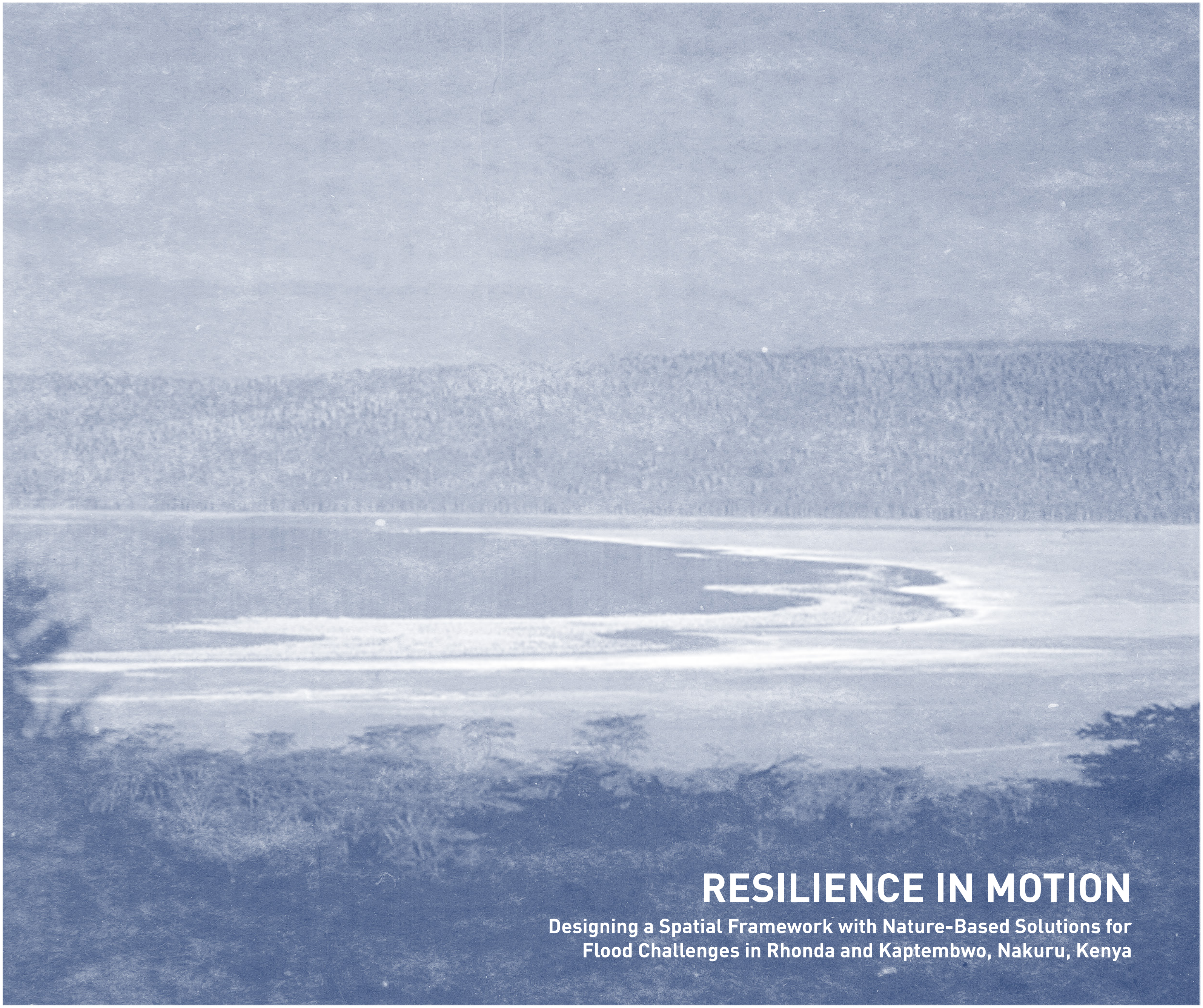

RESILIENCE IN MOTION

Designing a Spatial Framework with Nature-Based Solutions for Flood Challenges in Rhonda and Kaptembwo, Nakuru, Kenya

Master Thesis Report
MSc Architecture, Urbanism and the Built Environment
Landscape Architecture Track

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Urban Ecology Lab
First mentor: Nico Tillie
Second mentor: Mo Smit
Exam committee: Marjolein Spaans

Flowscapes Studio
Water as Leverage, Nakuru (WaL)

Location: Nakuru, Kenya
Unless stated otherwise all pictures and graphics by author

People of Nakuru
Photo credits: Author, Khadija M. Farah

Prologue

PEOPLE OF NAKURU

"At the beginning, we just thought it was a bad rainy season, that the water would recede when the dry season came. It didn't. People will have to leave this place and find somewhere else to live. If they were running a business, that means they probably will not have that business anymore. Life is drastically going to change."

---- James Owuor, former resident of nakuru

Acknowledgement

This thesis research marks the culmination of an intense and rewarding year of graduation work, rooted in my deep interest in the intersection of landscape architecture and urban resilience. Conducted as part of the requirements for the MSc Architecture, Urbanism and the Built Environment, Landscape Architecture track, at Delft University of Technology, this project focuses on adaptive housing transformations in Nakuru, Kenya.

I would like to extend my heartfelt gratitude to my mentors for their invaluable guidance and trust throughout this journey. Nico Tillie, thank you for your sharp insights, unwavering support, and for challenging me to push boundaries in both design and thinking. I am also deeply grateful to the thesis committee for their feedback and encouragement, which have helped shape this work into a more grounded and relevant contribution.

Special thanks go to the local experts, planners, and residents in Nakuru who generously shared their knowledge and lived experiences with me. Your openness provided the essential context and human dimension that this research is built upon. I am particularly thankful for the conversations that took place in low-income neighborhoods—your stories anchored my design thinking and reminded me of the purpose behind this work.

I would also like to acknowledge my studio peers for their companionship and stimulating discussions throughout the year. Your energy and honesty created a space where ideas could evolve with clarity and purpose.

To my family—thank you for your love, patience, and unshakable belief in my path, even from afar. To my close friends, thank you for being there through the highs and lows, especially during the final stretch, when encouragement and laughter made all the difference.

This thesis stands as a testament not only to academic inquiry but also to the power of empathy, collaboration, and persistence. I carry forward the lessons learned here with deep appreciation and hope for a more inclusive and resilient urban future.

Zhuoran Chen
25 May 2025

Water as Leverage, Nakuru
Photo credits: Joy Chege (2025.2)

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01 Introduction

Former Front Gate of Nakuru National Park
Photo credits: ZUMA Press (2022.5)

Study Motivation

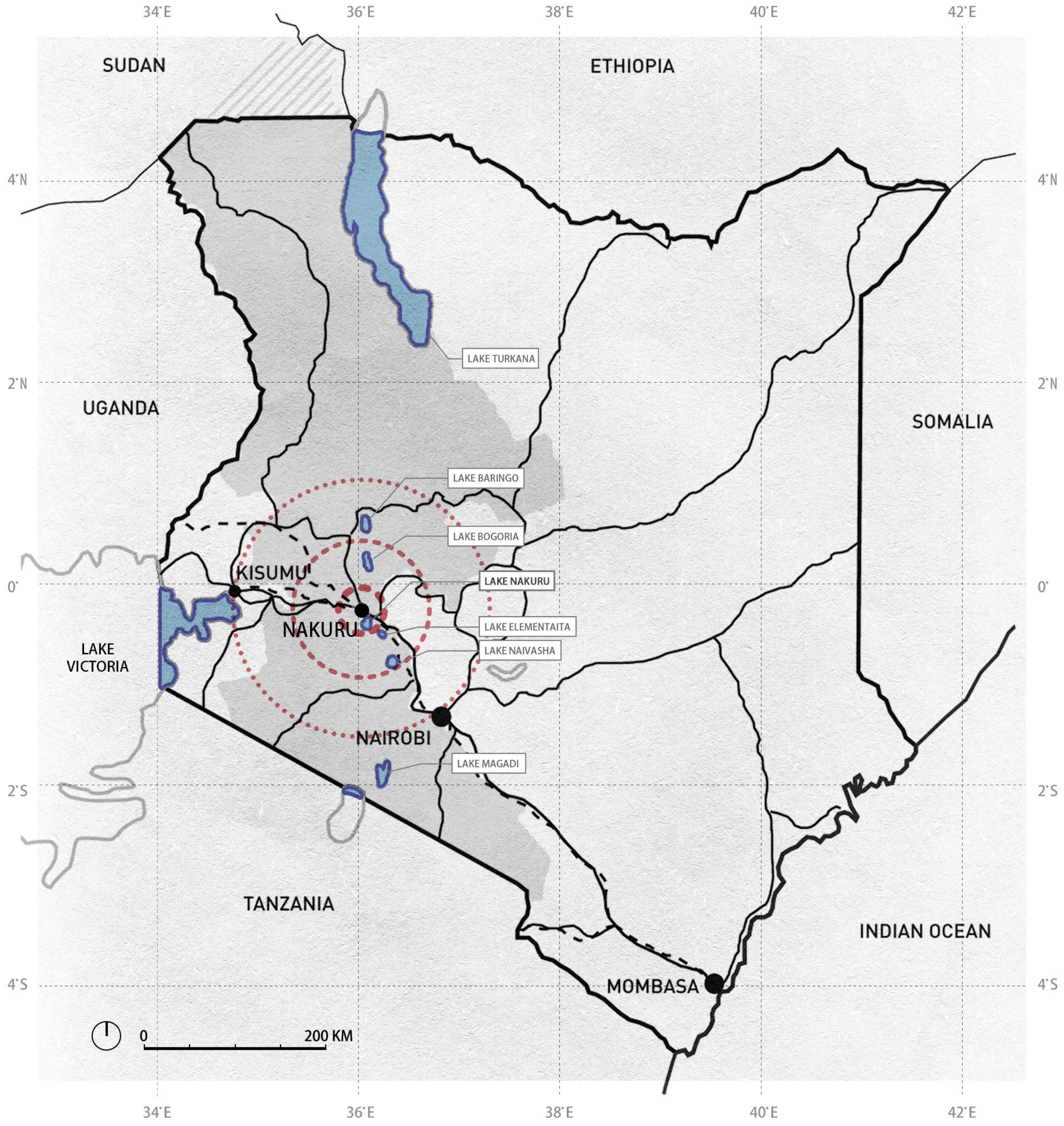
Urban water challenges in the Global South are intensifying due to rapid urbanization, climate change, and fragmented governance systems. Nakuru, a rapidly growing city in Kenya, reflects these dynamics through increasing flooding, water scarcity, and spatial inequality. As part of the Water as Leverage program, this research engages directly with Nakuru's local authorities, communities, and planners to explore nature-based and spatial strategies for climate adaptation.

The motivation for this research is both professional and personal. Growing up in southern China (Nanjing), I have witnessed the impacts of extreme rainfall and inadequate stormwater systems firsthand. These experiences have driven my long-standing interest in the relationship between hydrology, landscape design, and risk management.

Through one month of on-site research in Nakuru and previous collaboration with Wits University in South Africa on a WEF Nexus-related project, I have developed a deeper understanding of urban water governance in African contexts. This thesis builds on that foundation, focusing on the role of visual tools—such as GIS mapping and systemic landscape diagrams—as mediators between technical knowledge and inclusive decision-making. The aim is to develop strategies that are not only spatially effective, but also socially embedded and locally informed.

Nanjing China
Photo credits: Chinanews.com

Johannesburg, South Africa
Photo credits: Author



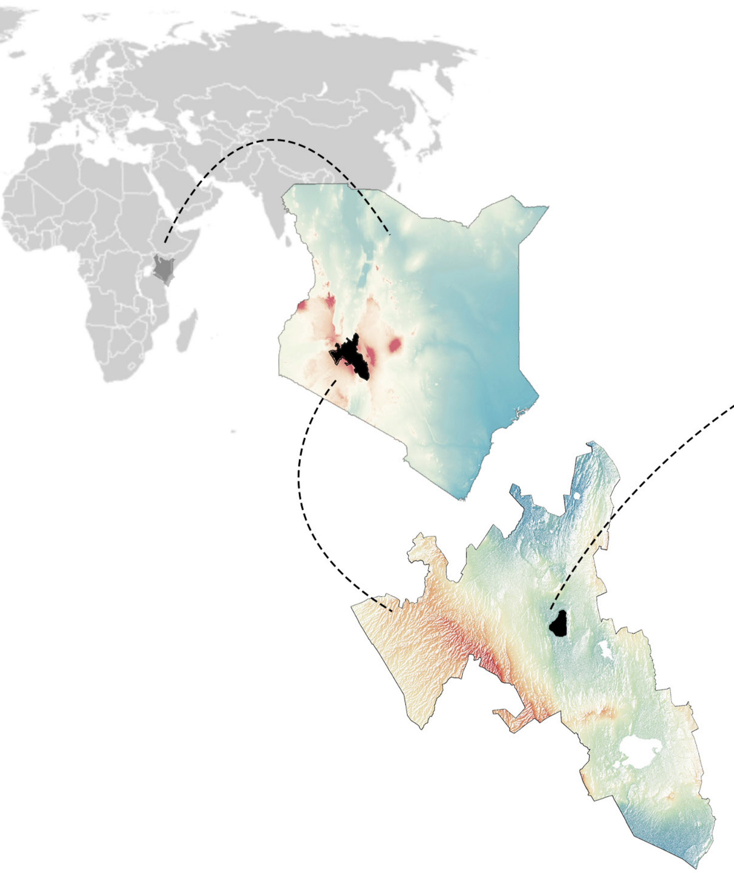
Water Level rising of lakes in the Rift Valley
Photo credits: Anthor

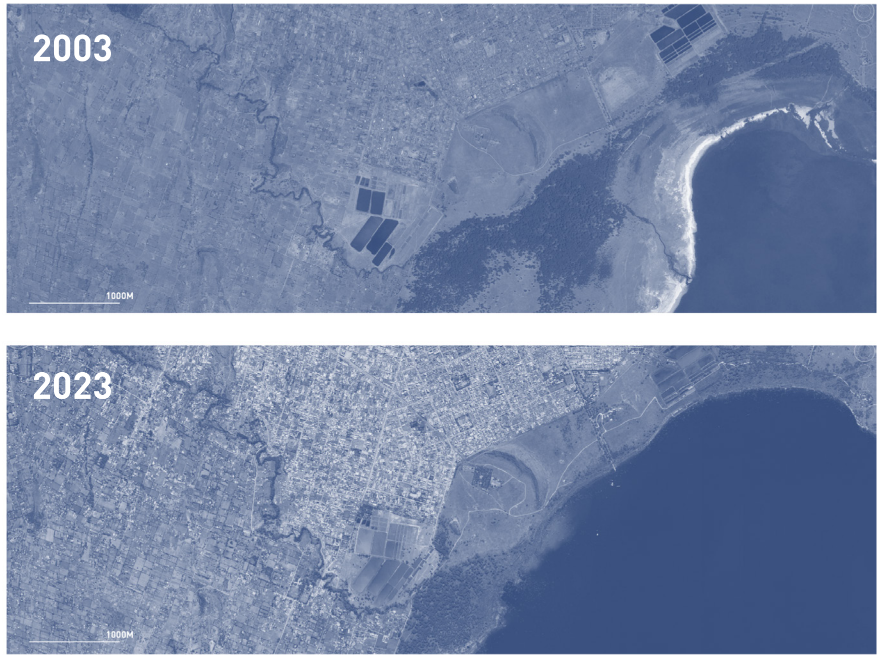
Site Context

Nakuru City is located in Kenya's central Rift Valley and serves as the capital of Nakuru County. Its proximity to Lake Nakuru—a designated Ramsar wetland and the centerpiece of Lake Nakuru National Park—has historically offered both ecological and socio-economic value. However, in recent decades, Lake Nakuru has undergone unprecedented hydrological changes, marked most visibly by a substantial rise in water levels. From around 40 km² in 2010, the lake expanded to over 70 km² by 2020, flooding roads, residential areas, and parts of the national park (Onywere et al., 2020).

This expansion is not a result of a single cause but of interconnected climatic, geological, and anthropogenic processes. Shifting rainfall patterns, particularly increased intensity during the long and short rainy seasons, have contributed to higher surface runoff and groundwater recharge from the Mau Forest catchment (KMD, 2020). At the same time, tectonic movements along the Rift Valley fault lines may have altered the lake's base morphology and reduced its natural outflow, exacerbating water retention (Olago et al., 2017).

However, the most critical accelerants are human-induced. Over the past decade, Nakuru's upper catchment has experienced rapid land-use changes driven by population growth, informal urbanization, and agricultural expansion. Deforestation, soil compaction, and extensive surface sealing have significantly reduced the land's infiltration capacity, resulting in greater volumes of runoff entering the lake (Mutisya et al., 2022).



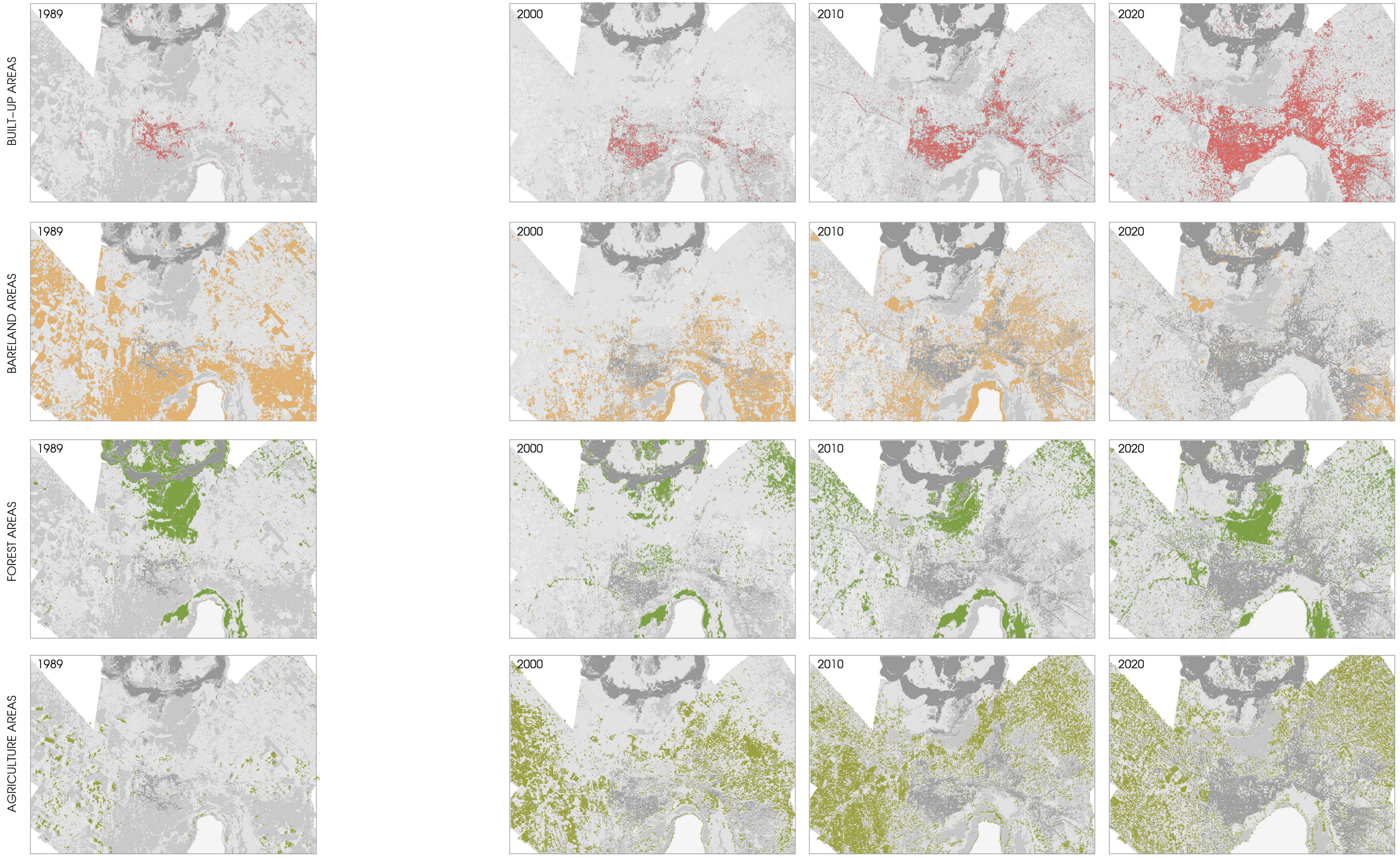


Water Level rising of the Lake Nakuru
Photo credits: Google earth

Additionally, informal settlements and unregulated agriculture have encroached upon riparian corridors and wetlands, disrupting the natural hydrological and ecological buffers that once stabilized the system.

Urban planning responses have not kept pace with these transformations. Many vulnerable zones lack effective flood-risk zoning, building setback regulations, or watershed management frameworks (NLC, 2020). Settlements continue to grow toward the lake's edge and into ecologically sensitive areas, exacerbating exposure to seasonal flooding, environmental degradation, and infrastructural vulnerability.

In this context, Lake Nakuru's transformation reflects more than a climatic anomaly—it reveals systemic failures in land management, planning governance, and resilience strategy.



Historical problem field of Nakuru county
Photo credits: Anthor

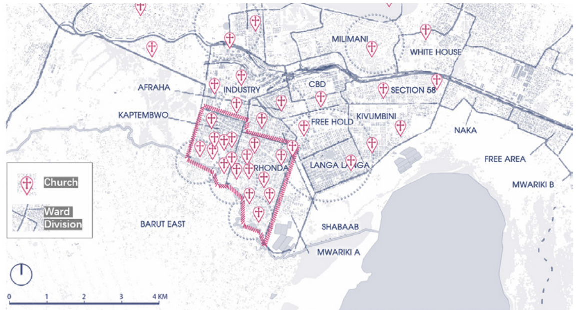
Problem Statement

The challenges facing Nakuru's urban edge—particularly in low-lying neighborhoods like Rhonda and Kaptembwo—are multifaceted and rooted in both socio-spatial vulnerability and ecological degradation. These interwoven issues have been exacerbated by the rising waters of Lake Nakuru, whose expansion intersects with unregulated development and fragile living conditions.

Social Dimension

Informal settlements in Nakuru have expanded rapidly, driven by rural-urban migration and economic precarity. In areas like Rhonda and Kaptembwo, housing is predominantly self-built using impermanent materials, with limited access to sanitation, drainage, or waste management infrastructure (UN-Habitat, 2021). The lack of tenure security further disincentivizes residents from investing in resilient housing upgrades, perpetuating a cycle of vulnerability. As floodwaters encroach, residents face repeated displacement, contamination of water sources, and increased risk of vector-borne diseases such as cholera and malaria (Mutisya et al., 2022). Additionally, informal dumping and insufficient public waste services have led to the accumulation of solid waste in drainage corridors, worsening flood impacts and undermining public health (Kariuki et al., 2020).

Nakuru's ethnic diversity
Photo credits: Google



Distribution of churches in Nakuru
Photo credits: Author

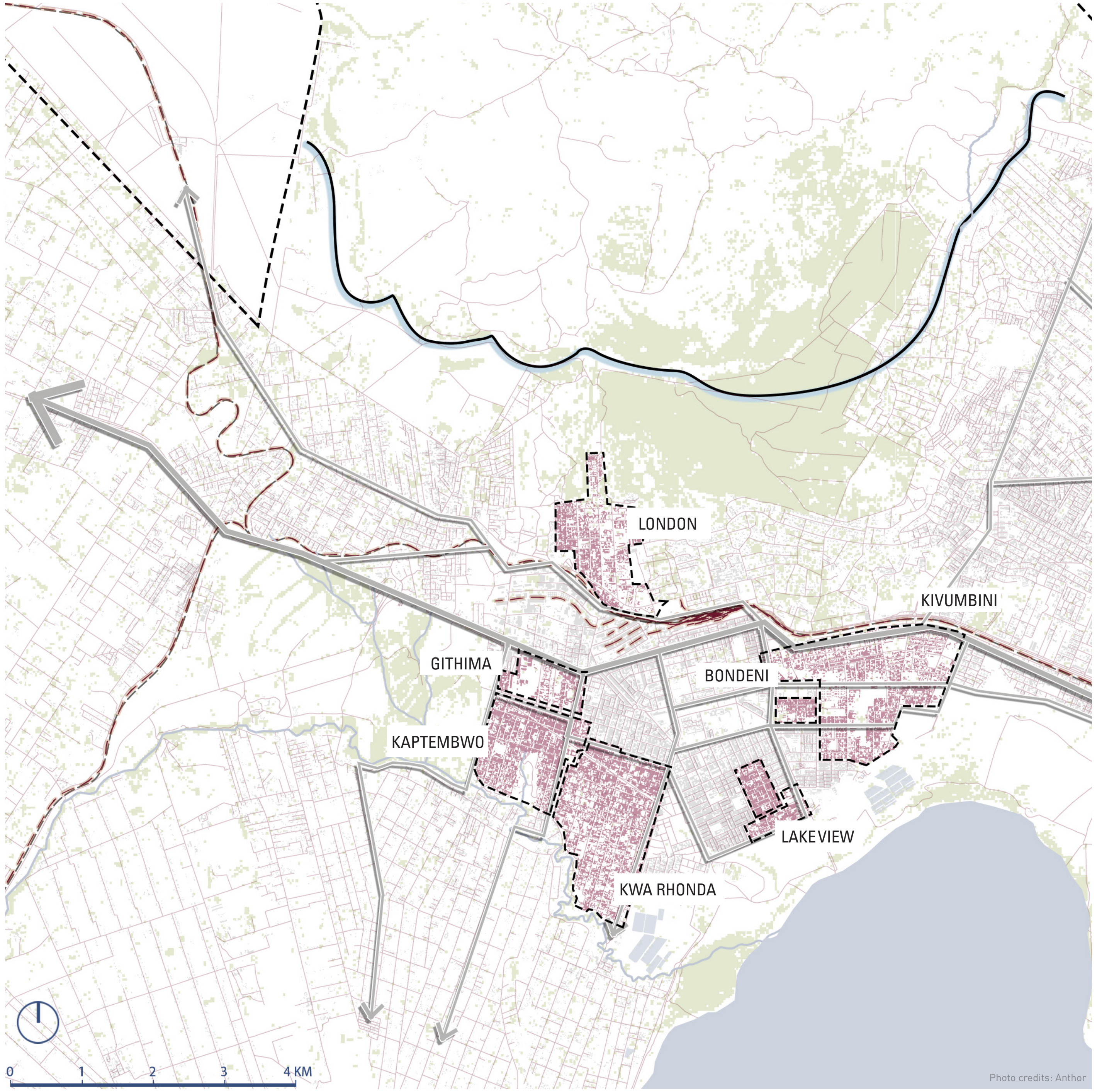


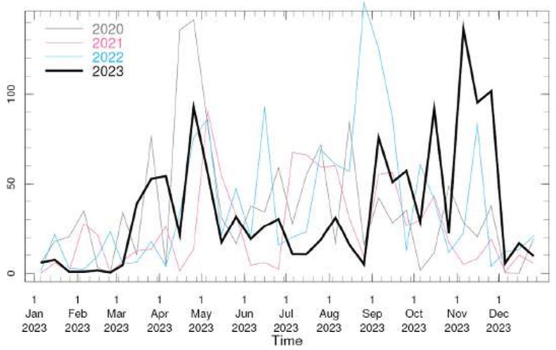
Photo credits: Anthor

Problem Statement

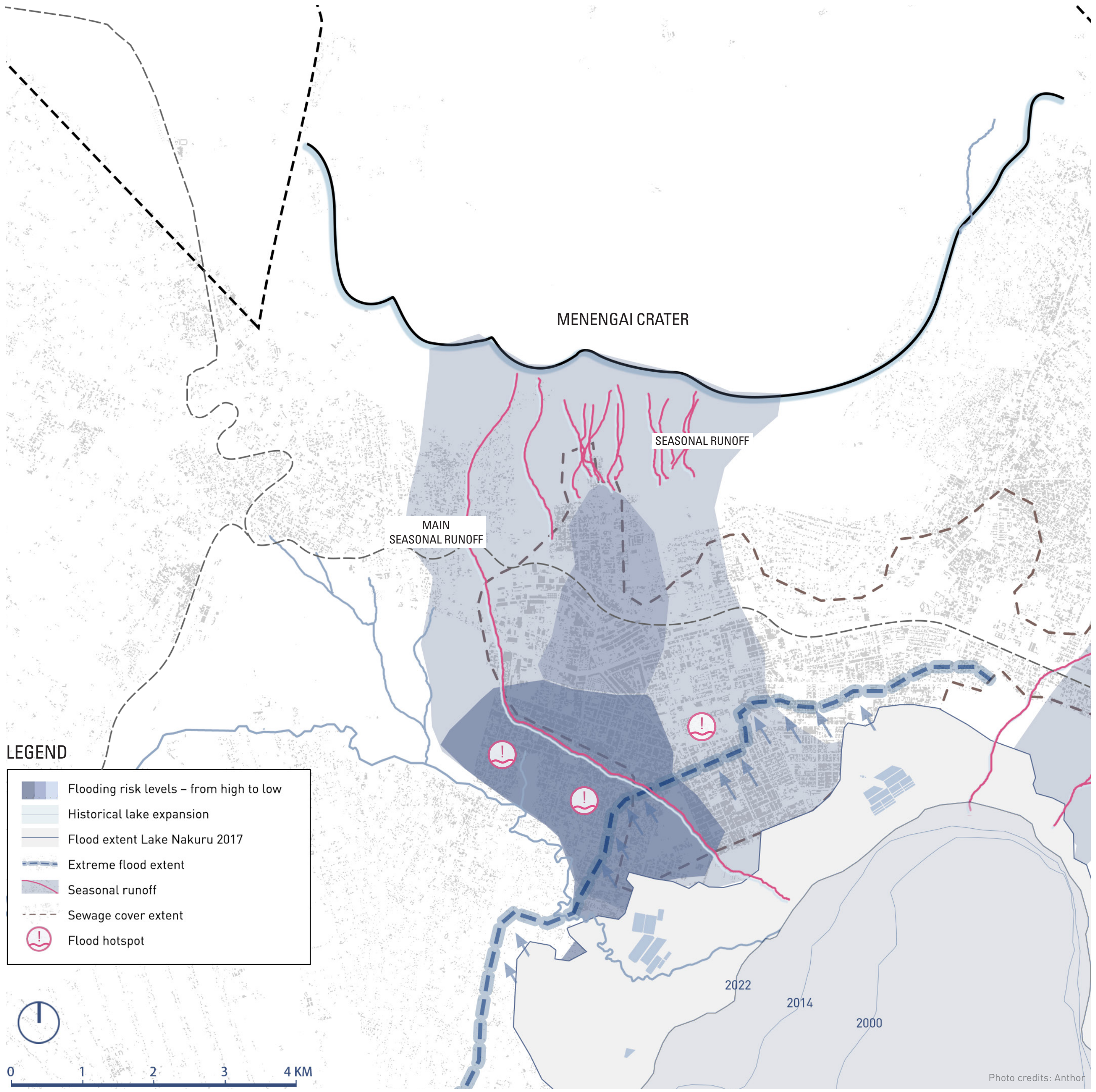
Ecological Dimension

On the ecological front, the expansion of the lake reflects a broader destabilization of regional watershed dynamics. Deforestation in the Mau catchment, coupled with soil degradation and poorly managed agricultural runoff, has overwhelmed Nakuru's natural absorptive systems (Onywere et al., 2020). These disruptions have intensified flood risks, altered soil moisture regimes, and contributed to localized land subsidence (Olago et al., 2017). Riparian ecosystems—once vital buffers—have been severely degraded, resulting in a loss of biodiversity and ecosystem services. Moreover, prolonged inundation has reduced arable land availability and affected peri-urban food systems, contributing to food insecurity in marginalized households (GoK, 2021). The combination of ecological erosion and unregulated development is accelerating a dangerous feedback loop of environmental stress and social precarity.

Polluted Riverbanks in Nakuru
Photo credits: Google



Changing Rainfall Intensities in Kenya's Main Rainy Seasons
Photo credits: Kenyan Meteorological Department, 2024



Problem Statement

Conclusion

Given this dual crisis of socio-spatial vulnerability and ecological degradation, the urgency for integrated, site-sensitive design interventions has become increasingly apparent. The current trajectory—marked by informal, unregulated urban expansion and the progressive breakdown of ecological infrastructure—not only threatens the physical safety and livelihoods of marginalized populations but also undermines the long-term environmental viability of Nakuru's urban edge. Isolated sectoral solutions, whether in housing, drainage, or conservation, have proven insufficient in addressing the complex interplay between natural and human systems.

Thus, this research posits that only through a holistic spatial transformation strategy—one that bridges architecture, landscape, and community planning—can we begin to address the layered challenges at hand. The aim is to articulate a resilient design framework that aligns built form with ecological function. Specifically, the project seeks to explore how adaptive spatial planning can mitigate flood exposure, improve the habitability and dignity of informal settlements, restore degraded riparian and wetland systems, and support sustainable community practices such as urban farming and micro-infrastructure development.

The focus will be placed on Rhonda and Kaptembwo, two highly vulnerable neighborhoods situated along the transitional zone between expanding urban fabric and dynamic lakefront conditions. These areas serve as microcosms of broader regional trends, where climate risk, land scarcity, and social inequity intersect. By understanding the spatial logic of risk and opportunity across these sites, the research aims to generate context-specific design strategies that are both ecologically grounded and socially inclusive.

In doing so, the study will contribute not only to the academic discourse on climate-adaptive urbanism in East Africa but also to practical frameworks for planning and design interventions in flood-prone, informally urbanized environments. The next chapter introduces the core research question, objectives, and methodology through which this inquiry is structured, laying the foundation for evidence-based spatial design proposals that respond to the urgent needs of Nakuru's most precarious urban landscapes.

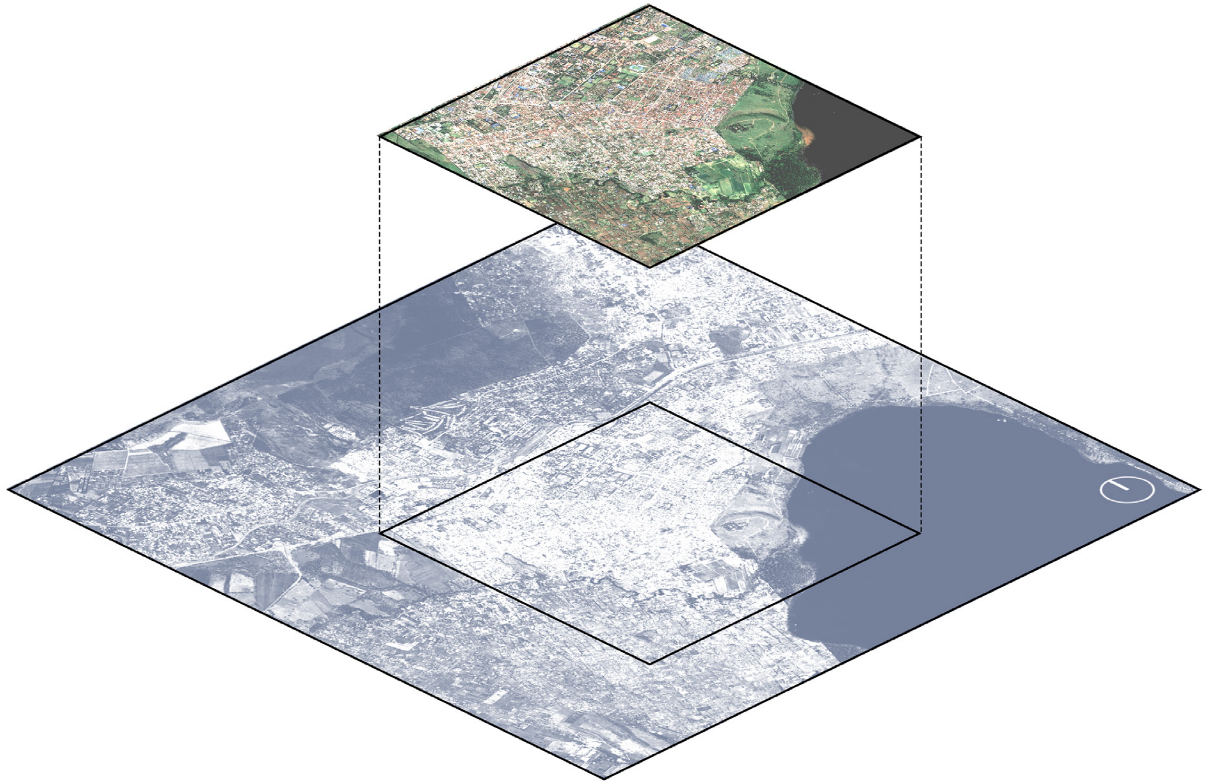


Photo credits: Anthor

02 Research Approach

Nakuru Flooded Residential Area
Photo credits: Cynthia van Elk

Research Objectives

This study aims to propose spatially grounded and context-sensitive design interventions to address recurrent urban flood challenges in the informal settlements of Rhonda and Kaptembwo, Nakuru. Utilizing nature-based solutions (NBS), the objective is to embed adaptive green infrastructure—such as bioswales, retention ponds, rain gardens, constructed wetlands, and permeable surfaces—within the existing socio-spatial framework of the community. These interventions are designed not only to mitigate flooding but also to improve public spaces, enhance ecosystem services, and support local socio-cultural practices, thereby contributing to long-term urban resilience.

The research further seeks to formulate a transferable planning framework that can guide sustainable upgrading efforts in other flood-prone informal settlements across sub-Saharan Africa. By aligning design strategies with the local hydrological context, community participation, and everyday spatial routines, the study promotes low-cost, incremental, and co-produced ecological infrastructure as an alternative to conventional top-down approaches. In doing so, it reframes slum upgrading as an opportunity for spatial transformation, dignity restoration, and inclusive environmental justice.

This approach is grounded in the broader goals of the 2030 Agenda for Sustainable Development, particularly SDG 11 (Sustainable Cities and Communities), SDG 3 (Good Health and Well-being), and SDG 6 (Clean Water and Sanitation). It also supports SDG 13 (Climate Action), SDG 15 (Life on Land), and SDG 12 (Responsible Consumption and Production) by improving land use, promoting biodiversity, and reducing ecological footprints (United Nations, 2015; Kelly, 2018). By using Rhonda and Kaptembwo as a pilot, the research aims to establish a scalable model for resilient and equitable urban futures in the face of increasing climate-related risks.

SDGs with sub-goals relating to project
Photo credits: unitednation.org

Research Questions

Main Research Question:

How to achieve socio-ecological resilience
by addressing urban flood challenges
through nature-based solutions within a community-based spatial framework in Rhonda and Kaptembwo ward, Nakuru?

Sub-Research Question 1
Enhancing Socio-Ecological Resilience
What is the concept of socio-ecological resilience in the context of urban informal settlements?

How do physical (infrastructure, green space) and non-physical (community practices, social networks) elements contribute to resilience?
How can urban ecology principles be integrated to promote environmental health and community well-being?
What indicators can be used to evaluate socio-ecological resilience in Rhonda and Kaptembwo?

Sub-Research Question 2
Addressing Urban Flooding Challenges
What are the underlying causes and spatial patterns of urban flooding in Rhonda and Kaptembwo?

What nature-based solutions (NBS) are most effective and context-appropriate in reducing flood risk in informal urban areas?
How can ecological infrastructure (e.g., wetlands, green corridors, permeable surfaces) be spatially integrated into the existing urban fabric?
How do nature-based approaches compare with conventional flood mitigation strategies in terms of sustainability and adaptability?

Sub-Research Question 3
Empowering Community-Based Spatial Frameworks
What local knowledge and adaptive practices exist in the community regarding flooding and environmental management?

How can participatory planning processes strengthen the role of communities in implementing and maintaining nature-based solutions?
What are the barriers and opportunities for co-creation of spatial strategies between community members, local government, and designers?
How can soft strategies (e.g., education, stewardship) complement hard ecological infrastructures in building long-term resilience?

Theoretical Framwork

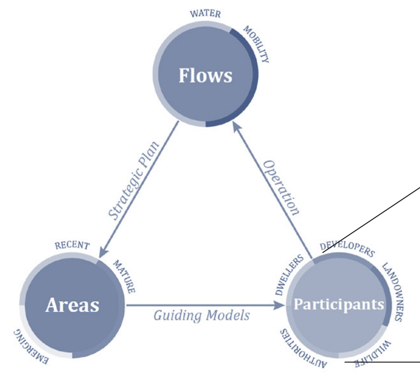
This project integrates three complementary frameworks—Ecopolis, the Circular Value Flower, and the Dutch Layer Approach—to construct a resilient, place-specific strategy for transforming flood-prone informal settlements in Nakuru, Kenya. These frameworks collectively provide the ecological logic, circular ambition, and spatial structure necessary to guide multiscalar design interventions.

The Ecopolis model (Tjallingii, 1995) offers a foundational lens by viewing the city as a living ecological system. It promotes integration between water systems, land use, and social processes. Its core principles—flow-oriented planning, participatory governance, and promoting liveability—serve as a conceptual guide for embedding blue-green infrastructure within community-driven development.

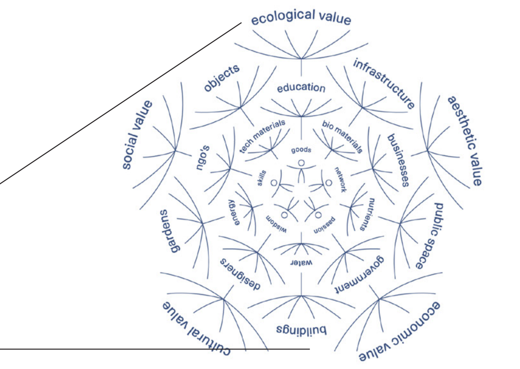
The Circular Value Flower (Metabolic, 2017) expands the ecological paradigm into seven interrelated dimensions: materials, water, energy, biodiversity, health, culture, and society. These values inform the regenerative ambition of the project: to transform vulnerable settlements not just through risk reduction, but through circularity—by closing resource loops, creating multifunctional spaces, and supporting local livelihoods through sustainable practices.

The Dutch Layer Approach (VROM, 2001) provides the methodological backbone for spatial analysis and intervention. It divides urban systems into three layers—substrate (natural systems), network (infrastructure), and occupation (human use)—and supports long-term transformation by sequencing actions according to each layer's temporal depth. In Nakuru, this allows for targeted landscape restoration, decentralized infrastructure repair, and reprogramming of public spaces to align with both environmental logic and community needs.

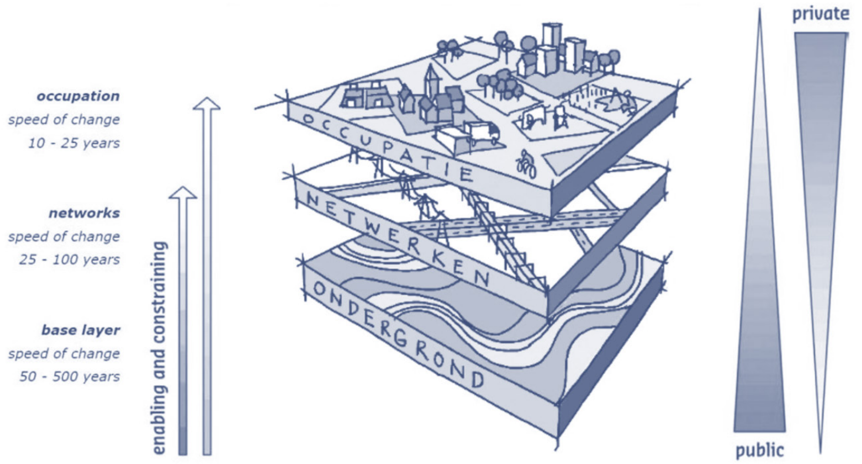
These frameworks are applied across multiple spatial scales—from regional ecosystems and watershed dynamics, to city-wide infrastructure systems, down to neighborhood-level spatial practices. Their integration enables a holistic design methodology that is rooted in place, yet broadly applicable to other African cities facing similar ecological and urban challenges.



Ecopolis model
Photo credits: Tjallingi



Circular Value Flower
Photo credits: circularcommunity.org



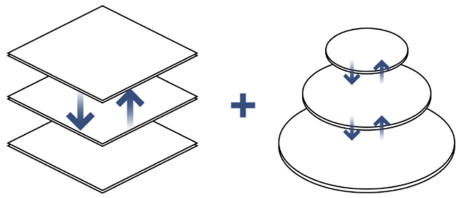
Dutch layer approach
Photo credits: van Schaick, Klaasen

Methodology Framework

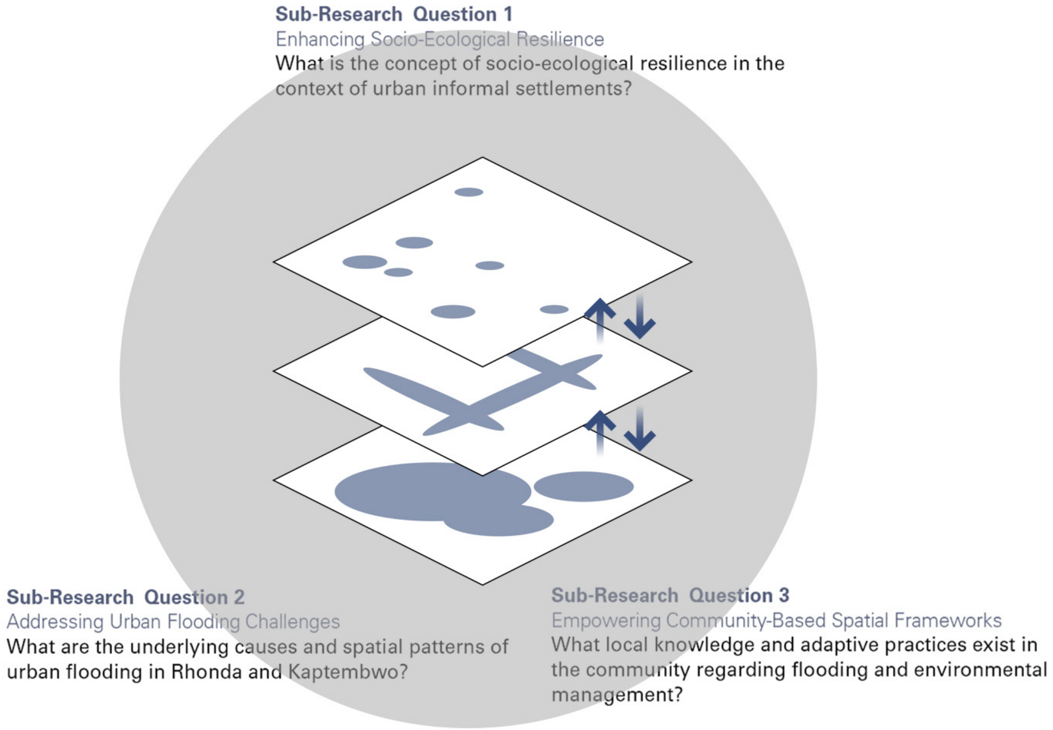
This project adopts a hybrid methodological framework that integrates the Dutch Layer Approach with a multi-scalar analytical lens to guide both the research and design process. The Dutch Layer Approach—comprising substratum (landscape and natural systems), networks (infrastructure), and occupation (land use and human activities)—offers a structured way to decode the spatial and functional complexity of urban systems. By applying this framework to Nakuru's rapidly transforming urban fabric, particularly in flood-prone informal settlements like Rhonda and Kaptembwo, it becomes possible to identify the deep structural conditions, infrastructural constraints, and socio-spatial dynamics that underlie patterns of informal growth and environmental vulnerability.

To complement this layered understanding, a multi-scalar research strategy is employed, operating across regional, city-wide, and neighborhood levels. At the regional scale, the study examines ecological processes such as watershed hydrology, lake level fluctuations, and land degradation, which have far-reaching effects on urban resilience. At the city scale, attention is given to infrastructure provision gaps, land-use conflicts, and the implications of fragmented spatial planning and governance systems. At the neighborhood scale, the research engages with residents' lived experiences, spatial practices, informal housing typologies, and bottom-up adaptive responses to recurrent flooding.

By combining these two methodological lenses, the project constructs a holistic and dynamic design narrative—one that bridges physical, social, and ecological dimensions. This approach enables a transformation strategy that is resilient, scalable, and locally grounded, offering not only technical solutions but also socio-spatial strategies that reflect community needs and environmental realities. Ultimately, it aims to develop a context-sensitive model of nature-based urban regeneration applicable to other rapidly urbanizing African contexts.



Layer and Scale Approach
Photo credits: Author

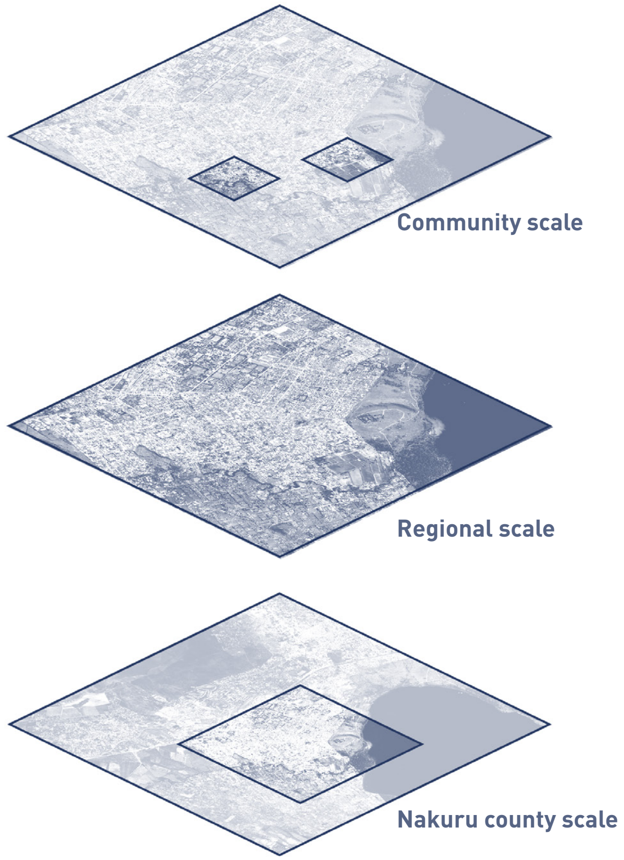


Methodology Framework applied to Reasearch Questions
Photo credits: Author

Project Structure

This project is structured across three interlinked spatial scales to address the complexity of socio-ecological challenges in Nakuru. At the county scale, the analysis investigates Nakuru's urban expansion in relation to Lake Nakuru's ecological dynamics and the broader drivers of environmental risk, such as deforestation in the Mau catchment and land-use change. At the regional scale, the focus narrows to the southern urban edge, where informal settlements like Rhonda and Kaptembwo intersect with vulnerable floodplains, fragmented infrastructure, and contested land. Here, zoning and risk mapping help translate regional ecological pressures into designable spatial strategies. Finally, at the community scale, the project engages directly with the lived conditions of residents — including housing typologies, water usage patterns, and collective adaptation practices. This level becomes the testing ground for small-scale, nature-based design interventions that integrate ecological function with daily life.

Together, these three layers form a multi-scalar framework that allows the project to move fluidly from landscape systems to neighborhood-scale transformation.



Threee scales
Photo credits: Author

03 Context Analysis

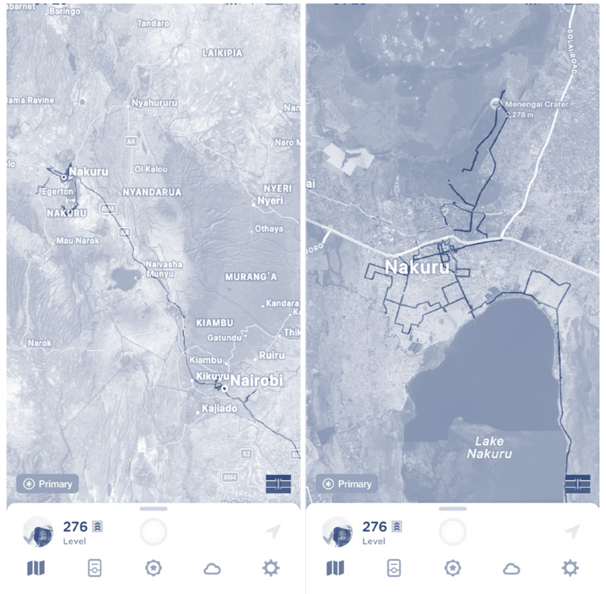
Lake Nakuru Flooding
Photo credits: ZUMA Press (2022.5)

Field Work

In February 2025, I embarked on a 20-day field research trip to Nakuru, Kenya, as part of the groundwork for this thesis. My journey began upon arrival at Jomo Kenyatta International Airport in Nairobi, from where I arranged a local Uber driver familiar with regional routes. The road trip from Nairobi to Nakuru stretched over approximately 160 kilometers, taking me westward across the dramatic landscapes of the Great Rift Valley. This scenic transition—marked by deep escarpments, sprawling savannahs, and sporadic roadside settlements—served as a vivid reminder of the geographic complexity and ecological richness of the region.

Upon reaching Nakuru, I was hosted by a local household located in the northwestern periphery of the city. Living with the family provided me with not only basic accommodation but also a unique cultural immersion. Daily interactions, shared meals of ugali, sukuma wiki, and grilled tilapia, and the harvesting of avocados and bananas from the backyard shamba (kitchen garden) offered invaluable insight into the rhythms of everyday life in Nakuru. These experiences, though anecdotal in nature, significantly enriched my spatial sensitivity and understanding of the sociocultural dimensions of the landscape.

Throughout the stay, I employed GPS tracking and satellite monitoring software to document my travel paths and observation points. These tools proved instrumental in georeferencing informal settlements, water bodies, and infrastructure patterns, ultimately shaping the spatial scope of my design inquiry. Key exploration areas included the rural villages near Rongai in the northwest, the commercial core near Nakuru CBD, and most critically, the flood-prone informal settlements along the southwestern edges near the Njoro River.



GPS track of 20 days of field work in Nakuru
Photo credits: Author

This latter region—home to the neighborhoods of Rhonda and Kaptembwo—emerged as the critical focus of my investigation, both due to its acute flood vulnerability and the intricate interplay between ecological degradation and informal urban expansion. Given the inherent sensitivity and complexity of the area, my research was conducted in collaboration with the ongoing Nakuru Water as Leverage (WAL) initiative, a multi-stakeholder design and planning program supported by the Kenyan government, local NGOs, and Dutch design experts. This platform provided not only institutional legitimacy but also access to professional networks and municipal data.

Through the support of Mr. Gitau Thabanja, Nakuru's City Manager, and a senior urban planner from the Nakuru County Government, I was able to conduct multiple field visits to otherwise inaccessible neighborhoods. These excursions allowed me to directly observe the hydrological constraints of the Njoro River corridor, the disrupted relationship between settlement and ecology, and the infrastructural challenges exacerbated by unplanned densification. For instance, the river's floodplain—once a functional retention zone—is now encroached upon by housing and waste, while hardened surfaces across Kaptembwo prevent infiltration and accelerate runoff. Drainage systems, where present, are frequently obstructed by refuse, leading to recurrent flooding that undermines both mobility and sanitation.

These insights underscored the urgency of rethinking flood management from a landscape-based and community-centered perspective. Recognizing the spatial variability within Rhonda and Kaptembwo, I identified three representative urban clusters to study in detail. These were selected based on differences in topography, urban morphology, and proximity to ecological risk zones:

A Kaptembwo river-edge cluster directly adjacent to the Njoro River's northern floodplain;
B Kaptembwo high-density inner cluster marked by compact housing and poor drainage;
C Rhonda cluster near Lake Nakuru, within a buffer zone prone to periodic inundation;

Three representative urban clusters
Photo credits: Author

Field Work

A. Kaptembwo River-Edge Cluster

Credits: Google Maps

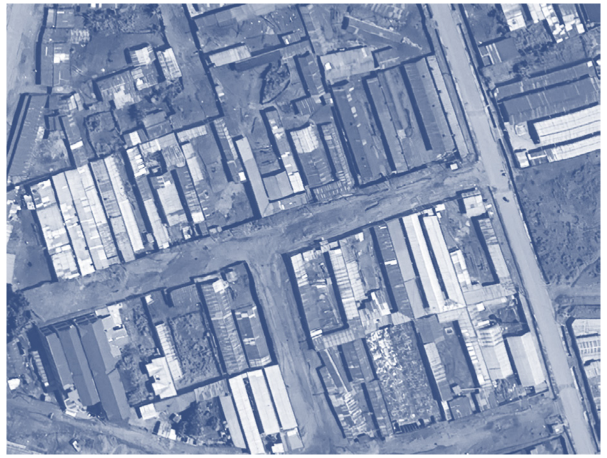
Located at the southern edge of Kaptembwo near the Njoro River, this cluster lies within a low-lying floodplain zone, highly susceptible to both fluvial flooding from the river and pluvial runoff during intense rainfall events. The site is characterized by degraded ecological conditions, with rampant waste accumulation clogging drainage ditches and culverts. These blockages severely impede stormwater flow, resulting in stagnant pools of polluted water that pose serious health risks. Dust storms and poor air quality are frequent due to the lack of green cover. The absence of vegetation exacerbates surface runoff, further weakening the area's hydrological resilience. Children were frequently observed bathing or playing in untreated floodwater, indicating a strong community affinity for water despite the high contamination risk.

Despite these vulnerabilities, the site holds potential for ecological transformation. The relatively open spatial configuration offers room for introducing decentralized green infrastructure, including constructed wetlands, vegetated buffer strips, and riparian parks. These interventions could restore the flood retention function of the floodplain while simultaneously addressing water quality and microclimatic issues. Additionally, the introduction of community gardens or productive wetland agriculture could align water management with local livelihoods, providing co-benefits in food security and social cohesion. Given the local population's visible interest in water interaction and public space use, this area represents an opportunity to shift from degraded hazard-prone land to a resilient eco-social corridor.

Photo credits: Author (2025.2)

Field Work

B. Kaptembwo High-Density Inner Cluster



Credits: Google Maps

This cluster sits deep within the interior of Kaptembwo and is typified by extremely dense informal housing, with little to no formal road layout or open public space. Residential structures are built closely together, resulting in poorly ventilated, hard-paved surfaces that exacerbate surface runoff and limit rainwater infiltration. Drainage systems, if present, are narrow, shallow, and heavily burdened—frequently clogged by solid waste. During site visits, several residents were seen manually clearing open drainage channels, reflecting a degree of local stewardship but also revealing the insufficiency of current infrastructure under increasingly erratic rainfall conditions.

Despite the compact urban fabric, social structures such as churches offer shared open spaces that occasionally host communal agricultural plots or water collection setups. These spaces serve both social and environmental functions and reveal existing modes of community-based adaptation. Small-scale greywater reuse systems and rudimentary rainwater harvesting methods—such as gutters draining into plastic barrels—were also sporadically observed. These micro-adaptations suggest potential entry points for landscape-based interventions that do not require extensive demolition or relocation. By leveraging the existing community networks and spatial assets, a bottom-up flood adaptation model could be developed, integrating bio-swales, permeable pavements, and productive community gardens into the dense matrix.

Photo credits: Author (2025.2)

Field Work

C. Rhonda Lake-Edge Cluster

Credits: Google Maps

Located near the southwestern edge of Rhonda, this peri-lacustrine cluster lies within a flood-prone buffer zone adjacent to Lake Nakuru. This area is acutely exposed to seasonal lake swelling and flash floods during extreme weather events. Many households here face compounding risks: fragile building materials, lack of formal drainage, and saturated soils that impede infiltration. As a coping strategy, residents have carved shallow drainage trenches within their home compounds to channel rainwater and reuse greywater. Makeshift levees—constructed from manually hauled sandbags and mounded earth—line the backyards of numerous homes, reflecting both the urgency and ingenuity of local flood mitigation practices.

Additionally, evidence of abandoned or deteriorating homes along the lakeshore suggests that this area has already begun to experience climate-induced displacement. Those who remain do so largely due to economic constraints, living in increasingly precarious conditions. Small agricultural plots are sporadically embedded between housing units, serving both as food sources and informal flood buffers. This spatial configuration offers fertile ground for introducing nature-based solutions tailored to both flood control and food production. With targeted interventions—such as reinforced bio-dykes, agroforestry corridors, and community water retention landscapes—this cluster could serve as a critical testing ground for integrated, climate-adaptive urban design in high-risk peri-urban areas.

Photo credits: Author (2025.2)

Flood Analysis

Understanding Local Flood Realities: Spatial Vulnerability in Rhonda and Kaptembwo

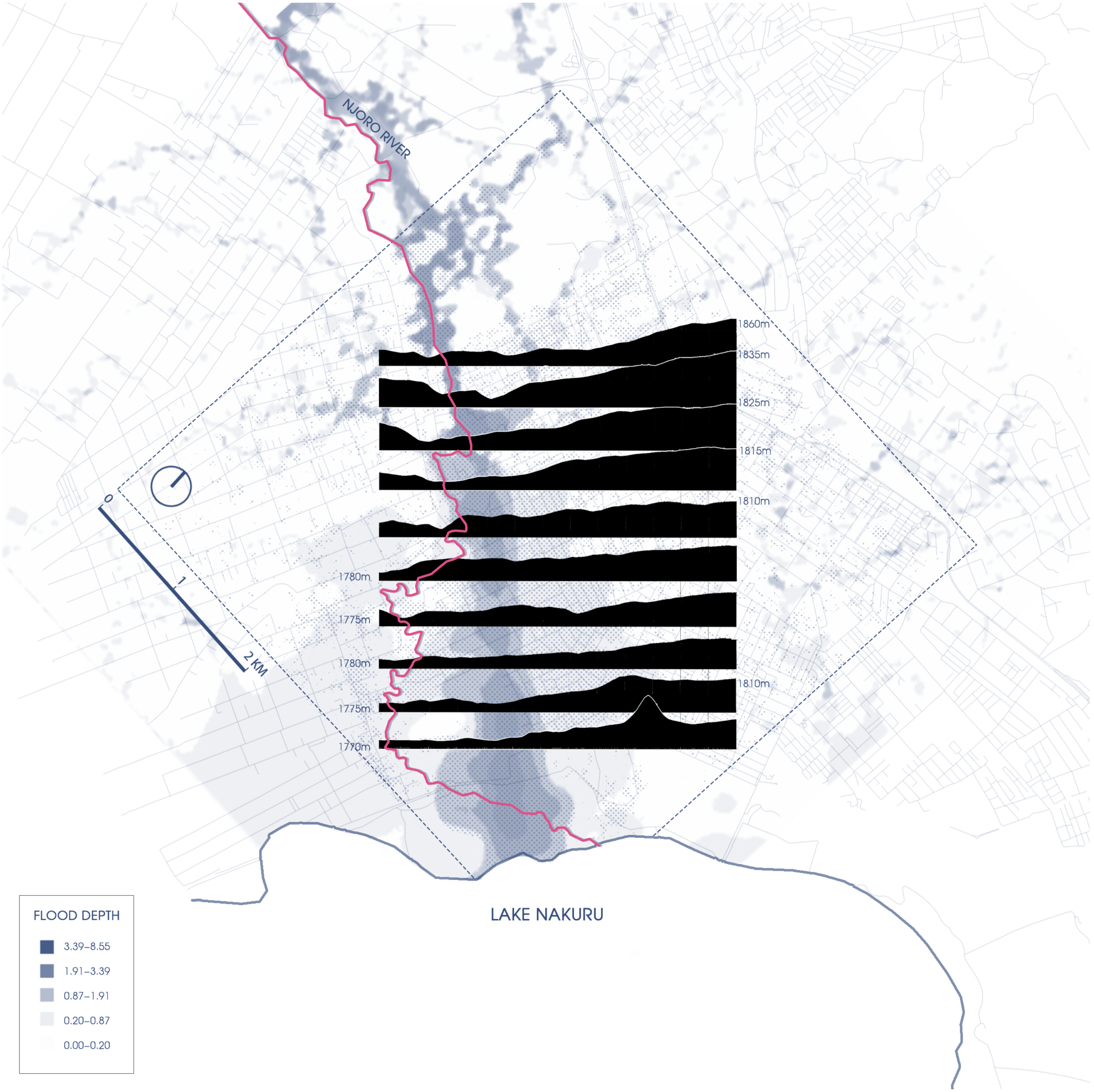
Flood hazard map of Nakuru
Credits: Tomorrow's Nakuru Activities Report, 2024

To further substantiate the severity and spatial specificity of urban flooding in Nakuru's informal settlements, this section builds upon the earlier problem statement by incorporating evidence from the Flood Hazard Map of Nakuru (Tomorrow's Nakuru Activities Report, 2024). The map illustrates the projected flood inundation depths resulting from a cumulative rainfall of 140 mm over a 12-hour period—an increasingly common intensity under current climatic conditions. The visualization underscores a critical spatial pattern: flood-prone zones are heavily concentrated in the southern belt of Rhonda and Kaptembwo, particularly along the northern floodplain of the Njoro River.

This low-lying riverine plain—likely corresponding to what is regionally referred to as a "seasonal flood basin" or alluvial fan plain in East African hydrological contexts—fails to provide adequate natural flood retention due to both ecological degradation and rapid urban encroachment. Originally a dynamic flood buffer zone, the Njoro River corridor has lost its hydrological functionality owing to deforestation along its upstream catchment, informal construction along its banks, and extensive soil sealing through impervious surfaces in nearby settlements. Instead of acting as a sponge-like system to absorb and delay runoff, the corridor now channels and accelerates surface water flow.

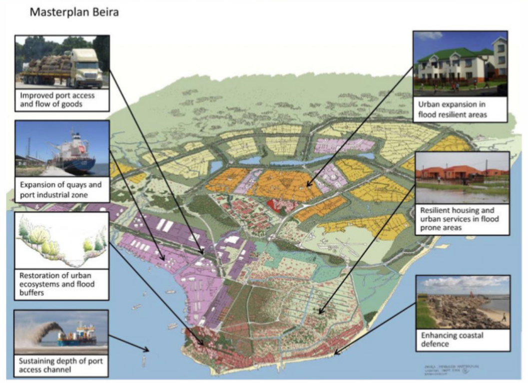
Compounding this issue is the poor state of urban drainage infrastructure. In many areas, stormwater drainage is either absent or dysfunctional, often blocked by accumulated solid waste due to inadequate waste management systems. Consequently, floodwaters stagnate in densely inhabited zones, directly threatening lives, property, and public health.

Within the broader landscape of Nakuru County, Rhonda and Kaptembwo represent some of the most ecologically and socially vulnerable urban zones. Their peripheral location relative to formal city planning efforts, combined with their topographical position in a downstream floodplain, renders them disproportionately exposed to climate-induced hydrological shocks. The data reinforces the appropriateness—and urgency—of selecting these settlements as focal points for spatial interventions aiming at socio-ecological resilience.



Case Study

Beira 2035 masterplan



The Beira 2035 Masterplan is a climate-resilient urban strategy for Beira, Mozambique, a coastal city vulnerable to flooding, cyclones, and sea-level rise. Developed with the Dutch government and international experts, it addresses infrastructure and ecological challenges through integrated, long-term solutions. Beira's low-lying terrain, poor drainage, and expanding informal settlements increase climate risks (City of Beira & Dutch Government, 2021).

A key feature is the "green-blue network," combining natural ecosystems like mangroves and wetlands with engineered elements such as retention basins and tidal barriers to manage floods and storm surges (Beira Masterplan, 2021). The plan also upgrades drainage, rehabilitates the Chiveve River corridor, and creates green public spaces as flood buffers and community areas.

Social inclusiveness is emphasized via phased informal settlement upgrades, urban agriculture, and community-based water infrastructure maintenance (UN-Habitat, 2022). The plan aligns with international climate adaptation goals, offering a replicable model for climate-sensitive urban resilience in sub-Saharan Africa.

Case Study

Rooftop Rainwater Harvesting in Wilson Community, Nairobi, Kenya

The Wilson community in Nairobi, Kenya, faces significant water scarcity challenges due to rapid urbanization and insufficient municipal water supply. Rooftop rainwater harvesting (RWH) has been adopted as a sustainable solution to supplement water needs, especially for non-potable uses such as irrigation and sanitation (Gikonyo et al., 2020). Wilson experiences an average annual rainfall of approximately 891 mm, making RWH a viable strategy to capture and utilize rainwater effectively during both wet and dry seasons (Njiru et al., 2021).

Studies show that institutional buildings lead the adoption of RWH systems in Nairobi, followed by residential buildings, including those in Wilson, where community-level efforts have increased awareness and infrastructure implementation (Kamau & Wachira, 2019). The harvested water reduces reliance on inconsistent municipal supply and provides a buffer against water shortages, contributing to improved water security at the household and community levels (Mwangi et al., 2022).

Despite challenges such as upfront costs and maintenance needs, the Wilson community's engagement with RWH demonstrates a locally adapted, low-cost, and environmentally friendly approach to urban water management. It exemplifies how decentralized water solutions can enhance resilience to water scarcity in rapidly growing African cities.

Local Knowledge

This locally grounded toolbox of Nature-Based Solutions (NBS), water harvesting strategies, and sponge city principles provides a comprehensive framework for understanding and applying sustainable water and land management in resource-constrained urban and peri-urban contexts. As part of my field research in Nakuru, this collection served as a critical component of knowledge intake and systematized learning, bridging indigenous practices with contemporary ecological urbanism.

Techniques such as Retention Ditches, Half Moons, Zai Pits, Negarim, and Fanya Juu/Chini represent low-cost, community-adaptable strategies for harvesting and managing rainwater through micro-topographic interventions. These methods are specifically designed to slow down surface runoff, enhance infiltration, and retain moisture in the soil—core objectives aligned with the sponge city concept. In flood-prone informal settlements like Rhonda and Kaptembwo, such decentralized water management solutions are not only pragmatic but essential to building long-term resilience against climate-induced disasters.

Moreover, infrastructure-focused approaches like Local Waste Treatment Plants and Waste and Material Reuse Strategies contribute to the broader circular economy by closing local water and material loops. These methods alleviate the burden on centralized systems, mitigate environmental pollution, and support peri-urban farming and community hygiene. The integration of Urban Farming and Nature in Buildings further demonstrates the potential for multifunctional landscapes that unite production, ecology, and daily life.

By analyzing and internalizing the toolbox's contents, I was able to develop a hybrid lens that combines site-specific knowledge with global best practices. This forms the conceptual backbone for my subsequent landscape design interventions in Nakuru, ensuring they are not only technically sound but also contextually rooted, culturally relevant, and socially inclusive.

Microcatchment water harvesting
Credits: WaL, 2025

04 Design Hypothesis

Nakuru Lakeview Waard
Photo credits: Cynthia van Elk

Urban Vulnerability Typologies

This chapter presents a transformative spatial vision for Rhonda and Kaptembwo, grounded in the principles of socio-ecological resilience. By embedding nature-based solutions (NBS) into neighborhood-scale planning, the project seeks to mitigate flood risks while enhancing the adaptive capacities of local communities. Drawing on the Dutch Layer Approach—Occupation, Network, and Base Layer—the design framework responds to varying degrees of hydrological vulnerability and social density through stratified, context-sensitive interventions.

At the core of the design hypothesis is the integration of water management into the everyday spatial fabric. The Base Layer treats soil and groundwater as permeable infrastructure, enhancing absorption and storage; the Network Layer reimagines roads and drainage corridors as conduits for ecological flow; the Occupation Layer incorporates water features into residential environments. This layered planning echoes both the Dutch Layers Approach and Sponge City principles, promoting rainwater retention, filtration, and reuse over discharge. Reference cases like Beira 2035 and Amsterdam's Waterplan inform a district-specific strategy for blue–green infrastructure.

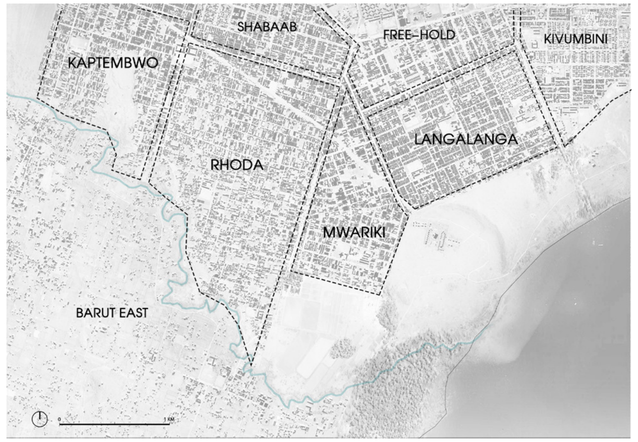
To translate this multi-scalar vision into actionable design, the project begins with a dual typological matrix that examines the intersection between housing morphology, open space configuration, informality, and flood risk. Developed through field observation and GIS analysis, this matrix serves as a diagnostic tool for assessing spatial vulnerabilities and guiding targeted interventions.

The settlement matrix categorizes six housing types—from highly vulnerable, self-built iron-sheet dwellings (Type a1) to formal public housing and private estates (Types c1 and c2)—based on construction material, structural stability, formality, and flood exposure. This reveals how informality and formality coexist, shaping unequal adaptation capacities.

The open space matrix maps six types of open spaces—ranging from domestic courtyards to communal flood buffers—based on surface condition, vegetation cover, and social use. These often-overlooked spaces play a vital role in mediating stormwater, supporting daily life, and fostering ecological connectivity.

By synthesizing built and unbuilt typologies, this approach bridges empirical research with spatial strategy. It lays the groundwork for designing adaptive, inclusive, and hydrologically responsive urban environments that reflect the lived realities of Nakuru's most vulnerable neighborhoods.

Residential Morphology Typology



Open Space Ecological Typology

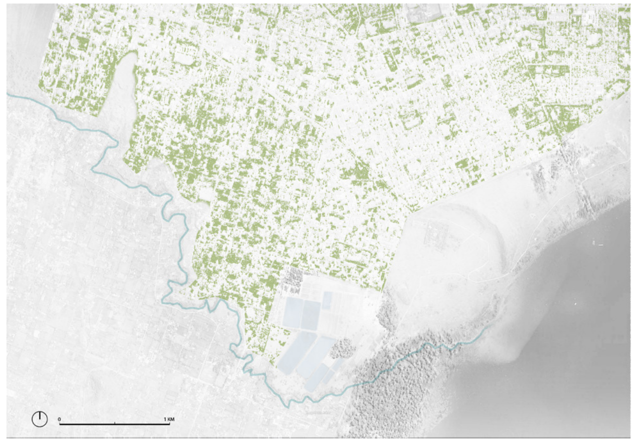


Photo credits: Author

Residential Morphology Typology

Housing conditions in flood-prone areas of Nakuru reflect a complex interplay between material availability, socio-economic constraints, and informal development practices. Informal and semi-formal structures dominate large portions of the urban fabric, often emerging without regulatory oversight or resilient design considerations. These self-built environments are highly heterogeneous, varying in construction quality, access to infrastructure, and exposure to environmental risks—particularly flooding.

This study identifies six representative housing types, classified into three broad categories: informal self-built (a1, a2), semi-formal upgrades and expansions (b1, b2), and formal planned housing (c1, c2). Each typology is defined by its construction materials, spatial organization, and the degree of integration with drainage and service networks. From single-story iron sheet dwellings to multi-room brick houses and multi-story public estates, the table captures a gradient of formality and flood resilience across Nakuru's residential landscape.

Understanding the spatial and material characteristics of these housing types is critical for assessing vulnerability and designing targeted adaptation strategies.

Code	Type Definition	Status Label	Materials	Construction	Flood Vulnerabilities
a1	Single-Story Iron Sheet House	Informal Self-Built	Corrugated iron sheets	Fully iron-built, lacking drainage systems	Complete surface exposure; high collapse risk during heavy rain
a2	Mud Timber House	Informal Self-Built	Timber, mud, iron roofing	Timber frame with mud-infill walls, iron roof, unpaved floors	Mud erosion, water pooling near foundations
b1	Multi-Room Brick House	Semi-Formal Upgrade	Fired clay bricks, iron roofing, concrete floors	Formalized masonry structure with improved indoor division	Impervious surroundings, clogged or uneven drainage systems
b2	Peripheral Brick-Mud House	Semi-Formal Expansion	Brick, iron roofing, mud flooring	Low-lying areas with poor road access; mixed building quality	Standing water, soil erosion along peripheries
c1	Private Estate Housing	Formal Planned	Concrete, brick	Planned private compounds with shared infrastructure	System overflow during extreme events
c2	Public Social Housing	Formal Planned	Brick, concrete	Multi-story structures with formal layouts	Hard surfaces lead to runoff, limited water retention

Urban Typologies Matrix
Photo credits: Author

Open Space Ecological Typology

Beyond building structures, open spaces in flood-prone areas of Nakuru play a critical yet often overlooked role in shaping community resilience and daily life. These spaces are not formally planned but emerge from necessity—serving domestic, agricultural, social, and ecological functions. However, their informality and unregulated use also expose them to significant flood vulnerabilities, such as erosion, waterlogging, and waste accumulation.

This study categorizes six prevalent types of open space, ranging from small household courtyards and food gardens to larger communal grounds and river buffer zones. Each spatial type is described in terms of its typical use, surface composition, vegetation structure, and level of exposure to flood risks. Particular attention is given to how these spaces interact with floodwaters—whether absorbing, deflecting, or exacerbating their impact.

Although often overlooked in formal urban strategies, these landscapes hold immense potential for decentralized, low-cost flood adaptation. The typological classification not only reveals functional patterns within informal neighborhoods but also supports the integration of ecological thinking into future design and planning processes. Alongside the built typologies, these landscape types form a comprehensive foundation for envisioning more climate-resilient and inclusive urban environments in Nakuru.

Code	Type Definition	Typical Use	Site Composition	Flood Vulnerabilities
d1	Earthen Household Courtyard	Daily domestic spillover — drying, storage, cooking	50–150 m²; clay soils; sparse grasses and shrubs	Surface erosion, mosquito breeding, pooling
d2	Food Garden Plot	Subsistence food cultivation	20–50 m²; loam soils; crops and grasses	Crop loss from waterlogging
d3	Riverbank Buffer Zone	Informal water access, laundry, bathing	Silt/clay soil; 3 vegetation layers (herbs, shrubs, trees)	Bank erosion, flooding during overflow
d4	Roadside Strip	Walking, informal vending, waste dumping	1–2 m wide; mixed soils; grasses and shrubs	Drainage blockages, waste accumulation
d5	Communal Farming Land	Church or community-organized agriculture	100–300 m²; loam soil; crops, shrubs, trees	Topsoil loss during storms
d6	Public Open Ground	Schoolyards, informal gathering, dumping, greening potential	200–500 m²; loamy soils; tall grasses, shrubs	Erosion, compaction, debris buildup

Urban Typologies Matrix
Photo credits: Author

Urban Typologies Matrix

Following the spatial diagnosis of housing and open space typologies, a strategic reclassification is necessary to bridge empirical analysis and spatial design. Rather than treating each typology as a fixed, site-bound entity, they are now reinterpreted as modular spatial elements—components that can be recombined, scaled, or adapted in the design phase based on their functional traits and ecological potential.

To facilitate this, a two-axis evaluative matrix is introduced, structured by two critical dimensions:

Static – Dynamic: This axis evaluates the temporal behavior and adaptability of the spatial element. "Static" refers to fixed, inert, heavily built structures with limited capacity for transformation; "Dynamic" refers to flexible, evolving, or seasonally responsive forms and uses.

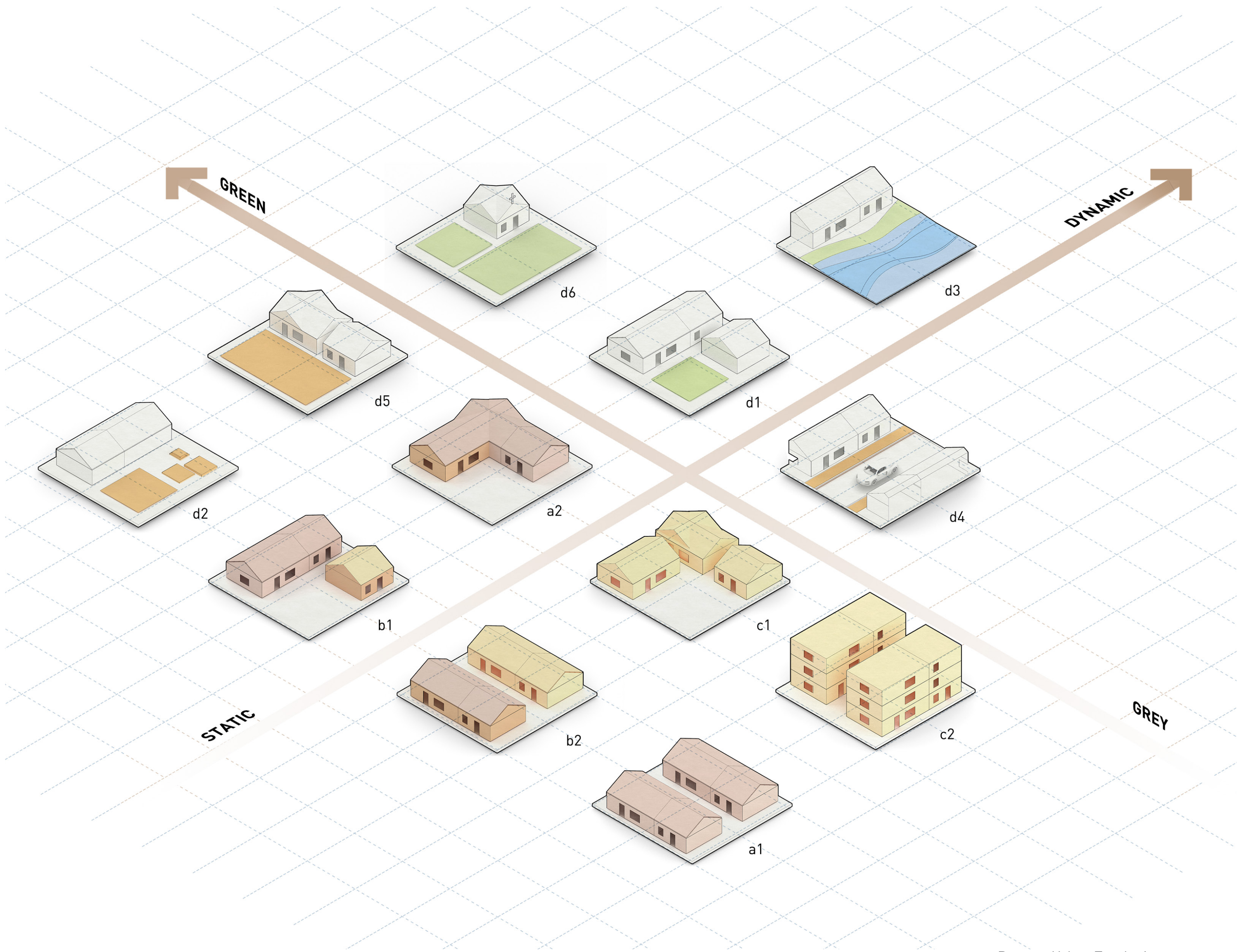
Grey – Green: This axis evaluates the ecological versus engineered character of each element. "Grey" indicates hard, impervious, and anthropogenically dominated surfaces; "Green" refers to permeable, vegetated, and ecologically regenerative systems.

This cross-matrix approach enables each typology to be positioned not just descriptively, but operationally—highlighting which spatial elements can be reused, hybridized, or phased into transformative spatial strategies for flood-adaptive design.

By repositioning typologies along this matrix, they become modules for action rather than constraints. Each can be leveraged for its adaptive potential based on its matrix quadrant:

Grey–Static modules (e.g., a1, c2) require reprogramming or ecological retrofitting—such as reintroducing vegetation, opening courtyards, or softening surfaces to enhance permeability and resilience.

Dynamic–Green modules (e.g., d3, d6) should be preserved, connected, and amplified—they represent socio-ecological infrastructures already aligned with seasonal rhythms and community practices.



Present Urban Typologies
Photo credits: Author

Rain-responsive toolbox
Photo credits: Author

This rain-responsive toolbox consists of sixteen integrated strategies that address both water management and food security in flood-prone informal settlements. At the household scale, elevated housing (s1) protects residents from floodwaters while enabling moist planting zones below. Productive yards (s2) and embedded kitchen gardens (s3) turn residual spaces into manageable food plots, often irrigated with greywater. Through spatial links between homes and gardens (s4), daily living merges with cultivation. At the community scale, shared farms (s5) foster cooperation and land reuse, while educational rain gardens (s6) raise awareness on stormwater management. To close the nutrient loop, micro-compost mounds (s7) and container composting (s8) transform organic waste into soil enrichers, offering both ecological and educational value.

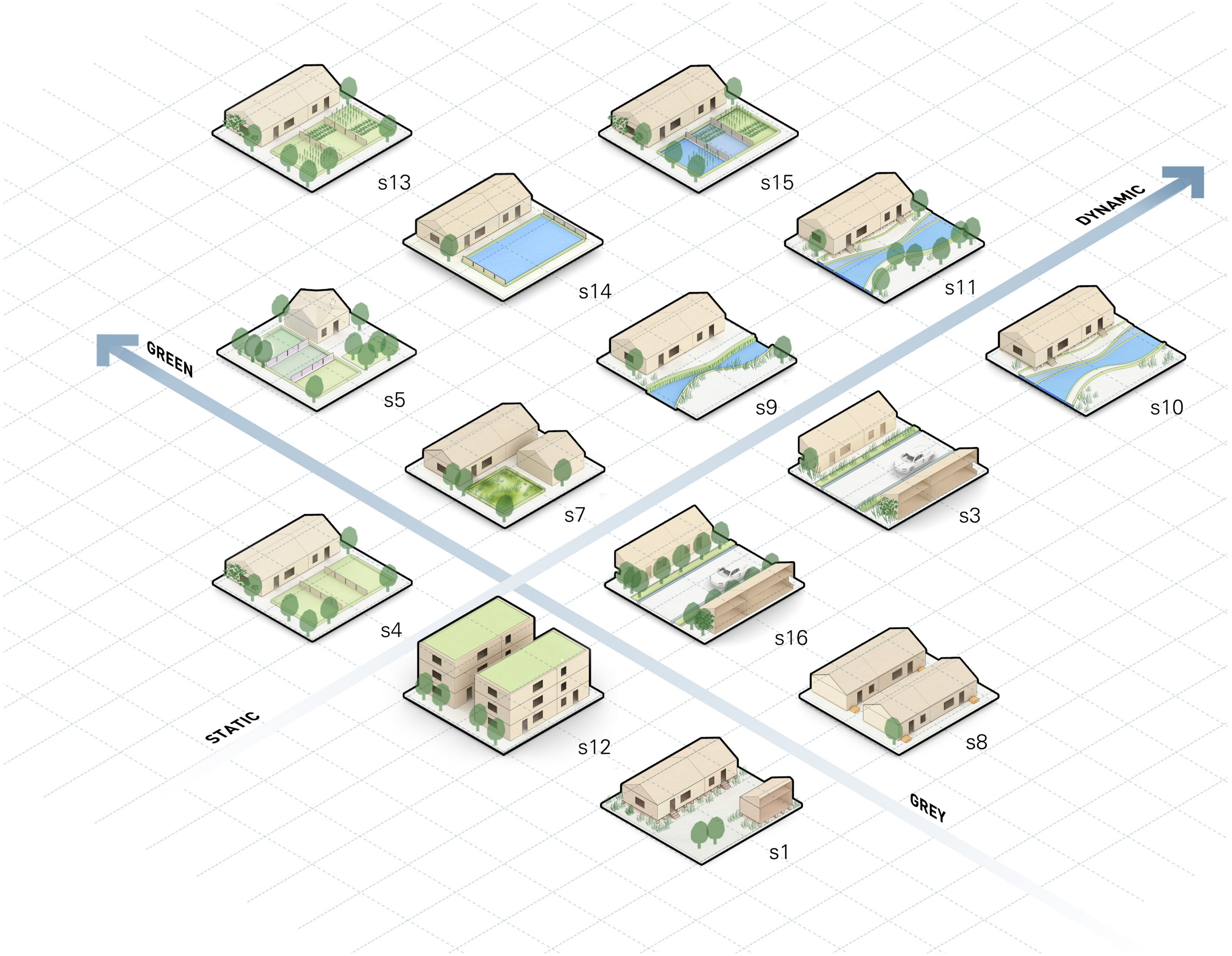
Hydrologically, strategies such as ecological embankments (s9) and buffer grasses (s10) filter runoff and stabilize edges. On slopes, contour planting (s11) reduces erosion and improves infiltration, while green roofs (s12) add ecological function to dense urban roofs. At the landscape scale, assembled field patches (s13) enhance visual and ecological diversity. Water-enclosed nurseries (s14) and seasonally ploughed basins (s15) retain rainwater for farming or aquaculture. Finally, native tree corridors (s16) reconnect fragmented green spaces, improve microclimates, and support biodiversity. Together, these strategies form a nature-based, low-cost, and culturally embedded design framework for transforming flood risks into opportunities for regenerative living.

By embedding the two design languages—Water-Oriented Strategies and Agriculture-Oriented Strategies—within the spatial logic of the adaptive transformation matrix, this project enables a flexible and context-responsive design framework. Each strategy (s1–s15) functions not as a fixed object but as a modular intervention, adaptable across different typologies based on ecological needs and social rhythms. Their placement along the Grey–Green and Static–Dynamic axes helps identify not only their material character and temporal behavior, but also their potential for ecological retrofitting, spatial recombination, and social integration.

To spatialize this logic, the matrix evolves into a design deployment tool—a grid through which interventions can be matched with site-specific typologies. For example, static–grey modules such as a1 (iron-sheet housing) may be retrofitted using green roofs (s12), kitchen garden inserts (s3) or container composting (s8) to introduce permeability and food production. Conversely, dynamic–green modules like d6 (seasonally flooded green corridors) can be enhanced with rain-fed agroforestry belts (s15) or native tree corridors (s16) to stabilize ecology while sustaining productivity. Modules that lie in intermediate zones—such as partially paved, semi-permeable open yards—can be layered with buffer grasses (s10), micro-composting mounds (s7), or educational rain gardens (s6) depending on their adaptability profile.

From this grounded matrix, the toolbox of spatial interventions emerges as a landscape-based suite of rain-adaptive strategies specifically tailored to the flood-prone wards of Rhonda and Kaptembwo. It seeks not only to mitigate seasonal inundation, but to regenerate degraded land, sustain livelihoods, and re-embed agriculture in the urban fabric. At its core is the principle of Agroecological Reclamation—transforming vulnerable open spaces into community-managed kitchen gardens, rotational farmlands, and seasonal wetland fields using low-cost, vernacular, and culturally rooted techniques.

Typologies such as Raised Housing with Integrated Food Yards combine spatial adaptation with daily sustenance, allowing families to cultivate staple crops while buffering against water rise. Contour-Based Buffer Farming, inspired by Fanya Juu terracing, is applied on sloped edges to stabilize soil and reduce runoff, reclaiming land for community use. Along drainage lines and lowlands, Rain-fed Agroforestry Belts blend fruit trees, grasses, and crops into green infrastructure that both filters and holds water. Meanwhile, Shared Cultivation Fields, Neighborhood Composting Hubs, and Rain Celebration Gardens foster collective engagement through food production, seasonal rituals, and ecological education. Reclaimed or biodegradable materials—used tires, clay pots, banana stems—are reimagined into Bio-social Structures like floating planters or micro-dykes, reinforcing the idea that resilience grows from within the community.



Designed Urban Typologies
Photo credits: Author

Three-layer approach

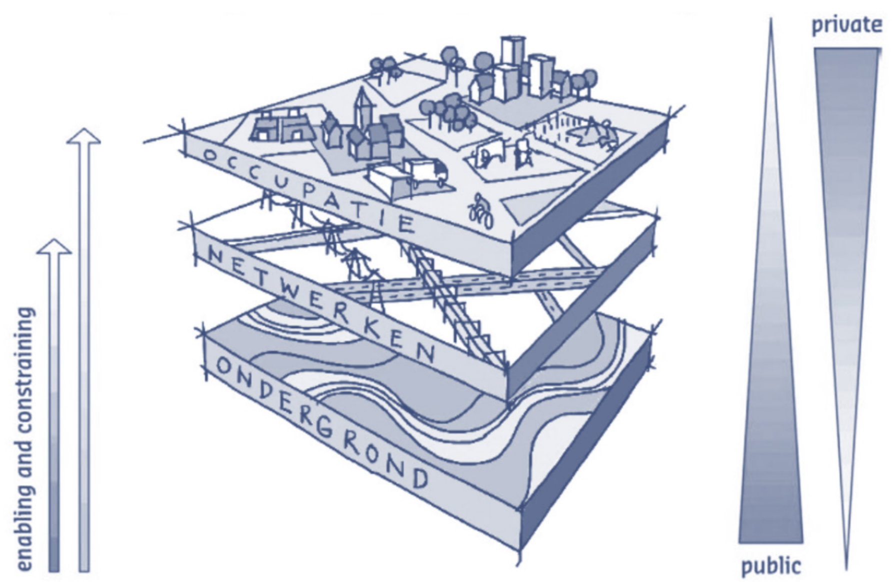
This research adopts the Dutch Layer Approach as the primary analytical framework to decode the spatial, ecological, and infrastructural complexities of Nakuru's rapidly transforming urban landscape. Originally developed in the Netherlands, the Dutch Layer Approach divides the urban environment into three interrelated layers—substrate (base), network, and occupation—each representing a distinct temporal and functional domain. By dissecting Nakuru through these layers, the study establishes a structured foundation for understanding flood vulnerability, urban informality, and the opportunities for spatial transformation.

The base layer in Nakuru refers to the underlying natural systems: geology, soil permeability, topography, and hydrology. This layer changes slowly and defines long-term constraints and potentials. Lake Nakuru and its watershed form the core of this layer, where tectonic activity, rainfall patterns, and landform gradients shape the flooding dynamics. Areas with low elevation, clayey soils, or proximity to blocked drainage channels are especially prone to waterlogging and inundation. Understanding the base conditions is crucial for identifying zones where water needs more room and where natural buffers can be restored.

The network layer encompasses the infrastructures that facilitate connectivity and urban functionality—such as roads, drainage systems, water supply lines, and electricity networks. In Nakuru, many informal settlements lack reliable network infrastructure, particularly drainage and waste management. The fragmentation or absence of infrastructure amplifies both physical and socio-economic vulnerability during flooding events. For instance, poorly connected road systems not only hinder emergency response but also disrupt livelihoods and isolate communities. Mapping this layer reveals both infrastructural gaps and latent corridors for green-blue infrastructure integration.

The occupation layer includes the built environment and human activities: housing typologies, land use patterns, economic activities, and social interactions. In Rhonda and Kaptembwo, this layer is defined by high-density informal housing, weak construction materials, inadequate sanitation, and a lack of public spaces. These occupation patterns are dynamic and responsive to short-term socio-economic needs, making them more flexible to design interventions. However, they are also highly vulnerable to environmental shocks and lack spatial regulation. Examining this layer uncovers how people live with risk—and where spatial transformation could enhance both safety and social resilience.

By applying the Dutch Layer Approach, the research creates a layered analytical base that informs all subsequent design interventions. This structure not only clarifies the interaction between natural systems, infrastructures, and human settlements but also sets the stage for a multi-scalar, systems-oriented spatial strategy.



Dutch layer approach
Photo credits: van Schaick, Klaasen

Three-layer approach

Zoning Strategy Overview

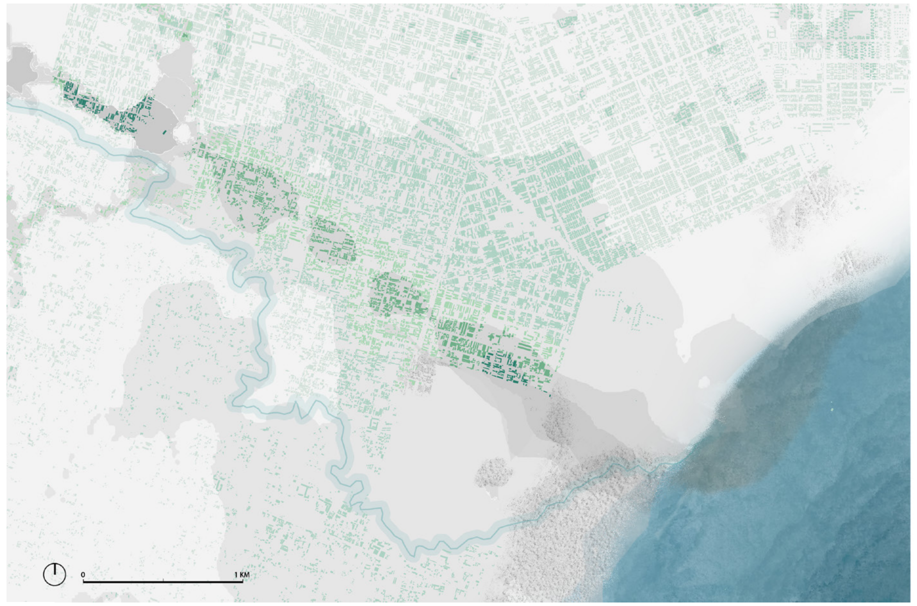
Building upon the Dutch Layer Approach, this research transforms layered analysis into a flood-sensitive zoning strategy based on the Flood Vulnerability Map. The map identifies three levels of risk—high, medium, and low—each reflecting different hydrological exposure and landscape conditions. These zones form the basis for differentiated spatial interventions that integrate ecological systems with urban resilience.

In areas with high flood risk—typically low-lying floodplains and wetlands near Lake Nakuru—the base layer plays a dominant role. These zones have been heavily encroached upon by informal development, disrupting natural drainage and amplifying water retention. Rather than resisting water, the design approach here seeks to respect hydrological dynamics by giving water more space. Strategies include restoring natural buffers, opening blocked drainage channels, and introducing flexible green spaces that accommodate seasonal flooding while supporting limited community use.

Moderate-risk zones, often located at transitional edges or along drainage paths, are shaped by both the base and network layers. Here, flood exposure is intensified by surface sealing and inadequate infrastructure. The focus is on enhancing the green-blue network—integrating vegetated corridors, detention spaces, and permeable paths that reduce runoff and restore ecological flows. These spaces also improve daily urban life by offering multifunctional public landscapes that serve both environmental and social roles.

In lower-risk zones, often situated on gently elevated land, informal housing is dense but less exposed to direct inundation. However, poor construction, insufficient drainage, and overcrowding still leave these areas vulnerable to secondary impacts such as waterlogging and health risks. Design responses prioritize incremental housing improvements, including better roof design for water harvesting, raised foundations, permeable yards, and improved layout for water flow and ventilation.

Through this zoning framework, the layered understanding of Nakuru's landscape is translated into spatial decisions that acknowledge environmental realities while supporting human needs. It sets the stage for targeted design interventions at multiple scales—from ecological restoration and infrastructure repair to housing transformation—building toward a more adaptive and resilient urban future.

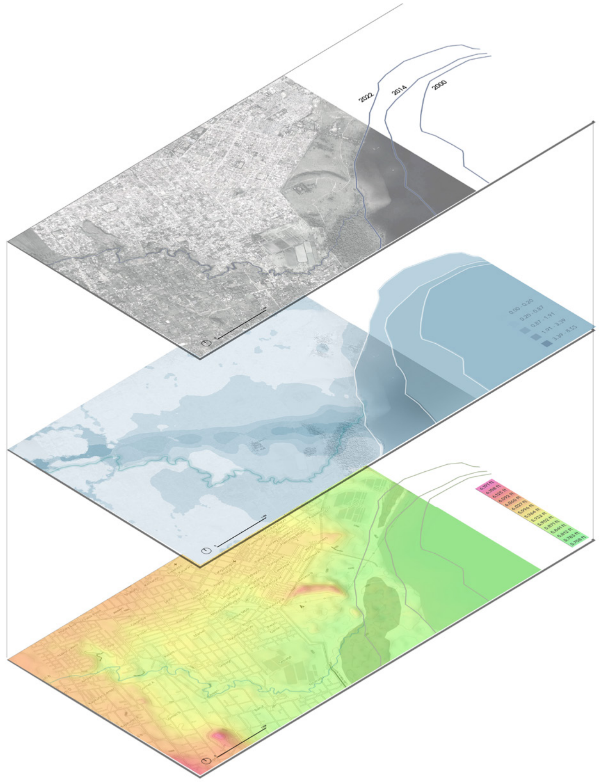


Level	Description	Rerence Quantitative Thresholds
High	Strong flood resistance, low maintenance requirement	Raised foundation of at least 0.5 meters; floodwater retention time < 2 hours
Medium	Moderate protection, effective only with rapid drainage	Raised foundation of 0.2–0.5 meters; floodwater retention time 2–6 hours
Low	Highly vulnerable, requires extensive maintenance	No significant elevation of foundation or floodwater retention time > 6 hours

Flood Vulnerability Map
Photo credits: Author

Three-layer approach

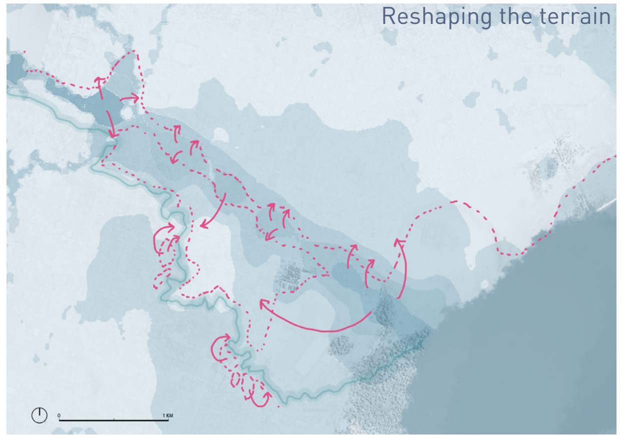
Base Layer

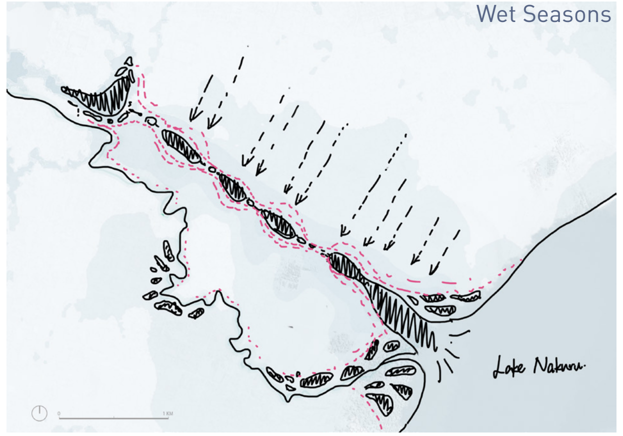


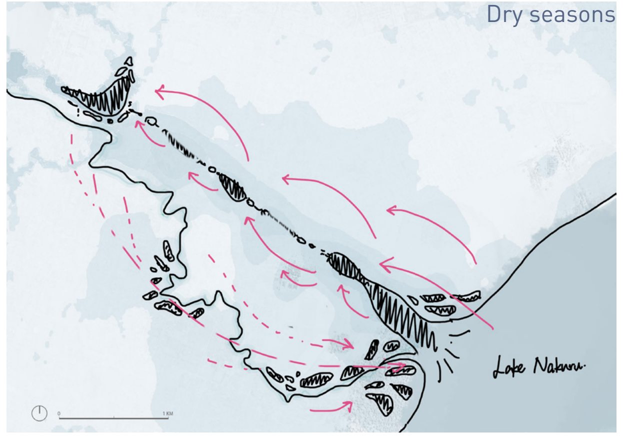
Present base layer
Photo credits: Author

"To live with water is not to fight it, but to give it space and time."

In the context of Nakuru's fluctuating lake levels and seasonal rainfall patterns, the base layer design focuses on reshaping the terrain to better accommodate and adapt to hydrological extremes. Using the Flood Vulnerability Map as a guiding tool, micro-topographies are sculpted to differentiate high, medium, and low flood zones, ensuring that each zone responds appropriately to both the wet and dry seasons. Depressions and gentle swales are introduced in high-risk areas to collect floodwater and temporarily store runoff, while elevated platforms and berms are formed to protect critical zones and allow for seasonal reuse. This terrain-based design respects natural water flows, increasing the landscape's capacity to absorb, delay, and convey water rather than resist it. The base layer thus becomes the foundation of a resilient hydrological system, reducing the destructive power of floods while maintaining ecological functions such as filtration, groundwater recharge, and habitat continuity.

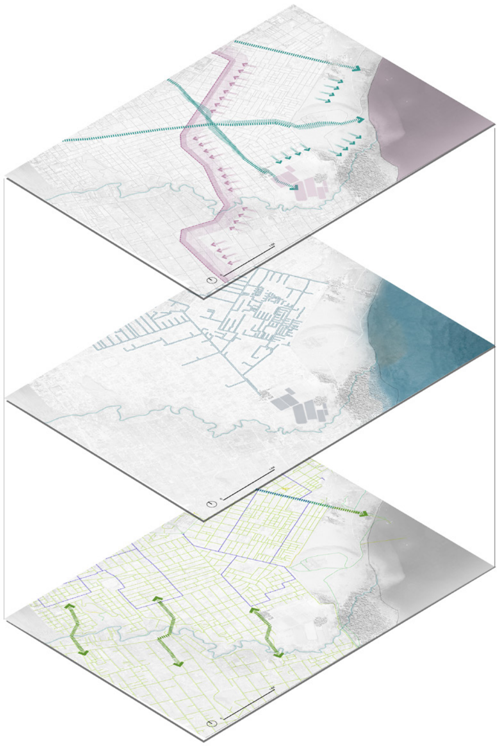






Three-layer approach

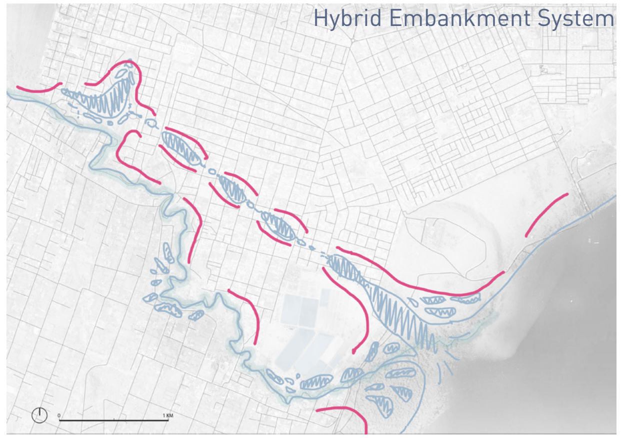
Network Layer

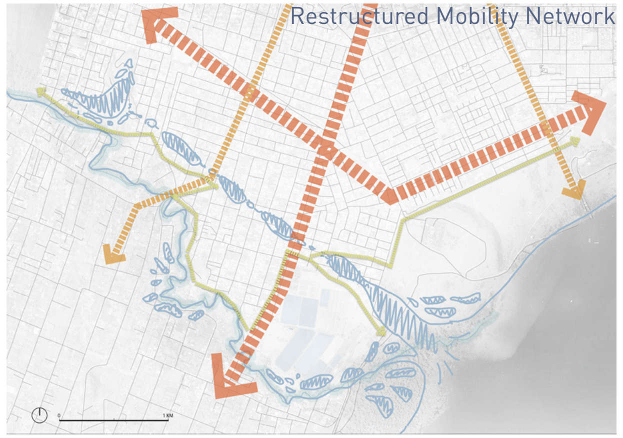


Present network layer
Photo credits: Author

“Where the land meets the lake, life flows—
not only water, but stories, people, and hope.”

The network layer restructures Nakuru’s fragmented and vulnerable urban edges through an integrated system of hybrid embankments, mobility networks, and green corridors. Along the lakefront and river edges, a flexible embankment strategy combines soft vegetated slopes with occasional hard protections, balancing flood defense with ecological and community use. These embankments are not solely barriers but serve as active social spaces—revitalizing waterfronts through walkways, seating terraces, and shade trees. Mobility interventions restructure key roadways and footpaths to create better evacuation routes, reconnect isolated neighborhoods, and facilitate daily circulation. Green corridors are overlaid to strengthen ecological connectivity, linking upland vegetated areas with riparian buffers. Together, these infrastructural layers serve a dual purpose: supporting environmental functions and infusing energy into the community realm, especially where informal areas have suffered isolation and neglect. The network layer thus amplifies the city’s capacity to adapt and thrive amidst climatic uncertainty.





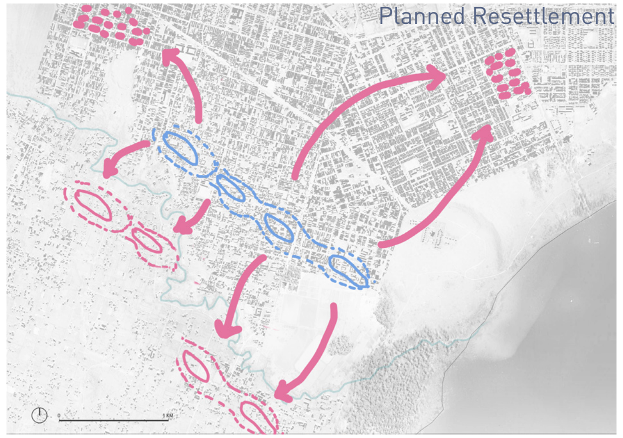
Three-layer approach

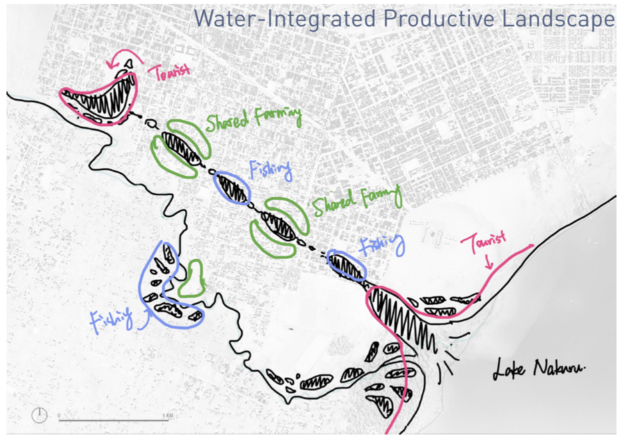
Occupation Layer

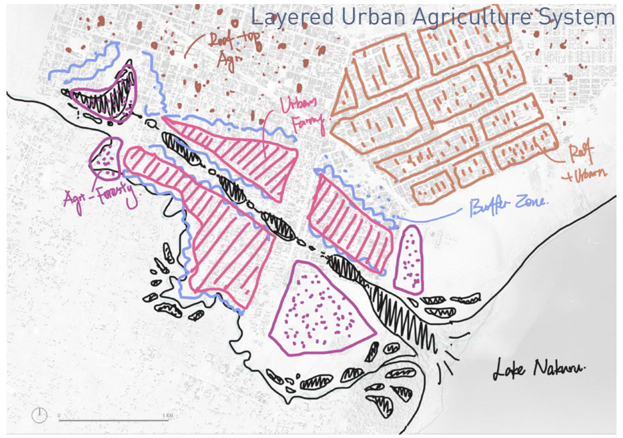
Present occupatin layer
Photo credits: Author

"A home is not just shelter—it is soil, seed, and the spirit of resilience."

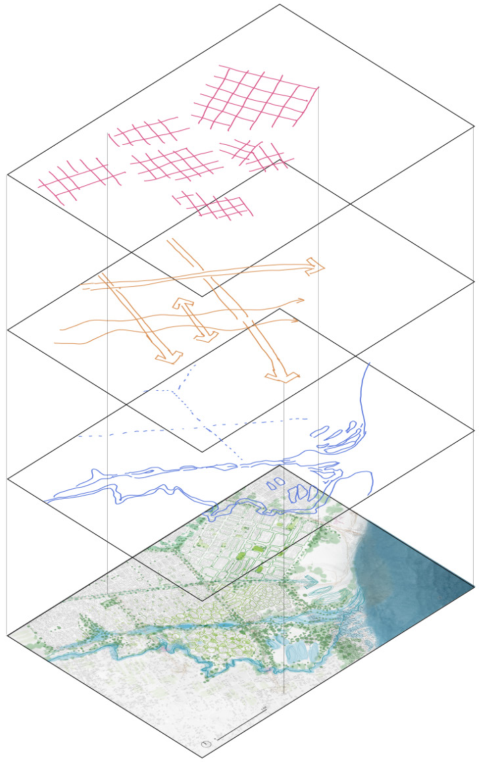
At the most dynamic layer, the design focuses on transforming Nakuru's informal settlements into adaptive and productive communities. Planned resettlement within lower-risk zones provides safer housing alternatives while preserving social cohesion. These new clusters are designed with water-sensitive layouts that incorporate retention spaces, green buffers, and porous surfaces. Within existing communities, the occupation layer is retrofitted through the introduction of layered urban agriculture systems that integrate food production, water management, and open space design. Rooftops are reimagined for harvesting water and cultivating crops, while shared courtyards support seasonal planting and communal resilience. The productive landscape model improves food security and livelihoods, while fostering environmental awareness and care for shared resources. This approach turns everyday life into a driver of resilience: residents are not only protected from floods, but also empowered to engage with and benefit from their landscapes. The occupation layer thus becomes a vehicle for both adaptation and socio-ecological transformation.





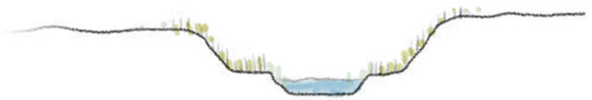


Vision




Green corridors
Plough Basins
Green Roofs
Vertical Farming
Ecological Bank
Fishing Ponds
Food Gardens
Rain Gardens
Composting Mounds
Communal Farms
Assemble Farms
Storage Ponds
0
1 KM

Dry Seasons



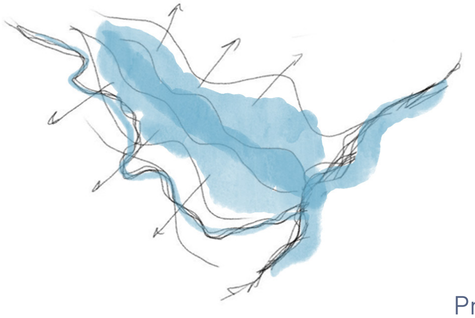
Wet Seasons

Phasing

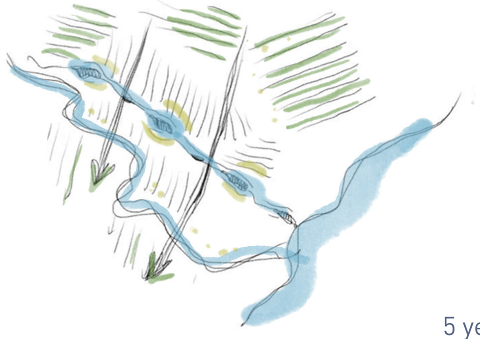
Phase 0 (Immediate to 5 years) focuses on foundational interventions that enhance safety and awareness. This includes elevating housing structures (s1), establishing rain gardens for education (s6), activating communal farms (s5), and initiating small-scale composting (s7, s8). These measures build community engagement, improve flood resilience at the household and neighborhood level, and establish a baseline for ecological restoration.

Phase 1 (5 to 20 years) emphasizes scaling and integration of agro-hydrological systems. Raised housing is linked with productive yards (s2, s3, s4), while contour farming (s10, s11) and ecological embankments (s9) stabilize landscapes and improve water retention. Green corridors (s16) are planted to enhance biodiversity and connectivity. Shared cultivation fields and neighborhood composting hubs mature into socio-ecological infrastructures supporting food security and local livelihoods.

Phase 2 (20 years and beyond) envisions a resilient, self-sustaining urban landscape where water-sensitive agriculture and community stewardship are fully embedded. Lowland basins (s15) serve as seasonal productive wetlands, green roofs (s12) mitigate urban runoff, and integrated nursery farming (s14) supports plant propagation and aquatic biodiversity. The cumulative effect transforms flood-prone areas into vibrant, multifunctional landscapes, balancing human needs with ecosystem health, and embodying a long-term vision of coexisting with water.



Present



5 years

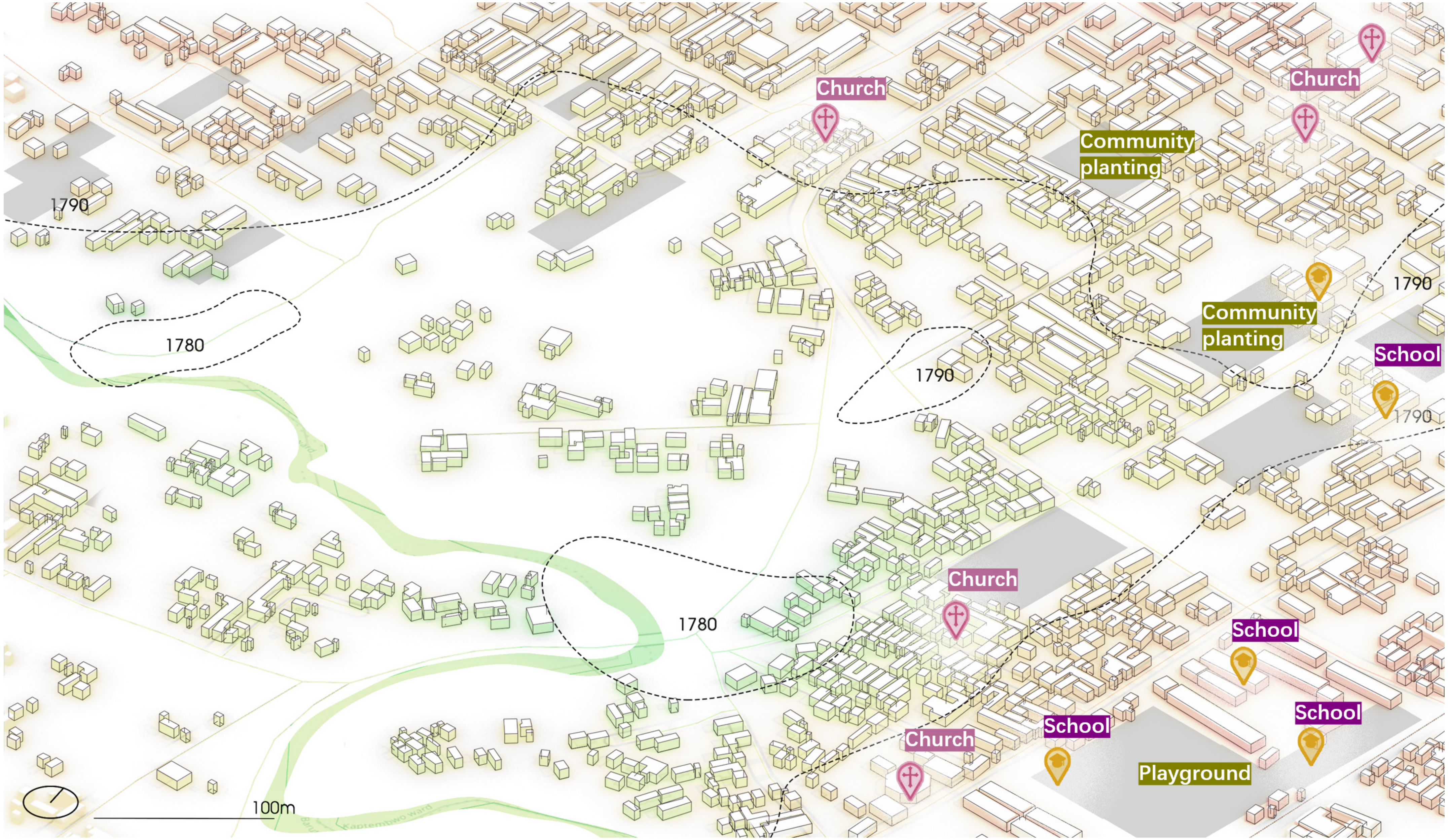
20 years

05 Design Elaboration

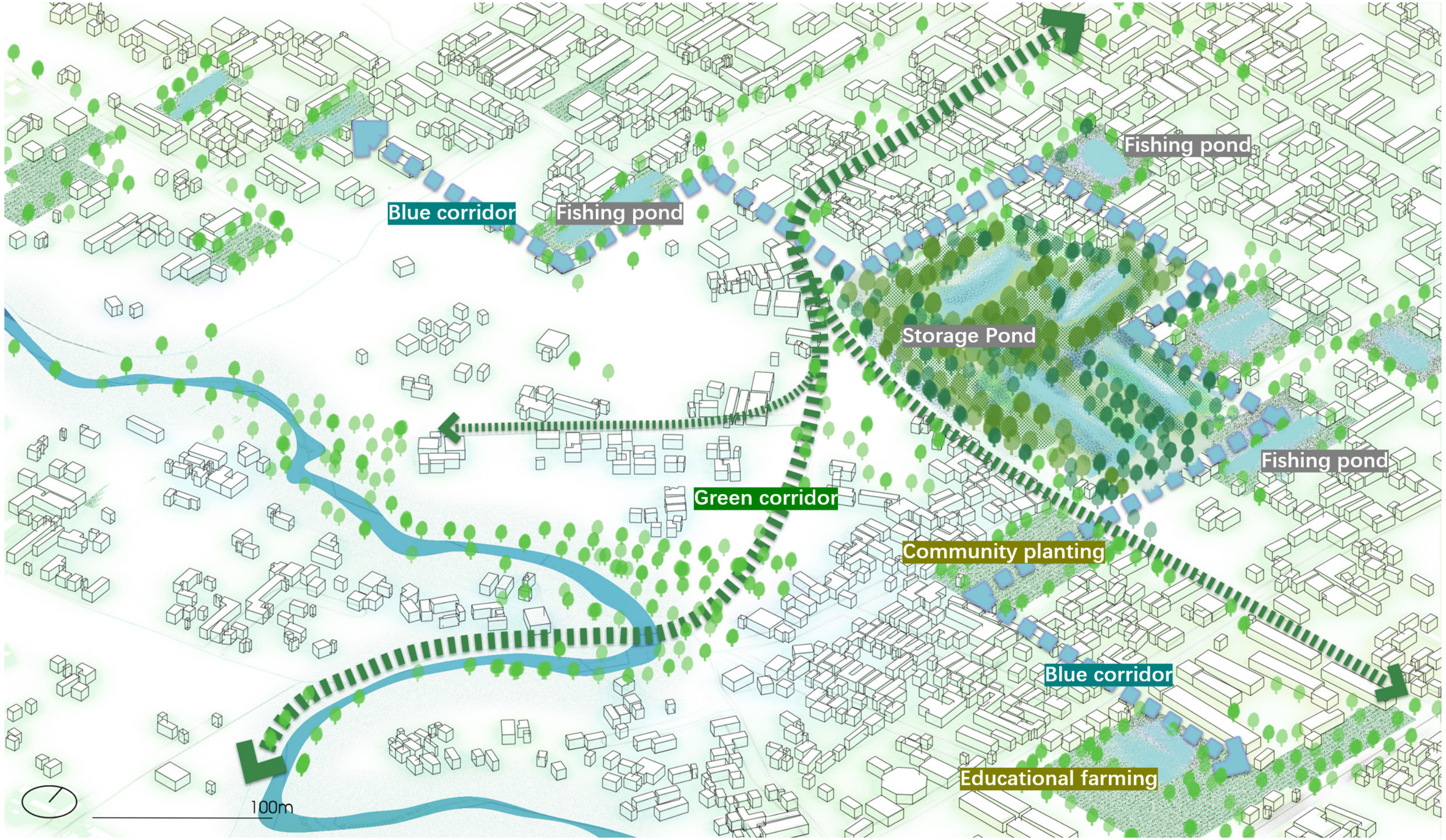
Pilot Site 1

Kaptembwo River-Edge Cluster

The Njoro riverbank area has historically suffered from severe pollution and frequent flooding, which has adversely affected both the environment and local communities. Satellite imagery indicates that despite these challenges, the site's soil and microclimate conditions are conducive to cultivation, suggesting potential for productive land use. Elevation mapping reveals that a large portion of the riverside lies at a low elevation, making it highly susceptible to seasonal flooding. Overlaying built-up urban (BUU) data with elevation further highlights the vulnerability of existing housing and infrastructure. Additionally, the site functions as a key transport hub and is densely populated with community facilities such as churches and schools, surrounded by numerous public green spaces. These multiple functions create both constraints and opportunities for integrated ecological and social interventions. Understanding these spatial and functional dynamics is critical for developing a design that addresses flooding risks while enhancing the area's multifunctionality and resilience.



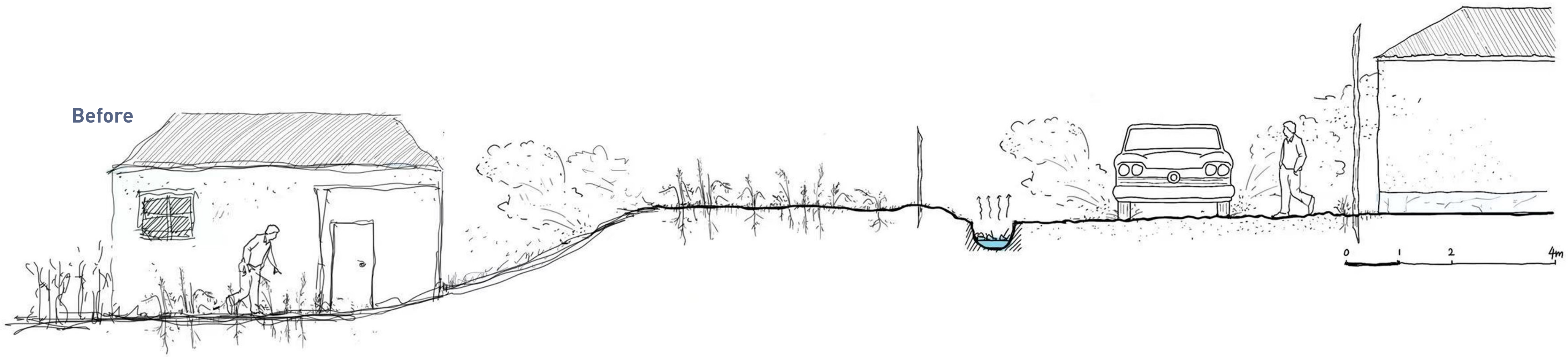
Based on the regional vision map and the multi-layered spatial analysis, a targeted design strategy has been developed to transform the Njoro riverbank area into a resilient and multifunctional landscape. To mitigate flood vulnerability, housing units situated in the lowest elevation zones prone to inundation are proposed to be removed and replaced with seasonal fish ponds during the rainy season. These ponds not only provide floodwater storage but can also serve as productive aquatic agriculture farms during dry periods, thereby enhancing food security and ecological value. Riverbank protection is strengthened by installing metal nets filled with stones, which reduce erosion and trap sediments, stabilizing the shoreline. The design also proposes creating a continuous green corridor by layering diverse vegetation, including tree planting, to improve biodiversity and provide shading. Ground surfaces are stabilized using permeable paving techniques to maximize stormwater infiltration and reduce runoff. Overall, the intervention integrates natural processes and community needs, fostering a sustainable, adaptive riverfront landscape that balances ecological restoration with human use.



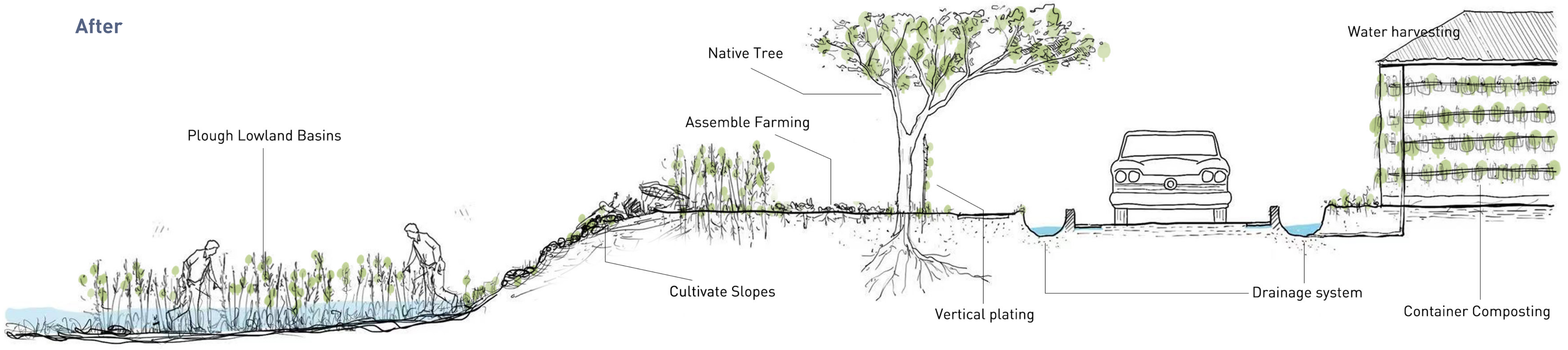
Dry Seasons

In the dry season, water levels in the Njoro river recede substantially, exposing the riverbanks and seasonal ponds. This period allows the seasonal fish ponds to be repurposed as aquatic agriculture fields, enabling communities to cultivate crops adapted to wet-dry cycles and enhance food security. The permeable pavements installed along roads and walkways maintain soil moisture by facilitating infiltration during sporadic rains, while reducing surface compaction and dust. Vegetation layers, including newly planted trees and shrubs, provide shading and microclimate regulation, improving comfort for residents and supporting urban biodiversity. Moreover, the stabilized riverbanks remain protected from wind erosion, preserving soil integrity. This dual-seasonal design approach ensures the site remains productive and resilient year-round, blending natural water dynamics with community-oriented land use.

Before



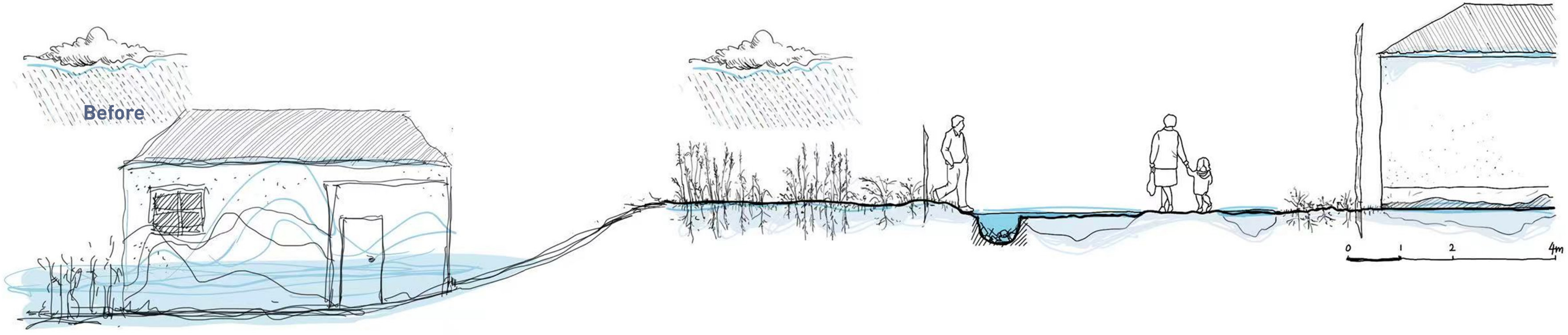
After



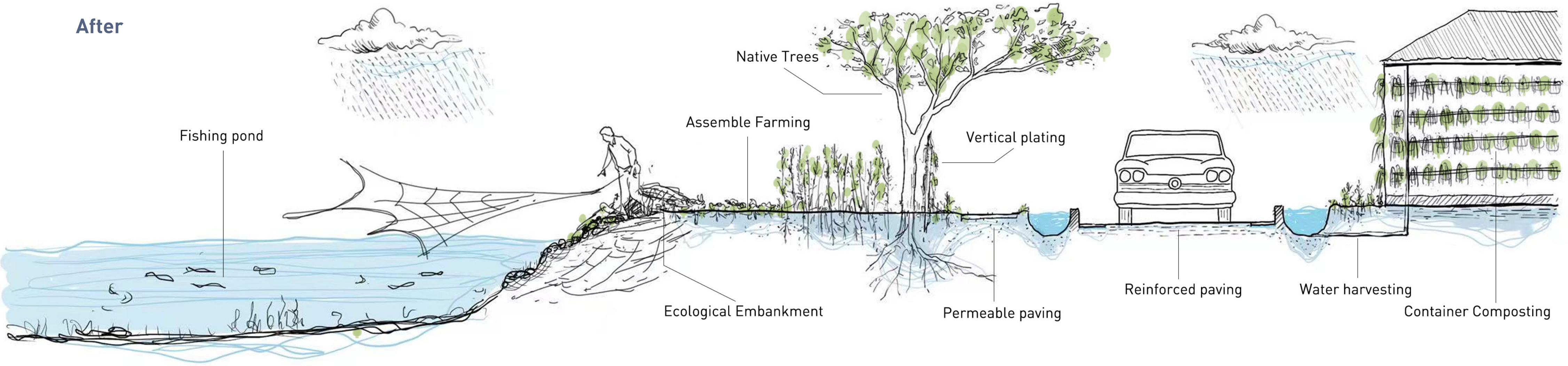
Wet Seasons

During the wet season, the Njoro riverbank area experiences significant flooding due to the low elevation and high runoff from upstream catchments. The seasonal rise in water levels often inundates vulnerable housing units and low-lying lands, exacerbating pollution dispersion and soil erosion along the riverbanks. However, this seasonal flooding also presents an opportunity for water-based land use; the proposed seasonal fish ponds act as natural flood buffers by temporarily storing excess water, reducing peak flows downstream. The enhanced riverbank protection measures, such as stone-filled metal nets, play a crucial role in preventing erosion caused by stronger water currents. Additionally, the expanded green corridors with dense vegetation help slow down surface runoff, promote infiltration, and improve water quality. Collectively, these interventions transform flooding from a destructive hazard into a managed, regenerative process that supports both ecological functions and local livelihoods.

Before



After

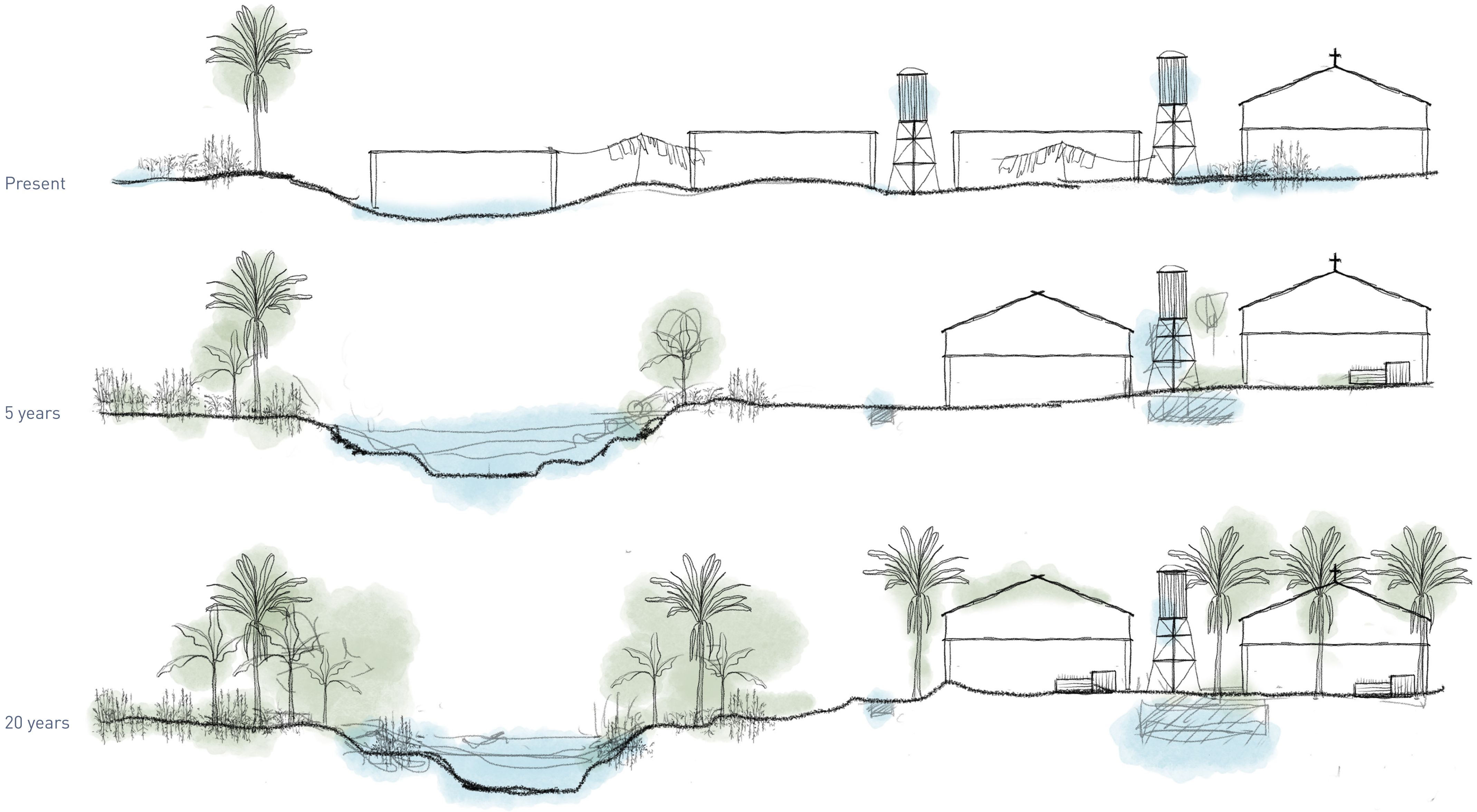


Phasing

Currently, the neighborhoods are highly vulnerable to flooding, shaped by impermeable surfaces, weak infrastructure, and fragmented social and ecological systems. Public spaces are underused, community engagement is limited, and there is little integration between daily life and environmental functions. This reflects a landscape that is reactive rather than resilient.

Over the next 0 to 5 years, the project focuses on initiating foundational, community-based interventions. These include elevating the most flood-prone homes, creating educational rain gardens, activating communal farming spaces, and introducing small-scale composting systems. These low-cost, highly participatory actions aim to strengthen household safety, raise ecological awareness, and rebuild collective practices tied to water and land use.

In the 5 to 20-year phase, these scattered interventions grow into a more cohesive green infrastructure network. Productive yards linked to raised homes, contour farming on sloped areas, and ecological embankments help stabilize terrain and regulate water flow. Green corridors not only enhance biodiversity but also serve as spaces for community gathering, farming, and environmental education. By this stage, decentralized water and compost systems are fully embedded in daily routines, creating a socially and ecologically resilient neighborhood. The landscape evolves into a multifunctional system shaped by community stewardship, where living with water becomes a shared cultural and spatial practice.



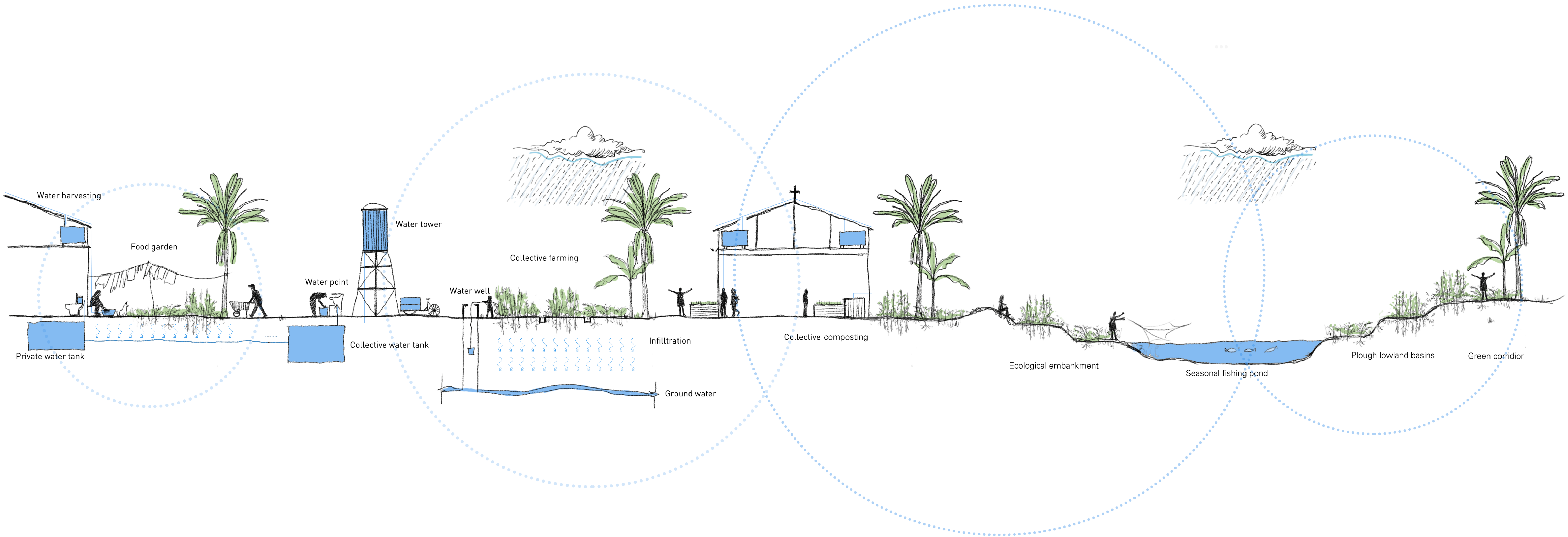
Pilot Site 2

Rhonda Lake-Edge Cluster

Located near the southwestern edge of Rhonda, this peri-lacustrine cluster is situated within a flood-prone buffer zone adjacent to Lake Nakuru, making it highly vulnerable to seasonal lake swelling and flash floods triggered by extreme weather events. Many households in the area face compounded risks due to fragile building materials, the absence of formal drainage infrastructure, and saturated soils that severely limit natural infiltration. To cope with frequent flooding, residents have created shallow drainage trenches within their compounds to channel rainwater and recycle greywater. Makeshift levees made from manually transported sandbags and earthen mounds line numerous backyards, demonstrating both the urgent need for flood protection and the resourcefulness of the community. The presence of abandoned or deteriorating homes along the lakeshore signals ongoing climate-induced displacement, while remaining residents often endure precarious living conditions constrained by limited economic options. Small agricultural plots interspersed among housing units serve dual functions as food sources and informal flood buffers, highlighting the critical interplay between livelihood and environmental challenges.

Building upon the spatial and socio-environmental context, the proposed design strategy emphasizes integrated, nature-based solutions to address both flood risk and food security within this vulnerable cluster. Reinforced bio-dykes planted with native vegetation will stabilize the lakeshore and reduce erosion, serving as living flood barriers that adapt to seasonal water fluctuations. Agroforestry corridors, strategically woven between housing clusters and agricultural plots, will enhance biodiversity, provide shade, and improve soil structure, contributing to ecosystem resilience. Community-scale water retention landscapes, including rain gardens and constructed wetlands, are designed to capture and store excess stormwater, facilitating gradual infiltration and reuse while reducing flood peaks. These interventions aim to replace fragile and makeshift defenses with sustainable, multifunctional infrastructure that strengthens local adaptive capacity. By integrating ecological restoration with community livelihoods, this approach seeks to transform the cluster into a model of climate-adaptive peri-urban development in flood-prone environments.

Water cycle


Water harvesting
Food garden
Private water tank
Water point
Water tower
Collective water tank
Water well
Collective farming
Infilltration
Ground water
Collective composting
Ecological embankment
Seasonal fishing pond
Plough lowland basins
Green corridior

Present Streetview

06 Design Evaluation

Nakuru Lakeview Ward
Photo credits: Cynthia van Elk

As this project nears its conclusion, I find it necessary to step back and critically reflect on what it has achieved, where it has fallen short, and what it has taught me—not only as a designer, but as a learner situated between systems, communities, and landscapes.

At the outset, this research set a clear and urgent ambition: to explore how nature-based spatial strategies could enhance flood resilience and improve community well-being in Nakuru's informal settlements. This aim was not approached through abstract theorization, but grounded in layered fieldwork, spatial typology, and community observation. The strategies proposed—ranging from multifunctional wetlands to decentralized rain gardens and agroforestry corridors—were designed not simply as technical solutions, but as spatial responses to the ecological, infrastructural, and cultural dynamics observed on site. And yet, the question lingers: did the work truly answer its own question?

In many ways, I believe it did. The designs emerged not in isolation, but as the product of a deeply contextual process. They responded to the specific vulnerabilities of Rhonda and Kaptembwo, while also proposing scalable, modular systems that could adapt to other flood-prone areas. The work did not just address water as a hydrological issue, but as a lived one—something that moves through streets, stalls in courtyards, pools in kitchens, and shapes the very logic of urban survival. However, the work's strength lies more in its propositional clarity than in its implementation roadmap. It offers a spatial vision grounded in evidence and empathy, but the institutional mechanisms required to activate this vision—land tenure reform, multi-actor funding, ongoing community stewardship—remain beyond the thesis's direct control. In that sense, the project articulates possibility more than certainty. It designs for resilience, but cannot guarantee it.

The theoretical frameworks chosen—Ecopolis, the Circular Value Flower, and the Dutch Layer Approach—were instrumental in shaping the project's conceptual and methodological spine. Ecopolis offered a critical lens through which to view the city not as a machine for efficiency, but as a living system whose health depends on the alignment of environmental flows and human participation. This was perhaps the most deeply embedded framework in my thinking, especially in how I conceptualized the relationship between water infrastructure and social life. The Circular Value Flower was more catalytic—pushing me to think about waste, water, and materials not as linear flows but as regenerative cycles. While its application remained more thematic than metric, it nonetheless influenced key interventions, such as the inclusion of compost hubs and greywater reuse systems. The Dutch Layer Approach, on the other hand, provided an operational logic that allowed me to stratify the spatial complexity of informal settlements into actionable layers: base, network, and occupation. Its clarity helped translate diagnosis into design. Together, these frameworks provided both breadth and depth. Still, if I am honest, there were moments when their integration leaned toward symbolism rather than systemic precision. The design was always guided by theory, but in moments of complexity or uncertainty, practice and field intuition often took the lead.

Beyond conceptual and spatial evaluation, there is also the question of power: who controls, who decides, who maintains? One of the most revealing aspects of this project was the realization that flood resilience is not only a technical problem, but a political one. Informal settlements exist within asymmetrical structures of land ownership, governance, and capital. Any design, no matter how community-sensitive, risks becoming irrelevant if it ignores these dynamics. The interventions proposed in this thesis were imagined as participatory, but not naive; they rest on the understanding that true resilience cannot be imposed from above nor emerge solely from below. It must be co-produced. That co-production demands clarity of roles. The government must provide institutional support, regulatory adaptation, and infrastructural investment—particularly in managing ecological corridors and drainage networks. But it is the residents who must animate the system, embedding it into daily life, maintaining it, adapting it, and making it matter. This balance is delicate. Without governmental commitment, the vision evaporates. Without community agency, it withers. Ideally, the two would not act in parallel but converge in shared institutions—committees, task forces, or neighborhood trusts—that mediate between planning, lived knowledge, and long-term care.

Personally, this project challenged me in ways I did not expect. Working in a context so spatially and socially complex demanded humility. I had to unlearn many assumptions—about formality, about authorship, about speed. Limited access to data, language barriers, and time constraints forced me to rely more on observation, conversation, and mapping than on technical modeling. But in doing so, I learned to listen—really listen—to the landscape, and to the people living in it. If I were to do this project again, I would begin earlier with participatory engagement, spend more time prototyping on-site, and perhaps, most importantly, co-write the narrative with those who inhabit it daily. Because ultimately, this is their landscape—not mine. My role, at best, is to make it more livable, more legible, and more just.

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Pink flamingoes fringing Lake Nakuru
Photo credits: africa-expert.com