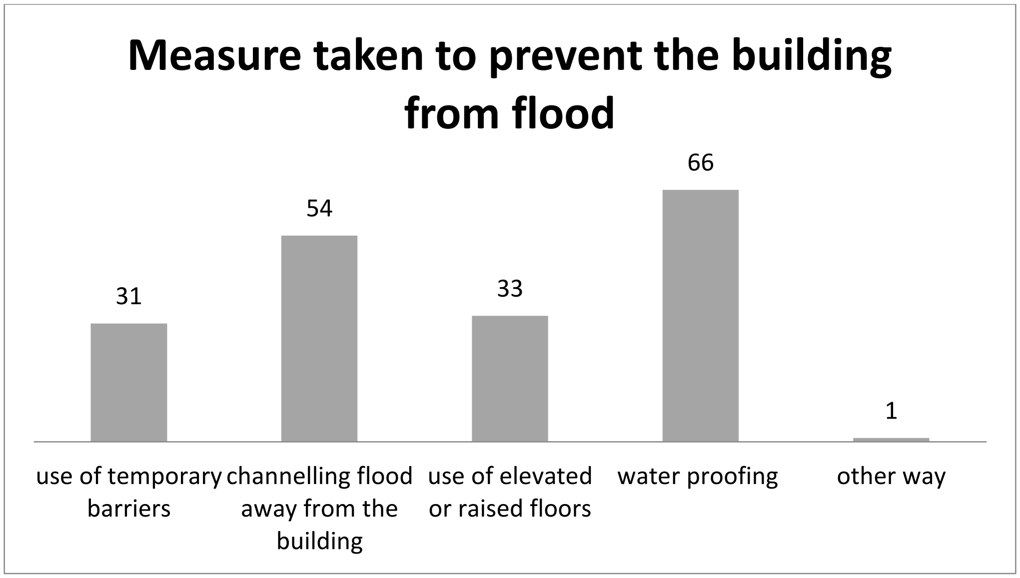

Figure 4.4: Showing Measures taken to prevent the building from flood

Source:Aurthors Research Work (2023)

4.1.11 Validity of measures taken to prevent the building from flood

From table 8 below, the measure taken by the respondents to prevent the building from floor only yielded a low result as only 25.6% of the respondents admit that the measure they have taken actually caused a reduction in flood risk. This percentage is very low; this implies that other measure need to be adopted in order to reduce flood risk as the initial measure did not result to a reduction in flood risk.

Table 4.7: Validity of Measures taken to prevent to prevent building from flood

		Frequency	**Percent**
Valid	Not applicable	13	7.5
	Yes	44	25.6
	No	63	36.6
	Maybe	52	30.2

Total	172	100

Source:Aurthors Research Work (2023)

4.1.12 Damage experienced as a result of flood

Figure III shows 17% of the respondent experience damage due to building fitting, 35% experience damage to exterior wall and 25% experience damage to interior wall, 9% experience damage to footing and foundation while only 7% of the respondent experience damage to opening such as doors and windows.

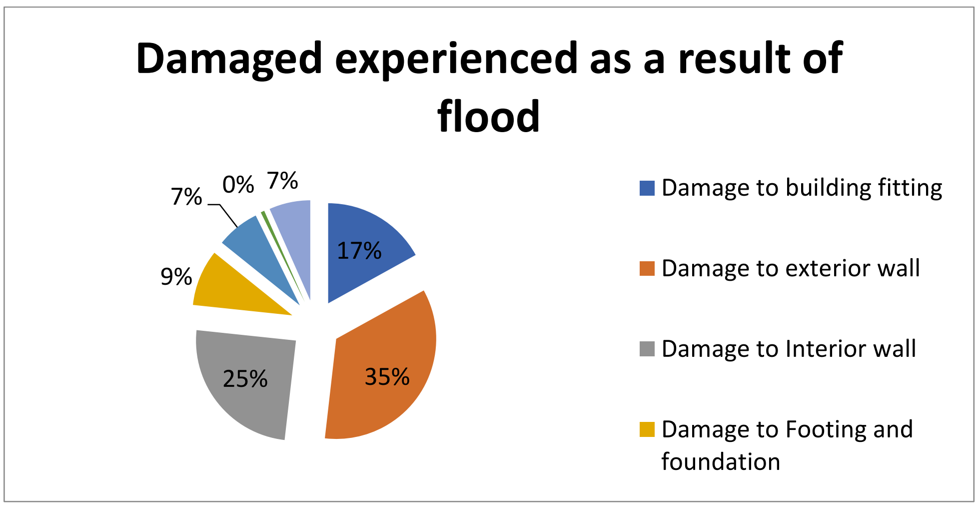

Figure 4.5: Data level of damage caused by flood

Source:Aurthors Research Work (2023)

4.2 Case Studies Findings (Qualitative)

4.2.1 Case study one: Falling waters by Frank Lloyd Wright

General Overview

Location: Pennsylvania, USA

Year: 1936-1939

Architect: Frank Lloyd Wright

Style: Morden Architecture

Region: Europe And North America

Plate VI: Showing the Falling Waters House by Frank Lloyd Wright

Source: https://www.mentalfloss.com/article/90823/12-facts-about-frank-lloyd-wrights-fallingwater

Falling Water Is a House Designed in 1935 By American Architect Frank Lloyd Wright (1867-1959) For The Kaufman Family, Owners of Pittsburgh's Largest Departmental Store. The Kaufmann Family Through 1885-1989 Used Falling Waters as A Vacation House During Their Lifetimes. Edgar Kaufmann Jr. Donated and Entrusted Falling Water and Its Surrounding 469 Acres of Natural Land to The Western Pennsylvania Conservancy.

Plate VII: Showing the exterior staircase leading to natural flowing water

Source: https://www.khanacademy.org/humanities/ap-art-history/later-europe-and-americas/modernity-ap/a/frank-lloyd-wright-fallingwater

Falling Water Is a House Partnership Was a Fruitful On Challenging New Boundaries and Ideas with A Holiday House Over the Water Fall. Water and Rocks Surround the Building with The Building Sitting On Above the Water Fall. The materials employed in the construction of the frank Lloyd's falling water Stone (flag stone), concrete, steel, glass and wood.

4.2.*2* Case study two: Makoko floating school, Lagos, Nigeria.

General Overview

Location: Lagos, Nigeria.

Year: 2012-2013

Architect: Kunle Adeyemi

Style: Morden Architecture

Region: West Africa

Plate VIII: Showing Makoko floating school during construction

Source: https://www.archdaily.com/344047/makoko-floating-school-nle-architects/51405b47b3fc4b33b000004b_makoko-floating-school-nle-architects_makokoschool_03-jpg

Makoko floating school is a prototype structure that addresses physical and social needs in view of the growing challenges of climate change in an urbanising African context. it is a movable 'building' or 'watercraft' currently located in the aquatic community of Makoko in the lagoon heart, Lagos, Nigeria. it is a floating structure that adapts to the tidal changes and varying water levels, making it invulnerable to flooding and storm surges. it is designed to use renewable energy, to recycle organic waste and to harvest rainwater.

Plate IX: Showing Makoko floating school during construction.

Source: https://publicdelivery.org/makoko-floating-school/

256 plastic drums were used to float the base of the school in the water and provide structural support to the spaces above. this design serves as a case study towards the function of materials, but unfortunately due to heavy rains that structure collapsed leaving the plastic roof and barrels intact leaving the remaining supports broken.

Plate X: Showing Makoko floating school after construction.

Source: https://publicdelivery.org/makoko-floating-school/

The most compelling attributes of the project are conceptual. adeyemi reimagined water as his project's construction site. he designed structures to harness and improve the skill sets of the artisans of the waterfront. the project was created from leftover materials donated by a local sawmill and locally grown bamboo, harnessing a sub-Saharan tradition of utility from waste. it took the tradition of personal floating structures and made them into a community centre. the structure is ten times larger than the local fishing vessels and stilt architecture used for residences and local businesses.

4.2.3 Case study three: Farnsworth house, Chicago, Illinios.

General Overview

Location: Chicago, Illinois.

Year: 1946-1951

Architect: Ludwig Miles Van Der Rohe

Style: International Style (Mordernist)

Region: North America

Plate XI: Showing Farnsworth house in autumn

Source: https://www.arch2o.com/the-farnsworth-house-mies-van-der-rohe/

The house was raised 5 feet 3 inches off the ground, allowing only the steel columns to meet the ground seamlessly. the house’s main structural support comprises eight white vertical i-beams, which connect the rectangular roof and floor slabs with floor-to-ceiling plate glass. the structure is suspended on those beams some 5 feet above the ground and about more than 8 feet above the fox river. a third of the slab is an open-air porch, and the only operable windows are two small hopper units at the eastern end in the bedroom area. the mullions act as structural support.

Plate XII: Showing Farnsworth house in a flood situation

Source: https://www.buoyantfoundation.org/illinois-farnsworth-house

In 1999, architectural digest covered the house’s then recent restoration, which was in response to a 1996 flood. at the time, dirk lohan, mies’s grandson who followed in his architectural footsteps to take over his studio, expressed the continuation of his worries. “i’m very concerned that the flooding could happen again,” lohan told writer roland flamini, in a comment that now reads as eerily prescient.

Plate XIII: Showing the building in relation with the environment

Source: https://inhabitat.com/iconic-farnsworth-house-gets-a-conceptual-sustainable-redesign

4.2.4 Case study four: The kentish classic, Kentish town, North London

General Overview

Location: Kentish Town, North London.

Year: 2016

Architect: The DHaus Company Ltd.

Style: Georgian Architecture

Region: North London

Plate XIV: Showing Proposal for Kentish Classic Housing in London England

Source: https://www.dezeen.com/2019/01/30/dhaus-company-kentish-classic-georgian-future-housing-mini-living-movie/

The london architecture studio's contest submission: the kentish classic by the d*haus company, a practice in north london, self-described as a “collective of architects, artists, sculptors, web developers and product designers”

Plate XV: Showing Proposal for Kentish Classic Housing in London England

Source: https://www.dezeen.com/2019/01/30/dhaus-company-kentish-classic-georgian-future-housing-mini-living-movie/

Kentish Classic is Georgian architecture that is characterized by its proportion and balance; simple mathematical ratios were used to determine the height of a window in relation to its width or the shape of a room as a double cube. regularity, as with ashlar (uniformly cut) stonework, was strongly approved, imbuing symmetry and adherence to classical rules.

Plate XVI: Showing Proposal for Kentish Classic Housing in London England

Source: https://www.dezeen.com/2019/01/30/dhaus-company-kentish-classic-georgian-future-housing-mini-living-movie/

Fully automated cnc plywood georgian terrace replicas are built on top of flood proof concrete plinths for a venetian take on kentish town 100 years from now, feeding the desire for the london period property long into the future while conserving as best we can certain styles in areas such as kentish town in north london.

4.2.5 Case study five: Amphibious houses of Maasbommel, Netherland

General Overview

Location: Maasbommel, Netherland.

Year: 2020

Architect: Dura Vermeer.

Style: Georgian Architecture

Region: Europe

Plate XVII: A Row floating houses during floods

Source: https://climate-adapt.eea.europa.eu/metadata/case-studies/amphibious-housing-in-maasbommel-the-netherlands

A collection of “amphibious” floating houses, with floating foundations to protect them against flooding, were built in the village of maasbommel in the netherlands, in areas that lie outside of flood protection infrastructure. this project shows how people in floodplains can better live with the water through housing that adapts to changing water levels.

The netherlands, much like southern louisiana, is located on a delta and experiences flooding from rivers and from ocean storms. the dutch approach to flood control is touted as the international best practice. most communities in the netherlands are protected by dykes, levees, and floodgates. however several small rural villages are located outside of the flood protection infrastructure. maasbommel, located along the meuse river, is one of those communities. it is known mostly for water-based recreational activities and is home to a small permanent population.

Plate XVIII: Rear view of the amphibious houses

Source: https://climate-adapt.eea.europa.eu/metadata/case-studies/amphibious-housing-in-maasbommel-the-netherlands

Dura vermeer's design is an innovative approach that combines the best features of floating house boats and elevated buildings to create homes that can adapt to changes in water levelthe amphibious houses in massbommel float like house boats sited on a floating concrete "hull." however, they are also secured against strong winds and waves by permanent mooring posts driven deep into the ground, similar to those used to elevate homes. these posts guide the building to rise up and lower down, in place, according to changing river levels. in non-flood conditions, the houses rest on the river bank, allowing for convenient water access and creating a flat walkable space between homes. the amphibious houses also have basements, decks, and small gardens all supported by their foundations. they feature flexible pipes for electrical, water, and sewer lines that will keep the home “on the grid” even in a flooding event.

Plate XIX: Side view of the amphibious houses

Source: https://climate-adapt.eea.europa.eu/metadata/case-studies/amphibious-housing-in-maasbommel-the-netherlands

Strategies Employed include:

1. Houses adjust to changing water levels, but are secure enough to withstand strong currents and winds.

2. Each building's utilities rely on municipal services and infrastructure hook-ups, but reconsider traditional materials and techniques to allow for flexibility.

3. The self-rising houses avoid damage from flood waters, eliminating costly repairs after storm events.

4. This design allows people to live along the water without relying on large, hydrologically and ecologically disruptive protective infrastructure for flood protection.

5. The features of a neighborhood network, such as gardens and pedestrian connections between homes, are preserved during non-flood conditions.

4.2.6 Case study six: Formosa, The Amphibious Houses

General Overview

Location: South Buckinghamshire, United Kingdom.

Year: 1950

Architect: Baca Architects.

Style: Modern Architecture

Region: Europe

Plate XX: Approach view of the amphibious house

Source: https://inhabitat.com/6-amphibious-houses-that-float-to-escape-flooding/

Baca architects designed the amphibious house, a flood-resistant home that enjoys gorgeous waterfront views without risk of water damage. sited on the coveted banks of the river thames in buckinghamshire's town of marlow, the luxury home, which is described as the uk's first amphibious house, rests on separated foundations that let the structure float upwards on extended guideposts when the river thames overflows. the buoyant home has a 2.5-meter-high floodwater clearance.

Plate XXI: Approach view of the amphibious house

Source: https://inhabitat.com/6-amphibious-houses-that-float-to-escape-flooding/

Clad in zinc shingles and ample high-performance glazing, the unique waterfront home rests on fixed foundations that are separated to allow the structure to float upwards when the river thames overflows its banks. he dock will be pumped full of water every five years as part of a flotation test that will raise the house upwards a half meter

Plate XXII: Approach view of the amphibious house

Source: https://www.baca.uk.com/amphibioushouse.html

An amphibious house, a building that rests on the ground when conditions are dry, but rises up in its dock and floats during a flood. the house itself sits in the ground and the floating base is almost invisible from the outside. the ground floor of the house is raised above the ground by less than 1 m rather than by almost 2 m as will be required if it were not amphibious.

4.2.7 Deductions from case studies

The buildings reviewed are various examples of flood resilient buildings around the world. With various strategies employed, the resilience of this structures are centered around the building elements, building materials and the building design it self. It is safe to also point out that location, geography, environment and culture plays an important role in the choice of resilient strategies that were employed. Below is table 4.8 shows the various case studies evaluated and their appraisal. This includes their location, architect, architectural style and strategies employed.

Table 4.8: Case study matrix showing case studies and their appraisal

S/N	Case Study	Location	Architect	Architectural Style	Strategies Employed
1	The Falling Water House (1936-1939)	Pensylvania, United States Of America	Frank Lloyd Wright	Modern Architecture	elevated floors water proof building materials
2	Makoko Floating School (2012-2013)	Lagos, Nigeria	Kunle Adeyemi	Modern Architecture	floating design
3	Franswort House(1946-1951)	Chicago, Illinios	Ludwig Miles Van Der Rohe	International Style (Modenist)	ambhibious design water proof material

4	The Kentish Classic (2016)	Kentish Town, North London.	The Dhaus Company Ltd	Georgian Architecture	elevated floors floating ambhious design (car ports)
5	Amphibious Houses (2020)	Maasbommel, Netherland	Dura Vermeer	Modern Architecture	amphibious design water proof materials
6	Amphibious House (1950)	South Buckinghamshire, United Kindom	Baca Architects	Modern Architecture	amphibious design water proof materials

Source: Author's Work (2022)

4.3 Design Report: Proposed Flood Resilient Residential Buildings

4.3.1 The design statement

This study is focused on evaluating the flood resilience strategies as response to the increasing flood vulnerabilities in residential properties. In achieving this aim, a threefold objective was set each tied to a research question.

4.3.2 The study area

4.3.2.1 Proposed site and its location

The site was selected is located at sangotedo, lekki, lagos state. with located at an elevation of zero meters (0 feet) above sea level, lekki has a tropical wet and dry or savanna climate. The district's yearly temperature is 29.46ºc (85.03ºf) and it is 0.0% lower than nigeria's averages. Lekki typically receives about 135.64 millimeters (5.34 inches) of precipitation and has 198.96 rainy days (54.51% of the time) annually.

Lagos, state, south-western Nigeria, on the coast of the Bight of Benin is the area of study. The topography of Lagos is dominated by its system of islands, sandbars, and lagoons. All the territory is low-lying, the highest point on Lagos Island being only 22 feet (7 metres) above sea level. Lagos state has a total Area of 3,577 square km sitting on 351,861 Hectares of land. According to National Population Census of 2006, Lagos state houses approximately 9,013,534 people with 20 Local Governments and 37 Local Council Development Areas.

Figure 4.6: Google earth image of the proposed site

Source: Google Earth 2021

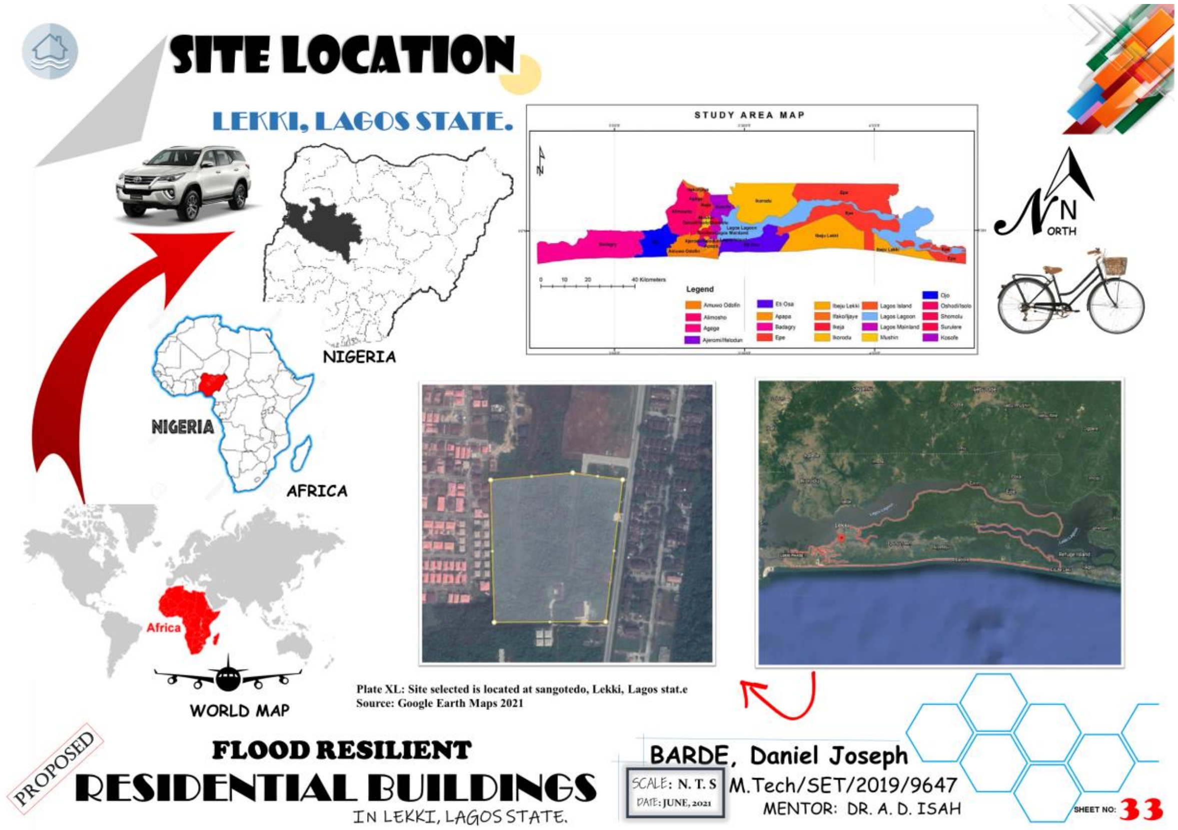

Figure 4.7: Image Showing Site Location

Source: Author's Work (2022)

4.3.2.2 Site selection criteria

From the existing land use map of lagos state, the portion of land selected are lands allocated for residential use. This is an important criteria for the selection of site as any development has to be done on legally alocated area so as to follow plan laid out forinfastructural development. Other criteria for the selection of the site above includes;

1. Topography- suitable size topography to ensure suitable lanscape for site planing of the estate.
2. Site zoning- semi quiet zone so as to ensure segregation nd quietness to foster concentration.

3. Availlability of water supply, sewage disposal, and electric power which are major utilities that were considered in this site selection.
4. Due to the large function of spaces that would be proposed in the estate, such as centra district with a mall, school, mosque and a police station. the size of land needed should be sufficient to match the need.

4.3.2.3 Site analysis

Site Characteristics were evaluated through careful analysis. The site has an existing access road which is north-bound. It also has a topography of relatively flat land with a gentle slop to the south. It has a nice vegetation cover of sparely distributed shurbs with lush green grasses and scattered trees. There is a presence of power line which can serve as a source of electricity to the building, with major winds nigeria been the North East trade wind and the South West trade wind with the dry atmosphere wind with dust causing harmattan from the north sahara desert.

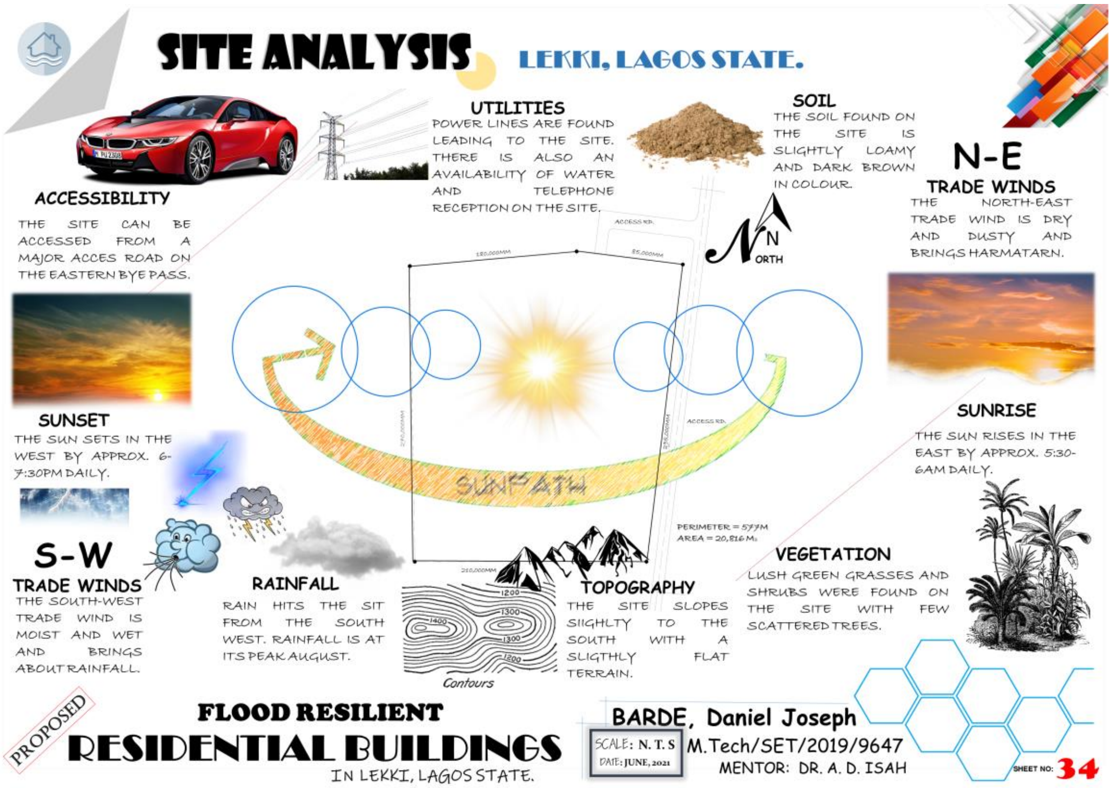

Figure 4.8: An Architectural Illustration Showing Site Analysis

Source: Author’s Work (2022)

4.3.3 Design brief

A proposal for the design of flood resilient residential buildings in Lekki, Lagos state. this is done by proposing prototypes for different building types for an estate in a flood prone area. The aim is to evaluate different flood resilient strategies in residential buildings. This is implemented with various considerations such as building strength, stability, durable materials, weather resistance and privacy. The different building types designed includes:

1. One-bedroom semidetached
2. Two-bedroom bungalow
3. Three-bedroom terrace with penthouse
4. Four-bedroom duplex

5. Shopping Centre
6. Studio Apartment

4.3.4 Conceptual analysis

The conceptualization of the design proposal was coined out of the understanding of water and its movement. This highlights the viable stratedies to pick from and inform the decision of a resilient design that works in floor intense areas. The school of thought that water can be treated in various ways around a built environment higlights attenuate, alleviate, restrict, create, realign and embrace as idealogies for flood adaptability. Certain elements of the building determines the buildings adaptability such as type of foundation, water proof material and amphibious structures come together to improve the resilience of the building to flood.

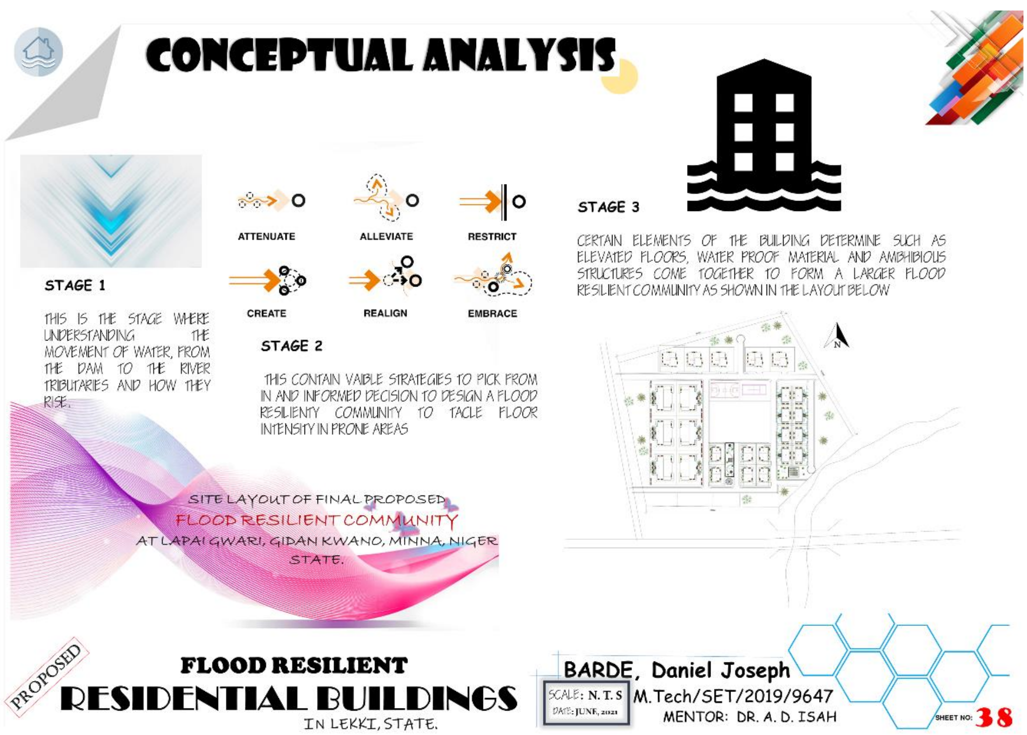

Figure 4.9: Showing conceptual analysis sheet

Source: Author’s Work (2022)

4.3.5 Site planning and layout

The entrance of the site is north bound towards the access road to the site. The entrance of the site is greeted with communual facilites such as the sports hub, the mosque, childreen playground and the shopping center which makes up the core facilities of the estate. Each of the building types are arrayed and bounded by both vehicular access roads and pedestrain walkways. The sides of the roads are also furnished with trees and security lights. Individuals buildings are bounded by short nested fences with shrubs for privacy.The site is also bounded by a drainage system that enables water to flow of water .The design of the site is aimed at improving the flow of water to and outside the site with every facility designed to withstand flooding.

4.4 Summary and Discussion of Result

From the Analyses above, numerous findings and insights were revealed about Flood resilence and building adaptablity. It was asscertain that flash floods and river floods are most common causes of floods as the study area is in a coastal region. This suggest that there is a high presence of rainfall in the region with most of the residents using unconventional means to adapt to the flood such as fleeing flood regions during flooding, using only top floors as flood waters evade lower floors, channeling flood waters away from the buiding by digging channels and water proofing of building materials such as walls after the flood. These data was collected across various social group factors (age, gender, ethnicity and the highest education obtained) to examine the relationship between the variables.

Case studies obtained points out how socio-cultural and geographical factors influence the choice of strategies used to adaptto flooding. With building of elevated houses as the most popular strategy, the development of floating and ambhibious houses are becoming popular in adapting to flooding. Buildings are made to adapt to flood water through the use of elevated floors by checking the existing trends of flood waters and elevating the ground floor to start at a height where floor waters cannot reach. The use of floating houses are also used in water front designs to keep buildings closest to water bodies functional. The principle of floatation is adapted and light weight materials used to minimize the weight of the building. Ambibious houses are a little trickier, buildings are both adaptable in dry land and on water. Ambhibious structure adopt the principle of floatation and hinged on dry land . Its floating ability is activated on the ingress of excess flood water around the building.

In conclusion, the end result led to the proses of designing flood resilient buildings to adapt to flood conditions in lekki, lagos state. The strategies discussed earlier where integrated into the design process. Strategies such as elevated building were adopted with various building types put in to consideration. A design prototype for one, two, three and four bedroom apartment to cut across various home sizes and a water front home type integrating amphibious building strategy. As Thurston *et al.,* (2008) has pointed out recommended adaptations are often rejected on aesthetic or familiarization grounds because they make properties look different or are designed to be functional without adequate consideration of good design. These structure exists to house people in flood prone areas and meet the required function of keeping the flood waters away from living spaces and preventing loss of life and damage to property.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This study is focused on evaluating the flood resilience strategies as response to the increasing flood vulnerabilities in residential properties. In achieving this aim, a threefold objective was set each tied to a research question. The first objective identified residential buildings prone to flood in Lekki, Lagos state. It was discovered that flood vunerability in the study area is usually in the wet and rainy season. Most residential houses suffer from poor planning, poor drainage systems and are obstructing waterways due to terrain. The second objective focused on determining flood resilient strategies that could be employed to mitigate flood risk in residential building. Three variable were considered as influencers in the choice of a prefered strategy to use in mitigating flood risk. They include water entry and inclusion, water exclusion and water avoidance technology. The third objective focused on the proposal of suitable flood resilience strategies for the safety of both the building and its occupants in lekki lagos state. This includes the construction of proper drainage channels to enable efficient draining of flood water, water proofing of the building structure to keep the structural stability in check and the adaptation of amphibious technology, water front design, elevated buildings and floating structures to adapt to the costal environment. In conclusion, the type of flood, the environment and Informed historical data affect the choice of strategy employed in resisting flood risk and adapting to climate change and this is the new climate reality.

5.2 Recommendations

From the study, the following recommendations will be of great help. This strategies that can result in flood resilience as climate adaptation for residential properties include;

1. Structures should be built retro-fitted to satisfy code guidelines dependent on risk and dangers associated with flood vulnerabilities.
2. Building code should be review with risk awareness as a factor with decisions made through knowledgeable findings.
3. The construction of proper drainage channels to enable efficient draining of flood water and water proofing of the building structure to keep the structural stability in check.
4. Adoption of water inclusive and adaptive strategies by the integration amphibious building approach, water front design, elevated buildings and floating structures to residential building design.

5.3 Contribution to Knowledge

This study highlighted the need for buildings to be able to adapt to their environment through the use of resilient design strategies. The findings highlighted that 11% of the buildings in the study area collapse due to flooding, 35.7% of people in the study area adopting the use of water proof materials as a measure to prevent the effect of flood on the buildings, 29.2% control flood waters by chanelling water away from the building. The findings from this study provides valuable insights on the adoption of water inclusive and adaptive strategies by the integration amphibious building approach which means buildings are able to stay afloat during flooding and hoister on dry land, water front design which involves buildings elevated to a considerable height and floating structures which naturally float on water. This is coupled with the use of water proof materials such as rapid hardening cement, water seals and the addition of waterproofing such as application of acrylic to floor finishes to the building structure to enable it withstand harsh conditions such as moisture.

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APPENDICES

Appendix A: Questionnaire

FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA NIGER STATE.

SCHOOL OF POST GRADUATE STUDIES, DEPARTMENT OF ARCHITECTURE

Thesis Title:

EVALUATION OF FLOOD RESILIENT STRATEGIES IN THE DESIGN OF RESIDENTIAL BUILDINGS IN LEKKI, LAGOS STATE.

We are currently researching the above topical and critical subject as it affects residential properties in Lekki, Lagos state, Nigeria. The purpose of the Survey is the evaluation of flood resilient strategies in the design of residential buildings in Lekki, Lagos state. You have been identified and selected as a participant for this research and your genuine response to this questionnaire will enable the researcher collect accurate data on the above stated topic in order to propose best obtainable flood resilient strategies for mitigating flood risk.

Disclaimer: This Questionnaire is collected by a Post Graduate student of the Federal University of Technology, Department of Architecture. This questionnaire is solely for academic purposes. All data collected is therefore anonymous and will be treated with utmost confidentiality.

Survey Date: ____

Survey Area: ____

Questionnaire no ____

Please fill appropriately

SECTION 1: GENERAL INFORMATION

1. Age of the respondents?

   1. 18 –39
   2. 40 – 59
   3. 60 and Older

2. How long have you been living in this building?

   1. 0-5years
   2. 6-10years
   3. 11-20years

4. 20 years above

SECTION 2: FLOOD RESILIENT STRATEGIES FOR RESIDENTIAL BUILDING

3. How often have you experience flood since living in this Location? (Given a scale of I-V: i= Extremely frequent, ii= very frequent, iii= frequent, iv= not frequent and v= Not at all)

1. i
2. ii
3. iii
4. iv
5. v

4. In your opinion, what will you say is the cause of flooding in your area?

1. Flash floods (flood due to Blocked drainage)
2. River floods (overflown river)
3. Coastal floods (Natural flood plain)
4. No idea.

5. What was the maximum duration of flood that you experienced around your building?

1. 0- 3 days
2. 4- 6 days
3. 7- 9 days
4. 9days and Above

6. Is your structure flood resilient?

1. Yes
2. No
3. Not sure

7. Please indicate the construction material employed in your building. (Please tick where appropriate)

Construction materials	Walls	floors
Sancrete block		
Mud		
Thatch		
Burnt clay		
Wood		

Steel		

8. What is the building structural type employed in your building?

1. Reinforced cement concrete (RCC)
2. Mixed (Reinforced Cement Concrete + Masonry)
3. Load Bearing Structure
4. Timber structure
5. Steel Structure
6. Mixed (steel + Masonry) Structure

9. Indicate if you experience any of the following problems during and after the experience of flooding in your house?

1. Negative Health Outcomes (e.g. malaria, typhoid, Mental health problems, famine, cold)
2. Building Collapse
3. Moisture
4. Material Deterioration
5. Death
6. Other ways (please specify ………………)

10. What measure(s) was taken to prevent the building from flood? (Tick multiple)

1. Use of temporary barriers
2. Channelling flood away from the building (e.g. Building canals, drainages and waterways)
3. Use of elevated or raised floors
4. Water proofing
5. Other ways (please specify………………)

11. Has the measure(s) taken caused a reduction in flood risk?

1. Yes
2. No
3. Not sure

12. What other strategies do you think can be employed to mitigate flood risk?

1. Use of temporary barriers
2. Channelling flood away from the building (e.g. Building canals, drainages and waterways)
3. Use of elevated of raised floors
4. Water proofing
5. Other ways (please specify…………….)

13. How do you rate this strategies? (Given a scale of i-v: I= Least effective and V= Most effective)

6. i
7. ii
8. iii
9. iv
10. v

SECTION 3: FLOOD LEVELS FOR RESIDENTIAL BUILDING

14. What extent on your building would you describe the highest level of water when there is flood?

1. Ground Level to DPC
2. Ground Level to the base of the window
3. Ground Level to the lintel level
4. Ground Level to the level above the lintel level

From your knowledge of your area and using a scale rating of 1-5, where 1 is the least effective and 5 is highly effective, to answer the following few questions. Please check as appropriate.

S/N		1	2	3	4	5
15.	How effective do you think a residential building raised 1 meter from the ground and rests on foundation beams would be in a flood prone area (Elevated approach)					
16.	In your area, how effective do you think a residential building which only floats when flood levels raises would be (Amphibious approach)					
17.	How effective would do you think a residential building which constantly floats would be in your area towards floods (Floating approach)					

18.	In your opinion, how effective would you say a building built along water lines be in flood prone areas					

19. From your answer above, how would you describe your building?

1. Raised above 1 meter from the ground (Elevated building)
2. Can float when flood level raises (Amphibious building)
3. Constantly floats on water (Floating building)
4. Built along water lines (Waterfront design)

SECTION 5: FLOOD IMPACT ON RESIDENTIAL BUILDING

20. Please indicate if you experience damage(s) to any of the following parts of you building

1. Damage to Building fitting and fixture such as mechanical and electrical appliances
2. Damage to Exterior walls,
3. Damage to Interior walls,
4. Damage to Footing and foundation
5. Damage to Openings such as doors and windows
6. Other (Please specify……………)

What is the extent of structural damage to your building during flood?

(please rate from 1 =lowest damage to 5= very serious damage)

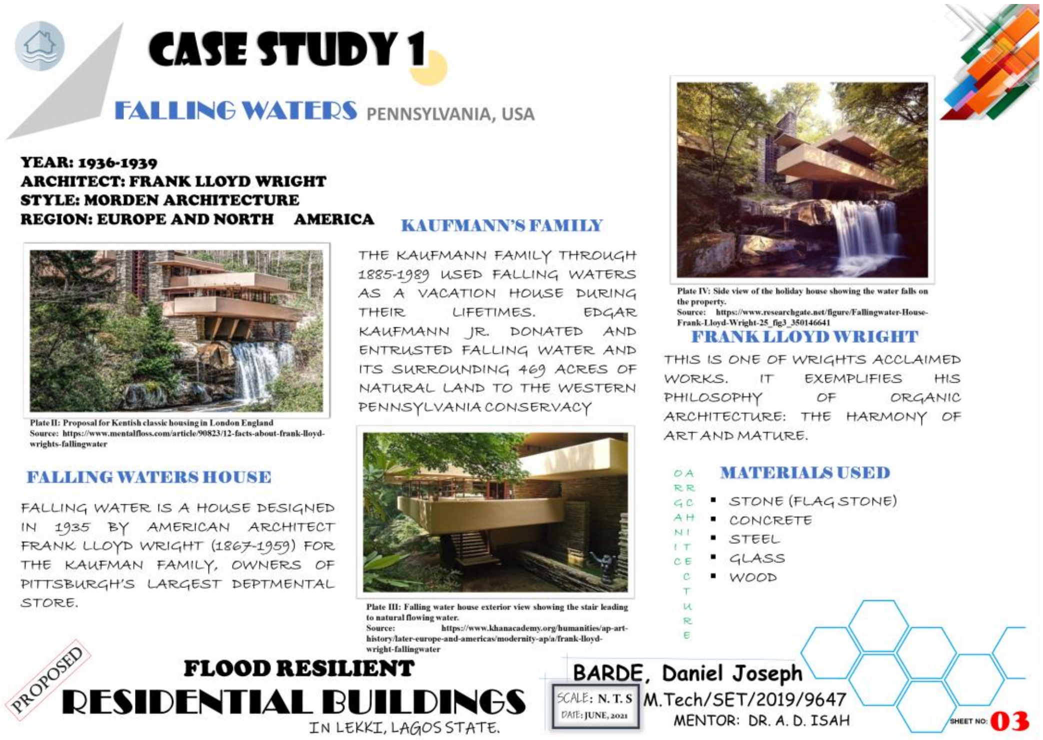
Damages	**1 Not Damaged**	**2 Negligible**	**3 Barely Damage**	**4 Serious Damage**	**5 Very serious damage**
21. Building fitting and fixture such as mechanical and electrical appliances					

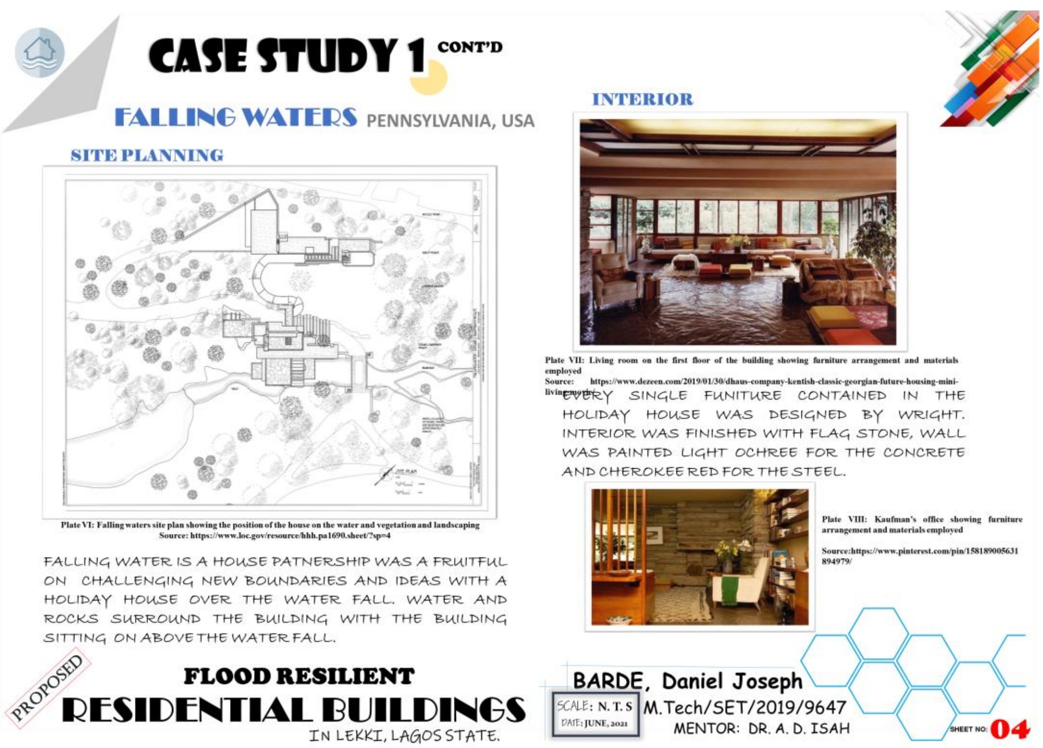
22. Damage to Exterior walls					
23. Damage to Interior walls					
24. Damage to Footing and foundation					
25. Damage to Openings such as doors and windows					

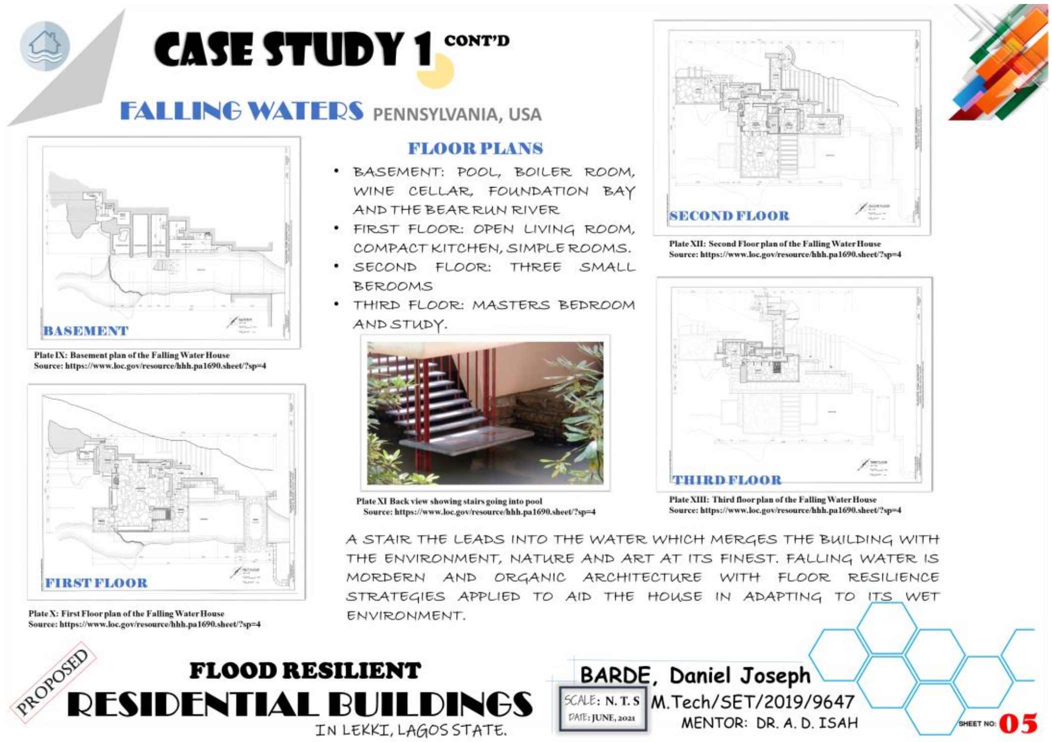
26. Others (Please specify)

………………………………………………………………….………

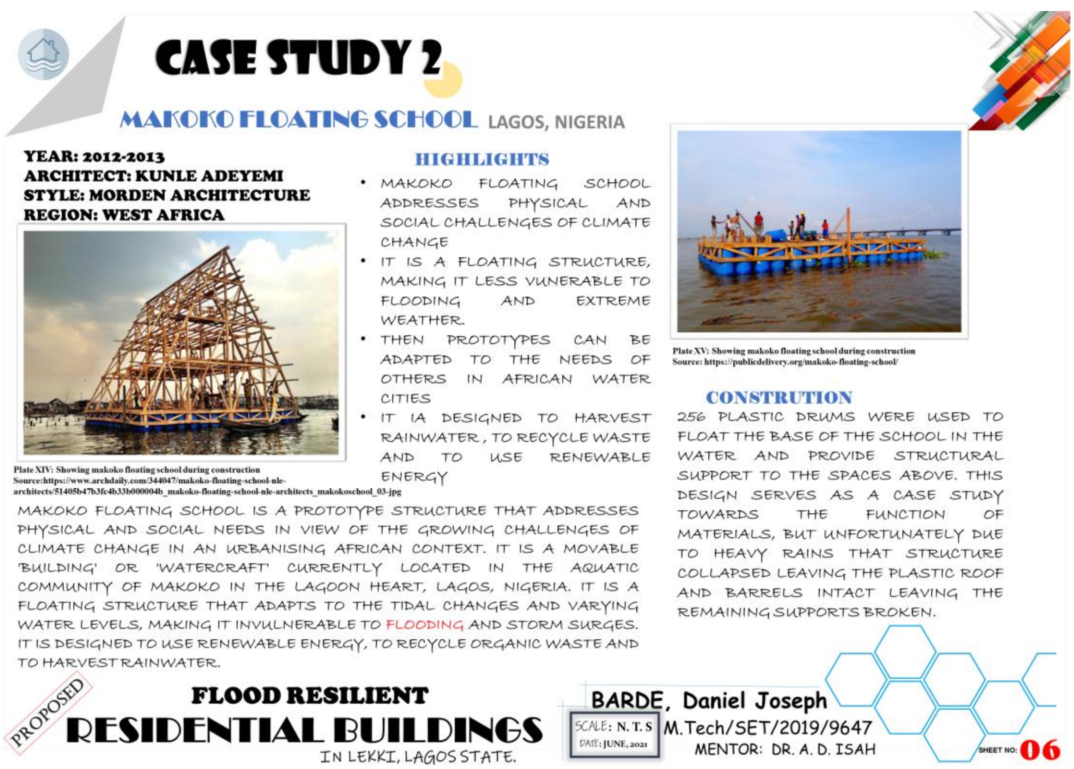
Appendix A: Case Study 1







Appendix B: Case Study 2



CASE STUDY 2 CONT'D

MAKOKO FLOATING SCHOOL LAGOS, NIGERIA

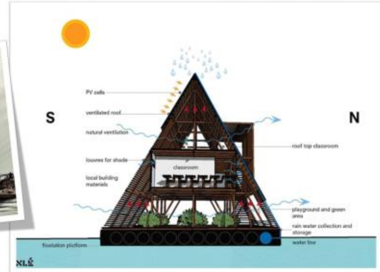


Plate XVI: Showing makoko floating school cross section
Source:https://www.archdaily.com/344047/makoko-floating-school-nle-architects/51405b67b3fc4b231400004f-makoko-floating-school-nle-architects-photo?next_project=no

MAKOKO SCHOOL

MAKOKO FLOATING SCHOOL IS THE DESIGN AND REALIZATION OF A PROTOTYPE FOR A SERIES OF SCHOOLHOUSES LOCATED IN LAGOS LAGOON, A DENSELY URBAN WATERFRONT WHERE DRY LAND IS AT A PREMIUM. THE FLOATING SCHOOL AN INGENIOUS SOLUTION TO THE CHALLENGE OF AFFORDABLE BUILDING LOTS TO SUPPORT PRIMARY EDUCATION FOR THE LOWEST INCOME FAMILIES. THE PROJECT IS AN AMBITIOUS URBAN DESIGN SOLUTION REALIZED BY SKILLED ARTISANS IN THE WATERFRONT COMMUNITY OF LAGOS.

THE MOST COMPELLING ATTRIBUTES OF THE PROJECT ARE CONCEPTUAL. ADEYEMI REIMAGINED WATER AS HIS PROJECT'S CONSTRUCTION SITE. HE DESIGNED STRUCTURES TO HARNESS AND IMPROVE THE SKILL SETS OF THE ARTISANS OF THE WATERFRONT. THE PROJECT WAS CREATED FROM LEFTOVER MATERIALS DONATED BY A LOCAL SAWMILL AND LOCALLY GROWN BAMBOO, HARNESSING A SUB-SAHARAN TRADITION OF UTILITY FROM WASTE. IT TOOK THE TRADITION OF PERSONAL FLOATING STRUCTURES AND MADE THEM INTO A COMMUNITY CENTER. THE STRUCTURE IS TEN TIMES LARGER THAN THE LOCAL FISHING VESSELS AND STILT ARCHITECTURE USED FOR RESIDENCES AND LOCAL BUSINESSES.

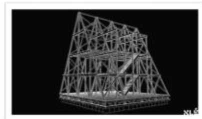


Plate XVI: Showing makoko floating school framework
Source:https://urbannext.net/makoko-floating-school/

PROPOSED
FLOOD RESILIENT
RESIDENTIAL BUILDINGS
IN LEKKI, LAGOS STATE.

BARDE, Daniel Joseph
SCALE: N. T. S
DATE: JUNE, 2021
M.Tech/SET/2019/9647
MENTOR: DR. A. D. ISAH
SHEET NO: 07

Appendix C: Case Study 3

CASE STUDY 3

FRANSWORT HOUSE CHICAGO, ILLINIOS

YEAR: 1946-1951
ARCHITECT: LUDWIG MILES VAN DER ROHE
STYLE: INTERNATIONAL STYLE (MODENIST)
REGION: NORTH AMERICA

Plate XVII: Farnsworth house in autumn Showing the environment
Source: https://www.arch2o.com/the-farnsworth-house-mies-van-der-rohe/

FARNSWORTH HOUSE IS ONE OF THE PRECEDENTS OF THE MODERN ARCHITECTURE DESIGNED BY MIES VAN DER ROHE.

Plate XVIII: Showing Farnsworth house in a flood situation
Source: https://www.buoyantfoundation.org/illinois-farnsworth-house

CONSTRUCTION

THE HOUSE WAS RAISED 5 FEET 3 INCHES OFF THE GROUND, ALLOWING ONLY THE STEEL COLUMNS TO MEET THE GROUND SEAMLESSLY. THE HOUSE'S MAIN STRUCTURAL SUPPORT COMPRISES EIGHT WHITE VERTICAL I-BEAMS, WHICH CONNECT THE RECTANGULAR ROOF AND FLOOR SLABS WITH FLOOR-TO-CEILING PLATE GLASS. THE STRUCTURE IS SUSPENDED ON THOSE BEAMS SOME 5 FEET ABOVE THE GROUND AND ABOUT MORE THAN 8 FEET ABOVE THE FOX RIVER. A THIRD OF THE SLAB IS AN OPEN-AIR PORCH, AND THE ONLY OPERABLE WINDOWS ARE TWO SMALL HOPPER UNITS AT THE EASTERN END IN THE BEDROOM AREA. THE MULLIONS ACT AS STRUCTURAL SUPPORT.

PROPOSED
FLOOD RESILIENT
RESIDENTIAL BUILDINGS
IN LEKKI, LAGOS STATE.

BARDE, Daniel Joseph
SCALE: N. T. S
DATE: JUNE, 2021
M.Tech/SET/2019/9647
MENTOR: DR. A. D. ISAH
SHEET NO: 08

CASE STUDY 3 CONT'D

FRANSWORT HOUSE CHICAGO, ILLINIOS

RETROFITTING FARNSWORT HOUSE

Plate XIX: Farnsworth house showing the proposed retrofitting as an amphibious house
Source: https://www.arch2o.com/the-farnsworth-house-mies-van-der-rohe

IN 1999, ARCHITECTURAL DIGEST COVERED THE HOUSE'S THEN RECENT RESTORATION, WHICH WAS IN RESPONSE TO A 1996 FLOOD. AT THE TIME, DIRK LOHAN, MIES'S GRANDSON WHO FOLLOWED IN HIS ARCHITECTURAL FOOTSTEPS TO TAKE OVER HIS STUDIO, EXPRESSED THE CONTINUATION OF HIS WORRIES. "I'M VERY CONCERNED THAT THE FLOODING COULD HAPPEN AGAIN," LOHAN TOLD WRITER ROLAND FLAMINI, IN A COMMENT THAT NOW READS AS EERILY PRESCIENT.

Plate XX: Farnsworth house showing the environment just after floods
Source: https://inhabitat.com/iconic-farnsworth-house-gets-a-conceptual-sustainable-redesign

PROPOSED

FLOOD RESILIENT
RESIDENTIAL BUILDINGS
IN LEKKI, LAGOS STATE.

BARDE, Daniel Joseph
SCALE: N. T. S
DATE: JUNE, 2021
M.Tech/SET/2019/9647
MENTOR: DR. A. D. ISAH
SHEET NO: 09

CASE STUDY 3 CONT'D

FRANSWORT HOUSE CHICAGO, ILLINIOS

FARNSWORT HOUSE

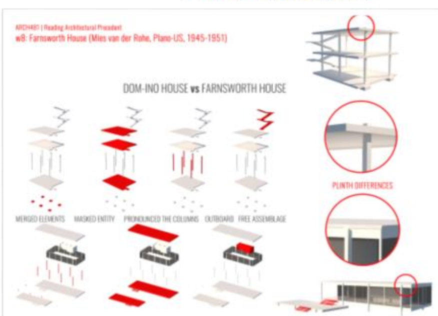


Plate XXI: Farnsworth house showing the structural systems
Source: https://haticeoztedu.wordpress.com/2018/11/17/precedent-analysis-of-farnsworth-house/

IN 1999, ARCHITECTURAL DIGEST COVERED THE HOUSE'S THEN RECENT RESTORATION, WHICH WAS IN RESPONSE TO A 1996 FLOOD. AT THE TIME, DIRK LOHAN,

Plate XXII: Farnsworth house showing the rear view
Source: https://www.dwell.com/article/farnsworth-house-flooding-ludwig-mies-van-der-rohe-a1d85bbd

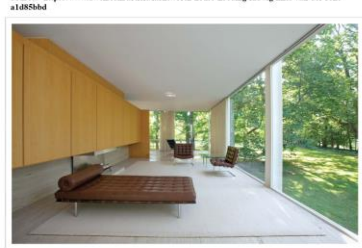


Plate XXIII: Farnsworth house showing an interior view
Source:https://www.archpaper.com/2020/08/edith-farnsworth-reconsidered//

PROPOSED

FLOOD RESILIENT
RESIDENTIAL BUILDINGS
IN LEKKI, LAGOS STATE.

BARDE, Daniel Joseph
SCALE: N. T. S
DATE: JUNE, 2021
M.Tech/SET/2019/9647
MENTOR: DR. A. D. ISAH
SHEET NO: 10

Appendix D: Case Study 4

CASE STUDY 4

THE KENTISH CLASSIC KENTISH TOWN, NORTH LONDON.

YEAR: 2016
ARCHITECT: THE DHaus COMPANY LTD
STYLE: GEORGIAN ARCHITECTURE
REGION: NORTH LONDON.

Plate XXIV: Proposal for Kentish classic housing in London England
Source: https://www.dezeen.com/2019/01/30/dhaus-company-kentish-classic-georgian-future-housing-mini-living-movie/

FULLY AUTOMATED CNC PLYWOOD GEORGIAN TERRACE REPLICAS ARE BUILT ON TOP OF FLOOD PROOF CONCRETE PLINTHS FOR A VENETIAN TAKE ON KENTISH TOWN 100 YEARS FROM NOW, FEEDING THE DESIRE FOR THE LONDON PERIOD PROPERTY LONG INTO THE FUTURE WHILE CONSERVING AS BEST WE CAN CERTAIN STYLES IN AREAS SUCH AS KENTISH TOWN IN NORTH LONDON.

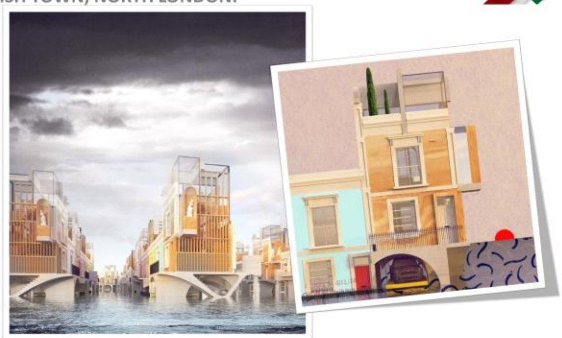


Plate XXV: Proposal for Kentish classic housing in London England
Source: https://www.dezeen.com/2019/01/30/dhaus-company-kentish-classic-georgian-future-housing-mini-living-movie/

GEORGIAN ARCHITECTURE IS CHARACTERIZED BY ITS PROPORTION AND BALANCE; SIMPLE MATHEMATICAL RATIOS WERE USED TO DETERMINE THE HEIGHT OF A WINDOW IN RELATION TO ITS WIDTH OR THE SHAPE OF A ROOM AS A DOUBLE CUBE. REGULARITY, AS WITH ASHLAR (UNIFORMLY CUT) STONEWORK, WAS STRONGLY APPROVED, IMBUING SYMMETRY AND ADHERENCE TO CLASSICAL RULES:.

PROPOSED
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RESIDENTIAL BUILDINGS
IN LEKKI, LAGOS STATE.

BARDE, Daniel Joseph
SCALE: N. T. S
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MENTOR: DR. A. D. ISAH
SHEET NO: 11

CASE STUDY 4 CONT'D

THE KENTISH CLASSIC KENTISH TOWN, NORTH LONDON.

Plate XXVI: Proposal for Kentish classic housing in London England
Source: https://www.dezeen.com/2019/01/30/dhaus-company-kentish-classic-georgian-future-housing-mini-living-movie/

Plate XXVII: Proposal for Kentish classic housing in London England
Source: https://www.dezeen.com/2019/01/30/dhaus-company-kentish-classic-georgian-future-housing-mini-living-movie/

THE LONDON ARCHITECTURE STUDIO'S CONTEST SUBMISSION: THE KENTISH CLASSIC BY THE D*HAUS COMPANY, A PRACTICE IN NORTH LONDON, SELF-DESCRIBED AS A "COLLECTIVE OF ARCHITECTS, ARTISTS, SCULPTORS, WEB DEVELOPERS AND PRODUCT DESIGNERS"

PROPOSED
FLOOD RESILIENT
RESIDENTIAL BUILDINGS
IN LEKKI, LAGOS STATE.

BARDE, Daniel Joseph
SCALE: N. T. S
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MENTOR: DR. A. D. ISAH
SHEET NO: 12

Appendix E: Case Study 5

CASE STUDY 5

AMPHIBIOUS HOUSES MAASBOMMEL, NETHERLAND

YEAR: 2020
ARCHITECT: DURA VERMEER
STYLE: GEORGIAN ARCHITECTURE
REGION: EUROPE

Plate XXVIII: A Row floating houses during floods
Source:https://climate-adapt.eea.europa.eu/metadata/case-studies/amphibious-housing-in-maasbommel-the-netherlands

Plate XXIX: Rear view of the amphibious houses
Source:https://climate-adapt.eea.europa.eu/metadata/case-studies/amphibious-housing-in-maasbommel-the-netherlands

Plate XXX: Side view of the amphibious houses
Source:https://climate-adapt.eea.europa.eu/metadata/case-studies/amphibious-housing-in-maasbommel-the-netherlands

A COLLECTION OF "AMPHIBIOUS" FLOATING HOUSES, WITH FLOATING FOUNDATIONS TO PROTECT THEM AGAINST FLOODING, WERE BUILT IN THE VILLAGE OF MAASBOMMEL IN THE NETHERLANDS, IN AREAS THAT LIE OUTSIDE OF FLOOD PROTECTION INFRASTRUCTURE. THIS PROJECT SHOWS HOW PEOPLE IN FLOODPLAINS CAN BETTER LIVE WITH THE WATER THROUGH HOUSING THAT ADAPTS TO CHANGING WATER LEVELS.

THE NETHERLANDS, MUCH LIKE SOUTHERN LOUISIANA, IS LOCATED ON A DELTA AND EXPERIENCES FLOODING FROM RIVERS AND FROM OCEAN STORMS. THE DUTCH APPROACH TO FLOOD CONTROL IS TOUTED AS THE INTERNATIONAL BEST PRACTICE. MOST COMMUNITIES IN THE NETHERLANDS ARE PROTECTED BY DYKES, LEVEES, AND FLOODGATES. HOWEVER SEVERAL SMALL RURAL VILLAGES ARE LOCATED OUTSIDE OF THE FLOOD PROTECTION INFRASTRUCTURE. MAASBOMMEL, LOCATED ALONG THE MEUSE RIVER, IS ONE OF THOSE COMMUNITIES. IT IS KNOWN MOSTLY FOR WATER-BASED RECREATIONAL ACTIVITIES AND IS HOME TO A SMALL PERMANENT POPULATION.

PROPOSED
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RESIDENTIAL BUILDINGS
IN LEKKI, LAGOS STATE.

BARDE, Daniel Joseph
SCALE: N. T. S
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MENTOR: DR. A. D. ISAH
SHEET NO: 13

CASE STUDY 5 CONT'D

AMPHIBIOUS HOUSES MAASBOMMEL, NETHERLAND

Plate XXXI: 3D view of the amphibious houses
Source: https://climate-adapt.eea.europa.eu/metadata/case-studies/amphibious-housing-in-maasbommel-the-netherlands

STRATEGIES

- HOUSES ADJUST TO CHANGING WATER LEVELS, BUT ARE SECURE ENOUGH TO WITHSTAND STRONG CURRENTS AND WINDS.
- EACH BUILDING'S UTILITIES RELY ON MUNICIPAL SERVICES AND INFRASTRUCTURE HOOK-UPS, BUT RECONSIDER TRADITIONAL MATERIALS AND TECHNIQUES TO ALLOW FOR FLEXIBILITY.
- THE SELF-RISING HOUSES AVOID DAMAGE FROM FLOOD WATERS, ELIMINATING COSTLY REPAIRS AFTER STORM EVENTS.
- THIS DESIGN ALLOWS PEOPLE TO LIVE ALONG THE WATER WITHOUT RELYING ON LARGE, HYDROLOGICALLY AND ECOLOGICALLY DISRUPTIVE PROTECTIVE INFRASTRUCTURE FOR FLOOD PROTECTION.
- THE FEATURES OF A NEIGHBORHOOD NETWORK, SUCH AS GARDENS AND PEDESTRIAN CONNECTIONS BETWEEN HOMES, ARE PRESERVED DURING NON-FLOOD CONDITIONS.

DURA VERMEER'S DESIGN IS AN INNOVATIVE APPROACH THAT COMBINES THE BEST FEATURES OF FLOATING HOUSE BOATS AND ELEVATED BUILDINGS TO CREATE HOMES THAT CAN ADAPT TO CHANGES IN WATER LEVELTHE AMPHIBIOUS HOUSES IN MASSBOMMEL FLOAT LIKE HOUSE BOATS SITED ON A FLOATING CONCRETE "HULL." HOWEVER, THEY ARE ALSO SECURED AGAINST STRONG WINDS AND WAVES BY PERMANENT MOORING POSTS DRIVEN DEEP INTO THE GROUND, SIMILAR TO THOSE USED TO ELEVATE HOMES. THESE POSTS GUIDE THE BUILDING TO RISE UP AND LOWER DOWN, IN PLACE, ACCORDING TO CHANGING RIVER LEVELS. IN NON-FLOOD CONDITIONS, THE HOUSES REST ON THE RIVER BANK, ALLOWING FOR CONVENIENT WATER ACCESS AND CREATING A FLAT WALKABLE SPACE BETWEEN HOMES. THE AMPHIBIOUS HOUSES ALSO HAVE BASEMENTS, DECKS, AND SMALL GARDENS ALL SUPPORTED BY THEIR FOUNDATIONS. THEY FEATURE FLEXIBLE PIPES FOR ELECTRICAL, WATER, AND SEWER LINES THAT WILL KEEP THE HOME "ON THE GRID" EVEN IN A FLOODING EVENT.

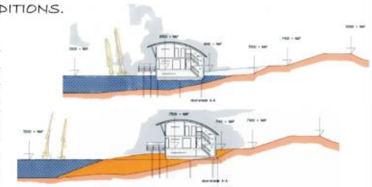
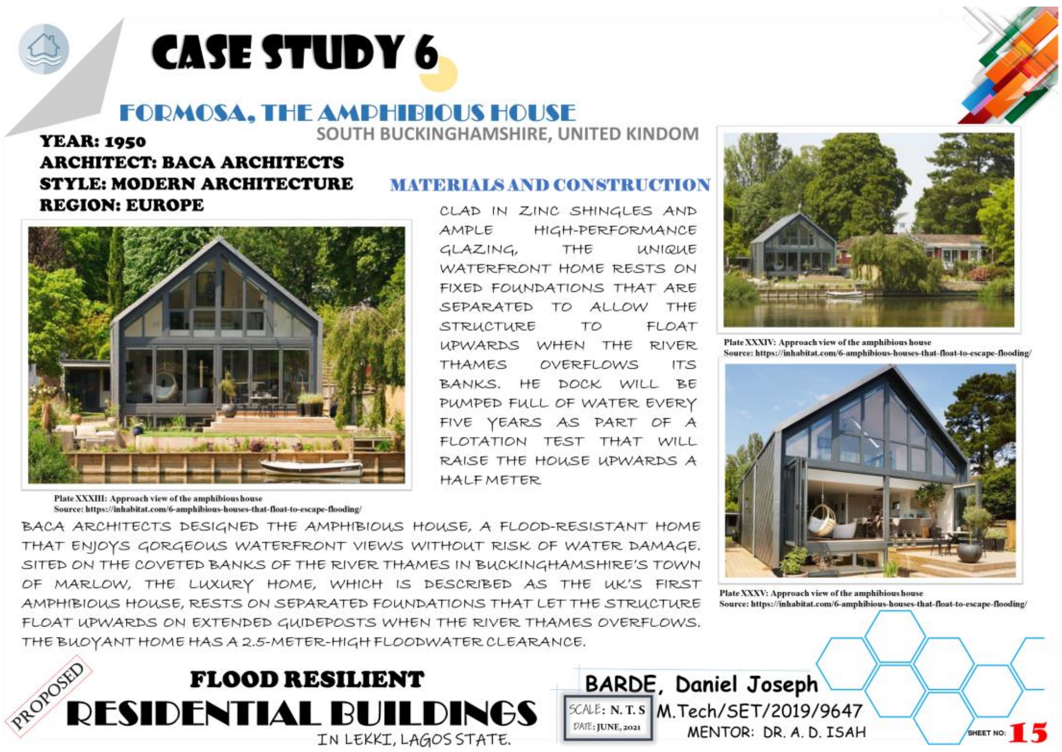


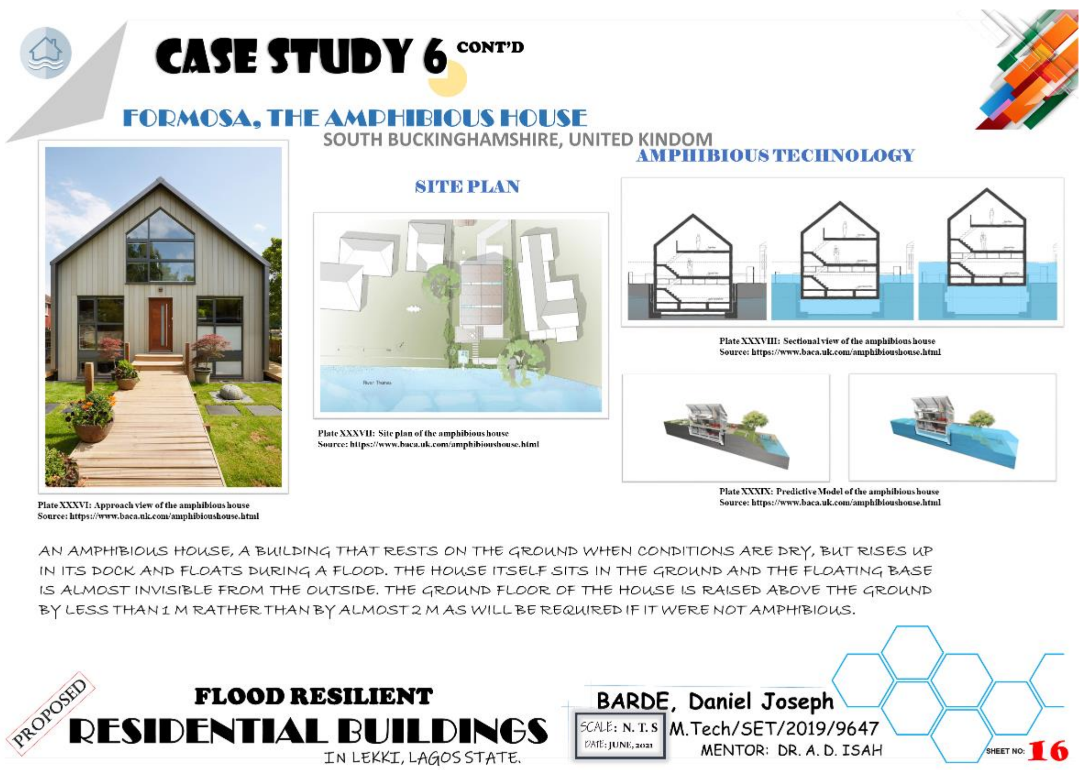
Plate XXXII: Sectional view of the amphibious houses
Source: https://www.urbangreenbluegrids.com/projects/amphibious-homes-maasbommel-the-netherlands/

PROPOSED
FLOOD RESILIENT
RESIDENTIAL BUILDINGS
IN LEKKI, LAGOS STATE.

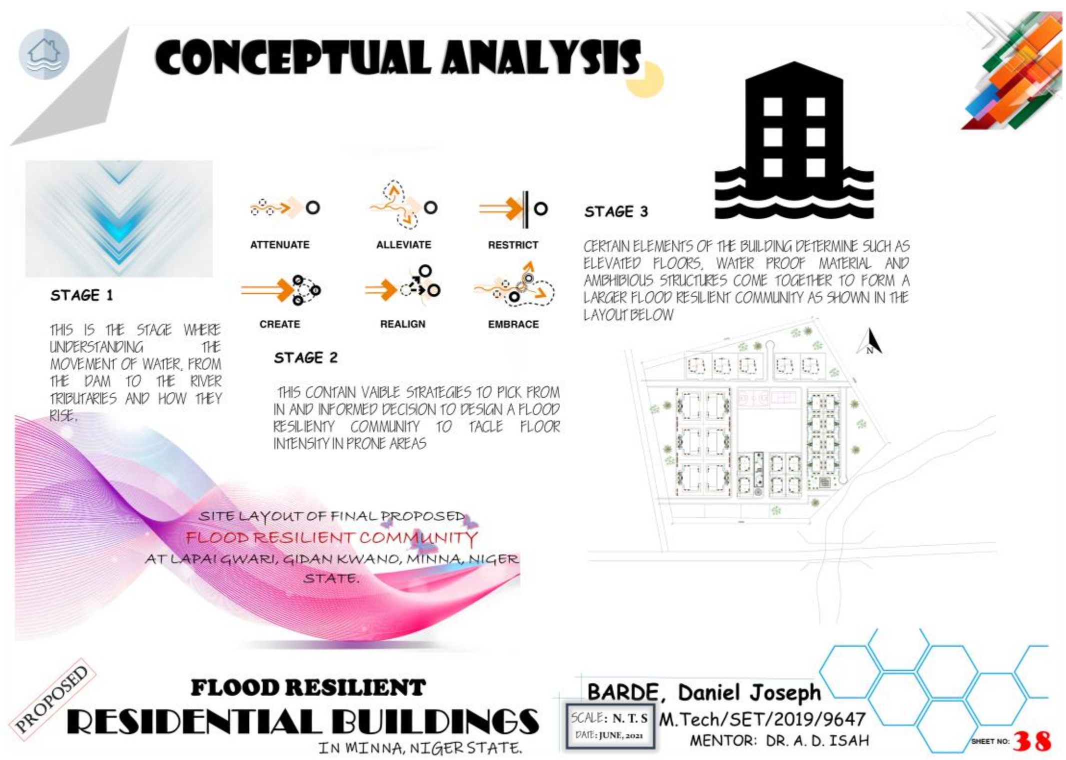
BARDE, Daniel Joseph
SCALE: N. T. S
DATE: JUNE, 2021
M.Tech/SET/2019/9647
MENTOR: DR. A. D. ISAH
SHEET NO: 14

Appendix F: Case Study 6

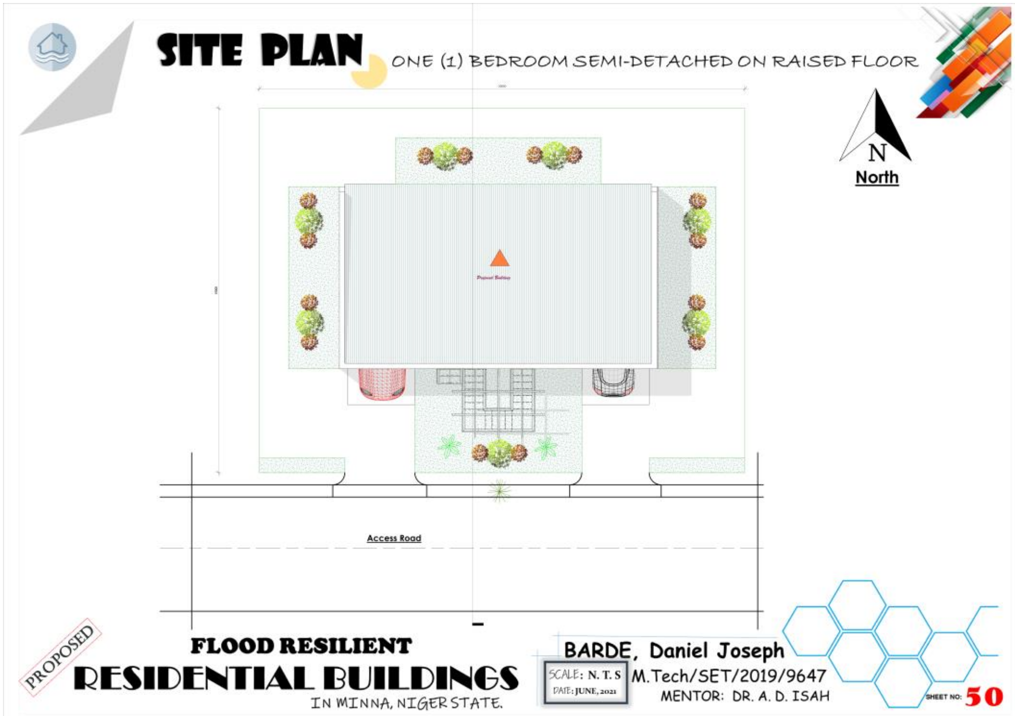


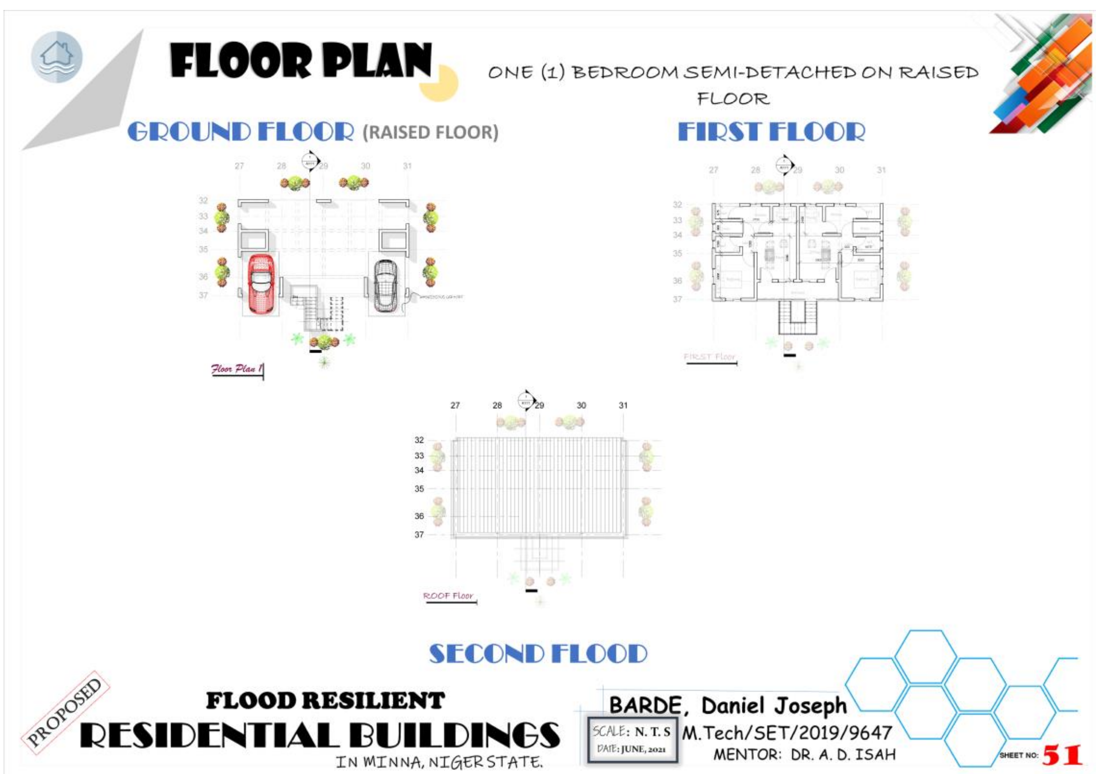


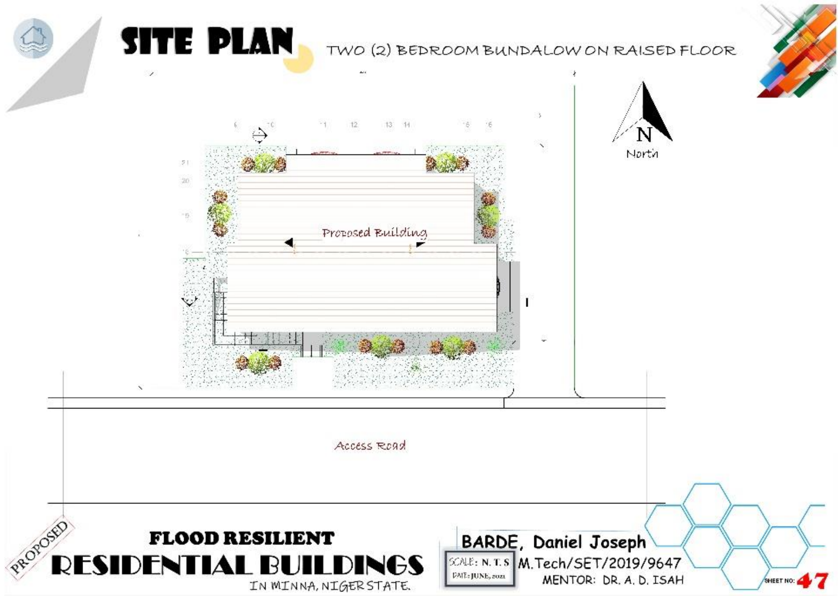
Appendix G: Concept Analysis



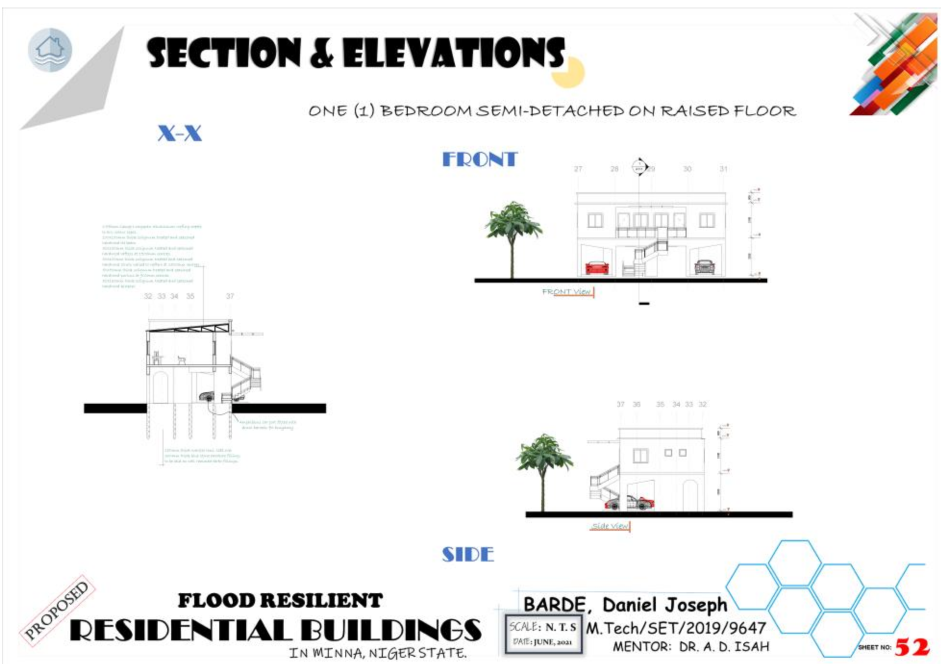
Appendix H: One Bedroom Semi-Detached

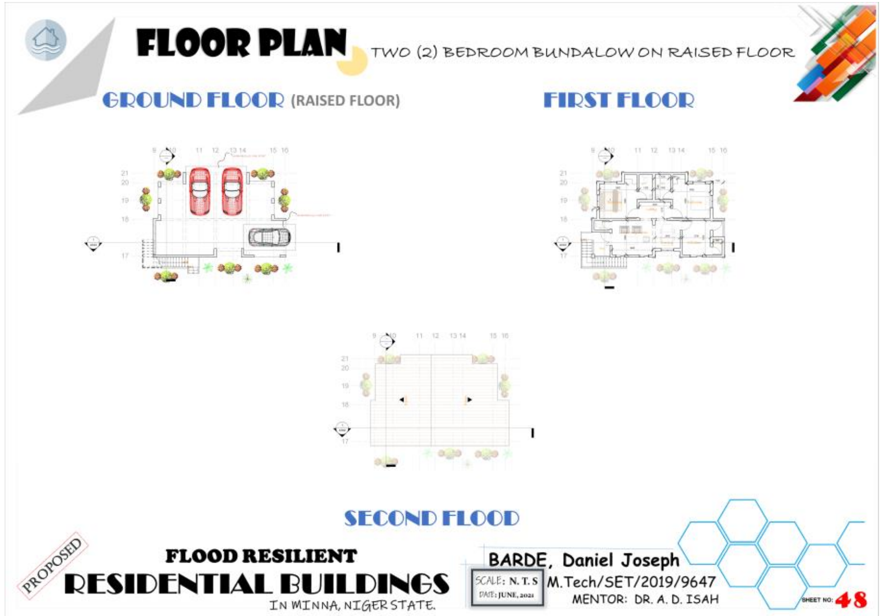






Appendix I: Two Bedroom Bungalow




FLOOR PLAN
TWO (2) BEDROOM BUNDALOW ON RAISED FLOOR
GROUND FLOOR (RAISED FLOOR)
FIRST FLOOR
SECOND FLOOD
PROPOSED
FLOOD RESILIENT
RESIDENTIAL BUILDINGS
IN MINNA, NIGER STATE.
BARDE, Daniel Joseph
SCALE: N. T. S
DATE: JUNE, 2021
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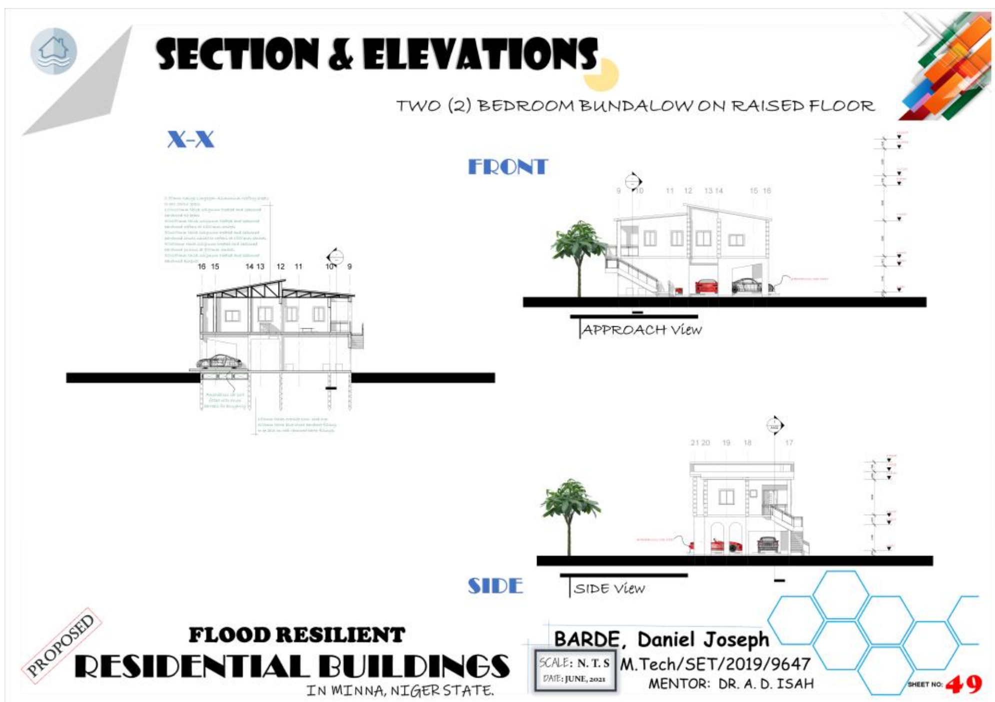
SHEET NO: 48


SECTION & ELEVATIONS
TWO (2) BEDROOM BUNDALOW ON RAISED FLOOR
X-X
FRONT
APPROACH View
SIDE
SIDE View
PROPOSED
FLOOD RESILIENT
RESIDENTIAL BUILDINGS
IN MINNA, NIGER STATE.
BARDE, Daniel Joseph
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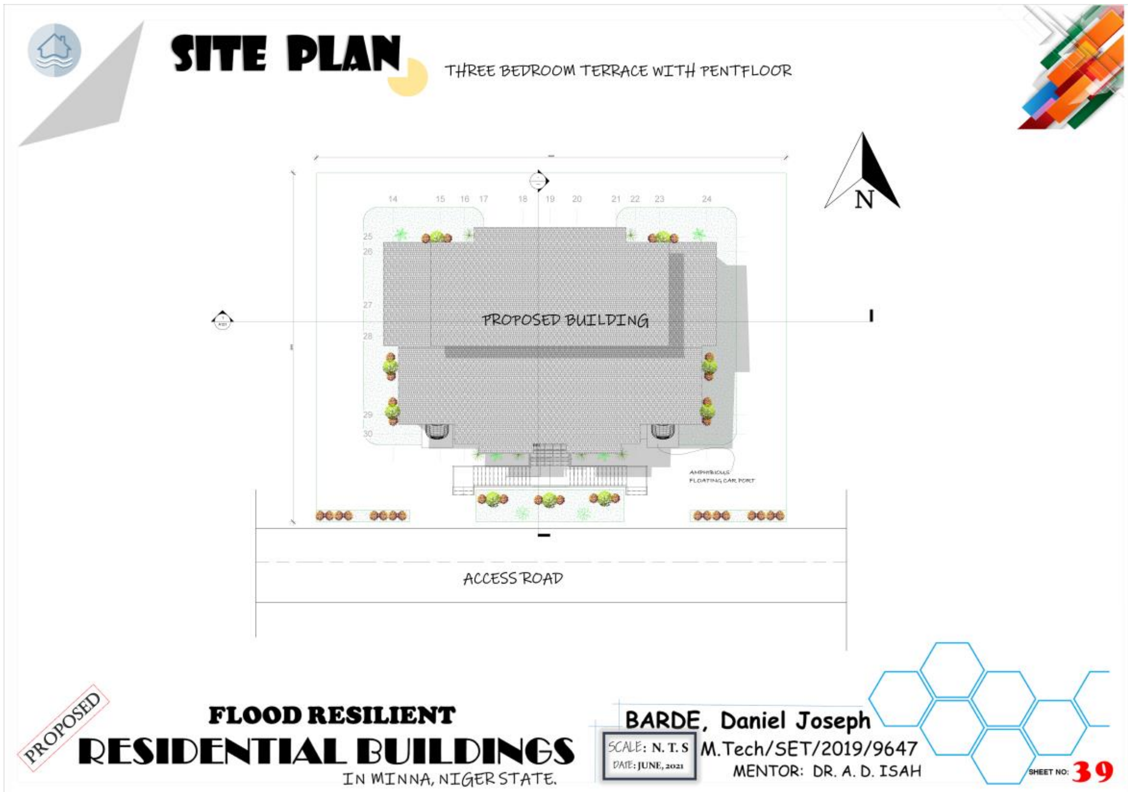
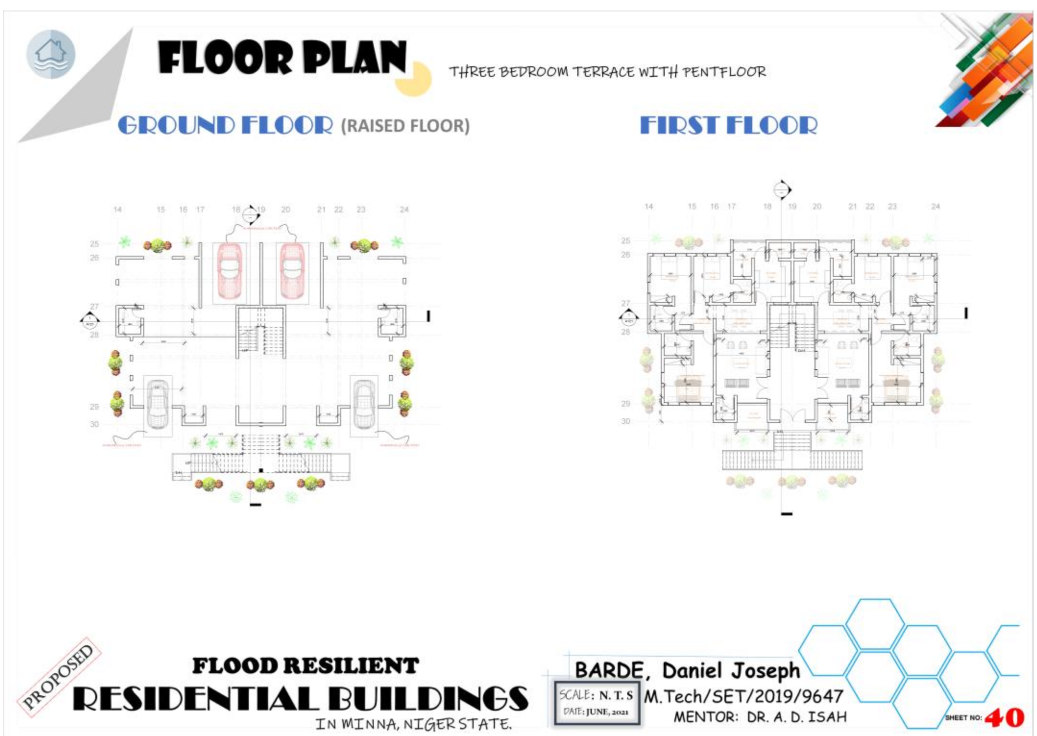
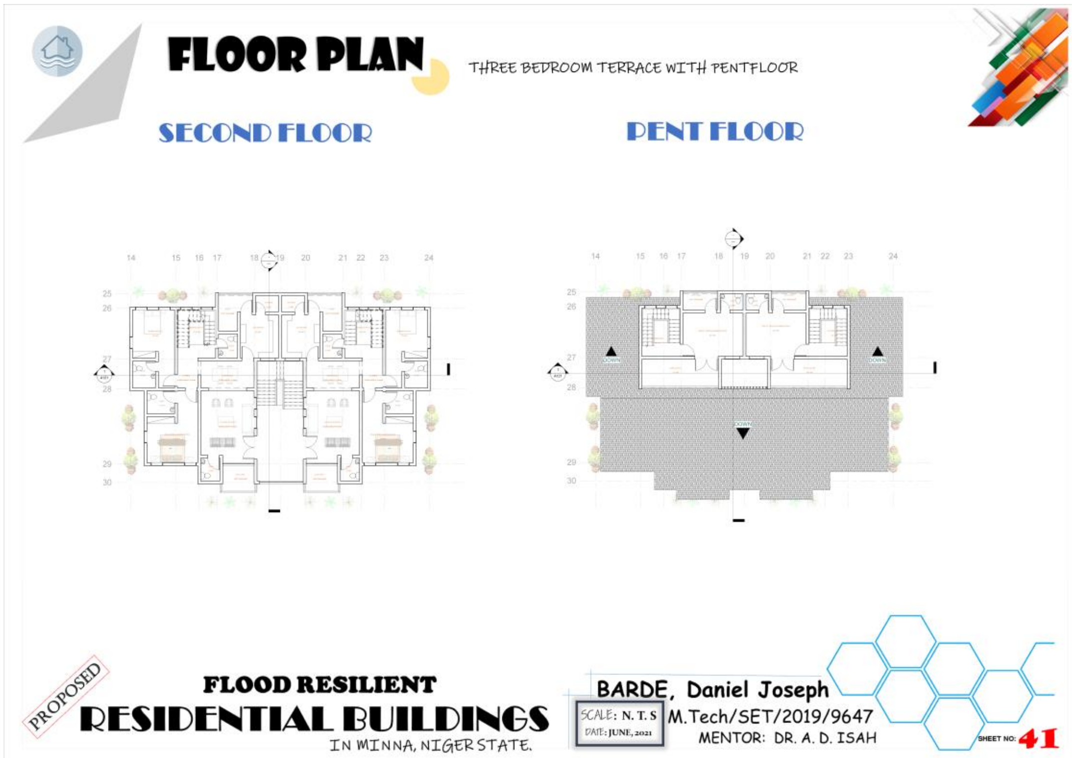
SHEET NO: 49

Appendix J: Three Bedroom Terrace






FLOOR PLAN
THREE BEDROOM TERRACE WITH PENTFLOOR
SECOND FLOOR
PENT FLOOR
PROPOSED
FLOOD RESILIENT
RESIDENTIAL BUILDINGS
IN MINNA, NIGER STATE.
SCALE: N. T. S
DATE: JUNE, 2021
BARDE, Daniel Joseph
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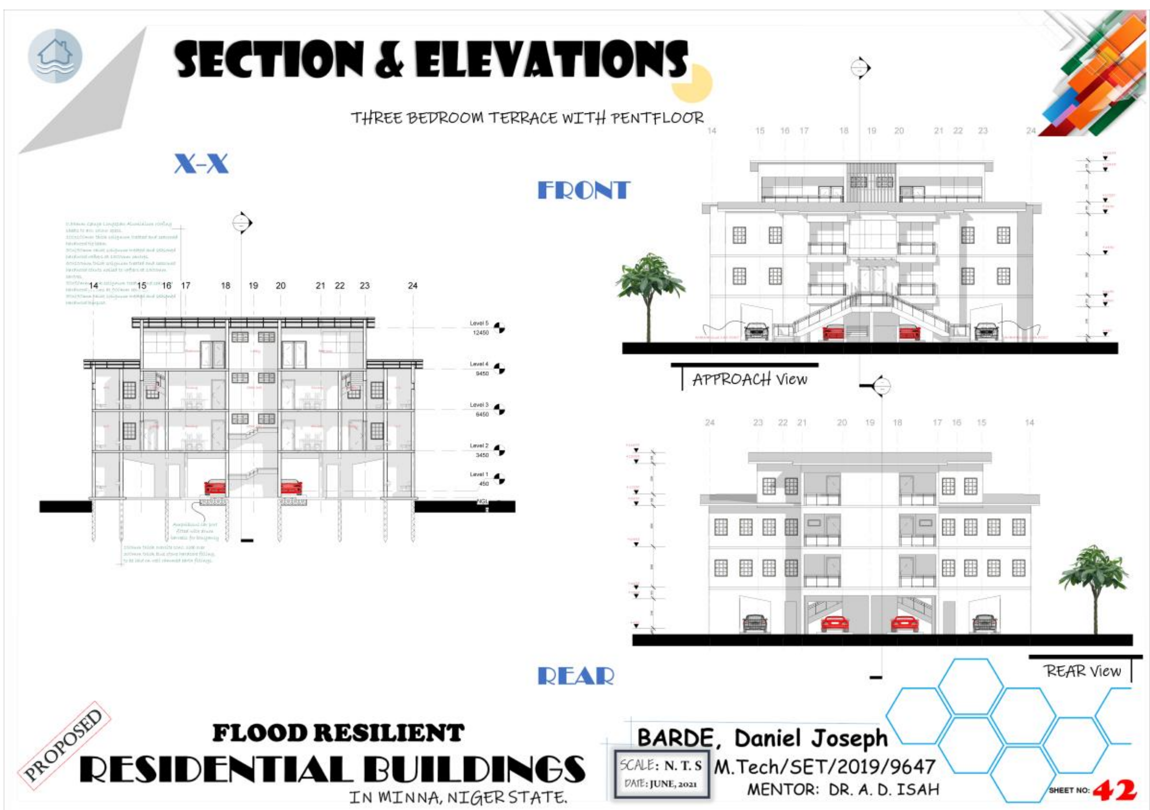
MENTOR: DR. A. D. ISAH
SHEET NO: 41


SECTION & ELEVATIONS
THREE BEDROOM TERRACE WITH PENTFLOOR
X-X
FRONT
APPROACH View
REAR
REAR View
PROPOSED
FLOOD RESILIENT
RESIDENTIAL BUILDINGS
IN MINNA, NIGER STATE.
SCALE: N. T. S
DATE: JUNE, 2021
BARDE, Daniel Joseph
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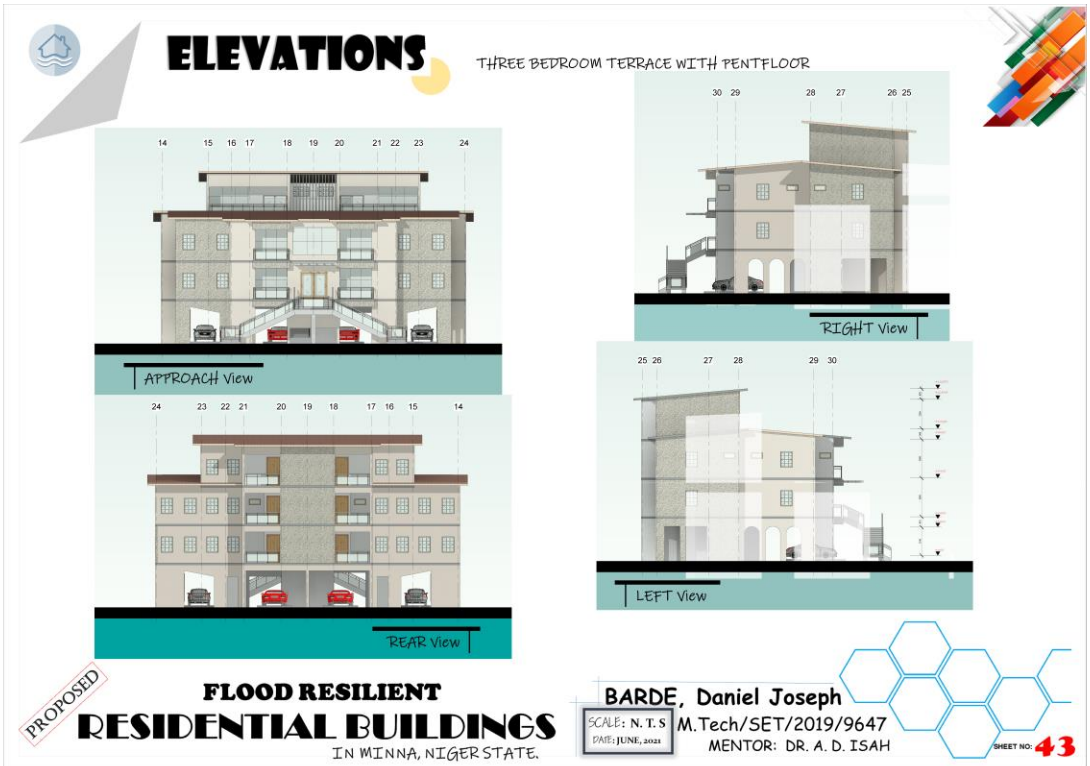
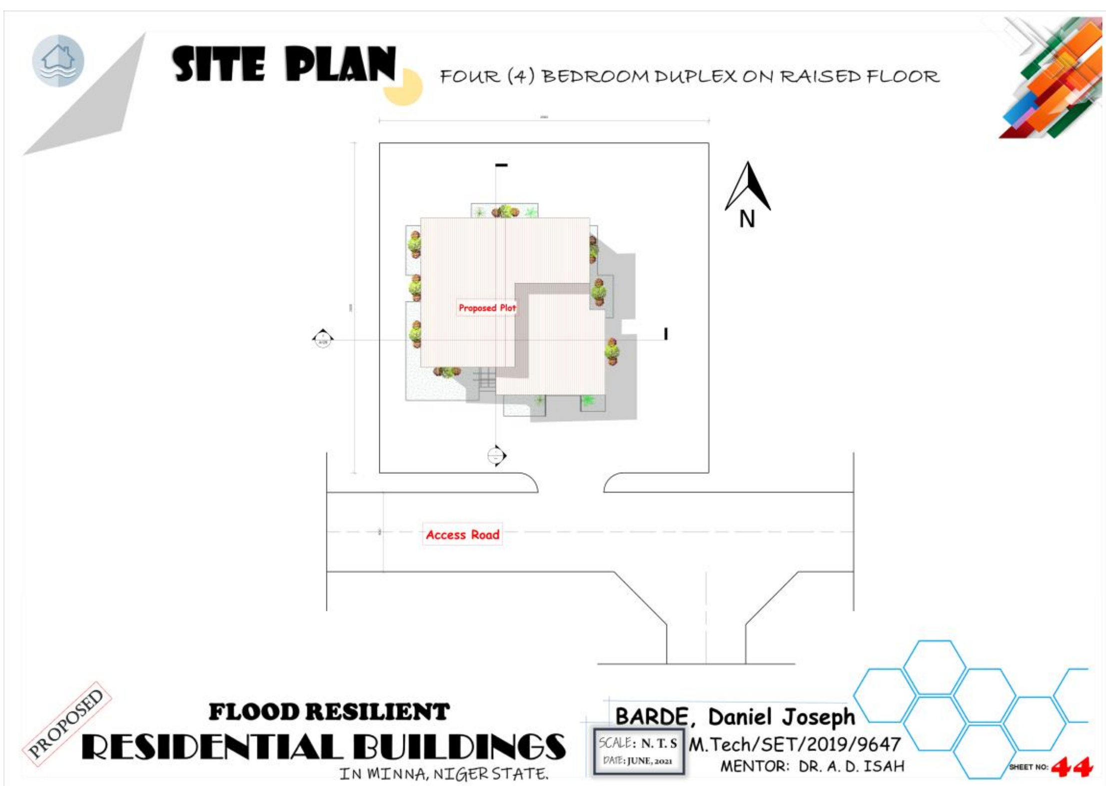
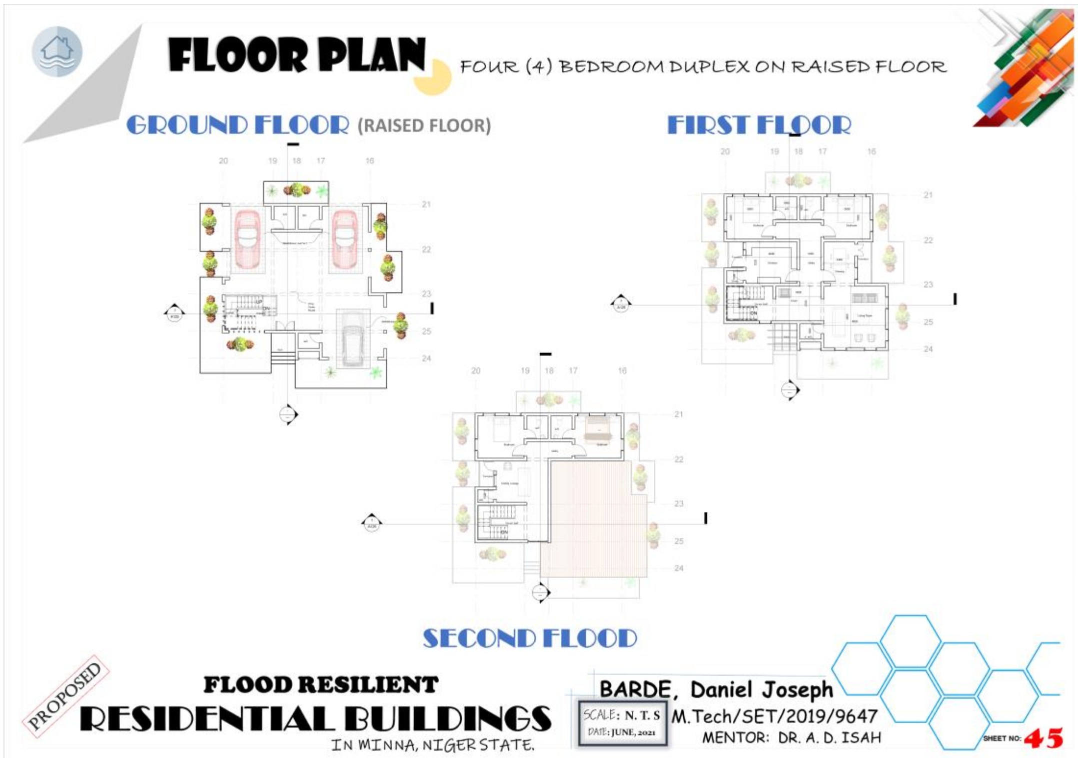
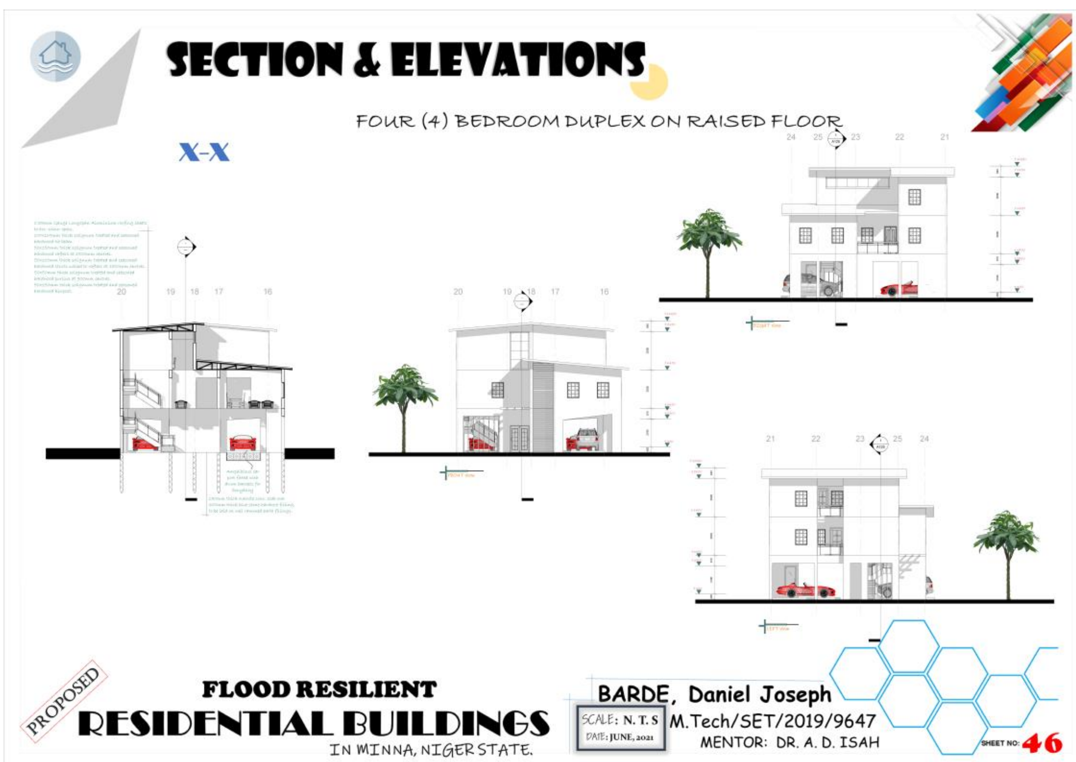
MENTOR: DR. A. D. ISAH
SHEET NO: 42



Appendix K: Four Bedroom Duplex




FLOOR PLAN
FOUR (4) BEDROOM DUPLEX ON RAISED FLOOR
GROUND FLOOR (RAISED FLOOR)
FIRST FLOOR
SECOND FLOOD
PROPOSED
FLOOD RESILIENT
RESIDENTIAL BUILDINGS
IN MINNA, NIGER STATE.
SCALE: N. T. S
DATE: JUNE, 2021
BARDE, Daniel Joseph
M.Tech/SET/2019/9647
MENTOR: DR. A. D. ISAH
SHEET NO: 45


SECTION & ELEVATIONS
FOUR (4) BEDROOM DUPLEX ON RAISED FLOOR
X-X
PROPOSED
FLOOD RESILIENT
RESIDENTIAL BUILDINGS
IN MINNA, NIGER STATE.
SCALE: N. T. S
DATE: JUNE, 2021
BARDE, Daniel Joseph
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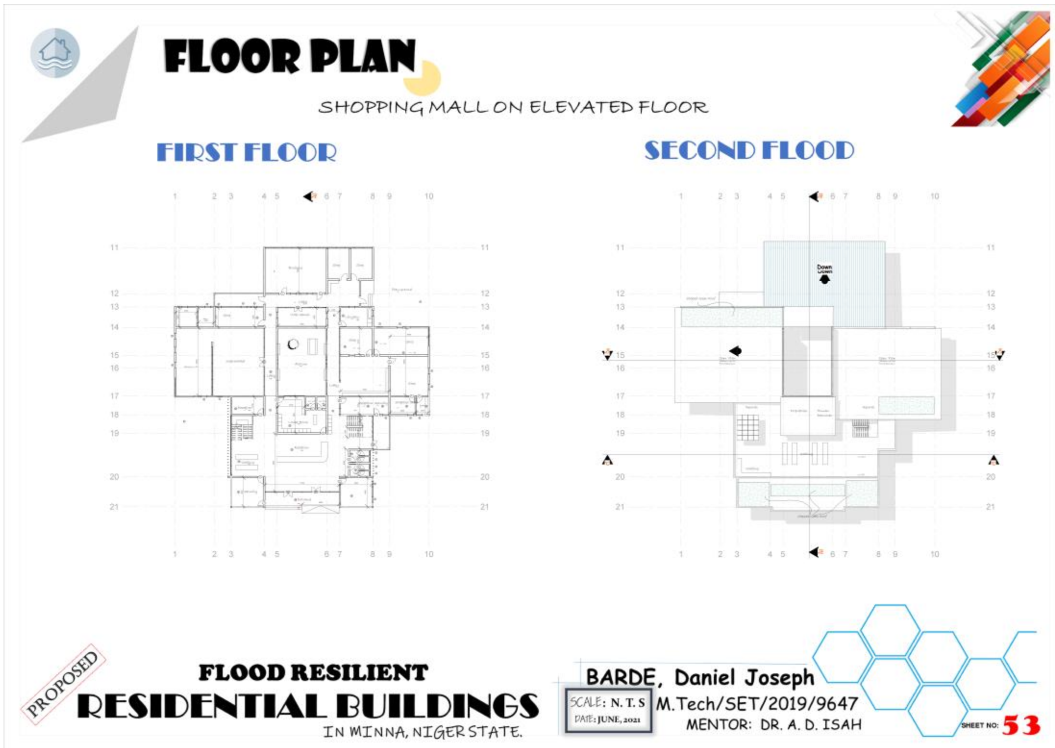
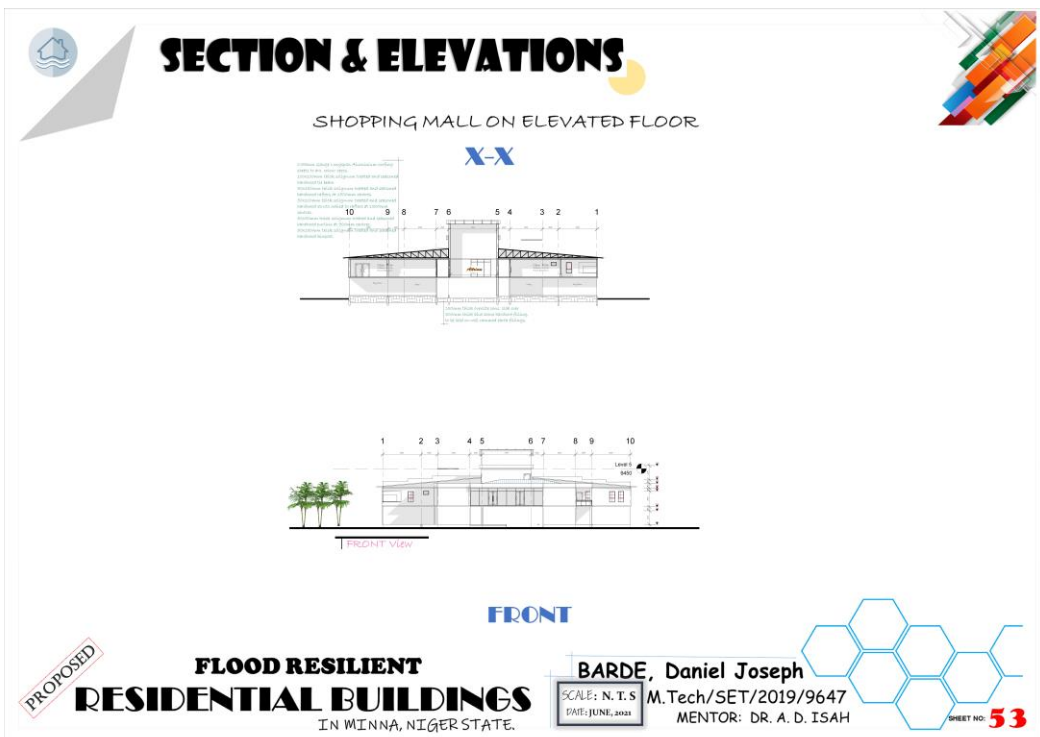
MENTOR: DR. A. D. ISAH
SHEET NO: 46

Appendix L: Shopping Mall





Appendix M: Details