# FLOODAPTIVE DESIGN

## DESIGNING FOR A CHANGED CLIMATE


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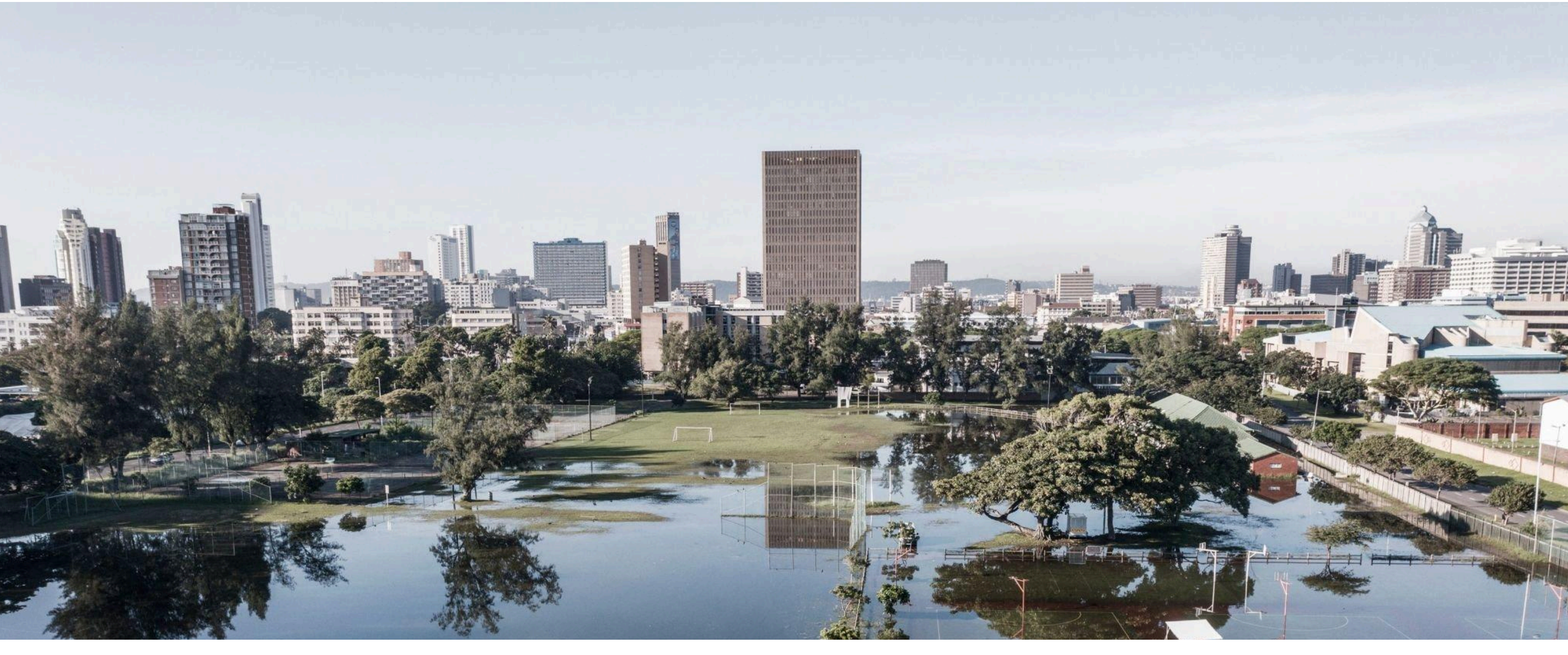
Fig 01 - Image of central Durban flood condition in Afrin 2022 by M. Longari (2022)



# Abstract

In the dynamic and diverse landscapes of KwaZulu-Natal, the increasing frequency and intensity of flooding pose significant challenges to communities, infrastructure, and the environment. This design project aims to address these challenges through innovative flood adaptation strategies that enhance resilience. Utilising sustainable design principles, the design approach seeks to create multifunctional spaces that not only adapt to flood risks but also serve as valuable community assets. Through adaptive architecture. The project aims to create architecture and spaces which are not only climatically robust and flexible in use, but foster a sense of safety and belonging.

A key focus of the flood adaptive design project is the reinforcement of existing infrastructure of educational facilities. This is in response to the devastating impact of the April 2022 floods, which affected 608 schools across the region, and resulted in major disruptions in the educational program. The design aims to create resilient school environments that can withstand future flooding while providing safe spaces for learning and community engagement.

By integrating adaptive features such as elevated structures, flexible layouts, and rainwater harvesting systems, the project seeks to ensure that schools remain operational and accessible even during extreme weather events. This approach not only supports the continuity of education but also fosters a sense of stability and hope within affected communities. Brettonwood High School was identified as a key site to develop an exemplary flood adaptation project due to its vulnerable position along the floodline of the Umbilo River. This project highlights the urgent need for resilient design solutions to safeguard educational infrastructure and ensure the continued safety of students, staff and community stakeholders during frequent flooding events.

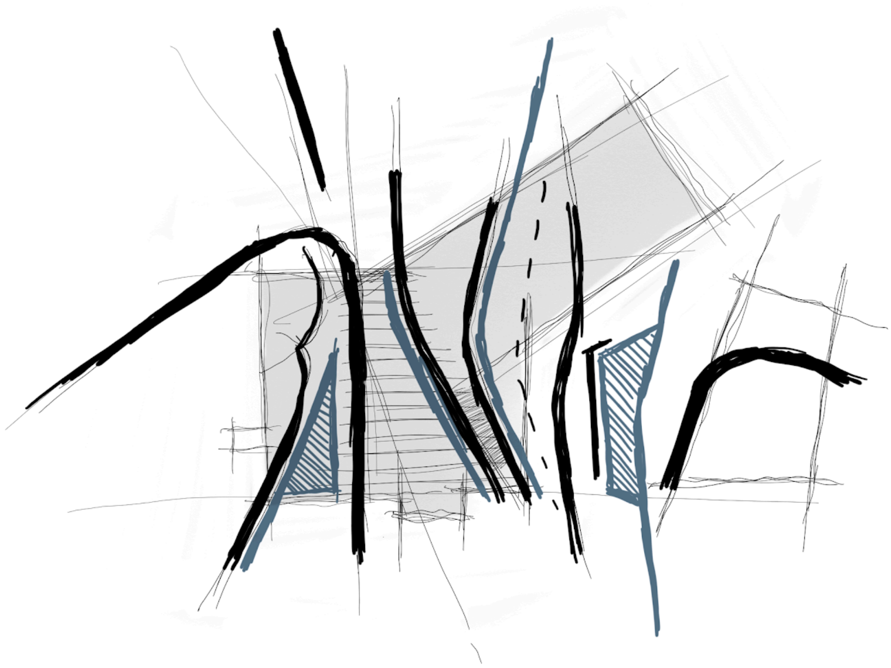


Fig 02 - Conceptual diagram by Author (2024)

# Background and Context

## Climate change

Climate change is one of the most urgent and pervasive global challenges of our time, and the impact of this change is increasingly visible in the form of extreme weather events, including but not limited to more frequent and intense flooding. Rising global temperatures, caused by human activities such as deforestation and the burning of fossil fuels, have led to shifts in weather patterns, resulting in stronger storms, higher rainfall, and melting glaciers (IPCC, 2021). As sea levels rise and rainfall patterns become more erratic, coastal and low-lying areas are particularly vulnerable to flooding, while inland areas are seeing more severe river floods (Kundzewicz et al., 2014). These events have led to widespread displacement, damage to infrastructure, loss of life, and significant disruptions to ecosystems and economies (Hallegatte et al., 2016). In many parts of the world, flooding is no longer just a seasonal occurrence, but a year-round threat that exacerbates inequality and strains the ability of governments and communities to respond effectively (UNDP, 2020).

In South Africa, particularly in KwaZulu-Natal (KZN), the annual flooding crisis has become a devastating reality, exacerbated by climate change and inadequate infrastructure. The climatic region of KZN is known for its heavy rainfall and occasional flooding, especially during the summer months, but in recent years the region has experienced increasingly severe floods. Flash floods, landslides, and storm surges have caused widespread destruction of homes, roads, schools, and critical infrastructure, displacing thousands of people and disrupting local economies (SA Weather Service, 2022). The KZN provincial capital city of Durban has been hit hard by these recurring disasters, with flash floods sweeping through urban neighbourhoods, while rural areas also struggle with inadequate drainage systems that cannot cope with the intensity of rainfall (Binns et al., 2018). These events not only cause significant loss of life and property but also further expose the region's vulnerability due to ageing infrastructure and urban planning that has failed to keep pace with growing populations and climate risks (Cukrowska et al., 2021).

Addressing the flooding crisis in KwaZulu-Natal requires not only urgent but comprehensive action. There is an immediate need for large-scale investment to increase the capacity and resilience of infrastructure to withstand such extreme weather events. This includes the construction and upgrading of stormwater drainage systems, the building of flood-resistant roads and bridges, and the establishment of better early warning systems to provide communities with time to evacuate or take preventive measures (World Bank, 2019). Additionally, urban planning must prioritise flood resilience, ensuring that new developments are built with adaptive solutions that protect people from future disasters, while addressing existing urban vulnerabilities (Satterthwaite et al., 2019). In rural areas, flood management systems must be enhanced, and communities need to be equipped with the necessary knowledge and resources to mitigate flood risks (UN-Habitat, 2021). Importantly, there must be greater collaboration between local governments, the private sector, and communities to foster climate-smart solutions that build resilience at all levels. By taking decisive action now, KwaZulu-Natal can work towards creating cities and communities that not only survive but thrive in the face of climate change, reducing the devastating impacts of flooding in the future and ensuring that the region can adapt to a rapidly changing climate (Pelling, 2021).

## Flood relation to education

The 2022 floods in KwaZulu-Natal (KZN) were one of the most devastating natural disasters to hit the province in recent history. The impacts were felt across various sectors, including education, with thousands of students and educators suffering from the disruption caused by the flooding. According to the Department of Basic Education (DBE) in South Africa, more than 600 schools were either damaged or destroyed during the floods, severely affecting the educational landscape in the region (DBE, 2022). Many of these schools were located in rural and peri-urban areas where infrastructure was already considered vulnerable, and the floods further exacerbated existing inequalities. In some cases, entire school buildings were washed away, while others sustained structural damage, rendering them unsafe for students and staff. In addition to physical damage, many schools were also affected by the displacement of families, with classrooms being used as temporary shelters for those who lost their homes. The disruption to education was particularly acute in areas like Durban, where entire communities were displaced, leaving thousands of children without access to their schools for weeks or even months.

The disruption caused by the 2022 floods highlights the urgent need for a more resilient education sector with systems and infrastructure that can withstand extreme weather events, such as floods, hurricanes, and severe storms. This requires a multifaceted approach, beginning with the construction of flood-resistant school building infrastructure. According to the South African Council for Educators (SACE), the damage to school building infrastructure during the 2022 floods set back efforts to ensure equitable access to quality education, especially for vulnerable students in rural KZN. The DBE's assessment estimated that over 200,000 learners were directly affected by the closure of schools, with many missing out on critical learning time, impacting both their academic progress and mental well-being (DBE, 2022). In the district of eThekwini, nearly 70 schools were either partially or fully destroyed, affecting tens of thousands of learners and causing significant delays in academic calendars.

In addition to the immediate physical damage, the floods disrupted educational programs and resources. Many schools were forced to abandon the curriculum for extended periods, while teachers and learners faced significant challenges in returning to normalcy, often working in temporary facilities or under unsafe conditions. The floods also highlighted the need for enhanced disaster preparedness and response within schools, including the creation of emergency protocols and infrastructure to safeguard against future events. Educational authorities, along with local governments and community organisations, must invest in building disaster-resilient schools, where the physical environment and educational continuity are prioritised. This could include the development of multi-purpose facilities that can function as community hubs during disasters while continuing to provide education in more resilient structures.

A longer-term programmatic focus must also include comprehensive education on climate change and disaster preparedness. It is argued that integrating awareness of climate resilience into the school curriculum will equip young learners with the knowledge they need to understand climate risks and take action to protect themselves and their communities in the future. Furthermore, it would be crucial to train educators and school staff in disaster risk reduction and climate change adaptation, ensuring that they are well-prepared to respond in the event of another extreme weather event. The floods of 2022 have pulled into focus that without significant investment in both physical infrastructure and educational preparedness, the region's education system will continue to be vulnerable to the impacts of climate change. As such, improving the resilience of schools to flooding and other climate-related risks must be seen as an integral part of building resilient cities and communities in KwaZulu-Natal.

# Aim of investigation

The aim of this investigation is to assess the impact of the 2022 floods on infrastructure and systems in KwaZulu-Natal, South Africa, with a particular focus on the resilience of schools in the region to extreme weather events. The project seeks to identify the key challenges faced by the education sector in the aftermath of the floods, including the destruction of school buildings, disruption to learning, and displacement of students and educators. The investigation will explore the underlying vulnerabilities in the design and construction of educational infrastructure, as well as the capacity of local governments and educational authorities to respond to climate-induced disasters.

The goal of this investigation is ultimately to contribute in the development of a more robust, climate-resilient system in KwaZulu-Natal, ensuring that architecture is better equipped to continue with its program despite the increasing frequency of extreme weather events caused by climate change.

The Durban City Plan currently utilises zoning strategies that designate open spaces like schools, parks, and sporting grounds along river edges to act as water catchment areas during heavy rainfall and floods. This approach is a smart and cost-effective way to manage flooding, as it uses these open spaces to absorb and temporarily store excess water, preventing it from overwhelming urban infrastructure. However, while the planning strategy is effective in theory, the architecture on these sites often fails to fully co-exist with this water management approach.

Many buildings in these flood-prone areas, including schools and public spaces, are not designed to adapt to or integrate with the natural flow of water. Instead, traditional infrastructure often obstructs water flow or exacerbates flood risks, as buildings are constructed without considering the need for water passage, elevation, or flexible space for flood management. This strategic misalignment means that these spaces that are intended to function as flood mitigation zones, are not fully optimised and may even contribute to flood damage rather than prevent it. To address this, future architectural designs need to be more attuned to the greater flood strategies,

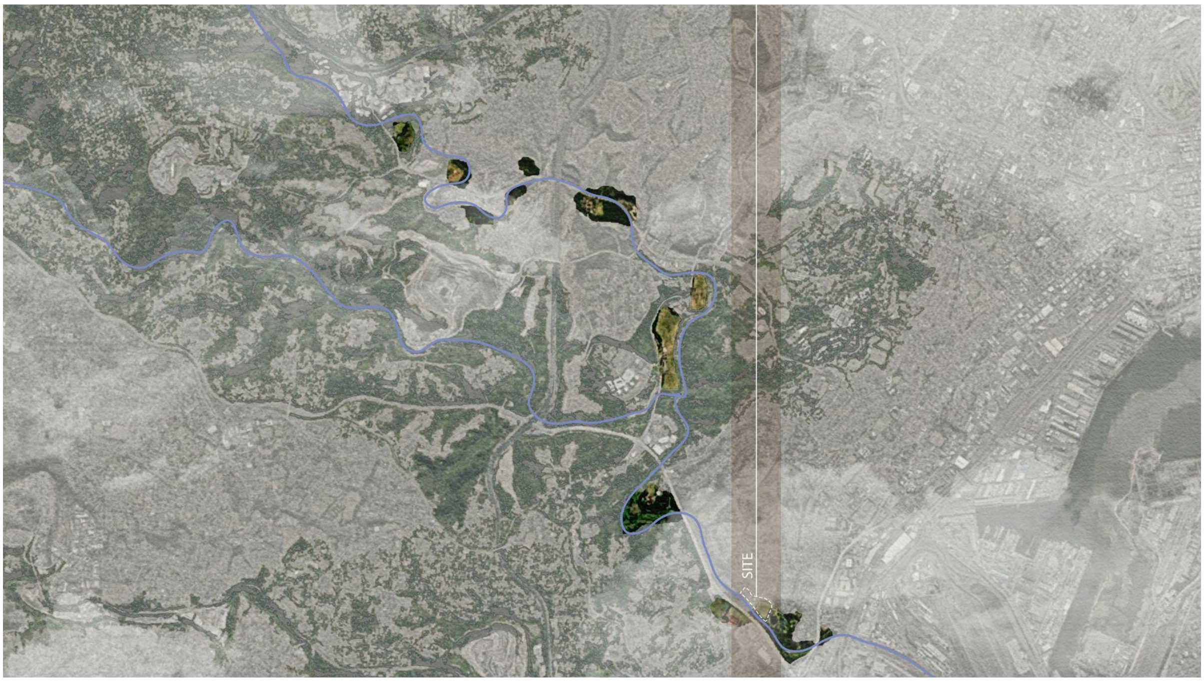



Fig 03 - Open space mapping along Umbilo river by Author (2024)

# Site selection

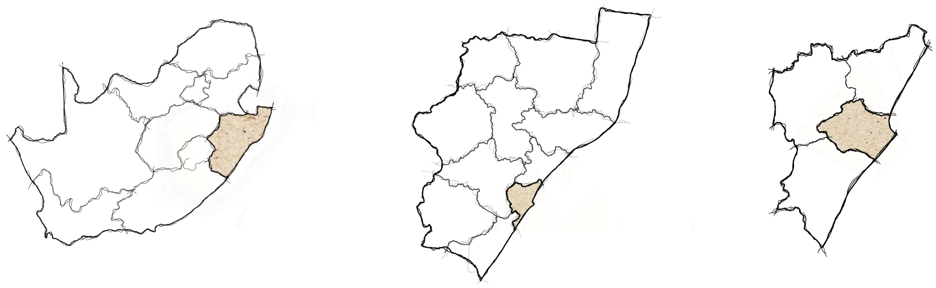
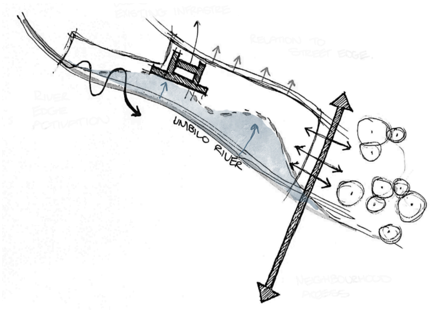


Fig 04 - locality mapping of central Durban, Kwazulu Natal, South Africa by Author (2024)

Brettonwood High School, located in the Umbilo area of Durban, serves as a critical example of the vulnerabilities faced by educational institutions situated along flood-prone areas, particularly those near rivers. The school is positioned along the banks of the Umbilo River, a location that places it within the 50 and 100 year floodline, making it highly susceptible to the kind of flash floods and storm surges that have become increasingly common in Durban due to climate change.

The selection of Brettonwood High School as a site for this design project is not only rooted in the physical realities of its geographical location but also in the broader context of how such schools face compounded risks during extreme weather events. The Umbilo River has historically been prone to flooding, particularly during the summer months when heavy rainfall is common. However, climate change has exacerbated these events, leading to more frequent and intense flooding in the region. In April 2022, for example, the heavy rains that triggered devastating floods in Durban had a direct impact on schools situated along flood-prone areas like Brettonwood. The floods washed away sections of roads, damaged school buildings, and displaced students and staff, disrupting education for weeks and causing severe logistical challenges for the school management and local education authorities (South African Broadcasting Corporation [SABC], 2022).




The base case model scenario that will be used is the conditions of the 2022 floods that occurred on the Brettenwood High School site. This Base case will form part of the simulation and analysis used to understand the flooding situation under normal conditions, without any additional interventions or modifications. This base case serves as a benchmark for assessing the impacts of various flood management strategies and improvements.

Fig 05 -Illustration of potential responses and impacts of flooding on the site by Author (2024)

By analysing the base case scenario, planners and engineers can identify vulnerabilities and weaknesses in the current flood management strategies. This helps in developing effective interventions, such as improved drainage systems or flood defences, and in preparing for future flood events to reduce their impact on Brettenwood High School and the surrounding community.


Fig 06 - Representation of site context and study focus area by Author (2024)

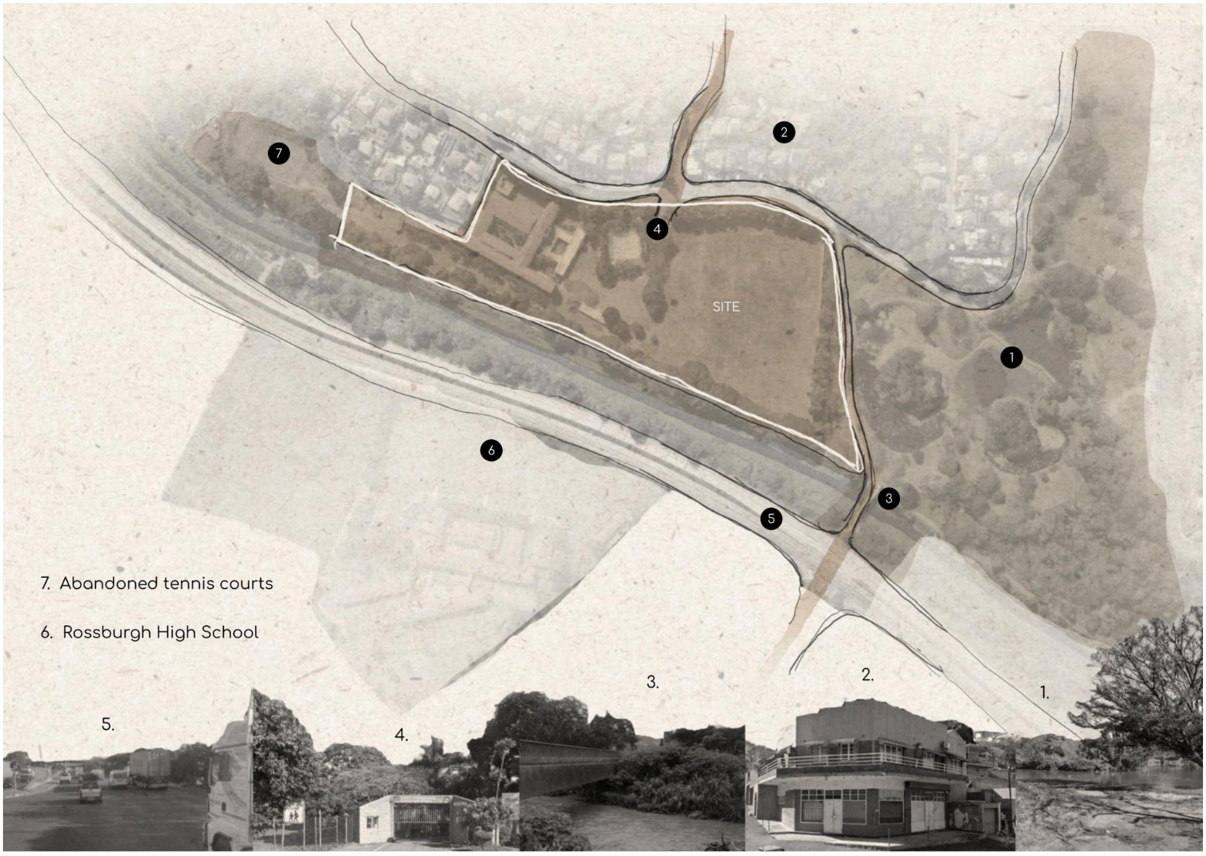



Fig 07 - Collage of site photographs composed against site map to illustrate the contextual language and natural components by Author (2024)

## Precedents

### Makoko Floating School

The Makoko Floating School in Lagos, Nigeria, offers an innovative design precedent for flood-adaptive infrastructure, particularly in flood-prone regions. Built on floating platforms made from locally sourced materials, this school is elevated above the water level, allowing it to rise and fall with changing water levels, ensuring its continued operation during flood events. This design is especially relevant for areas like KwaZulu-Natal (KZN), South Africa, where rising sea levels and extreme rainfall increasingly threaten schools located near flood-prone rivers, such as Brettonwood High School in Durban. By incorporating sustainable, locally available materials and creating flexible, resilient structures, the floating school model demonstrates how educational infrastructure can adapt to climate change, ensuring continuity of education despite flood risks. This approach could serve as a valuable solution for building more resilient schools and community centres in KZN and other coastal regions facing similar challenges.

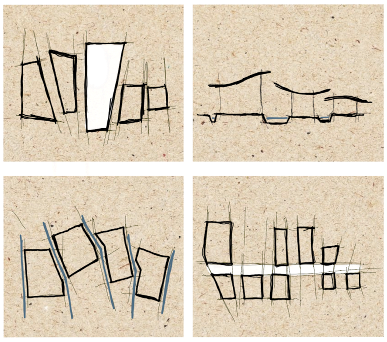
Fig 08 - Diagrams of architectural strategies employed in precedent by Author (2024)

### Etania Green School

Etania Green School in Ecuador is another notable example of innovative flood-adaptive design, showcasing how schools can be built to withstand environmental challenges, particularly in areas prone to flooding. Located in the Chone River basin, a region known for seasonal flooding, the school's design incorporates sustainable architecture principles aimed at addressing both flooding risks and environmental sustainability.The key design feature of Etania Green School is its elevated structure, which sits on stilts to ensure that the buildings remain above the floodwaters during periods of heavy rainfall and river overflow. By raising the classrooms and other facilities off the ground, the school avoids water damage, ensuring that educational activities can continue even when flooding occurs. Additionally, the design includes rainwater harvesting systems and natural ventilation, making it not only flood-resilient but also energy-efficient and sustainable. The school's use of local, sustainable materials further integrates it with the surrounding environment while minimising its ecological footprint.


Fig 09 - Diagrams of architectural strategies employed in precedent by Author (2024)

# Design approach



The design approach for the new Brettonwood High School celebrates the presence of water on site by integrating flood-resilient features that allow for the natural flow of water during heavy rains. Located along the Umbilo River in Durban, the school will be elevated above the 50 year floodline, with the main buildings raised on stilts to ensure that floodwaters can pass beneath the structure without causing damage.

Fig 10 - Developed design response strategies by Author (2024)

This approach embraces flooding as a natural occurrence, allowing water to be managed sustainably through permeable surfaces and stormwater channels that direct water away from critical areas. By incorporating these features, the design fosters a connection with the surrounding environment and provides a safe, adaptable space for education, while also promoting resilience in the face of increasingly frequent floods in the region

The design will utilise a spatial and technical matrix that categorises each area based on its specific functions and conditions. By addressing the unique needs of spaces such as classrooms, recreational spaces and community facilities, the design will tailor architectural responses that enhance safety and usability. For instance, classrooms will be elevated to to reduce flood risk, while green spaces will manage stormwater runoff

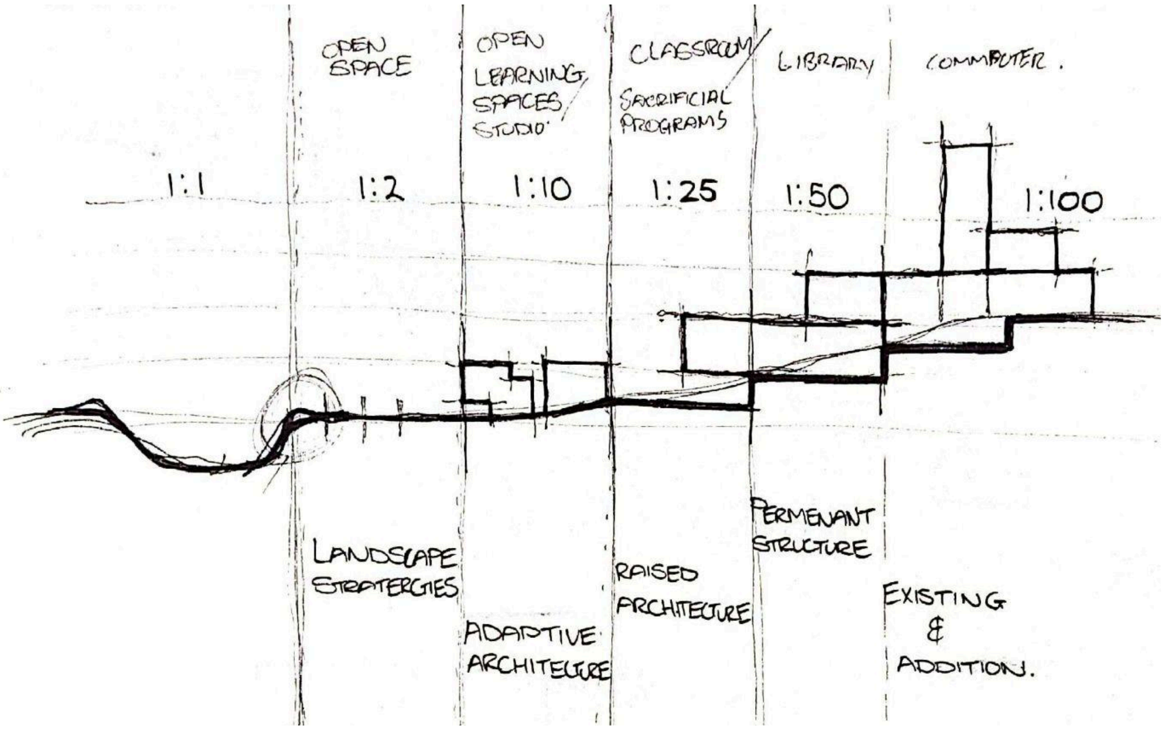
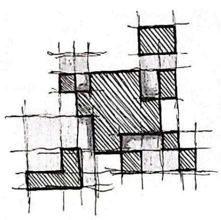
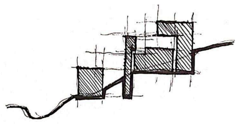



Fig 11 - Degree and type of intervention and adaptation against the potential flood risk. Positioning building programme on a sliding scale of potential exposure to flood risk by Author (2024)



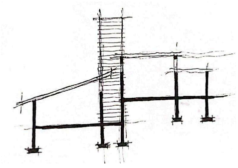
The adaptive component of the spatial matrix will focus on flexibility and responsiveness to changing conditions. Each designated area will incorporate features that allow for easy modification in response to flood events or evolving community needs. The adaptive design will make use of amphibious architecture allowing classrooms within high risk classifications to have movable and floating structures.

Fig 12 - Adaptability sketch diagram by Author (2024)



The raised architecture component will incorporate sacrificial programs designed to accommodate flood events without compromising the overall integrity of the structure. The strategy involves elevating critical facilities above anticipated flood levels while allowing sacrificial open program spaces to flood.

Fig 13 - Raised architecture sketch diagram by Author (2024)



The existing parts of the school will remain in areas indicated in the low risk areas of the spatial matrix as they won't be affected by the flood conditions. This will allow for the programs they need water protecting such as computer spaces and libraries.

Fig 14 - Existing architecture sketch diagram by Author (2024)

## Design principles

The design will integrate natural materials and elements, natural light and ventilation, and thoughtful spatial organisation to create a welcoming environment. Thresholds and passage spaces will be designed to help guide movement and connect spaces fluidly. Passive design strategies will maximise the use of natural daylight and ventilation. A distinctive landmark design will make the school a recognizable, central point in the community, blending function with symbolism.

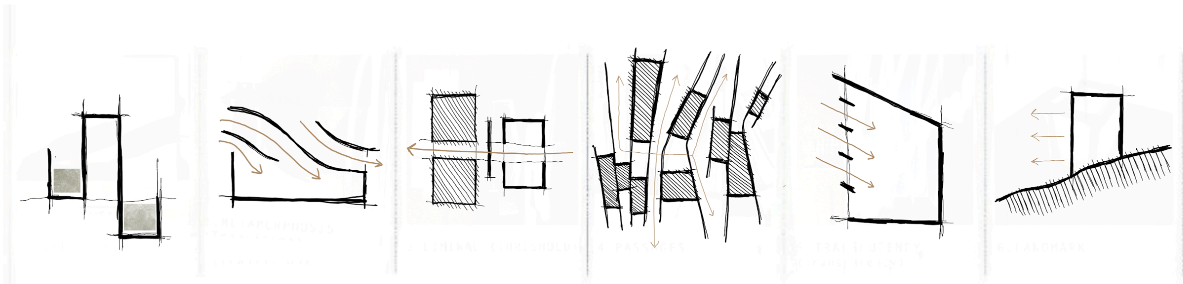


Fig 15 - Design principle diagrams by Author (2024)

# Early design iterations

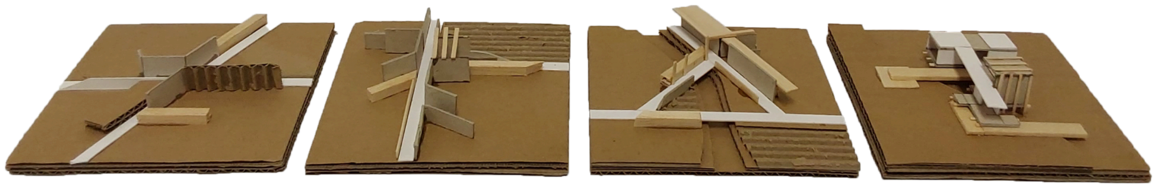


Fig 16 - A set of explorative maquettes exploring pathways **(a)**, thresholds **(b)**, Chennells **(c)** and raised architecture **(d)** by Author (2024)

The first set of design iterations explored different approaches to dealing with flood water on the site. Different configurations of articulated  channels to direct floodwater onto the site was explored, as well as the potential impact of transforming the landscape each year as floodwaters reach their peak. Pathways and spaces could be designed to adapt to these conditions, with channels guiding water through the site, and certain areas becoming submerged or evolving into temporary wetland zones. Elevating or raised structures could withstand the flood, while permeable paths allow for water integration, offering a unique experience of the flood event. This design celebrates the flood's maximum capacity as a natural, annual occurrence, testing how spaces, materials, and pathways can harmoniously integrate with and even embrace the changing water levels.

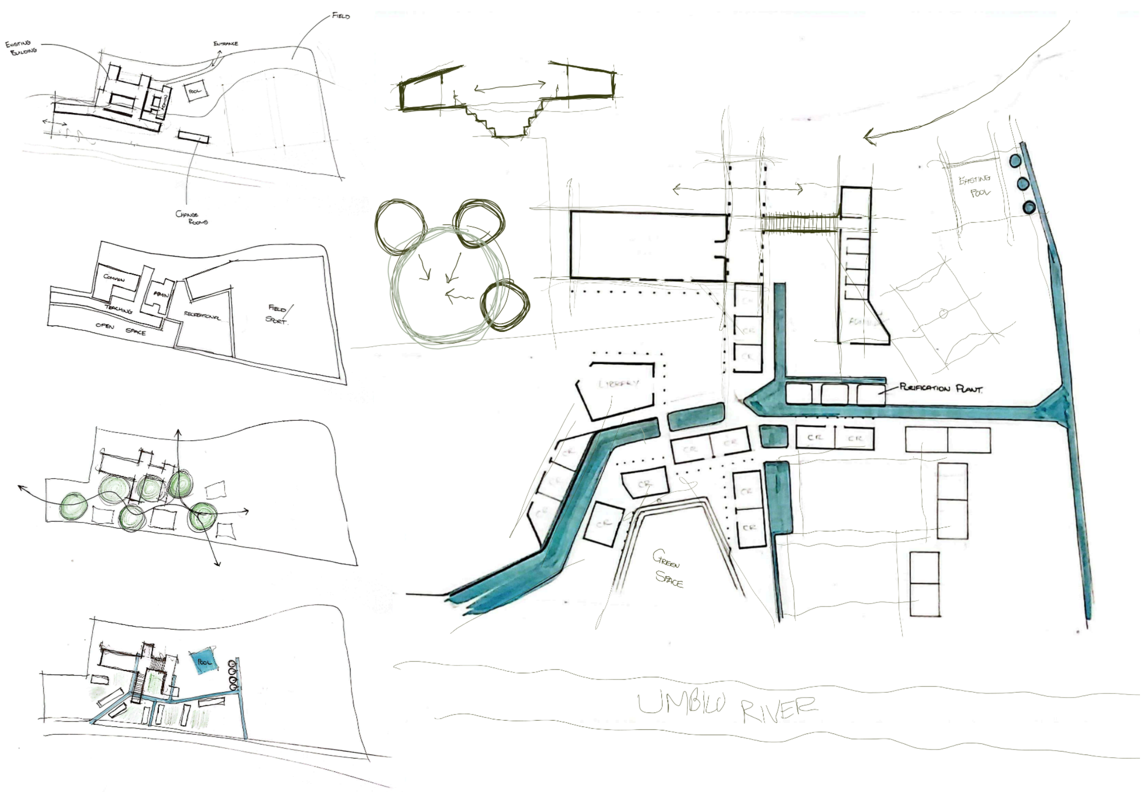



Fig 17 - Sketch iterations exploring water channel usage on site (2024)

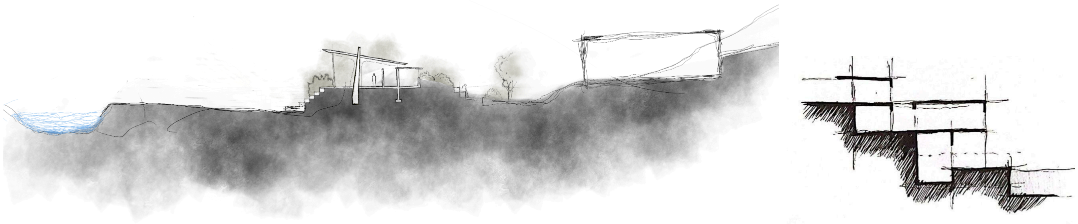


Fig 18 - Section water channel usage on site by Author (2024)

## Early design iterations

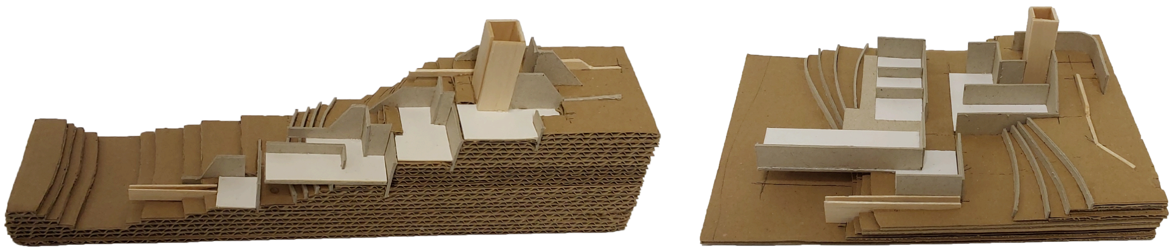


Fig 19 - Model explorations testing form and classroom orientation by Author (2024)

Following the initial design iteration, it became clear that the site's water capacity would not sufficiently accommodate the floodwater volumes directed by the proposed channels, given that a majority of the site would be affected. As a result, the design evolved to integrate a more nuanced, adaptable approach to flood management. This led to the development of a flood spatial matrix, which maps out varying flood scenarios across the site. The matrix guides the implementation of different flood strategies in specific areas, ensuring that each zone is tailored to handle flooding in the most efficient and sustainable way. For example, areas with higher water retention could incorporate wetland-like features to absorb excess water, while lower-lying regions could use permeable surfaces or raised pathways to manage water flow. Elevated or floating structures might be used in flood-prone zones, while more robust, flood-resistant infrastructure could be applied to key urban areas. By adapting the strategy to the site's specific needs and flood patterns, the design offers a flexible,

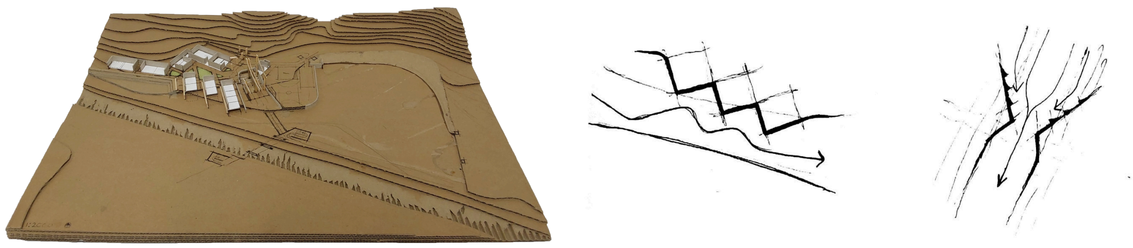


Fig 20 - Exploration of rubble redirection strategies by Author (2024)

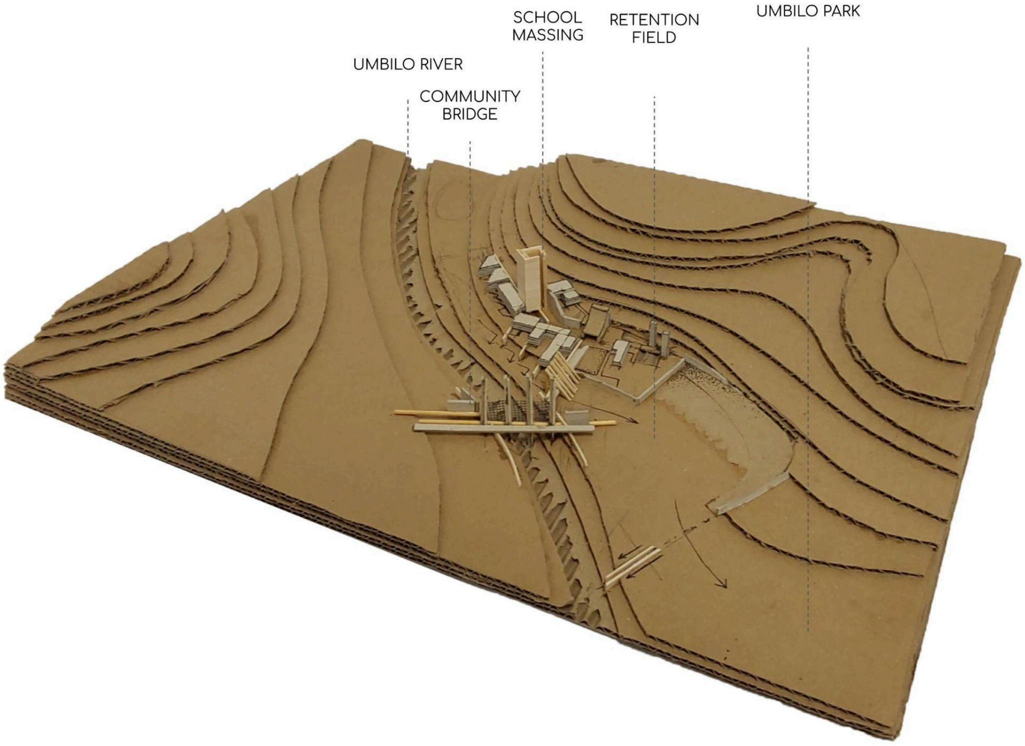



Fig 21 - Model explorations of site massing and community linkage by Author (2024)

## Early design iterations

In the next iteration, the design focuses on adaptability, using lightweight materials like tensile fabrics and buoyant platforms in flood-prone areas to shift or float with rising water levels. These flexible materials would be used for temporary structures like walkways and pavilions. Meanwhile, more durable materials like concrete and steel would be applied to protect critical infrastructure and ensure structural integrity. This combination of adaptable and resilient materials allows the site to respond dynamically to flooding, maintaining both flexibility and safety while celebrating the natural flow of water

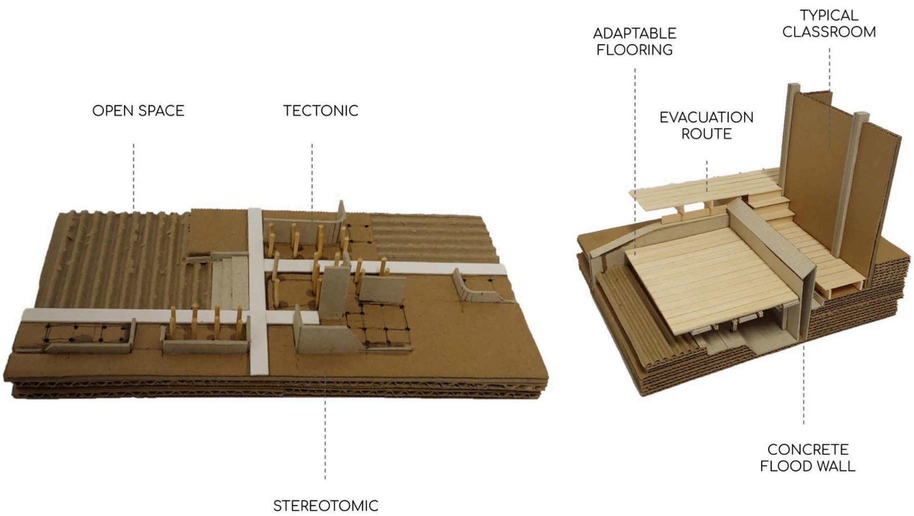



Fig 22 - Model explorations of adaptable architecture typologies by Author (2024)

## Final design iterations

The final design integrates adaptive flood strategies along the site where the most flooding is projected to occur. Lightweight, flexible materials allow pathways and structures to rise with flood heights, while durable materials protect key infrastructure. A safe, elevated public bridge ensures the community can cross the river during floods. The design creates a resilient, safe environment for both the school and the broader community


Fig 23 - Final ground floor plan by Author (2024)

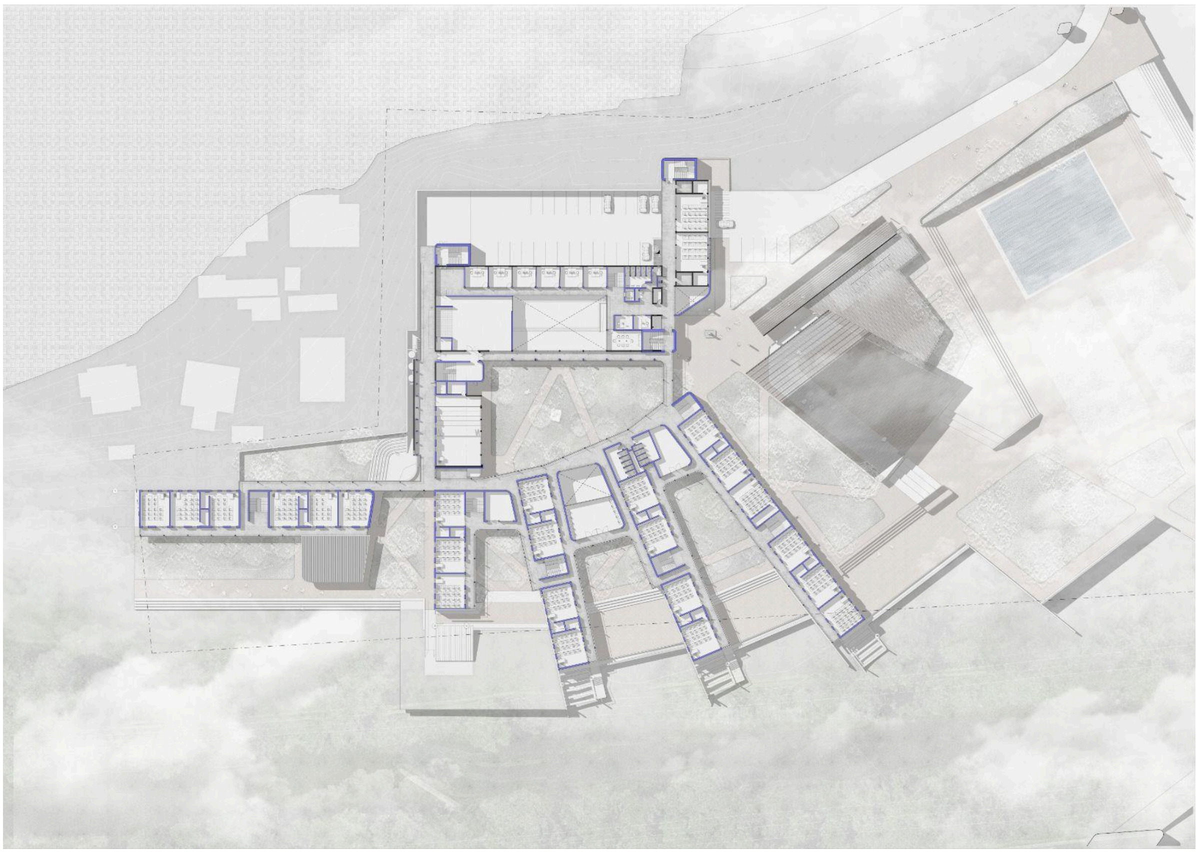


Fig 24 - Final first floor plan by Author (2024)

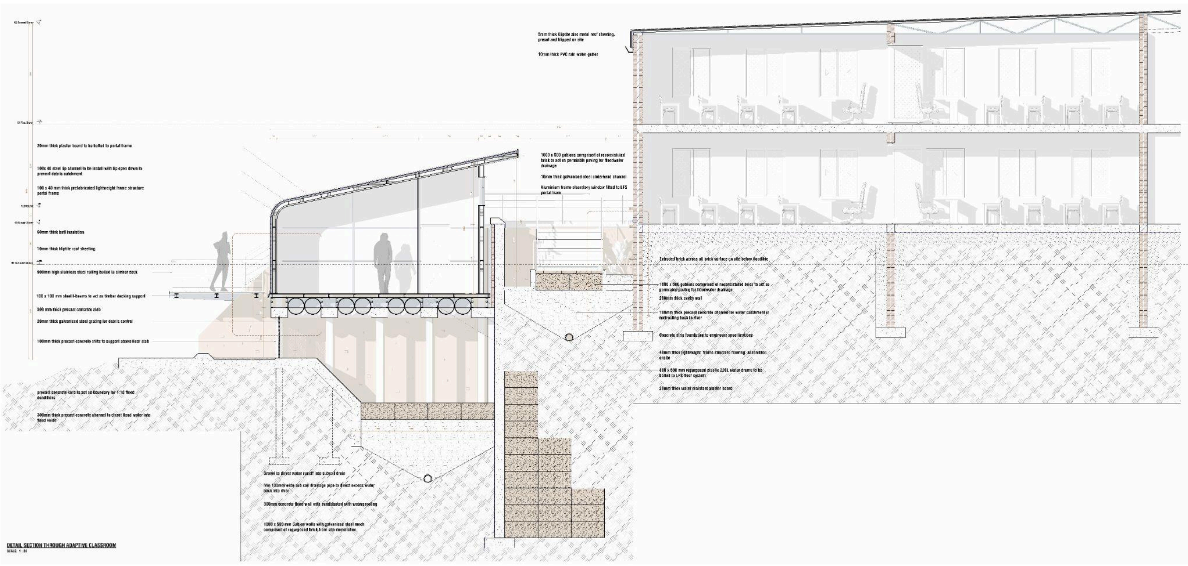


Fig 25 - detail section through adaptable classroom by Author (2024)

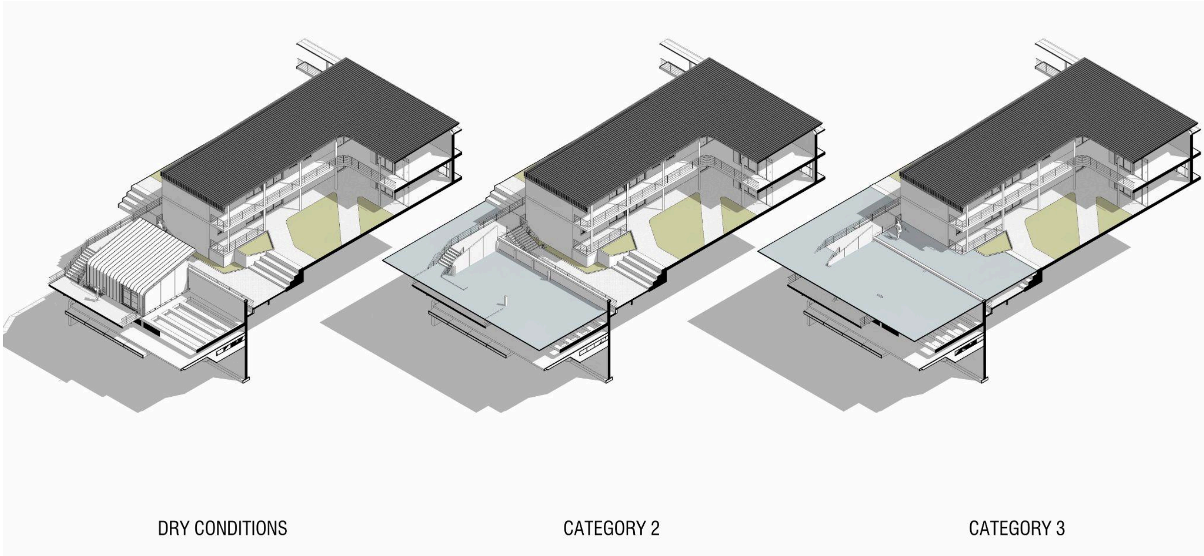



Fig 26 - Flood condition categories by Author (2024)

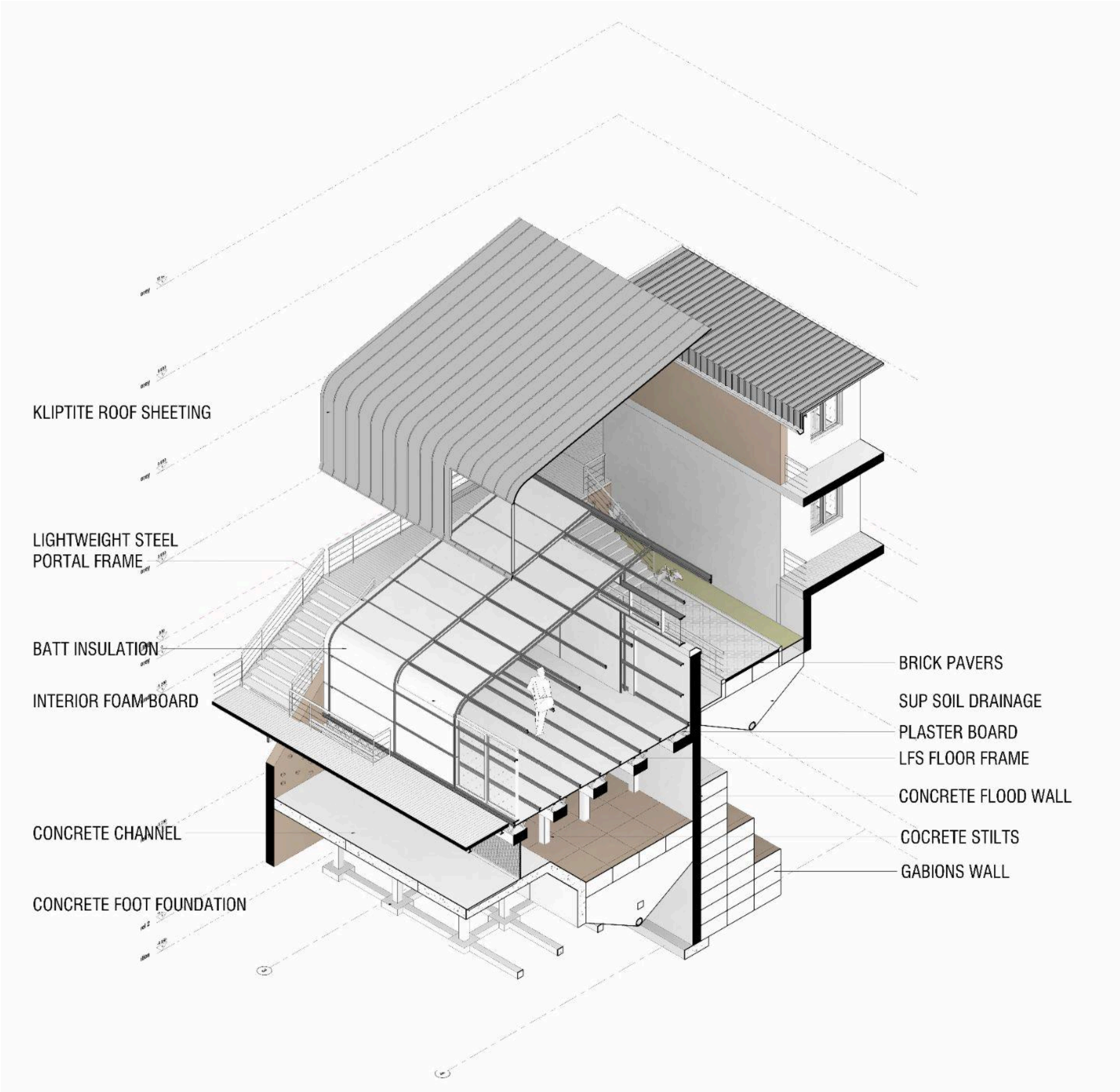



Fig 27 - Detailed axo of typical classroom by Author (2024)


Fig 28 - Initial 3D view 1 by  Author (2024)

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