WaterWoven:

Living on the margins in the Roncador River region, Brazil

by
Maria Luiza de Souza Oliveira Ottoni

A thesis
presented to the University of Waterloo
in fulfillment of the
thesis requirement for the degree of
Master of Architecture

Waterloo, Ontario, Canada, 2022
© Maria Luiza de Souza Oliveira Ottoni 2022

Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

Informal settlements located on river edges in impoverished Brazilian urban peripheries, such as the Roncador River region in Duque de Caxias city, have been increasingly suffering from the effects of more intense urban floods. In the context of a degraded urban watershed precariously inhabited by informal settlements, how to promote a transformation toward a more sustainable way of living, entailing the river rehabilitation while enhancing the community capacity to adapt to floods and improve their lives on a long-term basis? The Aquatecture approach, as a non-defensive nature-based solution, has great potential to restore the river's environmental qualities, reduce floods and integrate with the building scale by working with water instead of controlling it. However, if applied in the Roncador River context, this solution could potentially add to the housing crisis, as it would require the removal of marginal settlements and their residents' relocation. Under the current inefficient social housing program, these people would likely be redirected to distant and low-quality social housing, thus, disrupting their livelihoods.

Therefore, this study proposes integrating nature-based parks along the Roncador River and within the urban fabric with amphibious evolutionary housing, which allows the residents to safely stay and grow over time in their communities and achieve flood mitigation and adaptation. The methodology was based on analyzing the selected region context to identify its main problems and opportunities, followed by an integrated design proposition in the watershed, neighbourhood, and housing scales. The research steps consist of (i) conducting a literature review about flood mitigation through the lens of the Aquatecture approach and on evolutionary housing and amphibious architecture as solutions for social housing in floodable riverine areas; (ii) mapping the vacant and underutilized sites in the region, as they present a potential to address the housing crisis and informality; (iii) and selecting two of these vacant lands to (iv) propose two types of evolutionary housing intervention - one as a single-family house and another as a low-rise multi-family building. By restoring the watershed based on the Aquatecture approach and integrating with amphibious evolutionary housing, this thesis aims to offer an alternative solution for affordable housing in floodplains to empower these vulnerable communities to thrive in a healthier riverscape. Since the problems in the Roncador River surroundings are typical of metropolitan peripheries in Brazil, this solution could also be applied to improve the livelihood of other riverine vulnerable communities in similar informal contexts.

Acknowledgements

My greatest thanks to Elizabeth, my supervisor, for your invaluable and sincere pieces of advice on this thesis topic but also in many other areas. You have always been so patient and humble in teaching me new concepts, pushing me with critical thinking, and an inspiring person with your outstanding and passionate work at the BFP. Thank you for all the opportunities you gave me to learn from you.

Val, my committee member, I have always admired your presentations and thoughts about the planet's future and how the concept of green infrastructure is paramount to envisioning a better and harmonious future. I am grateful to have the opportunity to receive your theoretical and practical contribution to this work.

Jane, my internal reader, I greatly appreciate your work with material cycles and movements, highlighting an essential perspective that I tried to bring to my thesis, which sees the use of local materials as one solution for sustainability. The invaluable importance of cyclical approaches to achieve regeneration is fundamental for this work. Thank you so much for contributing to this thesis with your experience and critical thinking.

And Richard, I am extremely grateful for having you as my external reader and for providing your expertise from your inspiring work. I have learned so much in the past year by reading your book and articles, which inspired this thesis and aligned so much with the values I tried to bring to seek a better future for our cities, one that connects water, architecture, and people.

Dedication

To my parents, grandparents, sister, husband, and parents-in-law, for always encouraging me to follow my dreams. To my father, for constantly reminding me of the importance of living in equilibrium with nature, especially by respecting water; To my mother, for always teaching me with her examples to be persistent, reinventing herself to adapt to new circumstances, and never giving up.

Table of contents

ii | Author's Declaration
iii | Abstract
iv | Acknowledgements
v | Dedication
vii | List of figures
xxi | Quote

01 | Introduction
Problem and Contextualization
Research Question and Statement
Existing Literature
Methodology
Proposal
Impact

17 | PART 1 | Water
Water-related issues in the Roncador River surroundings
Nature-based & Water-centric approaches and theories
Designing with Water in scales

75 | PART 2 | Community
Social problems in the Roncador River surroundings
Repurposing vacant lands
Theories and design strategies for adaptability in scales

119 | PART 3 | Water & Community
Interventions in phases
Interventions in scales

203 | Conclusion

213 | Bibliography

List of figures

Introduction

figure 0.01 *xviii* Daily life on the margins of the Roncador River. *Photo by researchers at the Laboratoty of Urban Water Studies - UFRJ (LEAU / PROURB - UFRJ), in field visit on September 2019. Adapted by author.*

figure 0.02 *xix* Informal housing expansion to the Roncador River banks. *Photo by researchers at the Laboratoty of Urban Water Studies - UFRJ (LEAU / PROURB - UFRJ), in field visit on September 2019. Adapted by author.*

figure 0.03 *xx* Aerial photograph showing the informal houses at the banks of the Roncador River. *Source: Google Maps. Adapted by author.*

figure 0.04 *01* Location of the Roncador River in a periphery in Brazil. *Source: Image by author.*

figure 0.05 *11* Timeline Diagram of research methodology. *Source: Image by author.*

figure 0.06 *15* Diagram summarizing the problems addressed, the design strategies adopted, and the outcomes achieved in this thesis, which inform the thesis structure. *Source: Diagram by author.*

Part 1 | Water

figure 1.01 *19* Baixada Fluminense map, highlighting Duque de Caxias city and the Roncador River watershed. *Source: Rocha, 2015. Adapted and translated by author.*

figure 1.02 *21* Flooding was always part of Duque de Caxias existence due to its low-lying geological characteristic. News article published in 1960. *Source: Duque de Caxias que passa, 2017.*

figure 1.03 *22* Rectification of a river in Duque de Caxias city in 1943. *Source: Duque de Caxias que passa, 2017.*

figure 1.04 *23* A meandering river in Duque de Caxias city before channelization and rectification

interventions started. *Source: Duque de Caxias que passa, 2017.*

figure 1.05 25 Roncador River watercourse before and after the rectification intervention. *Source: Adapted from Ottoni, 2021.*

figure 1.06 27 The beginning of unplanned urban occupation in the Imbariê district in the mid-twentieth century happened mostly on riverbanks and railway edges.
Source: Duque de Caxias que passa, 2017.

figure 1.07 27 The beginning of unplanned urban occupation in the Imbariê district in the mid-twentieth century, lacking proper urban infrastructure.
Source: Duque de Caxias que passa, 2017.

figure 1.08 28 The beginning of unplanned urban occupation in the Imbariê district in the mid-twentieth century highlighting the practice of self-construction, often in floodable areas.
Source: Duque de Caxias que passa, 2017.

figure 1.09 29 In the beginning of urban occupation in Imbariê district, people and rivers had a positive relationship.
Source: Duque de Caxias que passa, 2017.

figure 1.10 30 Map of susceptibility to floods and landslides in the Roncador River watershed. *Source: INEA and CPRM, elaborated by LEAU (PROURB/ UFRJ) in October 2020. Adapted and translated by author.*

figure 1.11 31 Map of demographic density in areas of high susceptibility o floods in the Roncador River watershed. *Source: INEA, IBGE, and CPRM, elaborated by LEAU (PROURB/ UFRJ) and IPPUR/UFRJ in November 2020. Adapted and translated by author.*

figure 1.12 33 Contextualization and identification of problems in the Roncador River region.
Source: Image by author.

figure 1.13 *35* Flood in the Roncador River surroundings in 2013.
Upper and middle photos: Geraldo Roberto Fotografo, 2013. Lower photo: Daniele Meireles, 2013.

figure 1.14 *37* Water aspects of the Roncador River: sanitation and floodable areas. *Sources: Observatório das Metrópoles (IPPUR/UFRJ) and Laboratory of Urban Water Studies, (LEAU / PROURB – UFRJ) on November 2020. Data from INEA, IBGE, and GPU/SMPHU Duque de Caxias. Adapted and translated by author.*

figure 1.15 *39* Sea-level rise due to climate change will affect coastal regions in Duque de Caxias city, and will likely reach Imbariê district.
Source: Jornal O São Gonçalo de 6 de maio de 2011, apud Relatório sobre Vulnerabilidade da Região Metropolitana do Rio de Janeiro às Mudanças Climáticas. Adapted by author.

figure 1.16 *41* Nature operates as in the right-hand networking option, through redundancy of connections to resist disturbances. *Source: Delaqua, 2019. Adapted by author.*

figure 1.17 *49* LifE concept. *Source: Baca Architects website.*

figure 1.18 *51* LifE's principle of Making Space for Water and how it works during a flood event.
Source: Adapted from Barker and Coutts, 2016.

figure 1.19 *56* Successful riverfront: integrating and balancing nature and public spaces. *Source: Adapted from Barker and Coutts, 2016.*

figure 1.20 *58* Don River Valley regeneration project.
Source: Crombie, 1992.

figure 1.21 *61* Street bioswales and raingardens.
Source: Image by author.

figure 1.22 *62* Retention and detention basins. *Source: Image by author, adapted from Woods Ballard et al., 2015.*

figure 1.23 *63* Wetlands. *Source: Image by author, adapted from Woods Ballard et al., 2015.*

figure 1.24 *63* Green roofs and Rainwater harvesting and reuse in the building. *Source: Image by author, translated and adapted from Lotufo, 2020.*

figure 1.25 *65* "Unified urban block" concept by Lotufo (2020). *Source: Image by author, translated and adapted from Lotufo, 2020.*

figure 1.26 *66* Underground Septic Tanks. *Source: Image inspired by Green Initiative, 2015, and produced by the author.*

figure 1.27 *66* Green Septic tank connected to Banana Tree Circle. *Source: Image inspired by Figueiredo and Tonetti, 2019. Image produced by the author.*

figure 1.28 *68* Living Machine system for sewage treatment. *Source: Image by author, adapted from Organica Ecotechnologies.*

figure 1.29 *68* Filtering Garden for sewage treatment. *Source: Image by author, adapted from EMBRAPA, Green Initiative, 2015.*

figure 1.30 *70* Building types that adapt to floods. *Source: Image by author, adapted from Januchta-Szostak and Karaskiewicz, 2020.*

figure 1.31 *71* A building retrofitted with buoyant foundation. *Source: Bullough, Khokhar & English, 2019.*

figure 1.32 *72* Amphibious Architecture system. *Source: English et al., 2016, drawing by BFP.*

Part 2 | Community

figure 2.01 *76* Start of occupation of Duque de Caxias city in the beginning of 20th century, usually settled in railways or riverbanks edges. *Source: Duque de Caxias que passa, 2017.*

figure 2.02 *78* Urbanization process in Imbariê district, in Duque de Caxias city.

Source: Adapted from Silveira and Ribeiro, 2017. Image by author.

figure 2.03 *91* Proportion of impoverished people in the Roncador River surroundings. *Source: IBGE, INEA, and Atlas do Desenvolvimento Humano in Brazil. Elaborated by LEAU (PROURB/UFRJ), translation by author.*

figure 2.04 *92* Irregular waste disposal in the Roncador River banks. *Source: Image retrived from Google Street view.*

figure 2.05 *92* Precarious conditions of informal houses in the Roncador River banks. *Source: Photo by researchers at the Laboratoty of Urban Water Studies - UFRJ (LEAU / PROURB - UFRJ) in field visit on September 2019.*

figure 2.06 *93* Expansion of informal human occupation on the margins of Roncador River. *Source: Photo by researchers at the Laboratoty of Urban Water Studies - UFRJ (LEAU / PROURB - UFRJ) in field visit on September 2019.*

figure 2.07 *95* Synthesis of the socioenvironmental problems faced by the residents in the region. *Source: Image by author.*

figure 2.08 *97* Contextualization and synthesis of opportunities and socioenvironmental problems in Region A. *Source: Image by author.*

figure 2.09 *97* Contextualization and synthesis of opportunities and socioenvironmental problems in Region B. *Source: Image by author.*

figure 2.10 *98* Contextualization and synthesis of opportunities and socioenvironmental problems in Region C. *Source: Image by author.*

figure 2.11 *99* Section illustrating the context and synthesis of opportunities and socioenvironmental problems in Region A. *Source: Ottoni, 2021. Translated by author.*

figure 2.12 *99* Section illustrating the context and synthesis of opportunities and socioenvironmental problems in Region B. *Source: Ottoni, 2021. Translated by author.*

figure 2.13 *105* Distribution of vacant or abandoned lands in the surroundings of the Roncador River. *Source: Image by author.*

figure 2.14 *110* The six types of adaptability: adjustable, versatile, refitable, scalable, convertible, and movable. *Source: Schmidt III and Austin, 2016.*

figure 2.15 *112* Open Building: Support and Infill elements. *Source: Adapted from Kendall, 2003.*

figure 2.16 *113* Decision-making levels in the Open Building approach. *Source: Kobayashi & Fujimoto, 2003, translated to English by Costa, 2016.*

figure 2.17 *115* Incremental housing design in Villa Verde, Chile. *Source: Moore, 2016.*

figure 2.18 *117* Working with flexible lots in the 468 James Street North development in Hamilton, Ontario, Canada. It provides opportunity for horizontal expansion of units. *Source: JvN/d, 2018.*

Part 3 | Water and Community

figure 3.01 *119* Proposed strategies for intervention in the Roncador River region, divided in four phases. *Source: Image by author.*

figure 3.02 *121* Three scales for intervention: Watershed, neighborhood, and housing scales. *Source: Image by author.*

figure 3.03 *123* Strategy 'Making space for water' in the watershed scale. *Source: Image by author.*

figure 3.04 *125* Strategy in the watershed scale: 'Making space for water (and for people)'. *Source: Image by author.*

figure 3.05 *127* Strategy in the Neighborhood scale: 'Living with Water', in the Regions A, B, and C.

Source: Image by author.

figure 3.06 *129* Strategy in the Neighborhood scale: 'Living with Water', in the Region A. *Source: Image by author.*

figure 3.07 *131* Strategy in the Neighborhood scale: 'Living with Water', in the Region B.
Source: Image by author.

figure 3.08 *133* Strategy in the Neighborhood scale: 'Living with Water', in the Region C.
Source: Image by author.

figure 3.09 *135* "Living with Water" strategies in the Region A.
Source: Adapted and translated from Ottoni, 2021

figure 3.10 *137* "Living with Water" Strategies in the Region B.
Source: Adapted and translated from Ottoni, 2021.

figure 3.11 *140* Location of Sites 01 and 02 within the Region C, for proposing housing interventions.
Source: Image by author.

figure 3.12 *141* Location of Sites 01 and 02 and other vacant lands within the Region C, for proposing housing interventions. *Source: Image by author.*

figure 3.13 *143* Different housing types according to the lot size within Region C. *Source: Image by author.*

figure 3.14 *145* Alternative sewage treatment system in the Neighborhood scale: green septic tank connected to Banana Tree Circle and wetland.
Source: Image by author.

figure 3.15 *147* Collective food production in the Neighborhood scale: transition between the system of parks and the housing intervention. *Source: Image by author.*

figure 3.16 *149* Strategies to increase soil permeability in the transiton between the riverbanks and the residential area with a street separating them.
Source: Image by author.

figure 3.17 *151* Parti for the single-family housing proposition on Site 01. *Source: Image by author.*

figure 3.18 *152* Testing of buoyant foundation composed of reused water bottles and local bamboo framing by local residents. Sources: *Photo by Prithula Prosun, 2011.*

figure 3.19 *152* Preparation of buoyant foundation composed of reused water bottles and local bamboo framing by local residents. Sources: *Photo by Prithula Prosun, 2011.*

figure 3.20 *152* Modular composition of single-family housing proposition on Site 01. *Source: Image by author.*

figure 3.21 *153* Modular composition of single-family housing proposition on Site 01, with core or support elements concentrated in the center of plan. *Source: Image by author.*

figure 3.22 *155* Ground floor plan of single-family housing type on Site 01 in the starter / embryo condition. *Source: Image by author.*

figure 3.23 *156* Ground floor plan of single-family housing type on Site 01 in the expansion scenario. *Source: Image by author.*

figure 3.24 *157* Second floor plan of single-family housing type on Site 01 in the starter / embryo condition. *Source: Image by author.*

figure 3.25 *158* Second floor plan of single-family housing type on Site 01 in the expansion scenario. *Source: Image by author.*

figure 3.26 *159* Single-family housing proposition on Site 01: incremental design strategy and amphibiation to achieve adaptation in various levels. *Source: Image by author.*

figure 3.27 *161* Single-family housing proposition on Site 01: possible expansions over time. *Source: Image by author.*

figure 3.28 *163* Housing proposition on Site 01: possible vertical expansion over time, from single-family to multi-family building. *Source: Image by author.*

figure 3.29 *165* Single-family housing proposition: infill and support elements in the starter unit. *Source: Image by author.*

figure 3.30 *166* Single-family housing proposition: infill and support elements in Expansion 01. *Source: Image by author.*

figure 3.31 *167* Single-family housing proposition: infill and support elements in Expansion 02. *Source: Image by author.*

figure 3.32 *168* Single-family housing proposition: infill and support elements in Expansion 03. *Source: Image by author.*

figure 3.33 *169* Single-family housing proposition: infill and support elements in Expansion 04. *Source: Image by author.*

figure 3.34 *170* Parti of Multi-family housing proposition in a unified block with collective and green spaces in the center. *Source: Image by author.*

figure 3.35 *171* Multi-family housing proposition on Site 02: starter units. *Source: Image by author.*

figure 3.36 *173* Multi-family housing proposition on Site 02: Expansion scenario. *Source: Image by author.*

figure 3.37 *175* Multi-family housing proposition on Site 02: starter units. *Source: Image by author.*

figure 3.38 *177* Multi-family housing proposition on Site 02: expansion scenarios. *Source: Image by author.*

figure 3.39 *179* Multi-family housing proposition on Site 02: programme on the ground floor and second floor, and residential capacity in each starter unit. *Source: Image by author.*

figure 3.40 *181* Flexible strategies for unit expansion and

transformation over life stages in the Multi-family housing proposition on Building 1.
Source: Image by author.

figure 3.41 *183* Flexible strategies for unit expansion and transformation over life stages in the Multi-family housing proposition on Building 2.
Source: Image by author.

figure 3.42 *185* Flexible strategies for unit expansion and transformation over life stages in the Multi-family housing proposition on Building 3.
Source: Image by author.

figure 3.43 *187* Productive rooftop and rainwater harvesting for non-potable uses in the multi-family housing intervention. *Source: Image by author.*

figure 3.44 *189* Cross section cutting the proposed single-family and multi-family interventions in dry condition.
Source: Image by author.

figure 3.45 *191* Cross section cutting the proposed single-family and multi-family interventions in flood condition. *Source: Image by author.*

figure 3.46 *193* Longitudinal section cutting the proposed single-family and multi-family interventions in dry condition. *Source: Image by author.*

figure 3.47 *195* Longitudinal section cutting the proposed single-family and multi-family interventions in flood condition. *Source: Image by author.*

figure 3.48 *197* Bird's-eye view showing the proposed interventions in the Roncador River watershed, highlighting Region C. *Source: Image by author.*

figure 3.49 *199* Eye-level perspective, showing the proposed interventions in the Roncador River watershed, highlighting the single-family and multi-family interventions in Region C.
Source: Image by author.

figure 3.50 *201* Eye-level perspective, showing the proposed interventions in the Roncador River banks,

highlighting the single-family and multi-family evolutionary interventions in Region C and their relationship with the river.
Source: Image by author.

figure 3.51 *203* Synthesis of design proposal, showing the before and after scenarios. *Source: Image by author.*

figure 0.01. Daily life on the margins of the Roncador River.
Photo by researchers at the Laboratoty of Urban Water Studies - UFRJ (LEAU / PROURB - UFRJ), in field visit on September 2019. Adapted by author.

figure 0.02. Informal housing expansion to the Roncador River banks.
Photo by researchers at the Laboratoty of Urban Water Studies - UFRJ (LEAU / PROURB - UFRJ), in field visit on September 2019. Adapted by author.

figure 0.03. Aerial photograph showing the informal houses at the banks of the Roncador River. *Source: Google Maps. Adapted by author.*

Quote

"The idea of self-denial for the sake of posterity, of practising present economy for the sake of debtors yet unborn, of planting forests that our descendants may live under their shade, or of raising cities for future nations to inhabit, never, I suppose, efficiently takes place among publicly recognised motives of exertion. Yet these are not the less our duties; nor is our part fitly sustained upon the earth, unless the range of our intended and deliberate usefulness include not only the companions, but the successors, of our pilgrimage.

God has lent us the earth for our life; it is a great entail. It belongs as much to those who are to come after us, and whose names are already written in the book of creation, as to us; and we have no right, by anything that we do or neglect, to involve them in unnecessary penalties, or deprive them of benefits which it was in our power to bequeath.

And this the more, because it is one of the appointed conditions of the labor of men that, in proportion to the time between the seed-sowing and the harvest, is the fulness of the fruit; and that generally, therefore, the farther off we place our aim, and the less we desire to be ourselves the witnesses of what we have labored for, the more wide and rich will be the measure of our success. [italics added]"

(John Ruskin, 1849, 176. The Lamp of Memory § IX)

Introduction

Problem and Contextualization

Informal settlements located on rivers' edges in impoverished Brazilian urban peripheries, such as in the Roncador River region in Duque de Caxias city (See figure 0.04), have been increasingly suffering from the effects of more intense floods. Informal housing on riverbanks is becoming more common in this region due to the growing housing crisis, lack of public investment in urban planning, and the capitalist logic intensification that generates land speculation, thus, exacerbating social inequalities and segregation. Consequently, their residents suffer from frequent floods and the lack of access to sanitation, increasing the risk of diseases and socio-economic impacts. The rivers in these informal contexts become the symbol of disruption and trauma when the flood occurs, creating an antithetical relationship between communities and rivers.

In the Roncador River neighbourhoods, as in several cities in Brazil and other peripheral countries, the uneven access to urban land and the informal housing production are typical problems derived from the unplanned urbanization process (da Silva et al., 2015). Because the government does not adequately address the needs of the low-income groups, the housing deficit keeps growing, which also increases the informal occupation of squatter settlements and slums as the only alternatives for the poor (Gattoni, 2009). In Duque de Caxias city, the chronic sanitation deficits worsen the informal residents' situation,

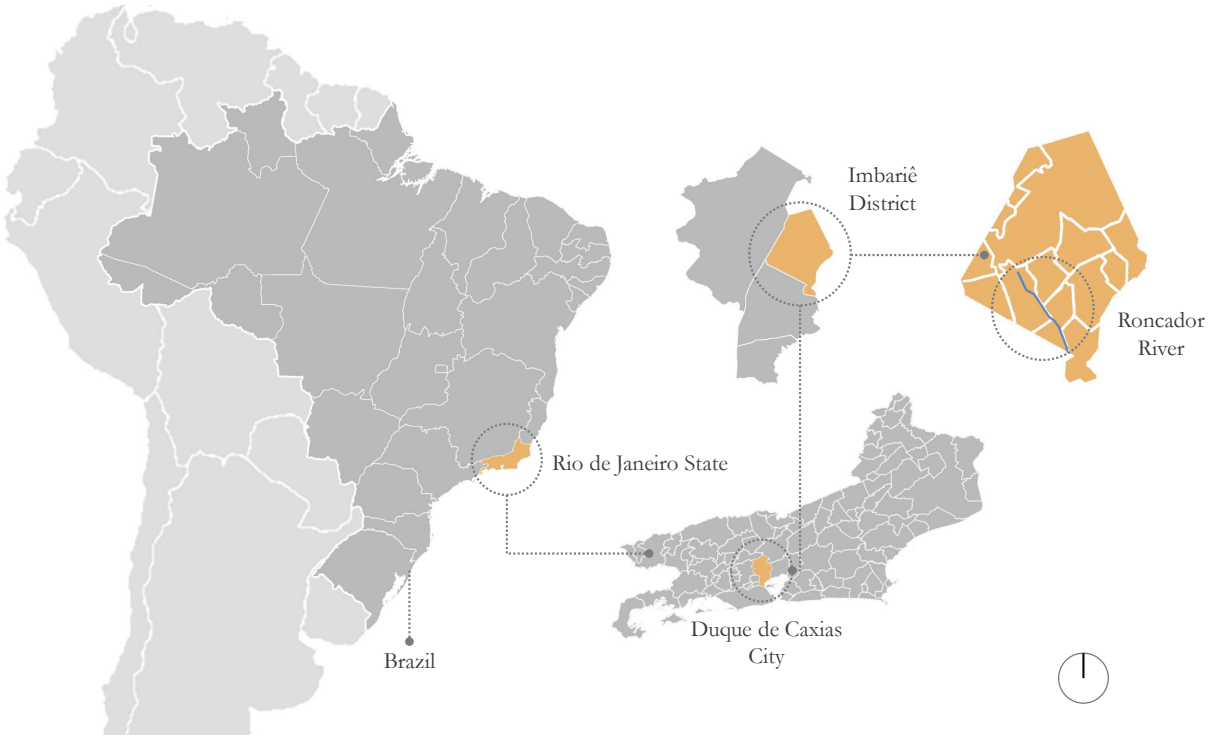


figure 0.04. Location of the Roncador River in a periphery in Brazil. *Source: Image by author*

especially for those located in risk areas such as on the rivers' edges. Since there is no sewage treatment system in the region, residents discharge their wastewater either in the drainage system, or in individual septic tanks, or directly into the river. The area also has more than 450 informal houses on the riverbanks and lacks recreational spaces. The frequent and intense floods threaten the local infrastructure, economy, and peoples' lives, generating numerous losses. It is imperative to address the housing problem in the Roncador River region, focusing on its river and seeking comprehensive responses that integrate both housing and water issues.

This thesis builds on previous research by the author in the Roncador River region, which focused on addressing the water quality issues by applying Water Sensitive Urban Design and Green Infrastructure strategies along the watershed (Ottoni and Britto, 2020; Ottoni, forthcoming). The main objective of this thesis is to expand the discussion to the housing issues within this "slum river"[1], identified as a gap in the previous research. Since the housing deficit in the region can increase by bringing a river restoration project, this thesis investigates alternative and long-term solutions to rehabilitate the riverbanks (and the watershed environmental qualities in general) while addressing the housing deficits reflected on the chronic informality issue.

The thesis investigates the place of in-betweenness: it questions the approaches to land division and edges. Land division and land value dictate who is worthy of inhabiting them, which excludes those who cannot afford it. The boundaries of valued lands are usually strictly respected and controlled, even if they are vacant. In contrast, other lands' edges, less valued, are neglected, becoming spaces of informality such as some riverbanks in precarious neighbourhoods. In vulnerable communities, such as some Duque de Caxias' settlements, edges nearby rivers are harder to define, where the occupation of instability (social, economic, and environmental) occurs. This in-betweenness is fundamentally about the threshold between land and water, where firm boundaries cannot be drawn since they are dynamic, transitory, and changeable by nature. The most vulnerable people inhabit this place of uncertainty, which occasionally is solid ground, and, suddenly, it transforms into rivers; at other times, it is some state in between water and land. Transformation is inherent to the Roncador River communities, including the own river's dynamics; it is part of life.

Notwithstanding, the top-down interventions, both in rivers and through the social housing program, reflect the destructive ideology of attempting to control and inhibit transformation and adaptation from happening. From channelizing rivers to the provision of rigid and poorly designed dwellings for the lowest incomes, the

1 Although the term 'slum' may not be the most appropriate one, as Gilbert (2020) stresses this term as a negative stereotype that may undermine and stigmatize people already marginalized who live in impoverished settlements.

government has been hindering a healthy evolution of life in the region, promoting no possibility of accommodating natural changes in different life stages. The result is dramatic: the intensifying floods have been damaging the already precarious houses and facilities and transmitting diseases due to water pollution and lack of sanitation. Likewise, the flawed public housing program and the lack of policies to tackle the chronic social inequality and lack of housing affordability have been causing the rise in housing deficit rates. Informal living happens in this threshold between water and land, but also in between problems and opportunities.

This thesis acknowledges that it is imperative to accept transformation as part of life if we want to shift the paradigm that sees water as a problem to water as a solution. This way, it would be possible to build the community's adaptive capacity to accommodate the increasingly uncertain changes that are natural to life, by seeking less rigid responses. Adaptation and flexibility allow transformation to happen without disturbing the system. As an analogy, houses should be like rivers: they should have space and opportunity to change according to the flow. That is why margins are essential; they are the spaces that are flexible enough to allow transformations to happen.

Therefore, living "on the margins" in the Roncador River region is not only about the excluded and marginalized people from society, forced to live informally in the most precarious ways. It is not also solely about the fact that they inhabit riverbanks because there is no option left for them. It is primarily because margins can be opportunities for improvement. They are spaces that allow transformation to happen, as the analogy with the river dynamics. The housing design, especially for these vulnerable communities, should incorporate the concept of "margins", accepting changes, and seeking a more adaptable approach that supports transformations over time by the users. An adaptable design would ultimately improve residents' lives and help reduce their vulnerability.

Research Question and Statement

In the context of a degraded urban watershed characterized by informality, which actions could trigger a transformation toward a more sustainable way of living? Sustainability, in this case, would entail river rehabilitation while enhancing the community's capacity to adapt to floods and improve their lives on a long-term basis. Which low-cost and low-impact design strategies would succeed in addressing the informal housing issues, from adapting to floods until empowering residents to reduce their vulnerability and increase their resilience? What architectural and urban design solutions would support a harmonic urban growth in the Roncador River surroundings, allowing both the community and nature to sustainably flourish together?

It is paramount to seek planning and design alternatives to rethink the growth of this urban space. These strategies must foster a holistic and fertile relationship with the environment and address the needs and aspirations of the marginalized populations. In this thesis, *Water* and *Community* are the key elements for generating a more sustainable and balanced way of living in the Roncador River region and will be combined in multiple scales to guide the design proposition.

The emphasis on economic growth in the previous centuries has been problematic because it has disregarded human rights and environmental preservation. The French philosopher Félix Guattari (2000) highlights the "three ecologies" as a framework toward more sustainable communities. In its efforts to increase profit, capitalism has generated ecological, social, and individual disequilibrium and separation, reducing environmental and comunities' capacity to adapt (Guatarri, 2000). Therefore, sustainability can be achieved by focusing on the interdependent relationship between communities, individuals, and the environment thought of as intertwined systems that are adaptable. A holistic response should address the three realms as if they were only one, in an integrated way. The socio-ecological problems in the Roncador River region evidence a disequilibrium in these three areas. Ecological degradation, lack of individual and social quality of life, social inequalities, and the absence of access to basic needs are common ground in this region.

David Harvey, a British economic geographer, mentioned the "right to the city" as not only the right to access resources embodied in the city. More importantly, it refers to the right to change oneself by having the agency to transform the city and participating in place-making, which entails a collective power to modify the process of urbanization (Harvey, 2008). It directly relates to the adaptive capacity of both individuals and groups triggered by an increased autonomy to make decisions on the housing and city-making processes. The *right to the city* criticizes the privatization and commodification of housing, land, and urban space,

which exclude some groups from using and transforming the space due to the focus on profit (Aalbers & Gibb, 2014; Samara, Sinha, & Brady, 2013). Similarly, the *right to housing* is not only to have access to a physical structure to live (a shelter) but the articulation with a variety of related policies that guarantee the right to the city and access to its services (Balbim, 2011; Rolnik, 2014). The process of urbanization, while absorbing the capital surpluses, entailed the dispossession of impoverished classes of the right to the city, forcibly relocating them to remote peripheries as a result of gentrification and privatization forces (Harvey, 2008). This process happened in the formation of Rio de Janeiro's metropolitan peripheries, such as in Duque de Caxias City. The Roncador River communities were formed by this process, where impoverished groups who could not afford to live in the formal city occupied the unserviced and abandoned lands in the fringes, usually in inadequate spaces such as riverbanks. Notwithstanding, these people have been adapting to this challenging situation with their resources by self-building with local materials and collaborating with their neighbours. Even in this adverse context, they created bonds and a sense of community.

In this scenario, surplus and underutilized urban land can play an essential role in allowing vulnerable communities to regain the right to the city. In Brazil, some laws and tools reinforce the social function of the city and the land to guarantee that all citizens have access to its services, including housing, albeit they have not been often practiced (Conti et al., 2014). Because vacant urban lands, whether public or private, must perform their social function, they provide an alternative for addressing the scarcity of affordable housing and public spaces for the poorest classes. Abandoned urban lands in Duque de Caxias, which, in the neoliberal system, act as the capital strategy for speculation, could instead be repurposed to fulfill the social needs, including housing, work, recreational, cultural, and public spaces. By focusing on redistributing underutilized lands to other collective uses, fostering local practices and economies, and providing residents with more agency over their spaces, these vulnerable communities will potentially regain the 'right to the city' and be empowered to thrive. Those who informally live in at-risk areas along the Roncador riverbanks would benefit from being relocated to vacant and safer lands within their neighbourhoods. Besides reducing the residents' vulnerability, their relocation to safer lands and proper housing in their community would also give the banks back to the degraded river to perform its natural processes and allow for restorative practices to take place.

The motivation for this thesis is to promote a paradigm shift from the rigid and profit-centred model to one focused on nature and on creating vibrant and adaptable spaces for the community to thrive. By envisioning water not as a problem but, alternatively, as an opportunity to

enhance the local community's life, this thesis is grounded on conceptual and practical approaches to allow the living-with-water framework to transform vulnerable flood-prone communities into adaptable and resilient. The focus lies on discussing the destructive practices of informal living on the riverbanks, both socially and environmentally degrading. The analysis is not limited to the riverbanks but is extended towards the urban fabric of the surrounding neighbourhoods.

Existing Literature

Aquatecture is a promising approach to sustainably envision and shape our cities, given the increasingly uncertain future ahead of us. Characterized by having water at the forefront of urban planning and design, this framework supports development growth while managing flood risk (Barker and Coutts, 2016). By bringing nature-based design strategies focused on increasing soil permeability, it questions traditional and rigid flood-control structures and fosters low-impact alternatives to strike a balance between development pressure and environmental demands. Consequently, their proposed interventions are very beneficial to communities and the environment because they are multipurpose. Ultimately, Aquatecture solutions to urban design help restore degraded river systems, as these measures improve environmental qualities and prioritize redistribution of space to ensure the water has enough room for its dynamics in an urban context (Barker and Coutts, 2016).

In the end, the paradigm shift predicated by Barker and Coutts (2016), with which I could not agree more, is to see water as an ally. And because water is powerful, and in many cases, it becomes a threat, we must learn to respect it, adapt to it, and transform it into advantages for us. Aquatecture speaks about the importance of adapting on several scales instead of attempting to control nature, which is why this concept is essential for this thesis. The authors demonstrate that working with water (and nature) is less expensive, less detrimental, and healthier for our cities in the long term. The only option for a more sustainable future is learning to live with it if we want to be resilient. This means accepting water dynamics and incorporating them into the design in an integrated approach.

An essential characteristic of the Aquatecture framework is that its design strategies must work across scales to be successful and efficient. Barker and Coutts (2016) describe the different interventions that are more appropriate for regional, city, neighbourhood, and building scales. This thesis works with three major scales for analysis and design application of Aquatecture strategies: watershed, neighbourhood, and building. Water permeates each scale in different ways. In the first two scales, water-sensitive interventions refer to increasing permeable surfaces and the quantity of space for accommodating water dynamics within the city.

In the building scale, amphibious architecture responds to the principles of Aquatecture by protecting houses from flood damages, not by controlling floodwaters but by accepting, adapting to, and working with them (English et al., 2016). This flood adaptation solution is designed to temporarily float when the flood occurs due to its buoyant base and rest again on the ground when the flood is over, reflecting an intention to interact with the water rather than denying it (Watson and Adams, 2011; English et al. 2016). Elizabeth English has been developing strategies to retrofit homes

based on the concept of amphibiation by using a buoyant foundation as a low-cost, low-impact, and place-specific solution for flood adaptation (English, 2009). As proved by English's work, this strategy works well in low-income contexts of developing countries and, thus, will inform this thesis and the proposal. Amphibious Architecture also interconnects with the holistic Aquatecture approach, and both can be applied to this thesis as flood adaptation measures that complement each other in multiple scales.

Besides addressing and incorporating floodwater into the design, other water-sensitive initiatives on the building scale can also refer to value rainwater and wastewater to seek a cyclical approach. By increasing their visibility and assigning them a function within the building processes, instead of treating them as waste, we acknowledge their role and importance in the water cycle and return it to the source without harming nature. To this end, it is essential to work with alternative water treatment processes, which will involve integrating with the neighbourhood scale.

However, a challenge with using the Aquatecture approach in consolidated urban settlements, especially in low-income informal communities, as is this thesis' intention, concerns the possibility of eviction. Applying this approach within the Roncador River context would mean removing the informal settlements located on its edges and relocating their residents, likely increasing the housing deficit. Consequently, their resettlement under the public housing policy in Brazil would probably redirect them to low-quality buildings in distant places, reducing their quality of life and disrupting their community life. Past top-down interventions in rivers for urban renewal only accelerated gentrification processes because the local communities were neglected, as it was not profitable to include them in the project process. Similarly, Aquatecture riverine interventions, if not conducted appropriately, can generate *green gentrification*[2], eventually resulting in the forced displacement of impoverished residents. It is imperative to find a solution that keeps low-income residents in their communities to harness a healthier riverscape.

Previous public housing programs in Brazil have provided residents with low-quality, homogeneous, and poorly designed housing units located in distant and unserviced lands, which disrupted these populations' livelihoods and community bonds (da Silva et al., 2015). The current National social housing program in Brazil keeps neglecting the local communities' aspirations, their struggles, and hopes for a better future, especially for the most impoverished families, addressing housing as a commodity (Placido et al. 2019; da Silva et al., 2015; GT Habitação e Cidade, 2020). And, most importantly, the government has been producing houses for the poor that are not capable of being transformed to adapt to the different users' needs over their life stages. This thesis discusses

2 Green gentrification will be explained in more details in the Part 1 subsection 1.3

this chronic housing issue by grounding on the conceptual framework of evolutionary and adaptable architecture, which ultimately increases housing affordability and accessibility. It draws on the Open Building theory[3] developed by the Dutch architect John Habraken, in which housing production is seen as an interactive process of transformation over time by the user as the agent of change. This goal is possible by separating building elements into independent systems or levels, composed of the *support* and *infill* elements. Both aspects need to work collectively and individually, and are under the responsibility of different actors. Proposing a low-cost housing solution that adapts to floods and a myriad of families' needs over time is a challenge that the Open Building approach can accommodate in combination with the Amphibious Architecture concept. Ultimately, adaptable buildings increase sustainability and quality of life.

3 The Open Building theory will be more detailed in Part 2

Past research has shown that addressing public housing production alone is insufficient to solve the housing deficit and the resulting informal housing problems in Duque de Caxias City (da Silva et al., 2015). Because these issues are intertwined with many others, including the lack of sanitation, increase in urban floods, and river degradation, the situation becomes complex and challenging. Therefore, it is imperative to think about the housing problem in the Roncador River region in relation to its river and the lack of other services and seek comprehensive responses that integrate both housing and water issues. The Aquatecture interventions in the Roncador River region must be combined with a more adaptive housing strategy. This strategy should be based on:

1. Identifying vacant and underutilized lands in the region that could fulfill their social and housing functions.
2. Building new low-cost and incremental houses on nearby vacant lands, adaptable to floods and integrated with a holistic Aquatecture system in the watershed scale.
3. Relocating the impoverished residents from the riverbanks to the new nearby houses, which will enhance their capacity to adapt to floods and increase their agency and control over the housing space and production.
4. Implement an Aquatecture system to mitigate floods.

Better quality housing can be achieved by bringing *adaptability* under three perspectives: internal/external incremental design, flood-adaptation, and adaptability to the site-specificity (including climate, materials, and constructive knowledge). By repurposing vacant lands in the neighbourhood to fulfill the housing function through resettling at-risk people living informally on the riverbanks, it is possible to provide nature-based spaces along the river and toward the urban fabric to restore the ecosystem services while keeping the residents in their communities.

Methodology

The methodology was based on the analysis of the selected region's context to identify its main problems and opportunities, followed by a design proposition of a system of parks in the watershed scale integrated with housing on the micro-scale. The intermediate scale, comprising the neighbourhood area, was also addressed as a smooth threshold between the watershed and the housing scales.

This thesis' research method entails the combination of ***observations***, followed by ***analysis***, and then by an ***experimentation*** phase. The ***observations*** phase comprised: field visits, informal conversations held with a resident, analysis of photos and videos, and a literature review that searched for both published and unpublished works, including academic and grey literature, to analyze the flooding issues in the region. In sequence, the ***analysis*** phase entailed the investigation of the water-related problems and opportunities in the region. This phase also consisted of the elaboration of maps and diagrams to support the analysis of local issues. Finally, the last phase used what was learned during the analysis to develop ***experimentations*** through design. The intention is to test solutions that address the identified issues through the lens of selected theories studied in the Literature Review. This phase was followed by writing up the thesis, which started by defining the thesis structure, organizing the Literature Review sources according to this structure, writing up, and proofreading (See figure 0.05).

The steps in this research consisted of (i) conducting a comprehensive analysis of the Roncador River watershed, which was completed by searching scholarly sources and grey literature, and by utilizing photos and notes done during a site visit in 2019. In sequence, maps, plans, sections, and diagrams were produced, allowing the analysis of challenges and opportunities in the site; (ii) selecting three areas with different urban densities in this region for developing a more detailed analysis and further intervention proposition; (iii) conducting a literature review on river restoration and flood mitigation through the lens of the Aquatecture approach, and on evolutionary housing and amphibious architecture as solutions for social housing in floodable riverine areas; (iv) mapping underutilized and vacant sites in the region by using Google Earth and Google Maps, as the local vacant lands present a high potential to address the housing crisis and informality; (v) and selecting two of these vacant lands to (vi) propose two types of housing intervention (one as a single-family house for small vacant lots and another as multi-family building for bigger lots or vacant blocks).

figure 0.05. Timeline Diagram of research methodology.
Source: Image by author

Proposal

This study proposes the integration of nature-based parks along the river and within the urban fabric with amphibious evolutionary housing, which allows the residents to safely stay and grow over time in their communities and achieve flood mitigation and adaptation. The Roncador River watershed was selected to propose these interventions given its location within a metropolitan periphery with precarious informal settlements on its riverbanks. Water and Community are the key elements for the design proposal. This thesis approaches them in three scales (watershed/macro, neighbourhood/intermediate, and housing/micro), based on the LifE concept, within the Aquatecture approach, brought by Barker & Coutts (2016). In the housing scale, the Open Building approach will inform the design guidelines for a more adaptive and flexible house for low-income groups, thought to support future expansions and shrinkages according to the users' needs. Hence, the outcome is a community- and water-centred housing design strategically planned to be flexible enough to accommodate changes in the present and future. This proposition aligns with the context of river restoration and the proposed system of green areas, as all these solutions are adaptable to accept and work with water instead of being a barrier to it.

…

Because *Water* and *Community* are critical points to the design proposal, this thesis structure reflects the intention of weaving them together, both conceptually and by practical strategies, to inform the design for a flood-resilient and evolutionary community. Accordingly, three parts compose this thesis:

Part 1 explores the central theme of *water* and the importance of an integrated approach for addressing flood issues. Subsection 1.1 aims to discuss the water-related problems in the Roncador River context. The chapter starts with discussing the effects of the rapid urbanization processes in peripheral cities like Duque de Caxias, including considering the impacts of climate change. In sequence, it investigates the Roncador River characterization and its urbanization process history within the Metropolitan Region of Rio de Janeiro, which led to antagonism between communities and water. Subsection 1.2 reflects more conceptually on this separation and the antithetical relationship between man and Nature and advocates the necessity to learn lessons of resilience and sustainability by observing living systems. In addition, this subsection discusses what it means to be a sustainable community through the lens of Guatarri's three ecologies, subverting the neoliberal logic. By focusing mainly on water, this subsection recognizes Aquatecture, including the concept of Amphibious Architecture, as a promising conceptual and practical framework that encompasses strategies for living with water across scales to generate

more flood resilient and sustainable communities. Finally, subsection 1.3 proposes an in-depth examination of the Aquatecture approach specificities, analyzing the design strategies at multiple scales. Drawing on the LifE approach proposed by Aquatecture, this thesis uses its three principles (making space for water, living with water, and eco-design) as guidelines for informing design strategies in the watershed / macro scale, neighbourhood / intermediate scale, and building / micro scale.

Part 2 investigates *community* as a core theme and the need for adaptive living to support sustainable growth. It focuses on the social realm for analyzing issues in the Roncador River context and discussing potential solutions. Subsection 2.1 examines the social problems and population characterization in Duque de Caxias city, particularly in the neighbourhoods surrounding the Roncador River. By bringing a historical perspective, the formation of peripheral cities in the Metropolitan Region of Rio de Janeiro resulted from processes of land value and displacement of the poorest groups, which characterized the evolution of Duque de Caxias city. This subsection compares the city's development process with the housing deficit associated with national public housing programs' failure to meet the housing demand. As well, it demonstrates the need for a more adaptable housing design for the lowest income groups. Subsection 2.2 discusses the importance of the right to the city and housing, under Harvey's perspective. It criticizes the existence and reproduction of vacant lands as a neoliberal speculation strategy and the dispossession process due to gentrification forces. Hence, it shows the potential of utilizing vacant lands within the neighbourhoods surrounding the Roncador River as a strategy to address the housing shortage and resettle people from inadequate and unsafe informal houses on the riverbanks. Finally, subsection 2.3 presents the design strategies from the Open Building approach and other frameworks for adaptability and flexibility to allow for an evolutionary housing production that puts the user and the community on the design core.

Part 3, by interweaving *water* and *community*, presents the design proposal for the regeneration of the Roncador River watershed integrated with the housing design for resettling the residents coming from informal houses on the riverbanks. It applies the Aquatecture design strategies in three scales, the watershed, the neighbourhood, and the building realms, combining with design strategies from the Open Building approach for designing the housing interventions. Subsection 3.1 describes the proposal in phases of implementation. Subsection 3.2 presents the design intervention, based on the Aquatecture concept and design strategies, divided into the watershed, the neighbourhood, and the building scales. When describing the design strategy for the watershed scale, it provides recommendations for river restoration by proposing an urban linear park and integrating it with a system of parks and pervious areas within the interior of blocks, aiming to

mitigate floods and enhance environmental qualities in the region. These strategies address water and community because they foster stormwater infiltration while bringing vibrant public and recreational spaces. In the neighbourhood scale, the intervention comprises the connections between the urban linear park, the new proposed housing, and the parks and green area systems within the urban blocks. This strategy also encompasses thinking about alternative and sustainable solutions for local sewage treatment, which also represent an opportunity for collective practices such as local food production and support for local economies, thus responding to both water and community aspects. Finally, in the building scale, water is addressed by thinking about the water flow inside the house (rainwater harvesting and reuse and onsite black and greywater treatment) and providing an amphibious foundation to adapt to floodwaters. The *community* element is addressed by applying the Open Building design strategies to support adaptability, flexibility, and evolution over time by the families, according to their budget and life stage needs. It is also reflected in the use of available local materials and construction techniques, which allow the residents to expand their houses by their own means. Figure 0.06 summarizes this thesis structure in a diagram.

Impact

This study entails an alternative solution for urban flood mitigation and adaptation. It prioritizes local community knowledge and nature-based strategies towards a healthier riverscape and uses evolutionary housing to empower vulnerable communities. The intervention comprises a system of green spaces alongside riverbanks and throughout the watershed's urban fabric, integrating with amphibious low-cost housing. The thesis addresses the housing issues generated by implementing a riverside park in the Roncador River area. It also seeks to respond to the existing local housing shortage and poor-quality of social housing design, approaching quality in terms of location in the same neighbourhood and bringing a more adaptable design.

This thesis questions the current government responses, including omission, to address social housing and urban flooding in Duque de Caxias city. Its (in)actions not only disregard the existing problems but create additional ones. Therefore, this work proposes to apply water- and community-centred solutions as efficient, low-cost, and low-impact responses to generate a greater quality of life and agency to the local communities, empowering their resilience. Since the problems in the Roncador River surroundings are typical of metropolitan peripheries in Brazil, this thesis method could be applied to improve the livelihood of other riverine vulnerable communities in similar informal contexts.

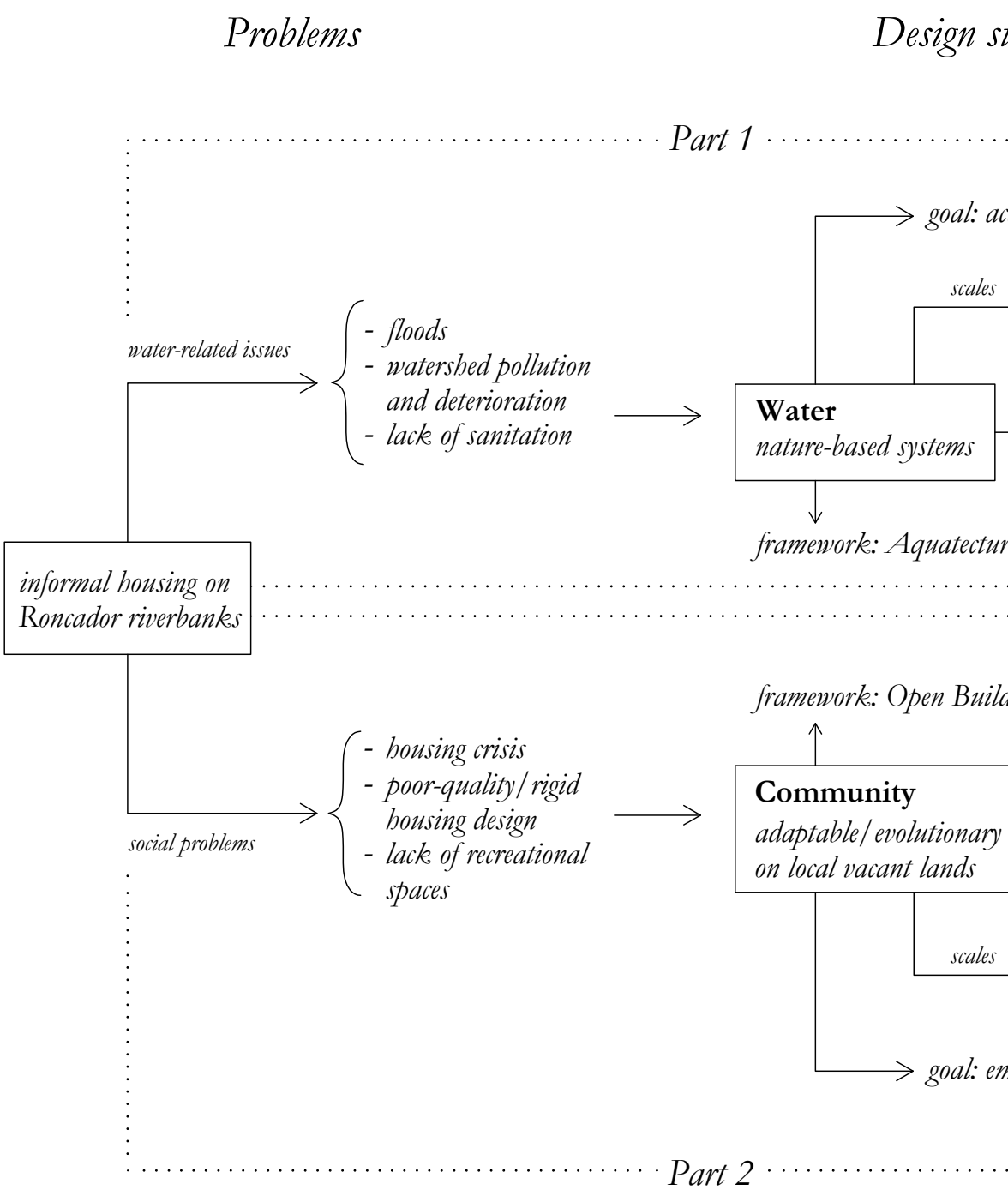
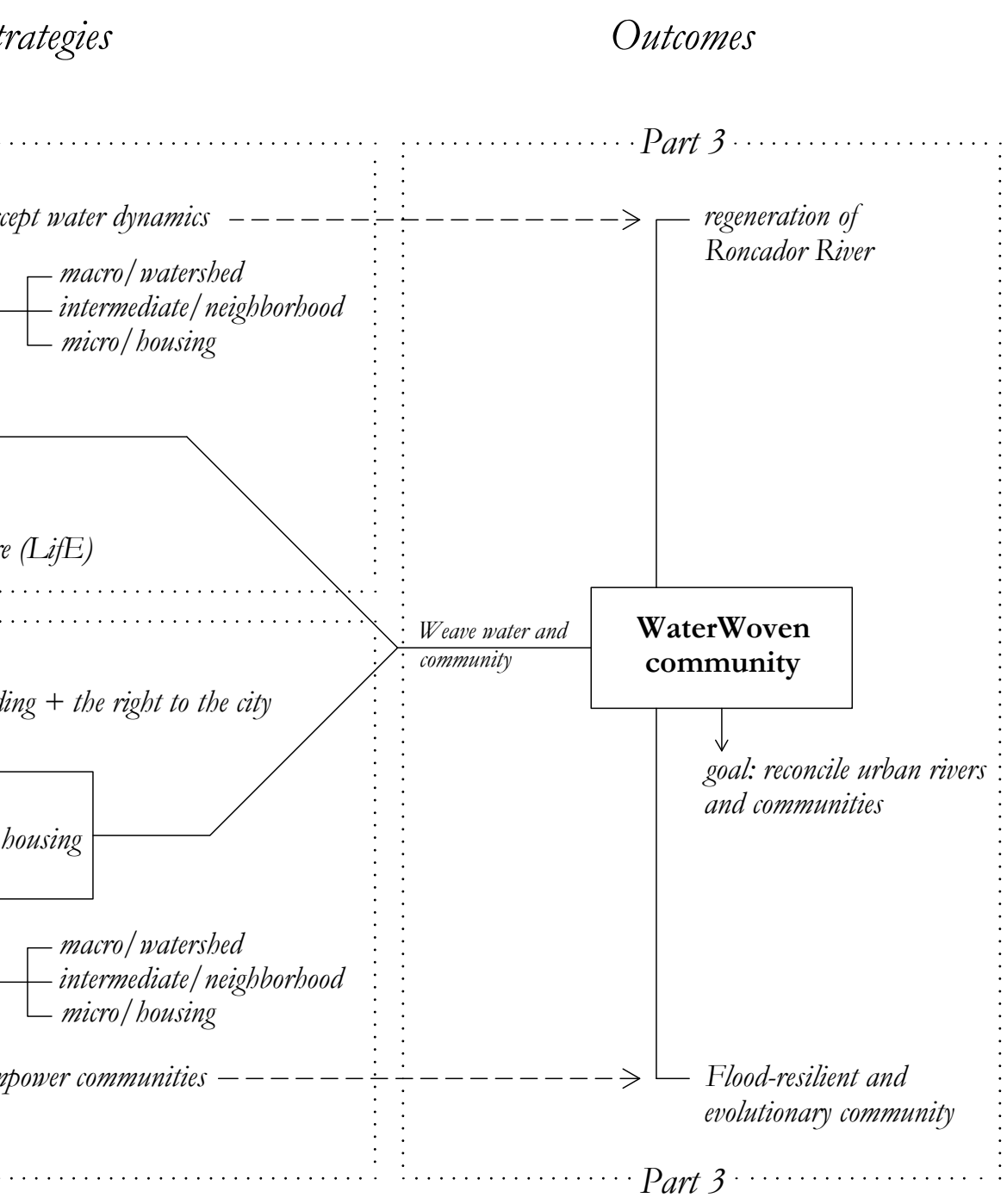


Figure 0.06. Diagram summarizing the problems addressed, the adopted design str
Source: Diagr



rategies, and the outcomes achieved in this thesis, which inform the thesis structure.
am by author.

Part 1 | Water

Integrated approach for flood mitigation and adaptation

1.1. Water-related issues in the Roncador River surroundings

The effects of rapid urbanization in peripheral countries and the intensification of urban flooding

The accelerated urban growth process that has been happening in the past centuries in many cities around the world generated several negative socioeconomic and environmental impacts. Particularly since the mid-twentieth century, these problems have been intensified due to the "Great Acceleration", causing climatic instability and massive species loss (Steffan et al., 2015), and a hyper-separation of humans from nature (McHarg, 1969; Hough, 1995; Gibson-Graham et al., 2016). The impacts of population growth, urbanization, and land-use change have been aggravated by the effects of climate change on freshwater systems and will get even more intensified due to the increase of water demand in the coming decades, directly affecting water infrastructures (Kundzewicz et al., 2007). Inconsequent anthropic modifications on the watersheds have been triggered by the development pressure, becoming one of the major causes of urban river systems imbalance as they have been dramatically reshaped and modified. Furthermore, the urban development toward rivers' floodplains has been a recurrent reality in the Global South countries. It is usually characterized by informal and precarious settlements located in peripheral landscapes and comprised of low-quality dwellings that lack several services and infrastructure (Grasshoff, 2020; Sánchez-Calderón, 2017; Penning-Rowsell, 2020). Urban areas are getting increasingly denser nearby riverine environments, pressuring the government at various levels to address the housing stock and plan areas for future expansion (Penning-Rowsell, 2020).

Our cities are experiencing a moment of disregard for social and ecological problems, in which economic development is prioritized without minding the consequences. As noted by Harvey (2008), urbanization, particularly under the neoliberal logic, has been fostering the absorption of capital surpluses (by privileging private property rights and profit) at the high cost of dispossessing marginalized groups depriving them of their right to the city. Consequently, the quality of urban life became exclusive for those who could afford it, which intensified spatial segregation, social inequalities, and individualism (Harvey, 2008).

The intensification of global climate change has been provoking more frequent extreme rainfall events and an increased risk of flooding in developed areas (Hettiarachchi, 2018; Pachauri et al., 2014). It has been posing risks to 20% of the world's populations that inhabit riverine floodplains. In addition, climate-induced floods have been disproportionally affecting low-income communities living in exposed areas but lacking basic infrastructure (Kundzewicz et al., 2007). Floods and erosions will be amplified in coastal and low-lying regions, projected to increase exposure and displacement (Pachauri et al., 2014). Flooding is one of the most impacting disasters worldwide, considered the fourth disaster that kills more people and the third responsible for the most significant financial damages within the past decades (Nunes, 2015). The ten worst flood episodes in the past two decades cost more than US$ 165 billion with damages and displaced over 1.1 billion people worldwide (CRED EM-DAT, 2015).

Brazil is among the ten countries hardest hit by floods in recent decades (COPPETEC, 2014), gradually increasing each year (Silva, 2009). Flood risk increases enormously in several Brazilian cities with human occupation on rivers' edges, disproportionately threatening these populations (Nunes, 2015). Millington (2018) and Sánchez-Calderón (2017) stressed that flooding affects particularly impoverished communities because of the enduring patterns of inequality and spatial segregation, which induces low-income populations to inhabit inadequate areas such as river edges and floodplains informally. Thus, it constitutes a scenario of chronic environmental injustice. Flooding can tremendously impact the most vulnerable by destroying properties and generating losses, economic impacts, residents' displacement and trauma of evacuation, livelihood interruption, and physical and mental health damages such as stress, depression, and chronic diseases (English et al., 2018; Thistlethwaite et al. 2020). According to English et al. (2016), current climate change mitigation and adaptation strategies require greater adaptability, which creates possibilities for the development of new housing types and retrofits that can better accommodate rapid and uncertain changes in the environment. Pachauri et al. (2014) and Watson and Adams (2011) indicate that vulnerability to floods in urban settlements can be reduced by building resilient infrastructure systems.

The urbanization process in Duque de Caxias city and in *Baixada Fluminense*

The Roncador River is located in the third district of Duque de Caxias city, part of the *Baixada Fluminense*[4] region within the Metropolitan Region of Rio de Janeiro, in the State of Rio de Janeiro (See figure 1.01). The extensive hydrographic network that composes the Baixada Fluminense

4 Baixada Fluminense is a low-lying region within the Metropolitan Region of Rio de Janeiro, composed of 11 cities. In the 19th Century it was a unique region, which suffered from an intense modification process during the 20th Century, and became associated with an image of periphery since the mid-20th century (Figuerêdo, 2016).

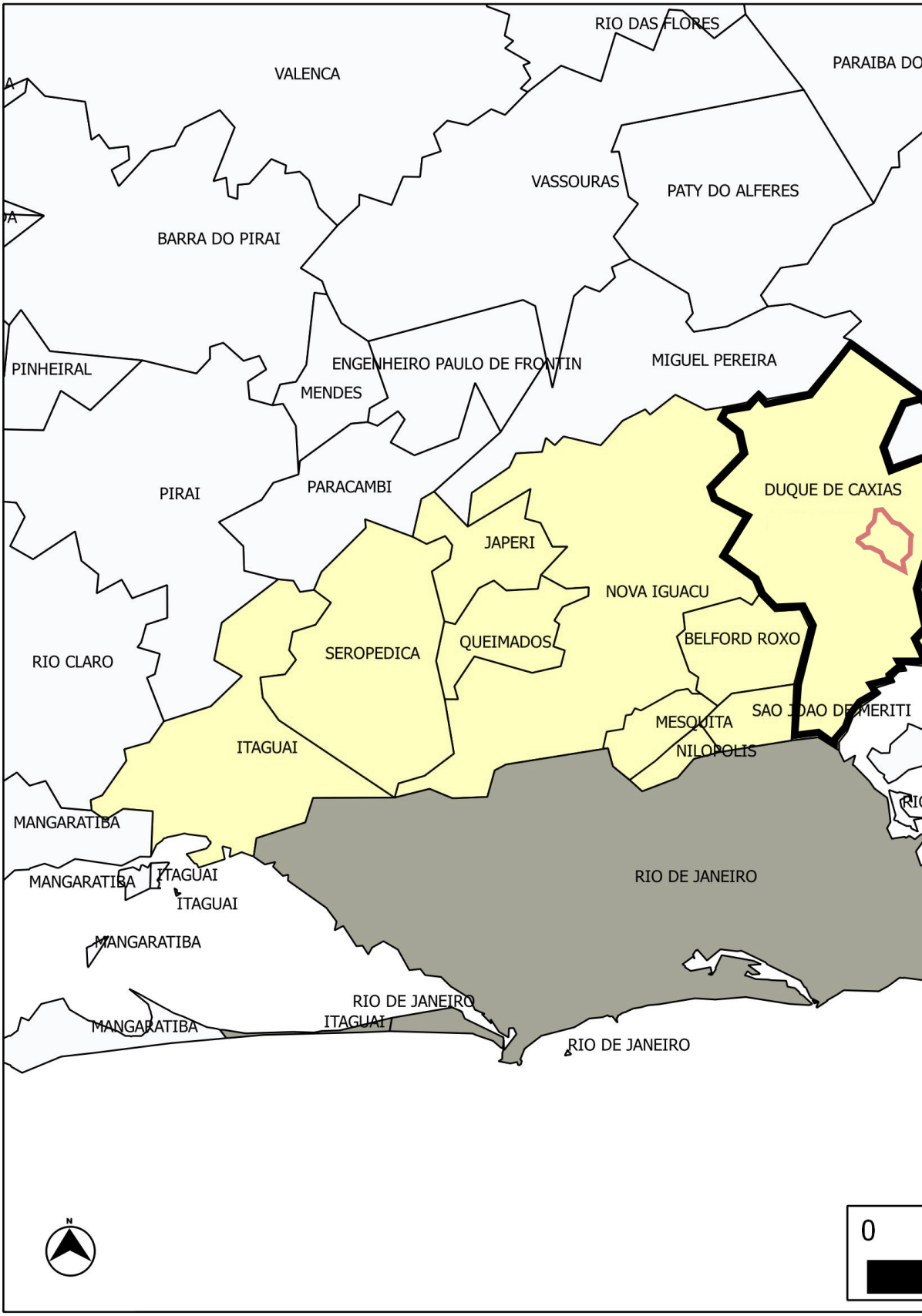
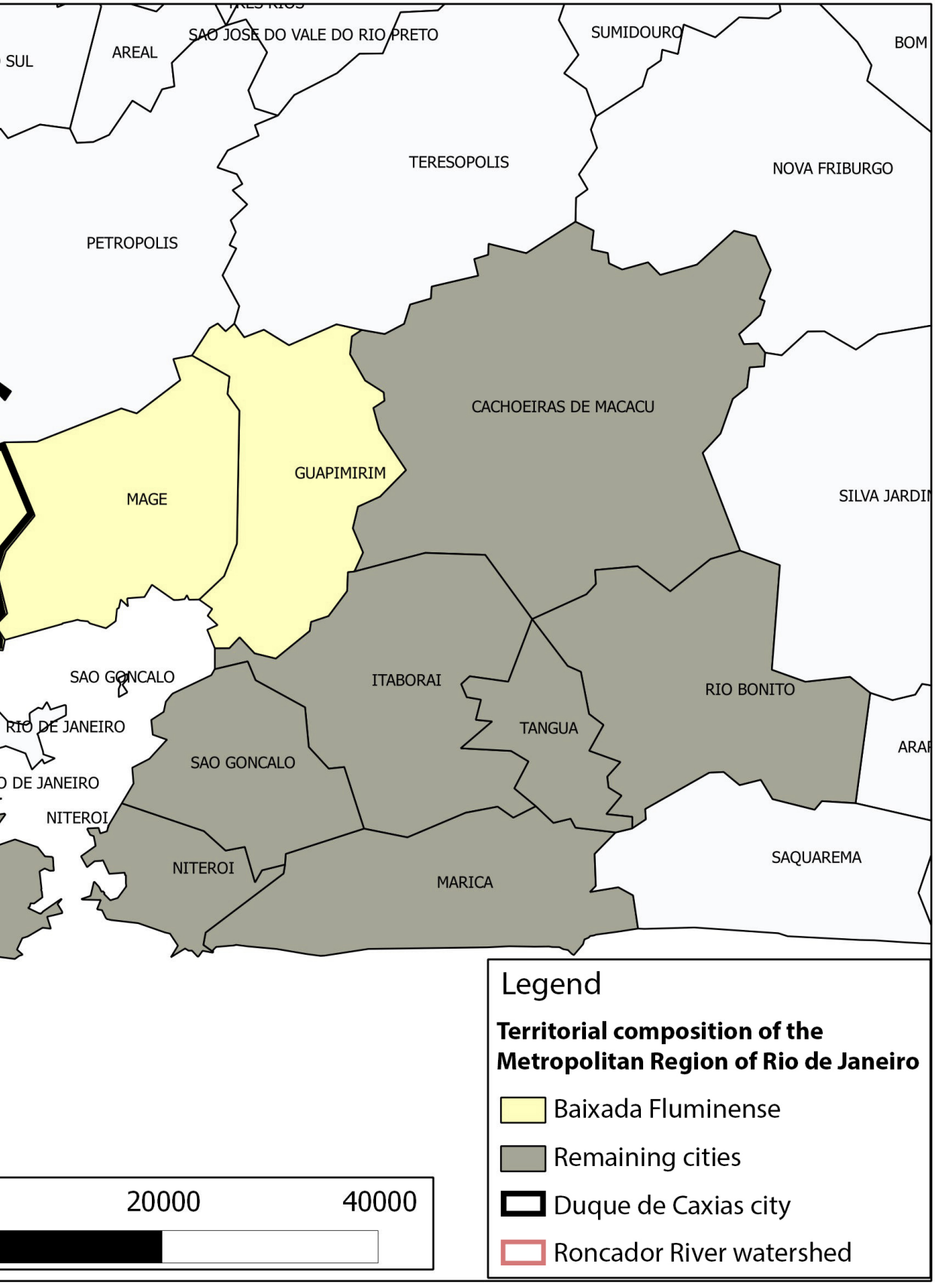


Figure 1.01. Baixada Fluminense map, highlighting Du
Source: Rocha, 2015. Adapt



uque de Caxias city and the Roncador River watershed.
ed and translated by author.

highly influenced its development since the rivers were the most used transportation mode for production outlets before the railway construction in the 19th Century, connecting the interior and coastal areas (Nogueira, 2008; Raulino, 2016). However, as Baixada Fluminense became more occupied, intense watershed deforestation occurred for timber harvesting. The prioritization of railway over water transportation led to the neglect of conservation works on rivers. Consequently, the rivers got more sedimented, and the lands became swamped, unhealthy, and a source of epidemics (Silveira and Ribeiro, 2017; Raulino, 2016). Frequent floods worsened the situation, making places like Duque de Caxias practically inhabitable, and thus, abandoned. Flooding has always happened in the history of the Baixada Fluminense's cities, including Duque de Caxias, mainly because of their low-lying geological characteristic and frequent precipitation due to the tropical climate (Oscar Júnior, 2013; Raulino, 2016) – See figure 1.02[5].

As pointed by Prominski et al. (2017), industrialization in many countries provoked massive river channelization processes to improve navigability,

Figure 1.02. Flooding was always part of Duque de Caxias existence, due to its low-lying geological characteristic. News article published in 1960. *Source: Duque de Caxias que passa, 2017.*

5 "Hooray!...Caxias has water! It doesn't need plumbing; it doesn't need anything. It only has a little rain and the water spills through the city streets. This is the only way that collectives (buses) do not run in our streets. And for those who do not believe in the existence of water in Caxias, the liveliest of reporters alive in Caxias, publish this photo, which is a masterpiece of the history of water in this land of Lime and Orange, I mean, e Silva."

(translation by the Author)

reclaim land, and protect cities from flooding. In the past two centuries in the Duque de Caxias, the government applied several traditional flood control interventions to prevent river sedimentation and floods. Based on conventional engineering practices of urban stormwater drainage, these interventions focused on quickly discharging pluvial waters away from urban centers (Millington, 2018; Prominski et al., 2017). Such efforts sought to create more space for urban and population growth processes, address sanitary issues related to swamps, and eliminate diseases such as malaria (Raulino, 2016). Nevertheless, they worsened the floods and were criticized for not integrating with the comprehensive regional planning (da Silva et al., 2015; Oscar Júnior, 2013; Raulino, 2016). Measures such as deforestation, river channelization, straightening processes, dredging, and other river interventions, have changed the natural course of water bodies, impacting the watersheds' health (See figure 1.03). In addition, as stressed by Molle et al. (2009), these massive hydraulic interventions worked to control not only the river waters but also the space and people, as they dictated how the space would be occupied and by whom.

Before these interventions, the local rivers had a meandering morphology, with ample margins to accommodate the dynamic natural sedimentation process, as shown in figure 1.04. These measures were accomplished by establishing seven sanitation committees since the end of the 19th century and creating the National Malaria Service and Sanitation Directorate of

Figure 1.03. Rectification of a river in Duque de Caxias city in 1943. *Source: Duque de Caxias que passa, 2017.*

Baixada Fluminense in 1936, which provoked the mangroves' removal (Cardoso, 2010; Raulino, 2016). As a result, the committees cleaned more than 6000 kilometres of rivers, greatly reduced the number of diseases, and improved the economy, although they freed up areas for capitalist accumulation (Britto, Quintslr, and Pereira, 2019). After implementing these engineered works on water bodies by the mid-twentieth century, Duque de Caxias attracted people to live in its lands (Silveira and Ribeiro, 2017). Notwithstanding, more systemic interventions toward sanitation services in Duque de Caxias only started to be implemented by the mid-1980s, including urban drainage and flood control measures (Raulino, 2016; Royse, 2009). Consequently, their legacy generated destructive floods in Duque de Caxias over the last decades, especially because they increased deforestation and impervious surfaces (Raulino, 2016).

Figure 1.04. A meandering river in Duque de Caxias city before channelization and rectification interventions started. *Source: Duque de Caxias que passa, 2017.*

Figure 1.05 shows the Roncador River's current watercourse compared with its meandering course before the rectification intervention at the beginning of the twentieth century. The start of the urbanization process in the Imbariê district coincided with the Roncador River channelization. Nevertheless, since 1950, when impoverished people from Rio de Janeiro's favelas started to be evicted due to urban renewal, Duque de Caxias' urban growth intensified.

In the Roncador River surroundings, the land occupation started between 1960-1980, mostly by low-income families that began to occupy lots on railway edges and later in the riverbanks, as shown in figure 1.06 (See Part 2 for more details). This region started to constitute a low-income suburban district since the land value was cheap and lacked proper urban infrastructure (See figures 1.07). Since there was no housing policy to address these impoverished groups, self-construction was the alternative found by the residents for housing production, sometimes configuring informal spaces (See figure 1.08). Figure 1.09 demonstrates that the people residing in the region positively connected with the river when it was still clean. This relationship changed over the years when the river started to propagate diseases due to contamination and generated trauma related to increased floods.

Figure 1.05. Roncador River watercourse be
Source: Adapted fr

efore and after the rectification intervention.
rom Ottoni, 2021.

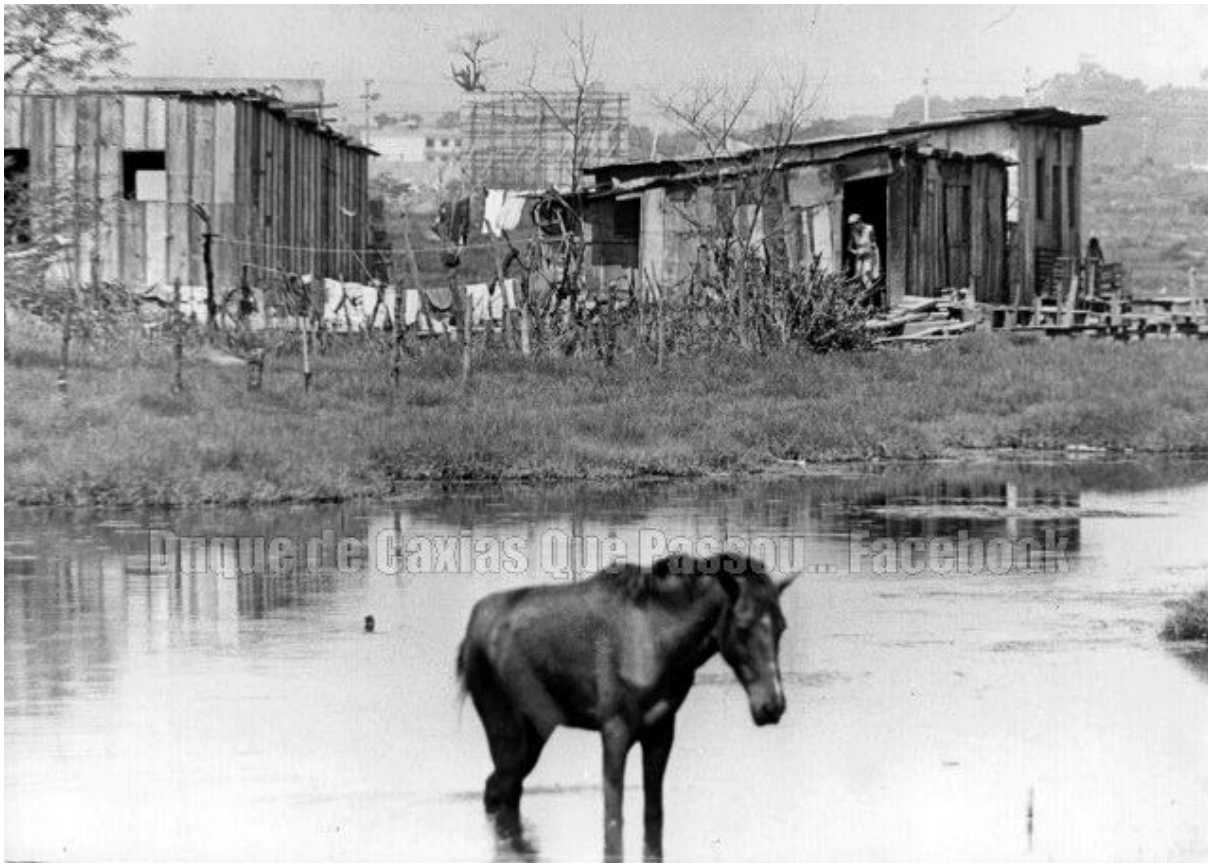


Figure 1.06. The beginning of unplanned urban occupation in the Imbariê district in the mid-twentieth century happened mostly on riverbanks and railway edges. *Source: Duque de Caxias que passa, 2017.*

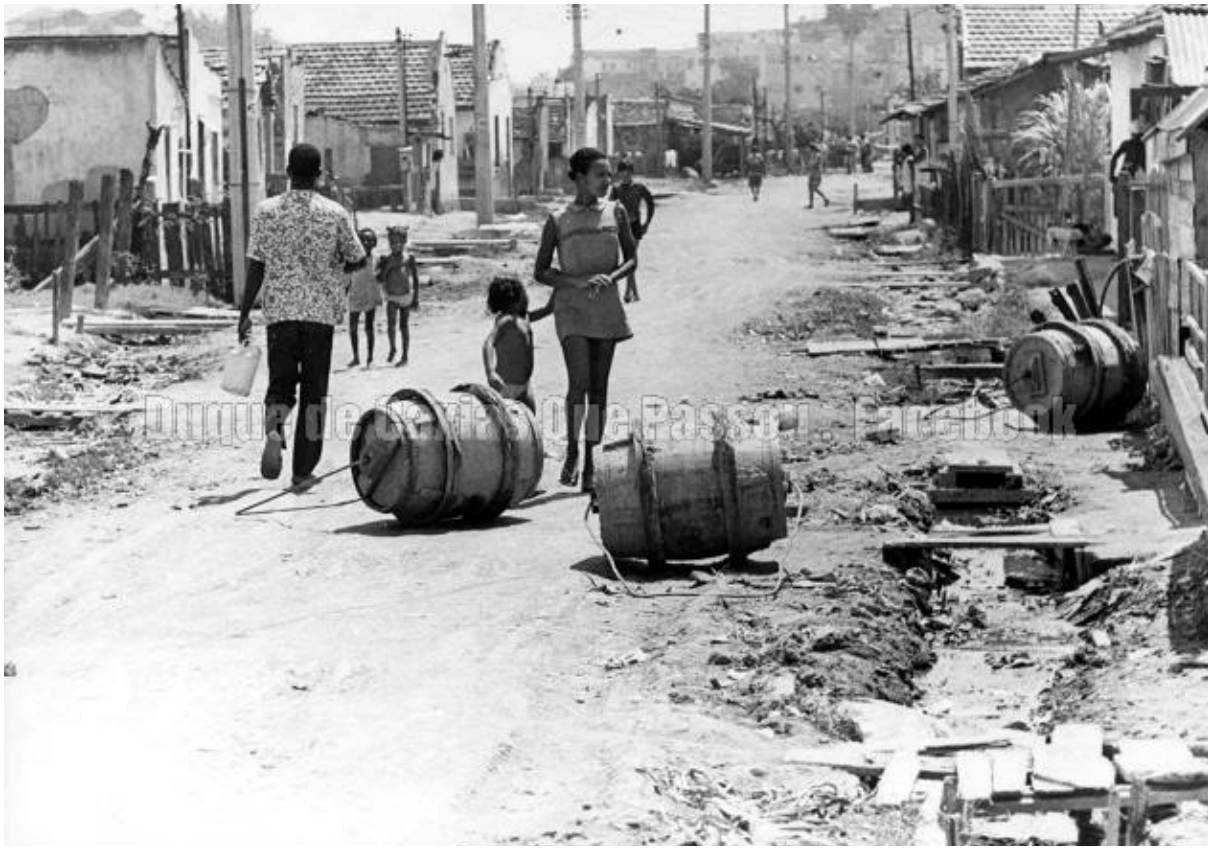


Figure 1.07. The beginning of unplanned urban occupation in the Imbariê district in the mid-twentieth century, lacking proper urban infrastructure. *Source: Duque de Caxias que passa, 2017.*

Figure 1.08. The beginning of unplanned urban occupation in the Imbariê district in the mid-twentieth century highlighting the practice of self-construction, often in floodable areas. *Source: Duque de Caxias que passa, 2017.*

Figure 1.09. In the beginning of urban occupation in Imbariê district, people and rivers had a positive relationship. *Source: Duque de Caxias que passa, 2017.*

Roncador River watershed characterization

Duque de Caxias city has a tropical climate and is a low-lying and flood-prone area, with altitudes close to the sea level, and where pluvial and fluvial drainage constitutes a challenge. Yet, these characteristics did not stop the urban occupation from growing, even faced by increased flood risk and lack of sewer system (da Silva et al., 2015). According to Oscar Júnior (2018), more than 40% of the Duque de Caxias territory has a high or very high susceptibility to rainfall, and the city has been suffering from rainstorms impacts at least since 1935 (Oscar Junior, 2015). In the Roncador River surroundings, the susceptibility to pluvial effects is very high (Oscar Junior, 2018), as the region's geomorphology is characterized by being a plain area, inappropriate for human occupation. In addition, the sea level rose an average of 1 centimetre per year between 1960 and 1980, impacting the drainage system and expanding the floodable areas in the region (Muehe, 2008; Oscar Júnior, 2018). Currently, the flooding level in the region is 3.5 meters (DCMDC, 2013). About 30% of the city presents a high susceptibility to floods, which corresponds to an area of 140.2 km2 (Neves et al., 2019). Figure 1.10 shows the flood and landslides susceptibility map in the Roncador River watershed, where the darkest shades of purple indicate higher susceptibility to floods. The dry season is short in Duque de Caxias, with the average annual temperature being 23.4 °C and rainfall being around 1704mm per year. Usually, the rainy season goes from October to April, with the most precipitation in January, and February is generally the warmest month of the year (EN-Climate-Data, 2021). Figure 1.11 juxtaposes a demographic density map with a flooding susceptibility map, demonstrating that the most occupied areas are, in fact, the most susceptible to floods.

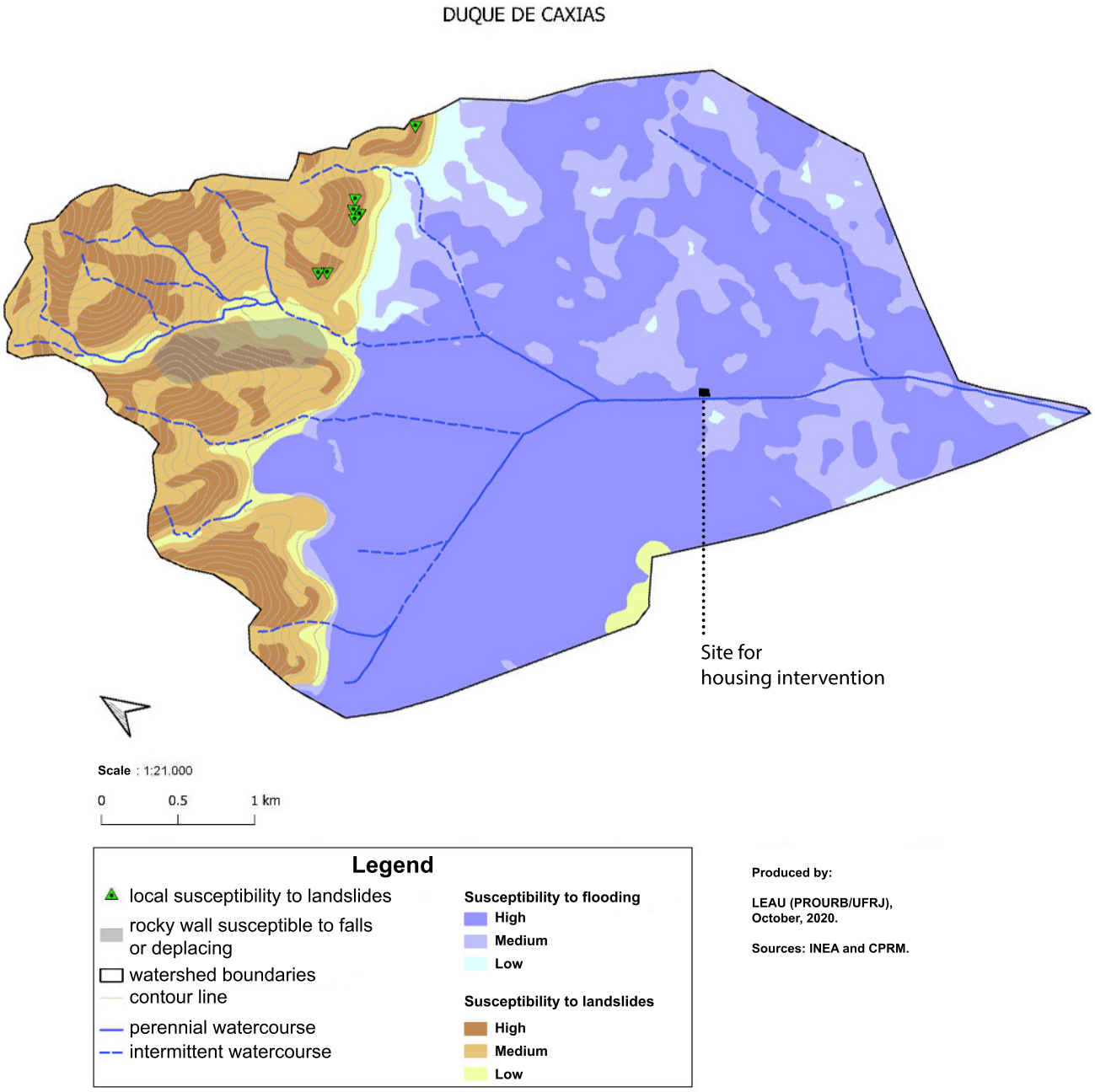


Figure 1.10. Map of susceptibility to floods and landslides in the Roncador River watershed.
Source: INEA and CPRM, elaborated by LEAU (PROURB/UFRJ) in October 2020.

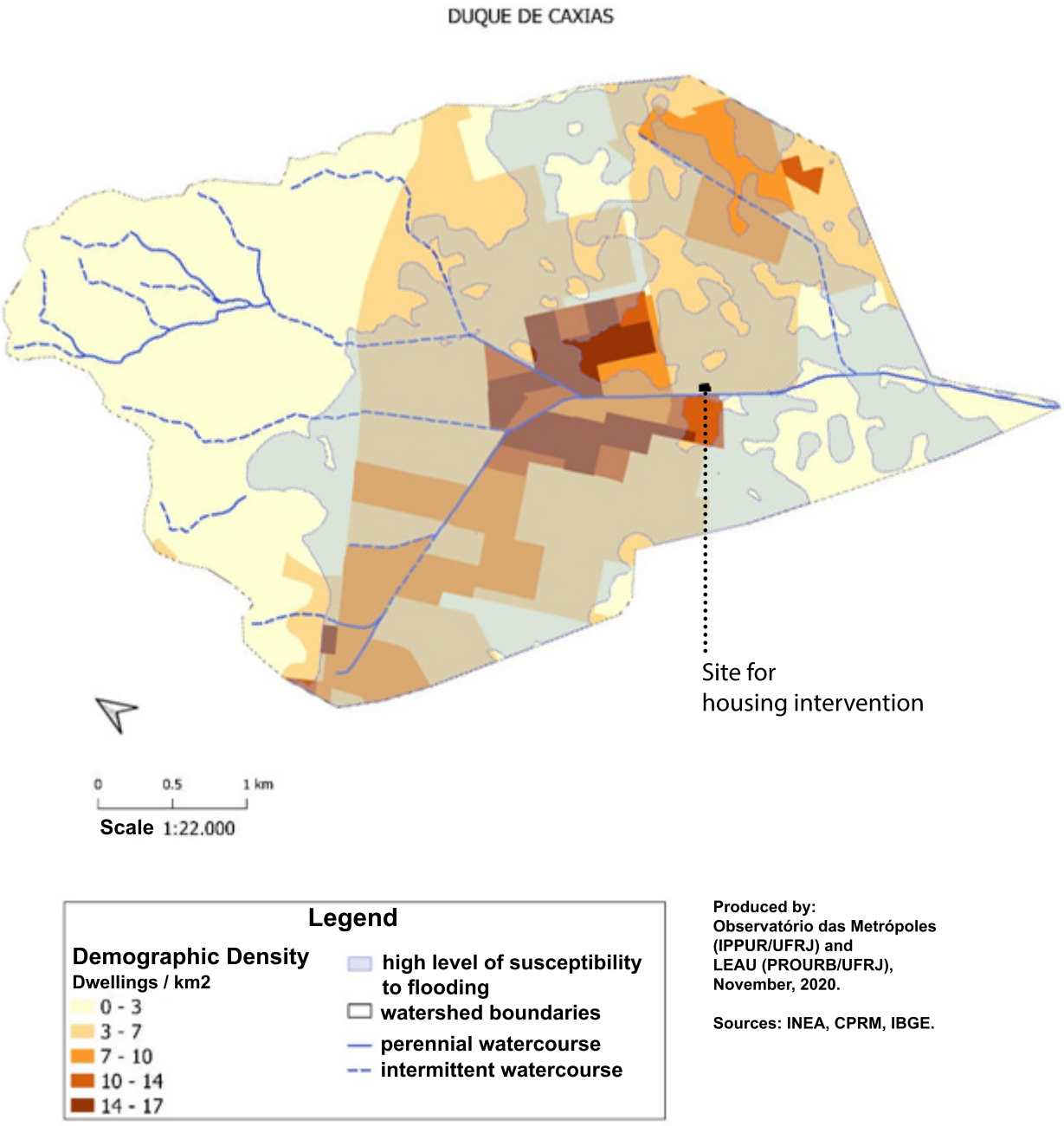


Figure 1.11. Map of demographic density in areas of high susceptibility o floods in the Roncador River watershed.
Source: INEA, IBGE, and CPRM, elaborated by LEAU (PROURB/UFRJ) and IPPUR/UFRJ in November 2020. Adapted and translated by author.

The Roncador River region has more than 450 informal houses on the riverbanks, besides lacking recreational spaces, as can be seen in figure 1.12. When informal urban settlements are located in floodplains or riverbanks, as commonly happens in the favela typology in Baixada Fluminense, efforts to implement sanitary infrastructure are hindered and definitely not prioritized by governments (Barboza, 2015).

As Millington (2018) stressed, there is a direct relationship between inequality, flooding, and tenure. The profit-centred urbanization process exacerbated social inequalities and spatial segregation, exposing the most vulnerable to environmental risk related to flooding (Raulino, 2016). Low-income marginal communities in Duque de Caxias' fringes live in what Yiftachel (2009) mentions as a 'permanent temporariness' reality. Their situation seems temporary because it relates to a lack of formal land tenure and essential infrastructure services, such as sanitation, rendering a low-quality life characterized by insecurity, trauma due to floods, and increased risk of diseases. However, it has a permanent character because these marginal communities do not have alternatives but live with unclear land tenure in the most undesirable lands (Millington, 2018). The region's more frequent and intense floods threaten the local infrastructure, economy, and lives, generating countless losses each year. Figure 1.13 shows a massive flood in the Roncador River in 2013, affecting the Parque Paulista neighbourhood and damaging 389 houses located closer to the river (Filho, 2013).

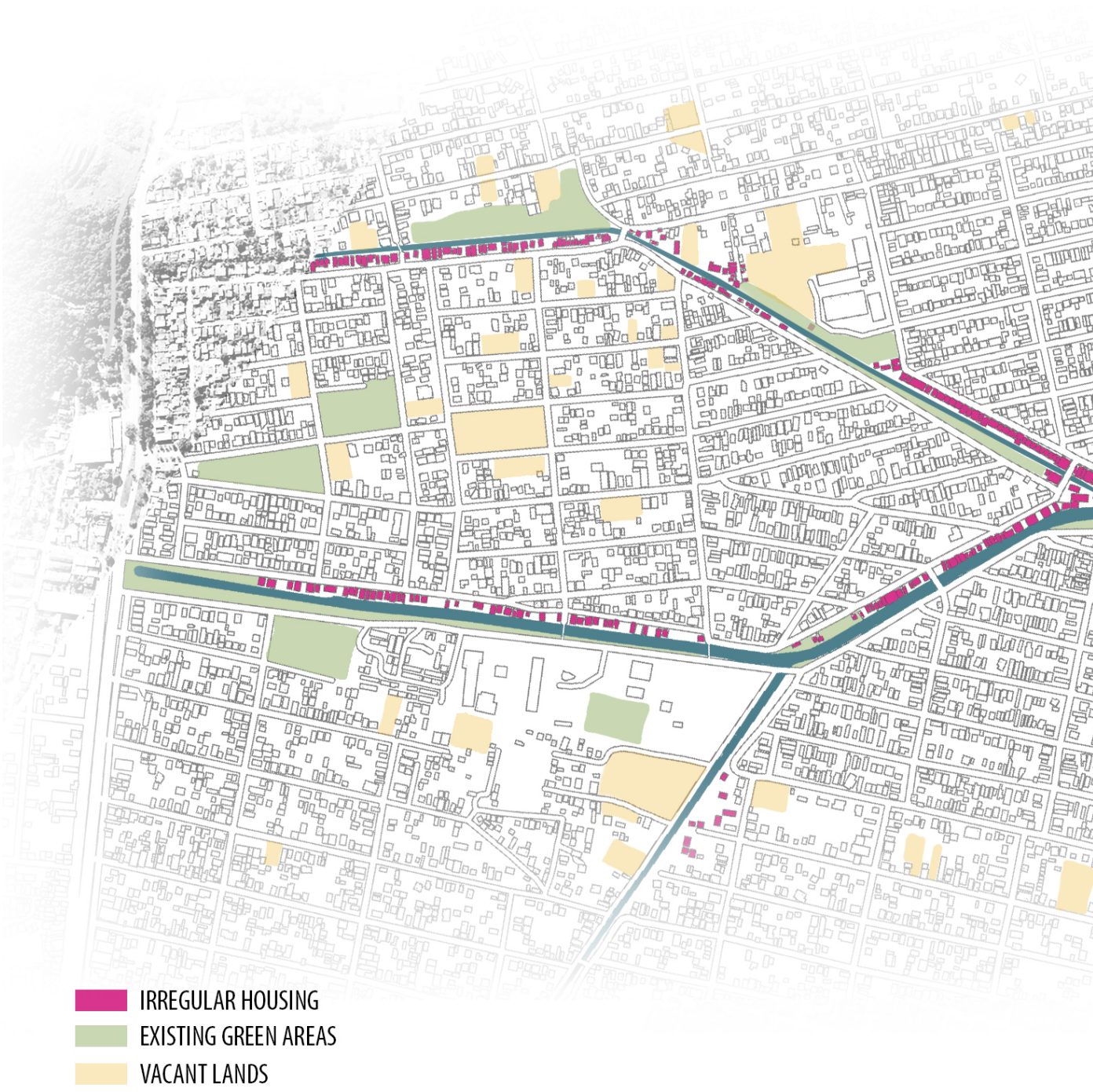


Figure 1.12. Contextualization and identificat
Source: Imag

ion of problems in the Roncador River region.
ge by author.

Figure 1.13. Flood in the Roncador River surroundings in 2013. *Upper and middle photos: Geraldo Roberto Fotografo, 2013. Lower photo: Daniele Meireles, 2013.*

In Duque de Caxias City, the historic sanitation deficits worsen the informal residents' situation, especially for those located in risk areas such as on the rivers' edges. Since there is no sewage treatment system in the region, residents discharge their wastewater either in the drainage system, in individual septic tanks, or directly into the river, as shown in figure 1.14. Consequently, as Costa (2017) documented, the region's pollution and surface and groundwater contamination have been generating several chronic diseases.

According to INEA (2001), the Population Vulnerability Map to Climate Change Impacts in the State of Rio de Janeiro indicates that one of the most vulnerable cities to climate change in the Health, Social, and Environment areas is Duque de Caxias. The city is also likely to be affected by the anthropogenic climate change due to the increase in precipitation rates and magnitude and sea-level rise, as shown in figure 1.15 (Raulino, 2016). Raulino highlights the disproportional risk of increased climate-related flooding to the population who inhabit Duque de Caxias' riverbanks, who are usually the most socially vulnerable groups and exposed to other types of risks (Raulino, 2016). This challenge will be aggravated in the coming years if the government does not address the housing issues and watershed preservation.

The housing problem in the Roncador River region cannot be addressed in isolation; an integrated approach allows a solution to be fully comprehensive and, therefore, effective to the context. The river and sanitation issues must be tackled at the same time, as they are imbricated. I argue that water must be interwoven with the community's interests and become more visible and valued in their routines to respond to this wicked problem. By rehabilitating the riverine system, from headwaters to riverbanks, increasing permeability, addressing residential wastewater on-site, and providing marginal residents with flexible and flood-resilient houses within their communities, it is possible to cultivate a long-term quality of life for both people and nature in this context.

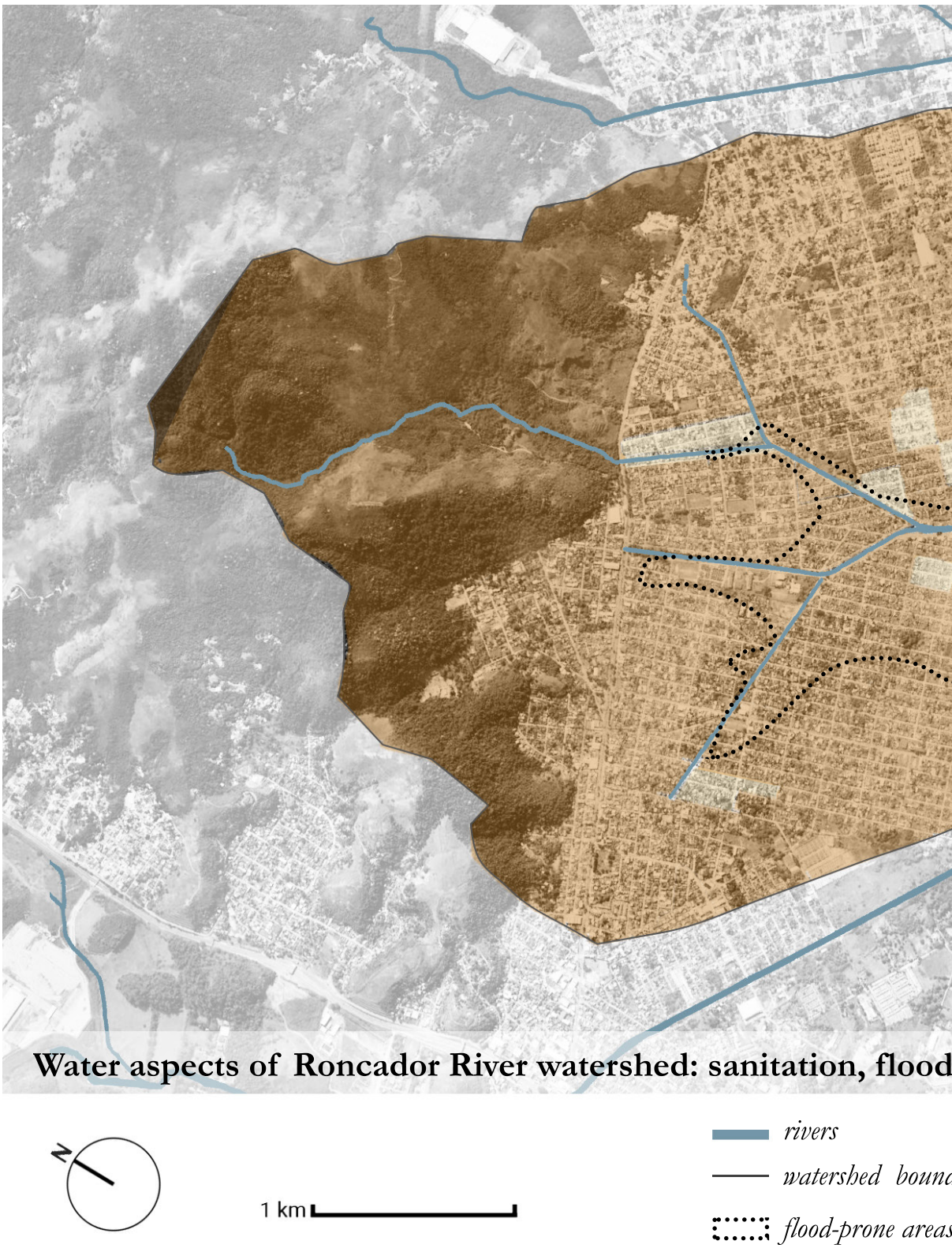
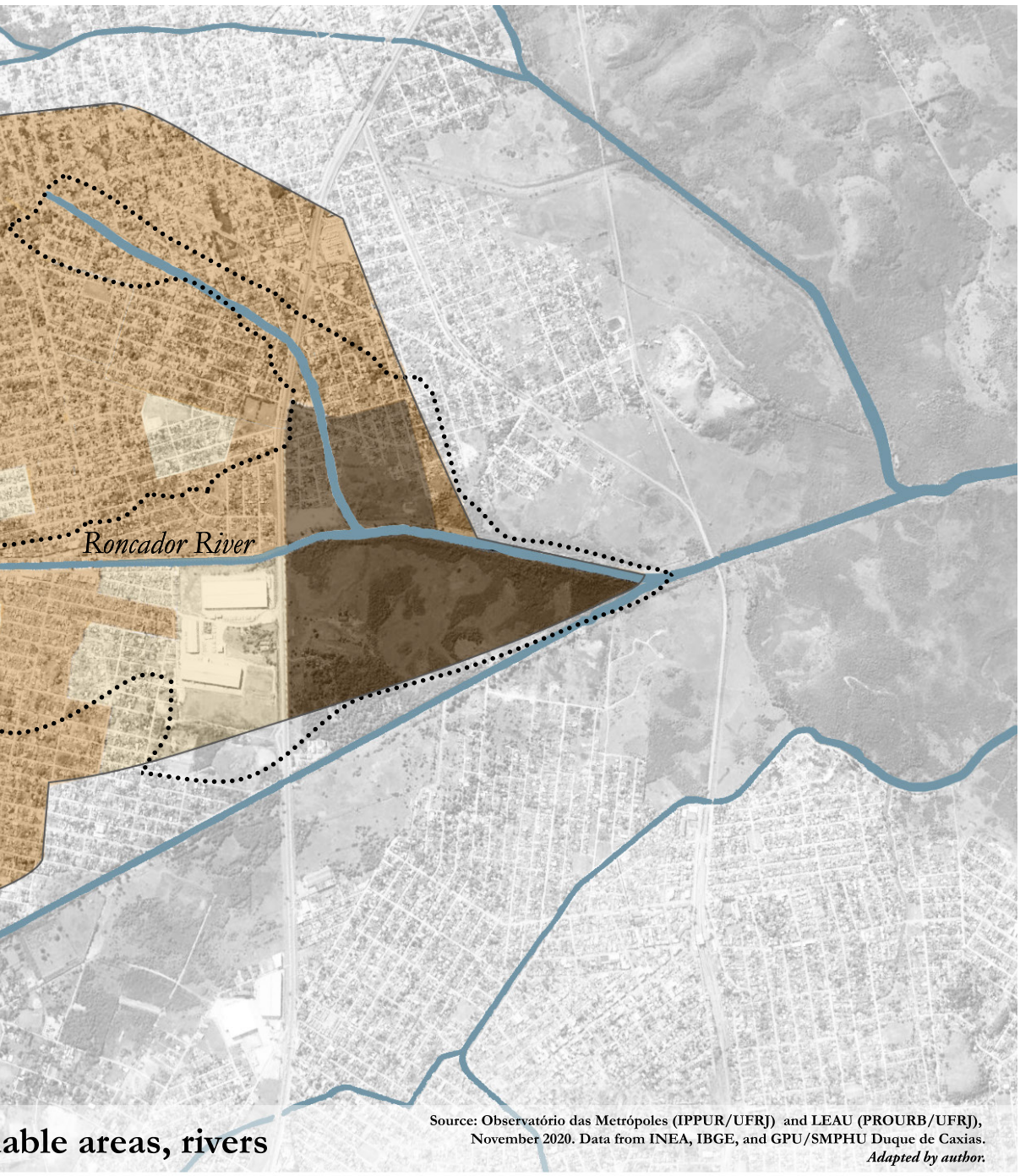


Figure 1.14. Water aspects of the Ronca
Sources: Observatório das Metrópoles (IPPUR/UFRJ) and Laboratory of Urban Water Studies, (LEAU / I
Adapted



dor River: sanitation and floodable areas.
PROURB – UFRJ) on November 2020. Data from INEA, IBGE, and GPU/SMPHU Duque de Caxias.
by author.

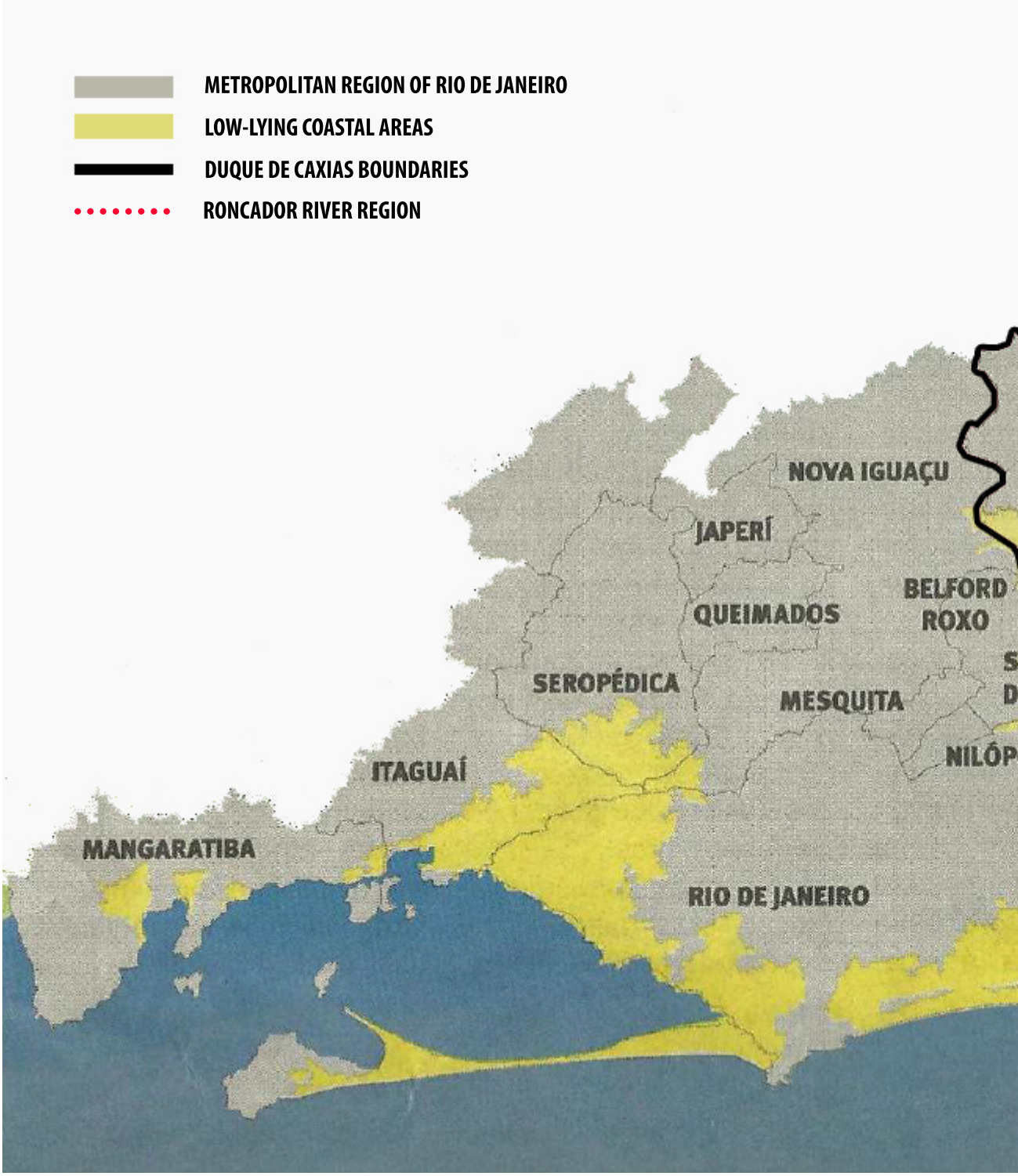
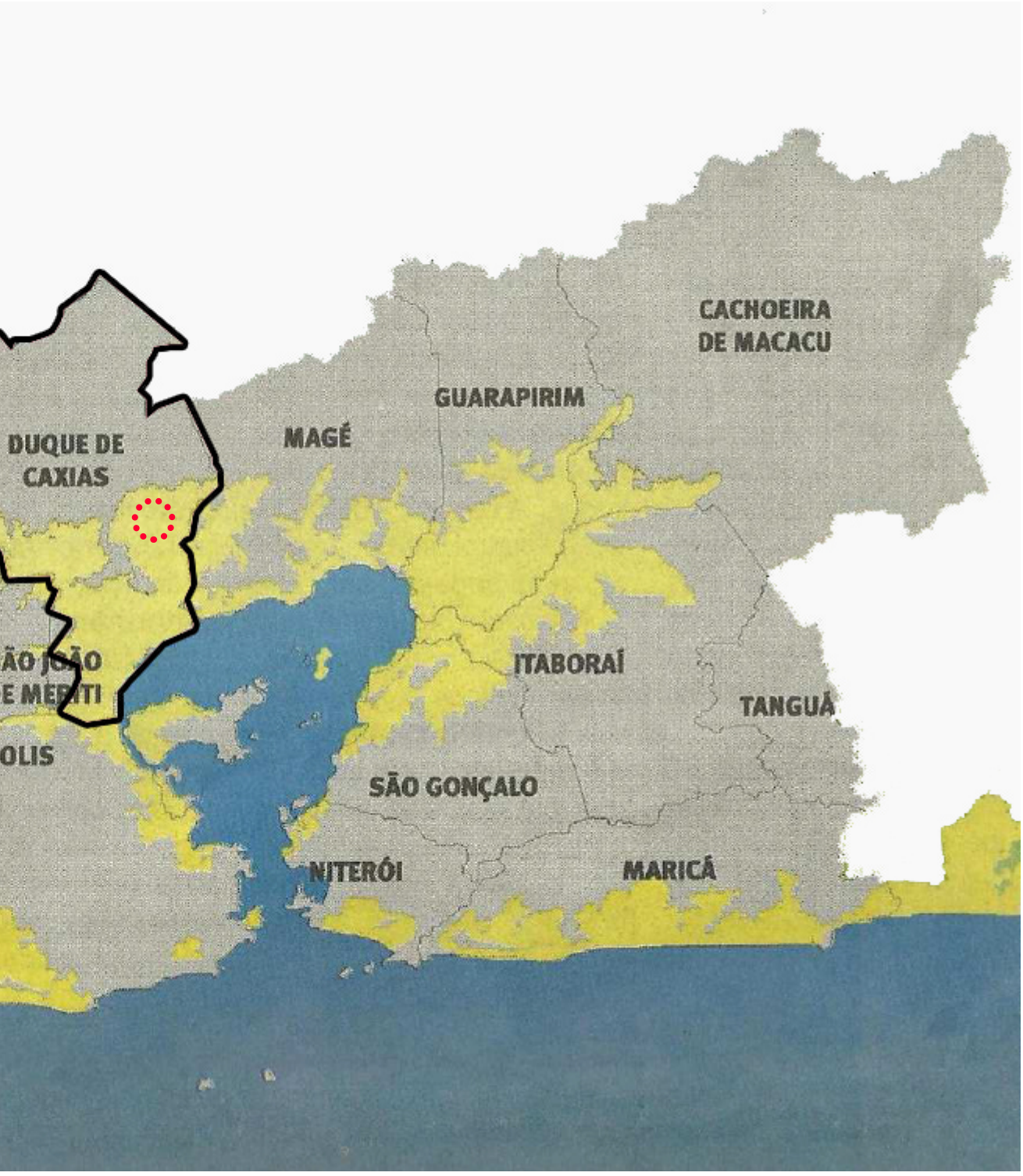


Figure 1.15. Sea-level rise due to climate change will affect coastal re
Source: Jornal O São Gonçalo de 6 de maio de 2011, apud Relatório sobre Vuln
Adapted



egions in Duque de Caxias city, and will likely reach Imbariê district.
erabilidade da Região Metropolitana do Rio de Janeiro às Mudanças Climáticas.
by author

1.2. Nature-based & Water-centric approaches and theories

Learning from living systems to build resilience

Resilience is defined by Watson and Adam (2011) as "the capacity to respond to stress and change of climatic conditions (…) and is evident in natural systems in strategies to adjust to variable and extreme conditions. Characteristics of resilient systems include buffering, storage, redundancy, self-reliance, decentralization, diversity, energy conservation, rapid adaptability, and replacement" (p. 257). Nature is resilient and wisely finds ways to adapt to a myriad of modifications in its surroundings. Thus, to find strategies for flood mitigation and adaptation in the urban context and simultaneously for the recovery of urban river environmental qualities, one must seek answers by observing Nature and learning its lessons. How does Nature operate to adapt to changes in its environment? What are the rules and tactics it uses for achieving resilience?

By analyzing the dynamics in a forest, there is a complex symbiotic network underground between trees' roots and fungi, the mycorrhizal network, responsible for inter-plant communication. It is responsible for sharing nutrients, water, oxygen, and even danger alerts by chemical signals, evidencing its efficiency by being extremely collaborative (Delaqua, 2019). This "tree talk" is a fundamental complex process to achieve adaptation (Gorzelak et al., 2015), representing a mutualistic mechanism. Nature operates as a network in which distribution is carried out through all points in a decentralized way. This redundancy of connections allows the system to keep functioning when it suffers disturbances as a way to adapt and achieve resilience (Delaqua, 2019), as shown in figure 1.16.

6 Mutualism is a type of ecological interaction, providing the capacity to exchange surpluses to achieve benefits among species.

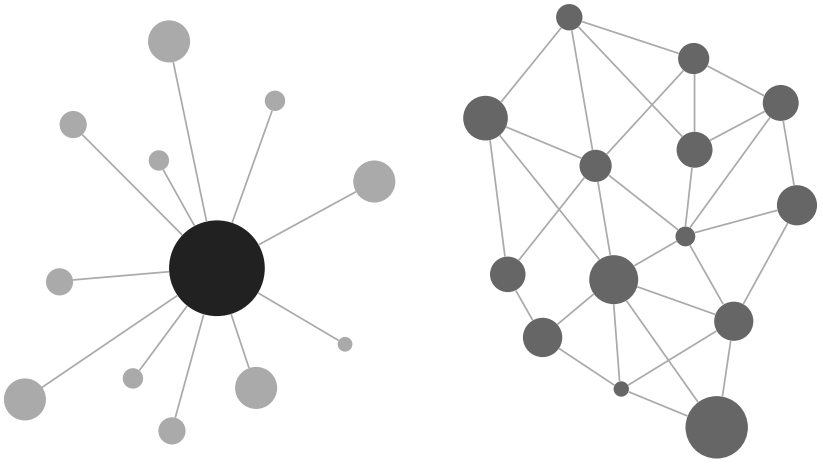


Figure 1.16. Nature operates as in the right-hand networking option, through redundancy of connections to resist disturbances. *Source: Delaqua, 2019. Adapted by author.*

Furthermore, the diversity of niches of occupations and distinct energy consumption levels according to each individual's needs at different times in the forest's metabolic balance teaches us that the diversity of functions is fundamental to achieving resilience. Permaculture, for example, has multifunctionality as one of its main principles, as important functions need to be supported by several elements (Rhodes, 2015). For a system to be resilient, its critical processes need to be supported in several ways and must continue to operate if one element fails (Rhodes, 2015). "The less it segregates, and the more mixed-use zones operate in a decentralized way, the more resilient it is" (Delaqua, 2019). Thus, a single solution to reduce risk cannot be considered resilient since redundancy and diversity are the essential qualities that characterize resilient initiatives; thereby, it needs to be integrated into multiple other solutions in a planning framework to achieve this goal (Doberstein, 2019). The Stockholm Resilience Centre summarized the seven principles for incentivizing social and ecological resilience: "1) Maintain diversity and redundancy, 2) Manage connectivity, 3) Manage slow variables and feedbacks, 4) Foster complex adaptive systems thinking, 5) Encourage learning, 6) Broaden participation, and, 7) Promote polycentric governance systems" (Simonsen et al. 2013, 3).

Nature also presents a valuable quality of regeneration, or the capacity to bring into existence again, as seen in the permaculture system, fundamental to resilience. According to Rhodes (2015), if a sustainable solution is not regenerative, it becomes unsustainable over a long-term period. A larger regenerative system can be composed of smaller regenerative units connected to "provide inputs for multiple human-inclusive-ecological systems" (Rhodes, 2015). This idea is linked to the Circular Economy approach, regarding the intentional lack of waste on Nature, as its systems work on closed-loop cycles. Hence, every element is fed back into the system to be reused for other processes, considered regenerative living systems (Ellen McArthur Foundation, n.d.). Buckminster Fuller (1957) also discusses the regenerative pattern present in biological systems, in which all life-accommodating organisms of Earth's biosphere are exclusively regenerated by solar energy, as seen for instance in the hydrological cycle. McDonough and Braungart (2001) apply the cyclical approach of Nature's systems into the architectural field by advocating for an "architecture designed as a nutrient, capable of providing more to the environment than it takes away". *Nature, therefore, teaches us to seek multifunctional, collaborative, decentralized, multi-scale, integrated, regenerative, and cyclical qualities for achieving adaptability and resilience through design.*

More specifically, Watson and Adams (2011) summarize eight lessons learned from Nature that are applicable to design and construction: (i) absorption (watershed planning and design); (ii) buffering (breaks,

riparian buffers, rain gardens, shuttering); (iii) core protection (zoning, decentralization, self-reliant sun-systems); (iv) diffusion (meanders, wetland and coastal zone landscape, open foundations); (v) rapid response (smart grid, early warning, emergency response systems); (vi) redundant circuits (green infrastructure, wildlife corridors, multiple service routes); (vii) storage capacity (aquifers, wetlands, reservoirs, cisterns); and (viii) waste/nutrient recovery (sustainable stormwater design and waste systems). Rhodes (2015), McHarg (1969) and Mann (1973) highlight the humans' fundamental role in this mission, with the potential to become Earth stewards to protect and encourage biodiversity across the world. Thus, how can Nature's lessons be applied to urban contexts to achieve flood resilience and restore the environmental qualities of urban rivers? Is it possible and feasible to be done in denser and more consolidated urban contexts? The challenge lies in achieving resilience because it involves dealing with deeply interwoven complex systems. To achieve it, one must build the "ability to adapt to the mobility of people and material structures and the temporality of flows of water and migrants, plant growth and solar energy" (Gibson-Graham et al., 2016).

Doberstein (2019) examined flood risk reduction approaches that increase resilience to climate change in Canadian communities. His study relates resilience thinking with a community's capacity to survive after a risky event and keep functioning in the long term, which directly refers to adaptability. Watson and Adams (2011) refer to a flood-resilient design as having the capacity to anticipate and generate preparation for floods by protecting natural and built environments and improving their adaptative capacity. They discuss practical strategies for flood-resilient design at the building scale, including adaptive foundation types, structures, exterior walls, roofing, and services (Watson and Adams, 2011). Meerow et al. (2016, 39) defined urban resilience as "the ability of an urban system and all it's constituent socioecological and socio-technical networks across temporal and spatial scales to maintain or rapidly return to desired functions in the face of a disturbance, to adapt to change, and to quickly transform systems that limit future adaptive capacity". Accordingly, a resilient design cannot be separated from sustainable and green building practices since energy-efficient, low-impact, and regenerative design strategies, such as waste and water recycling, enhance the building and community resilience (Watson and Adams, 2011).

The primary objective of a flood-resilient design is to learn from nature how to protect, restore, and improve the ecosystem services to mitigate the impacts of climate-related flooding (Watson and Adams, 2011). As stressed by Watson and Adams (2011), the principles for a resilient design include the impact on multiple scales, creative design collaboration, and innovation in design, policy, and technology, all of

which reduce the costs of conventional approaches and their maintenance.

Michael Hough (1995) discusses the need to seek conditions to cultivate a harmonious coexistence between nature and urbanization, criticizing how the traditional design of cities did not care about the environmental perspective. Accordingly, for Hough, urban design and other processes that shape cities, such as economics, politics, and engineering, should prioritize ecological awareness. It is fundamental to acknowledge the importance of healthy river ecosystems for cities and the human dependency on them for their existence. Hough (1995) presents the concept of diversity as ecologically and socially essential for maintaining the quality of life and health in the urban environment. Gibson-Graham et al. (2016) also point to the importance of diversity for achieving resilience, which involves fostering multiple and co-existing forms of labour besides species and ecological diversity. Among the wide range of natural resources on the planet, Roy Mann (1973) considers urban rivers the most intensively used and abused. In his work, "Rivers in the City", he focuses on the environmental values and issues on the banks of urban rivers and discusses both healthy and degrading practices (Mann, 1973).

Sustainability through the lens of the Three Ecologies

Since the past centuries, economic growth has predominantly prevailed over human rights and environmental conservation. Hitherto, the anthropic actions guided by capitalistic forces, especially with the rise of neoliberalism, have been putting massive pressure on natural resources by extraction and the substantial production of wastes (Harvey, 2008). To revert this detrimental urbanization model that privileges wealth, profit, and consumerism over collective and environmental welfare, Harvey (2008) stresses that we need a fundamental and radical change. Guatarri (2000) offers a relevant framework for sustainable design, highlighting three elements, 'the three ecologies', as inextricable to forge a path towards sustainability. Guatarri understands the increasing ecological disequilibrium and deterioration of human modes of life as a result of the erroneous division between the *socius*, the *psyche*, and *nature*, generated by capitalist actions to achieve profit (Guatarri, 2000). He also advocates that the social praxes have declined due to the failure of social and psychological praxes to adapt (Guatarri, 2000). Therefore, sustainability can be achieved by focusing on the interdependent relationship between communities, individuals, and the environment thought of as intertwined systems that are adaptable.

Schmidt & Austin (2016) stress that sustainable buildings are not the ones that last forever but that are capable of changing easily over time. *Thus, adaptation is a crucial element of sustainability.* Acting to solve problems

in only one realm will affect the others and not constitute an effective solution. A holistic response should address the three realms as they were one. The current problems in the Roncador River surroundings evidence a disequilibrium of these three realms. Ecological degradation, lack of individual and social quality of life, social inequalities, and the absence of access to basic needs are common ground in this region.

New ways of living and adapting

Life on the planet has been threatened by ecological disequilibrium generated by intense techno-scientific transformations and considerable demographic growth, which also provoked the deterioration of individual and collective human modes of life (Guatarri, 2000). Guatarri explains they generated problems such as unemployment, oppressive marginalization, loneliness, boredom, and anxiety. As mentioned by Donna Haraway (Mitman, 2019, p.18),

> "There will be no going back to some fully repaired place. That is not the same thing as saying there can be no repair, restoration, restitution, cobbling together again, and including new stuff, beings who are coming into the world, ways of living in the world that haven't been on this planet before".

In accordance with Haraway, Guatarri (2000) is not advocating a "return to the past to reconstruct former ways of living"; Instead, he stresses that we must, on the one hand, improvise and adapt; on the other hand, we must understand the importance of reconstructing objectives and methods of the social movement under today's conditions, changing our behaviour, since the planetary situation is irreversible (Guatarri, 2000). *To weave a more sustainable and equitable way of living, I advocate that we must dismantle the once considered dichotomy of nature vs people and generate a reconciliation between urban river ecosystems and communities, especially for the most vulnerable, by reconnecting them.*

Accordingly, water, green, and community are interwoven as structural elements that compose this thesis design proposal. The outcome is the creation of possibilities and relationships, of one becoming to "deterritorialize and reterritorialize" in the other becoming; *an interlink of becomings in a rhizome-like system* (Deleuze & Guatarri, 1987). The path chosen for finding a more resilient solution lies in observing nature, being open to learning from it and prioritizing it in design applications.

Larger nature-based approaches to flooding:
Blue-Green Infrastructure (BGI) and Sponge Cities

There are well-known sustainable (and multifunctional) models for managing stormwater in the urban context to not only ameliorate floods, but increase biodiversity, reconnect people to nature, and provide better leisure and recreational areas. Two largely/widely discussed concepts in the literature are the Sponge City and the Blue-Green Infrastructure, as nature-based approaches to manage urban stormwater.

The Blue-Green Infrastructure (BGI) is defined as an integrated and multifunctional network of natural areas, including water bodies and green spaces, designed to protect and enhance ecosystem services and biodiversity, improve water quality, manage water quantity, and provide recreational opportunities (Ghofrani et al., 2017; Brears, 2018). Consequently, BGI applications offer economic, environmental, and social benefits to urban communities in addition to providing flood-risk reduction. Due to its comprehensiveness, BGI is not limited to urban areas but can be applied in several scales and contexts in an integrated way (Ghofrani et al., 2017). For successfully implementing BGI through spatial planning, its measures must be part of a large-scale and interconnected rainwater management system to effectively mitigate flood risk (Brears, 2018).

The discussion around BGI derived from the major concept of Green Infrastructure since the 2000s in the urban planning and design realms, and has been more accepted and implemented in the Netherlands, Belgium, Japan, and United States (Ghofrani et al., 2017). Although it presents multiple benefits, economic, regulatory, and infrastructural obstacles still hinder its larger implementation in urban centers. Lack of awareness, as well as the initial high costs, are the major barriers to its broader application in other parts of the world (Thorne et al., 2015). More specifically, BGI needs longer periods to be implemented and to start showing its benefits, in addition to requiring more land than grey infrastructure, presenting initial high costs to be implemented in the short term (Brears, 2018).

The Sponge City is a relatively new concept that first emerged in the West in the 2000s, and that has been widely applied by the Chinese government since 2013 (Liu et al, 2017). Particularly in China, the Sponge City approach refers to having the urban environment performing as a sponge that absorbs and releases water, as a systematic urban planning and design strategy to reduce floods and enhance the environmental quality (Liu et al, 2017; MHURD, 2014). This approach promotes a paradigm shift from the traditional urban stormwater management (heavily based on hard

surfaces for rapid stormwater drainage) to more flood-resilient and green infrastructure practices, aiming to harvest, control, storage, and reuse rainwater more sustainably and effectively (Jiang et al., 2018).

As a policy initiative in China, this concept focuses on protecting the original natural environment in cities for water and ecosystem conservation, remediating contaminated waters, recovering ecosystem services to allow their continuity, alleviating flood risk, and improving the connectivity of river systems (Liu et al., 2017; Jiang et al., 2018). Some of the environmentally-friendly technologies this concept uses include permeable pavement in parking lots and paths, rain gardens, bioswales, and green roofs, combined with engineering solutions (MHURD, 2014; Chan et al., 2018). Engineering techniques involve the implementation of stormwater and sewage pipeline networks for water treatment and recycling before reuse. Therefore, the application of Sponge City practices requires government efforts, private investment, and public involvement, with a comprehensive and integrated urban master plan for its long-term success (Liu et al, 2017).

Both concepts are similar in terms of utilizing nature-based strategies in urban areas to increase rainwater infiltration and storage, decrease runoff and pollution, and ameliorate floods while enhancing environmental qualities and biodiversity and approximating people to nature. In fact, the Sponge City concept is considered analogous to the Blue-Green Cities concept applied in the United Kingdom (Thorne et al., 2015; Chan et al., 2018).

Although both are large approaches to sustainable urban stormwater management, this thesis does not follow them as the major theory to guide the design implementation. Particularly, this thesis focuses on the Aquatecture approach for living and designing with water because it is interested in the specific overlap between architecture, landscape, water and people. Since Sponge City and BGI are broader, more general and holistic concepts, it is possible to see many intersections and similarities with the Aquatecture approach, which will be discussed in the next sub-section.

Aquatecture: living with water across scales

The water-centric Aquatecture approach presents a high potential to restore rivers' environmental qualities, reduce floods and integrate with the building scale. As a nature-based solution, it provides non-defensive adaptive strategies in different scales that improve the capacity of the landscape to absorb floodwater and reduce flood risk, working with water rather than attempting to control it (Barker & Coutts, 2016). Designing in an integrated approach encompasses considering scales from national and regional until the neighbourhood and architectural scales, understanding the role water plays in each of them (Barker & Coutts, 2016). This concept merges architecture with water, highlighting the importance of designing with water in an integrated approach to creating resilience within communities, enabling them to adapt to the future climate challenges and take advantage of the benefits of water in the urban environment.

Barker and Coutts (2016) introduced the concept of LifE, Long-term Initiatives for Flood-risk Environments, as an integrated design approach to manage flood-risk and reduce the environmental impact but still foster a development growth (see figure 1.17). In this holistic concept, water and ecological design are at the center of spatial planning and building. LifE considers that the key issues to tackle are the development pressure (the need to build to support a growing and ageing population and enhance well-being), environmental change and degradation, and increased risk of flooding, in frequency and severity. Therefore, it proposes an integrated approach, guided by three principles: (i) making space for water (providing space for rain, rivers, and sea to expand during times of flood); (ii) living with water (creating the capacity to anticipate, accept, and recover quickly from floods); (iii) eco-design (developing low-energy building designs that reduce carbon emissions and positively impact on the environment).

In addition, Aquatecture does not rely on traditional engineered flood control structures that attempt to tame water; rather, it concentrates on making space for water to work with it. Although its primary focus is on providing flood mitigation and adaptation, the LifE approach presents multipurpose design strategies. For example, the spaces between buildings are seen as areas to store floodwaters and rainwaters and, when it is dry, they could serve for recreation or energy generation (Barker & Coutts, 2016). Penning-Rowsell (2020) pointed out that multipurpose approaches toward floodplains in urban areas are needed to improve urban resilience. Therefore, new urban spaces and buildings that follow these principles would reduce flood risk and mitigate climate change and provide sustainable, high-quality, and resilient settlements (Barker & Coutts, 2016).

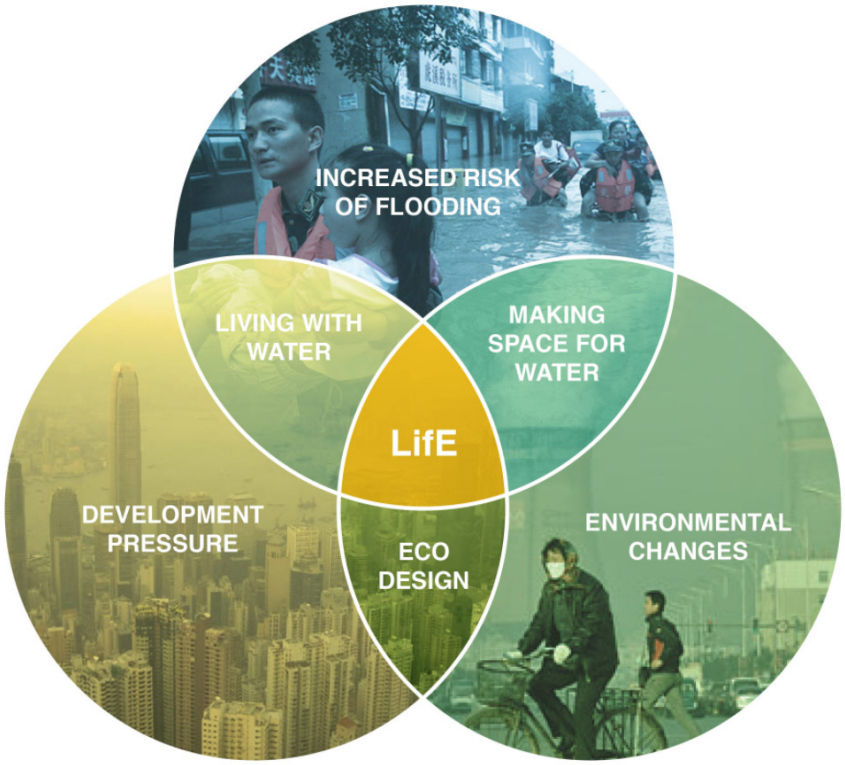


Figure 1.17. LifE concept.
Source: Baca Architects website.

To properly apply the flood-risk reduction strategies proposed by the Aquatecture approach, it is crucial to understand the concepts of flood risk, exposure, vulnerability, mitigation, and adaptation. The Floods Directive defines flood risk as "the combination of the probability of a flood event and of the potential adverse consequences for human health, the environment, cultural heritage and economic activity associated with a flood event" (Directive 2007/60/EC), in which flood risk is derived from the flood hazard (Januchta-Szostak and Karaskiewicz, 2020). Increasing soil permeability for natural or artificial water storage, as in retention and detention ponds, and technical flood-protection structures, like embankments, can help reduce the flood hazard (Januchta-Szostak and Karaskiewicz, 2020). Exposure is defined by Januchta-Szostak and Karaskiewicz (2020) as communities and buildings located in at-risk areas, and regulations to avoid building development in floodplains can help reduce the exposure to floods. Finally, vulnerability is the level of preparedness a community and a building have to face flood events and can be mitigated by implementing structural and non-structural measures (Januchta-Szostak and Karaskiewicz, 2020). Januchta-Szostak and Karaskiewicz (2020) highlight the importance of combining both structural and non-structural solutions in different areas and scales to help a community achieve flood resilience by increasing their ability to resist, flexibility to absorb floods, and creating efficiency that increases adaptation. Limiting exposure and vulnerability and mitigating sources of flood hazard are critical actions in this process. The Federal Emergency Management Agency (FEMA) defines flood hazard mitigation as "all actions that can be taken to reduce property damage and the threat to life

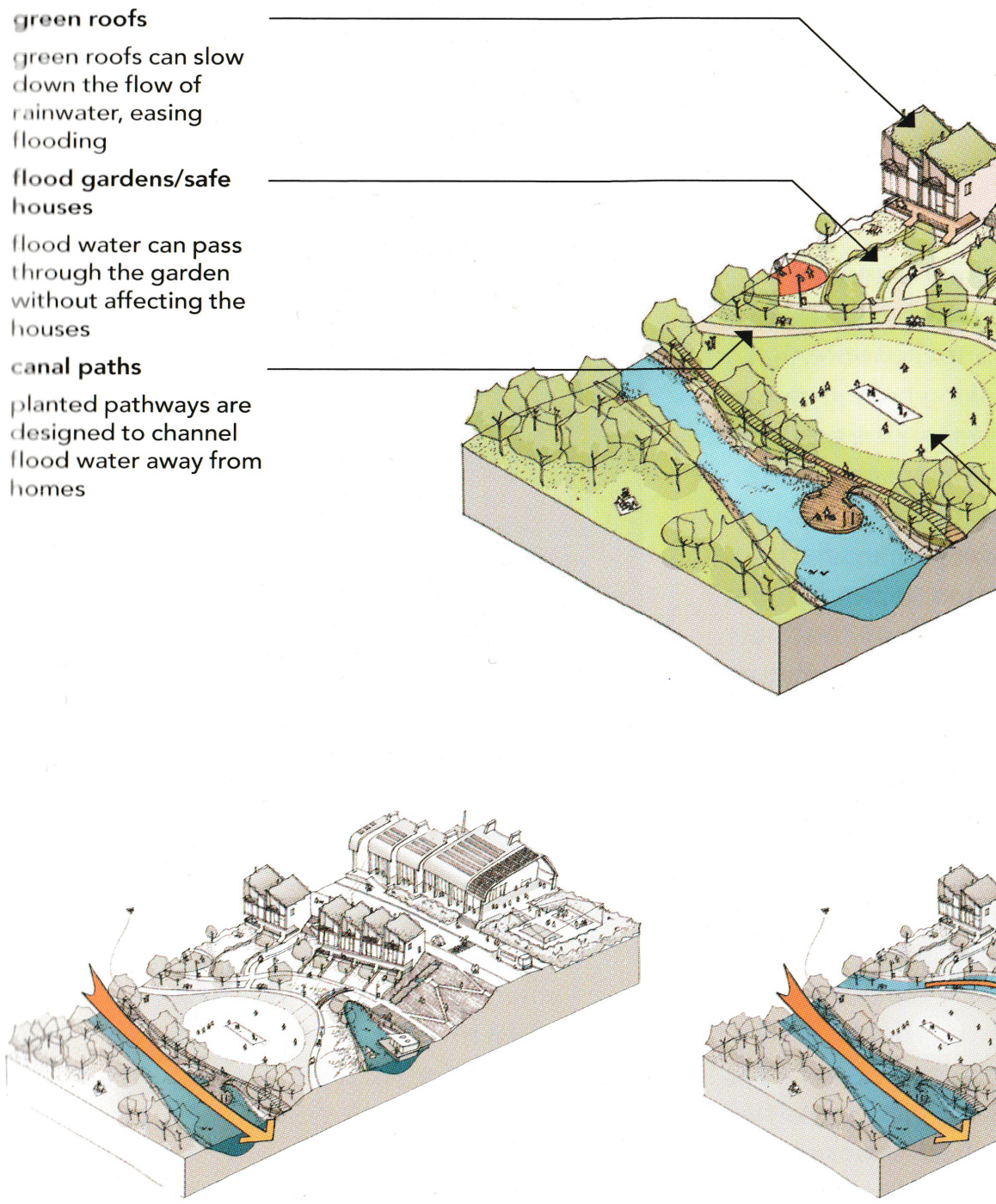
and public health from flooding" (n.d., 16). Flood adaptation refers to a group of actions that make existing socioeconomic and ecological systems stronger in the face of flooding impacts (IPCC, 2001; Pathak, 2021). Both mitigation and adaptation actions must be adopted to adequately address the climate change impacts, such as the increase in floods (Martens, 2012; Pachauri et al., 2014).

1.3. Designing with Water in scales

Aquatecture design strategies in the watershed scale |
Making space for water strategy

The principle of 'making space for water' must be prioritized in the watershed scale to manage flood risk without applying the traditional flood-control structures (Barker & Coutts, 2016). As a non-defensive strategy, this principle improves water absorption by the landscape and provides room for riparian processes (see figure 1.18). Prominski et al. (2017) understand the dynamic processes of rivers as a starting point to design river restoration projects, affirming the importance of also making space for plants, animals, and people, in addition to water. By shifting paradigms, they understand these actors' different demands as compatible when designing a riverine restoration project, creating opportunities for new synergies that bring together ecology, flood protection, and amenity (Prominski et al., 2017).

However, riverbanks should not be buildable areas to allow the river to expand in its natural dynamics. Instead, they should be a space for green public use and ecological preservation. Lotufo (2020) recommends the progressive eviction and resettlement of informal settlements in these regions and the implementation of urban linear parks instead to restore natural ecosystems. Nevertheless, informal settlements keep spreading toward riverbanks due to multiple dynamics, including social and spatial inequality, which lead to the lack of accessibility and affordability to adequate housing. Hence, designing urban river spaces also involves dealing with conflicts, especially in informal settlements in the riverbanks. Such projects might create disputes regarding environmentally induced displacement since this space poses risks of floods and sewage contamination to their inhabitants. Evictions and resettlement are likely to generate trauma, especially if the residents do not want to leave their homes and community. Accordingly, riverine park proposals must also consider the relocation process, which involves providing housing in an appropriate location and timing. The government must carefully plan the resettlement process prior to the project's implementation to avoid potential trauma, community disruption, and additional risks.



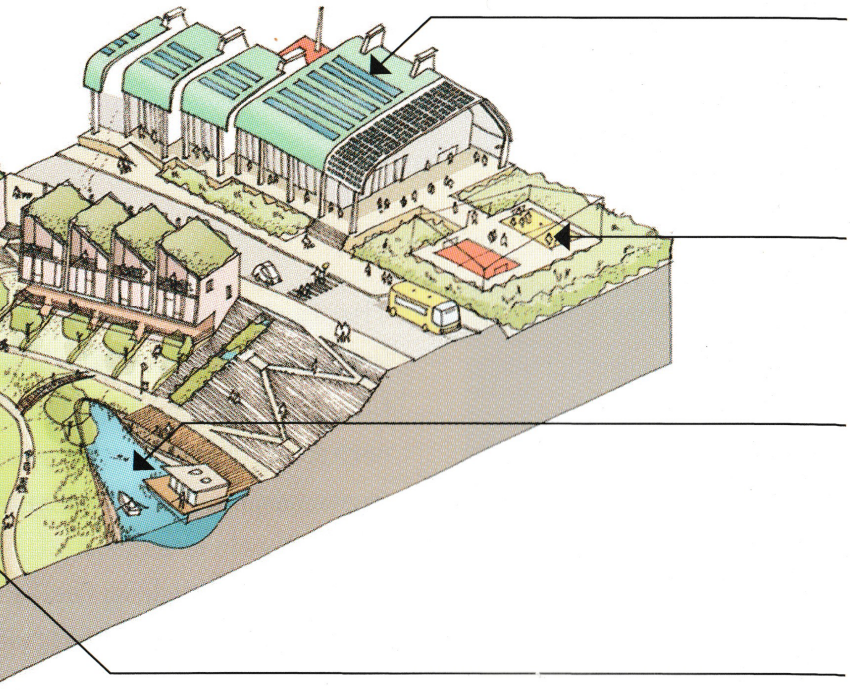
Everyday

For the majority of the time the river contains the flow of water.

During a storm (5% proba

Rainwater is held in dedica roofs of buildings; the rive from homes, in a predeter

Figure 1.18. LifE's principle of Making Space f
Source: Barker and



safe havens

resilient schools and community buildings provide safe spots to gather and centres for renewable energy

rain gardens

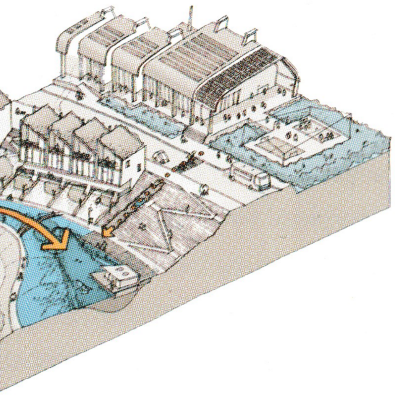
communal gardens collect and store rainwater away from rivers

village blue

small ponds are designed to expand during a flood. The rest of the time they can be used for boating, fishing and swimming

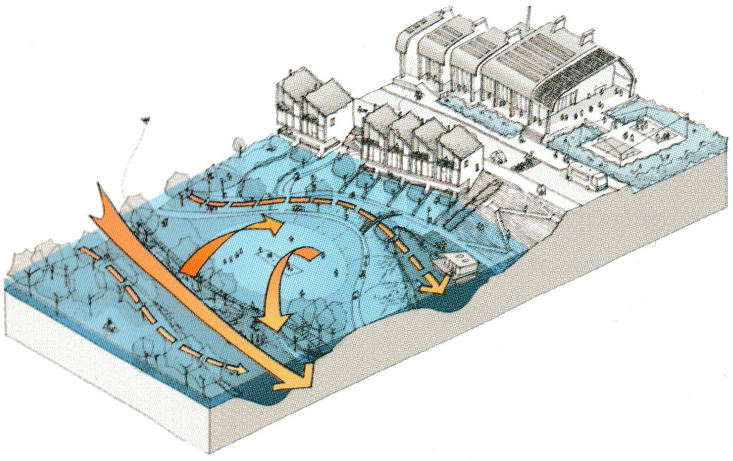
village green

play areas are designed to flood when a severe flood occurs



ability)

ated rain gardens and on the
r expands into channels, away
mined way.



During a very big storm (1% probability)

Rainwater is held in dedicated rain gardens and on the roofs of buildings; flood water is directed into multi-use recreation areas and gardens designed to cope with flood water.

or Water and how it works during a flood event.
Coutts, 2016, p. 59.

The Tietê River Valley Park in São Paulo, Brazil, is an appropriate example to discuss this issue. It consists of a linear park that, upon completion, will be the largest linear park in the world. This linear park will include the construction of leisure centers connected by bike lanes and green areas that will make space for the river to safely flood and for stormwater absorption while also hindering the informal settlements from occurring in the riverbanks (Millington, 2018). Millington (2018) points out that the government uses an environmental argument and city dynamics to justify the massive displacement toward the project's implementation. For the author, this project represents a clear case of environment-induced displacement of low-income residents living in precarious situations, posing several risks. The government of São Paulo argued that the informal occupation of riverbanks generates erosion, alteration of flood dynamics and puts people at risk of diseases and losses by flooding. Thus, these reasons justify the need for and the benefits of resettling them to public housing. Millington (2018) questions the specific forms through which the government conducts removals to implement this project.

The families living informally in the riverbanks receive specific funding from the government to cover their resettlement costs until the state-building housing is under construction. However, due to construction delays and bureaucratic slowness, these subsidies often become semi-permanent, evidencing a lack of an adequate plan and transparency (Millington, 2018). In many cases, the promised housing never gets ready, and many previously removed residents return to their original areas under a worse risk than before. In other cases, they are resettled to low-quality buildings in distant and insecure regions far from the urban core, breaking their connections with the original land and community. Additionally, their travel times increase, further marginalizing them, besides the challenging logistics of storing belongings in the unstable and long period of the removal process. In the Tietê region, the distribution of rent subsidies instead of turn-key actual housing perversely encouraged speculation and the raising of local rents. Millington (2018) stresses the need to apply new perspectives of peripheral landscapes' governance that account for histories of self-built housing and collective infrastructure in the region for decades.

In the case of proposing a similar intervention to the Roncador River context, informal settlements' removal and relocation would be needed, which could increase the housing deficit. A resettlement process under the public housing program would likely redirect these people to low-quality buildings in distant places, reducing their quality of life and disrupting community life. Which alternatives could allow such nature-based interventions to be applied to minimize floods without jeopardizing people's connections to their community?

Rivers need space to naturally transform their morphology in different water stages, which dynamically plays with sedimentation and soil permeability. Traditional anthropic interventions to shape rivers since the 19th century generated sealed riverbanks, hindering the essential dynamic characteristic of riparian landscapes to transform their morphology by reducing their space and, thus, biodiversity in urban areas (Prominski et al., 2017). Conventional approaches to stormwater management adopted channelization strategies to discharge rainwater away from urban centers quickly. As a result of losing retention areas, riverbank vegetation, and sufficient space for water to be accommodated in meandering configurations, the intensification of floods and reduction of flexibility were inevitable (Prominski et al., 2017).

Current riverine environment design should integrate more sustainable practices that focus on increasing natural water storage, infiltration, and retention capacities to mitigate flood effects, which essentially require space (Prominski et al., 2017). Rivers' dynamics constantly experience the continuous change process, making each river unique (Prominski et al., 2017). Therefore, riverine landscape design should adopt flexible strategies that provide room for change and welcome transformation. Accordingly, riparian corridors in urban areas must allow for diversity (of types of flow, sediment, flora, fauna, functions) to be accommodated, which will make the system more resilient (Prominski et al., 2017). Having enough space is essential for healthy riverine landscapes, which often becomes a constraint in consolidated urban areas. That is why restoring rivers to their original natural state in cities is not feasible nor desirable. Ultimately, we want urbanization to be compatible with the revitalization of riverine landscapes. Prominski et al. (2017) advocate that it is paramount to preserve and create new retention areas alongside watercourses and water retention strategies within the urban fabric, to alleviate the pressure on river systems and increase flexibility to absorb excess from extreme rainfall events.

The strategies brought by Prominski et al. (2017) for designing water spaces and riparian landscapes inserted in the urban fabric bring constraints and opportunities. Their discussion fosters the generation of urban water spaces as a balanced interplay between ecology, flood protection, and amenity by focusing on better understanding river dynamics. To this end, the authors categorized a new systematic approach for classifying river edges, besides using illustrations to represent the temporal-spatial interplay between water dynamics and design tools. Prominski et al. (2017) consider the following recommendations as fundamental to properly design urban river spaces: (i) consider the multifunctionality associated with the demands and needs in the context; (ii) have an interdisciplinary approach, constructing collaborative

discussions between professionals involved in the project; (iii) observe and understand the intrinsic principles and knowledge of the various water processes and internal dynamics.

They also identified design tools by studying precedents and grouped them into five 'Process spaces': (A) embankment walls and promenades; (B) dikes and flood walls; (C) flood areas; (D) riverbeds and currents; (E) dynamic river landscapes. By categorizing the process spaces, they developed 26 design strategies that inform 96 design tools. Designers can combine these tools to design waterside spaces that respond meaningfully to specific river processes. Thus, their study describes an approach or attitude toward the water (tolerate it, go with it, divert it, etc.).

Barker and Coutts (2016) discuss the anatomy of a successful riverfront related to its functions, as shown in figure 1.19. Its key components include:

1. Activities that attract interest, such as boating, fishing, and wildlife, are intercalated with fast-flowing areas to provide natural curiosity.
2. Provide access and continuous pedestrian low-level river walkways to bring movement and spontaneous activities.
3. Where not possible to have access, provide pathways over or floating on the water for the same purpose.
4. Provide outdoor public amenities and spaces along the river edge that could also work as habitat corridors.
5. In floodable regions on the river edge, buildings may be required to set back and be oriented parallel to the river to improve flood conveyance while creating a vista up and down the river.
6. Land-uses should be determined according to flood risk, and low-vulnerability uses such as parks and civic buildings may be more appropriate closer to rivers than residential or office buildings. Amphibious buildings may be an option where the flooding risk is more significant.

According to Watson and Adams (2011), professionals should design inland riverine landscapes to reduce runoff and maximize water retention. The use of vegetated systems and reducing impervious surfaces help achieve these goals more efficiently, such as rain gardens, bioswales, vegetation buffers, and permeable pavement in public areas (Watson and Adams, 2011). Millington (2018) affirms that green spaces along urban river edges, such as linear parks, are fundamental to retaining stormwater and slowing down its flow, reducing flooding in urban areas. This concept is opposed to the conventional urban drainage approaches that saw stormwater as a problem and managed to funnel it out of urban areas as fast as possible (Millington, 2018). Managing the urban water cycle by integrating

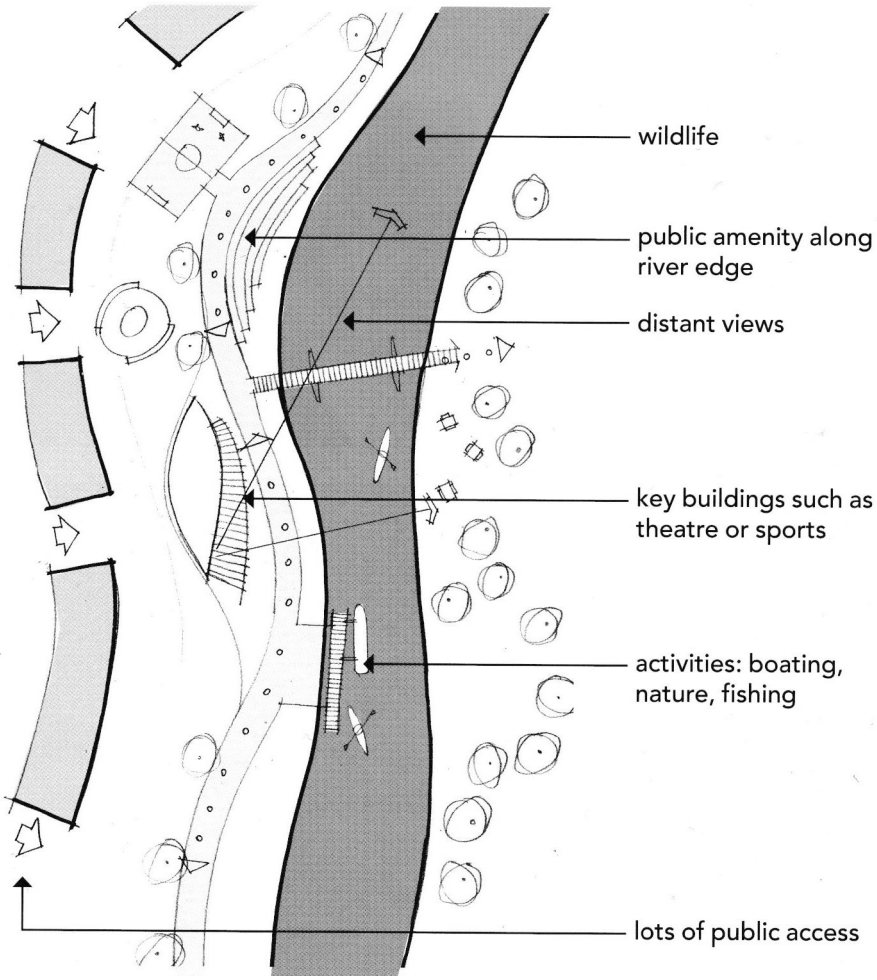


Figure 1.19. Successful riverfront: integrating and balancing nature and public spaces.
Source: Adapted from Barker and Coutts, 2016.

stormwater into green spaces provides flood reduction, pollution minimization, stormwater retention, landscape enhancement, and reduction in drainage investment costs (Ellis, 1995; Lawrence et al., 1999). In addition to public recreational functions (such as biking lanes, jogging trails, promenades), urban linear parks can also be part of an evacuation strategy, having higher-density housing and critical-needs constructions on higher ground. The use of demolition waste is a sustainable and creative strategy to raise ground levels. It is essential to provide greener spaces near rivers to help alleviate floods; they become even more effective if integrated with dense reforestation efforts and headwaters conservation, especially for degraded watersheds (Lotufo, 2020). However, when the urban human occupation is already dense and consolidated, the focus must be on runoff control, retention basins, and fostering stormwater infiltration (Lotufo, 2020).

New buildings close to linear parks can be water-resistant and incorporate green roofs to lessen the burden on the stormwater drainage system and store it for non-potable uses, such as irrigation, maintenance, and toilet flushing (Watson and Adams, 2011). Planning water-sensitive housing design interconnected with an urban linear park system requires holistically considering design-with-water strategies. It is crucial to

consider the watershed scale as a critical element when designing river restoration projects, seeking a comprehensive approach that works with the hydrological cycle in integrated ways across multiple scales (Ottoni and Britto, 2020; Ottoni, forthcoming).

Although ecological initiatives proposed by the Aquatecture approach are undeniably beneficial, there are challenges for their implementation and potential side effect on the local population. One problem that arises by analyzing the sustainable strategies for stormwater management is the long-term maintenance of these solutions in low-income contexts. It is imperative to conduct frequent conversations with the residents and include them as key participants of these projects to propose adequate solutions and guarantee they will have the resources and knowledge to maintain these technologies. Training for capacity-building is an essential step in this process, as the residents will be able to execute the maintenance by themselves and guarantee the durability of these strategies.

Riverine parks are also criticized for being primarily interventions toward aesthetics and usually do not encompass solutions for sewage treatment and other interrelated problems (Raulino, 2016). Planning green areas adjacent to the river should be multipurpose, especially in vulnerable contexts like Baixada Fluminense. In this case, they must address interconnected issues such as lack of sanitation and housing policies to be effective long-term. Otherwise, solutions such as linear parks would only be tackling the consequences of the problem and not its causes.

Torres et al. (2019) also point to another negative phenomenon that is likely to happen after implementing green initiatives such as the ones mentioned above: green gentrification. This term infers that an ecological revitalization project attracts higher-income groups to live in the region, thereby generating an increase in real estate values and, thus, expulsing lower-income groups who cannot afford to live in the region anymore (Torres et al. 2019). The authors also revealed that this phenomenon of greening urban areas tends to also “whiten” them. In the classic case of gentrification, a spatial enhancement generates the dispossession of the poorest and contributes to increasing sustainability in the long term. Alternatively, green gentrification refers to sustainability initiatives that trigger a gentrification process (Gould and Lewis, 2016). However, Torres et al. (2019) demonstrated that not necessarily ecological initiatives would result in social inequality and injustice. When the community actively collaborates in the decision-making process, also supported by public policies to ensure social equity is at the project's core, it is possible to avoid green entrification and build more inclusive urban projects that revert the neoliberal paradigm.

The Don River Valley regeneration project in Toronto is a relevant precedent that exemplifies effective strategies for successful river restoration in an urban area. The project respected important regeneration guidelines based on nature, similar to the Green Infrastructure[7] approach and aligning with many aspects for urban river space design described above (See figure 1.20).

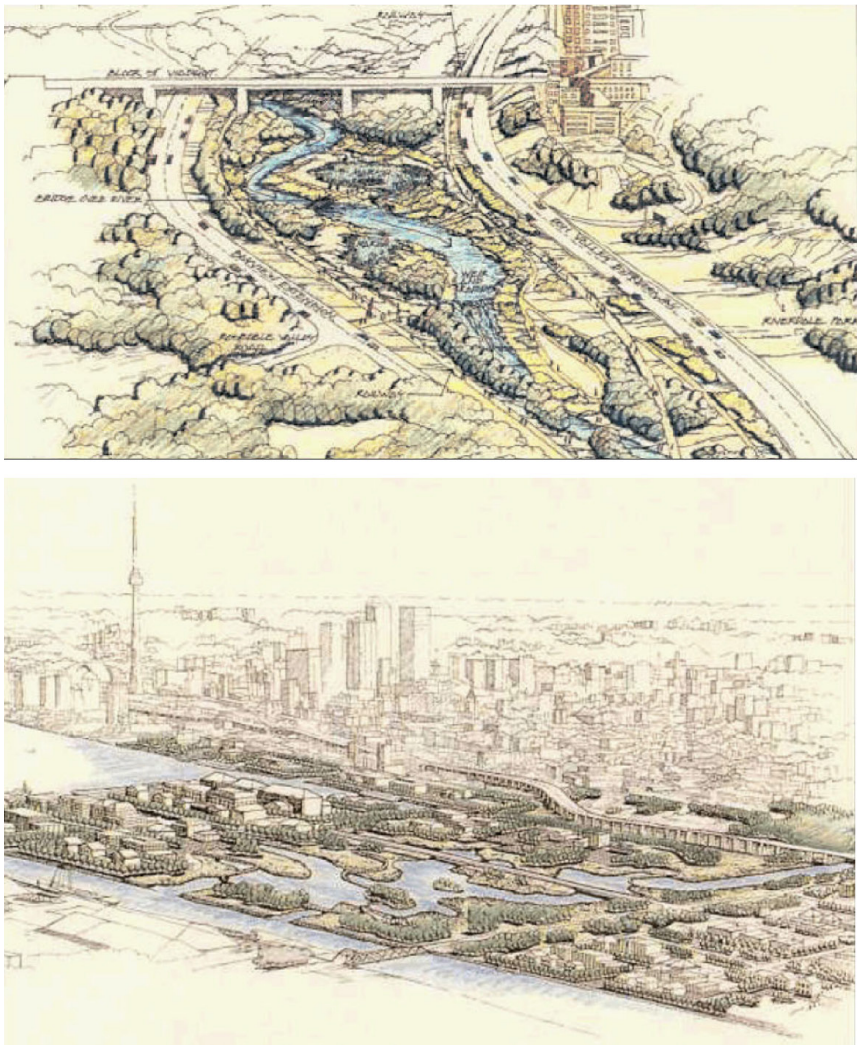


Figure 1.20. Don River Valley regeneration project.
Source: Crombie, 1992.

7 Green Infrastructure is defined by he Water Infrastructure Improvement Act (2019) as " the range of measures that use plant or soil systems, permeable pavement or other permeable surfaces or substrates, stormwater harvest and reuse, or landscaping to store, infiltrate, or evapotranspirate stormwater and reduce flows to sewer systems or to surface waters."

Don River Valley was once a healthy, fertile, and flourishing watercourse. Yet, human interventions toward urbanization development in the past century devasted its ecosystems, bringing pollution, deforestation, impervious surfaces, river channelization, and building massive engineered projects for transportation and energy generation. In addition, they exploited the land through mining activities and destroyed marshes, thus, turning their backs on the river (Hough, 1995; Crombie, 1992). Nevertheless, several activist citizens formed a group named Task Force in 1991 to pressure the government to create and implement a plan to "Bring Back the Don" in the city core. It consisted of a long-term project that integrates the principles of ecosystem planning and nature-based strategies and applies regeneration guidelines in a holistic approach but treats different watershed parts according to its specificity to heal this damaged watershed. The intention was to transform it into a “clean, green, usable, diverse, open, accessible, connected, affordable, and attractive” river (Crombie, 1992). It was guided by ecosystem planning strategies, also present in the Aquatecture approach, which can potentially regenerate any urban watershed. The guidelines included: (i) protect natural and cultural features, (ii) let topography and countryside define urban form, (iii) ensure that development enhances environmental health, (iv) intensify and diversify development, (v) maintain rural traditions, (vi) work with nature, and (vii) encourage watershed consciousness.

Crombie (1992) also discusses repurposing old and abandoned industrial buildings and lands to foster community practices, such as vegetable gardens, wetlands and retention ponds, or local mixed uses and economies to revitalize and diversify communities; as a result, creating watershed consciousness. Like Michael Hough (1995), Crombie brings practical measures by working extensively with nature, replacing hard and impervious surfaces into green spaces, implementing retention and detention ponds, wetlands, and watershed reforestation. In addition, the strategies helped the river create a natural marshland delta on the port lands and brought recreational features, such as cycling lanes, to transform the area into beautiful and diverse places for the community.

Aquatecture design strategies in the neighborhood scale
Living with water strategy

By working with an integrated design and spatial planning, Aquatecture spatially combines a set of measures in different scales to generate a holistic plan. On the intermediate scale, solutions alongside the watercourse, such as wetlands floodplain, green roofs, community gardens, wet woodlands, detention and retention ponds, among others, help create spaces for water for the residents to learn to live with it (Barker and Coutts, 2016).

Besides giving visibility and valorization to water, they can also help with local biomass and fertilizer production and energy generation (Barker and Coutts, 2016). Composting converts waste from community gardens and urban settlements into fertilizer and generates biogas using an anaerobic biodigester. In a circular approach, this fertilizer can be used, in turn, in the community gardens to produce local food. Thus, the solutions proposed by the Aquatecture concept integrate the management of water, waste, and even local food production. These strategies become highly beneficial, especially for low-income communities, since they can help increase local income generation through nature-based collective practices, raising environmental awareness.

Living with water under the Aquatecture approach is defined as creating the capacity to anticipate, accept, and recover quickly from floods (Barker and Coutts, 2016). Implementing hydroscape practices are effective strategies to integrate the neighbourhood and city scales, such as vertical flow reed bed system, floodable playgrounds and squares, terraced waterfront, permeable parking and paths, street bioswales and rills (Barker and Coutts, 2016). Street bioswales and rain gardens increase stormwater retention, infiltration, and filtering, besides helping with flood mitigation (See figure 1.21). Permeable pavement also contributes to increasing stormwater infiltration in urban areas (Lotufo, 2020). In addition, retention and detention ponds are multipurpose strategies that provide recreational areas while working as flood control structures (Hoyer et al., 2011). Different from retention basins, detention basins, also known as dry ponds, do not have a permanent pool of water and, in dry conditions, can work as recreational areas, such as skateparks and plazas. On the other hand, retention basins provide a certain level of water quality treatment by reducing pollutants, while detention basins only control water flow (Leber, 2015). Both act as ecological solutions to receive stormwater and watercourses' runoff and play an essential role in slowing and storing stormwater for mitigating floods, as shown in figure 1.22 (Leber, 2015; Lotufo, 2020). Constructed wetlands also alleviate flood peaks, but, most importantly, they provide water quality control and treatment, erosion control, and increase biodiversity in urban areas (See figure 1.23).

All these strategies maximize rainwater retention and improve water infiltration in the soil, slowing down the stormwater runoff and, thus, mitigating floods (Lotufo, 2020). Urban agriculture can be associated with these devices to increase multifunctionality and sustainably produce local food. Some of these practices in the intermediate scale can also extrapolate and integrate into the building scale by bringing green infrastructure solutions, such as green roofs and rainwater harvesting, to support the continuity of ecosystem services (Lotufo, 2020) as seen in figure 1.24.

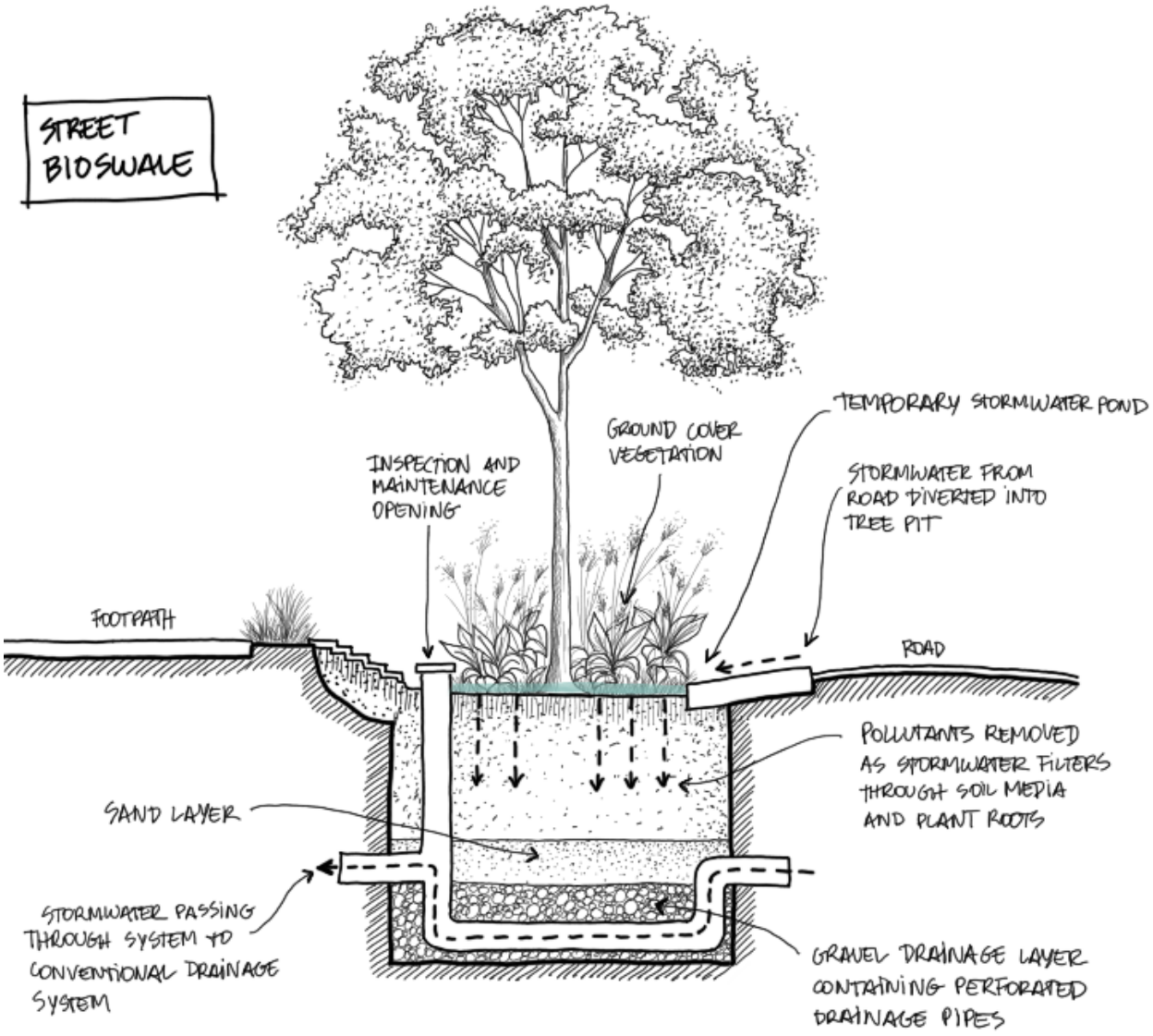


Figure 1.21. Street bioswales and raingardens. *Source: Image by author.*

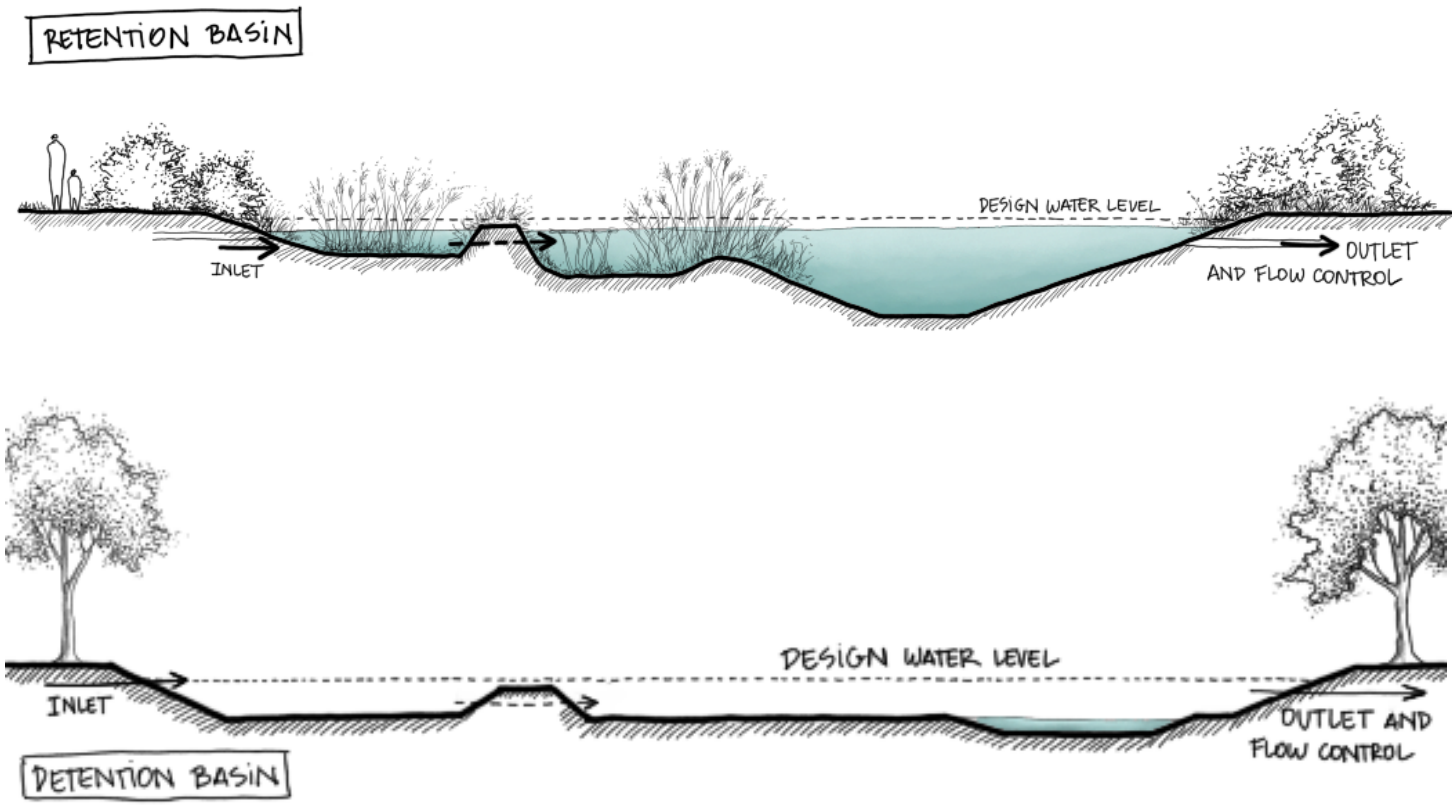


Figure 1.22. Retention and detention basins. *Source: Image by author, adapted from Woods Ballard et al. 2015.*

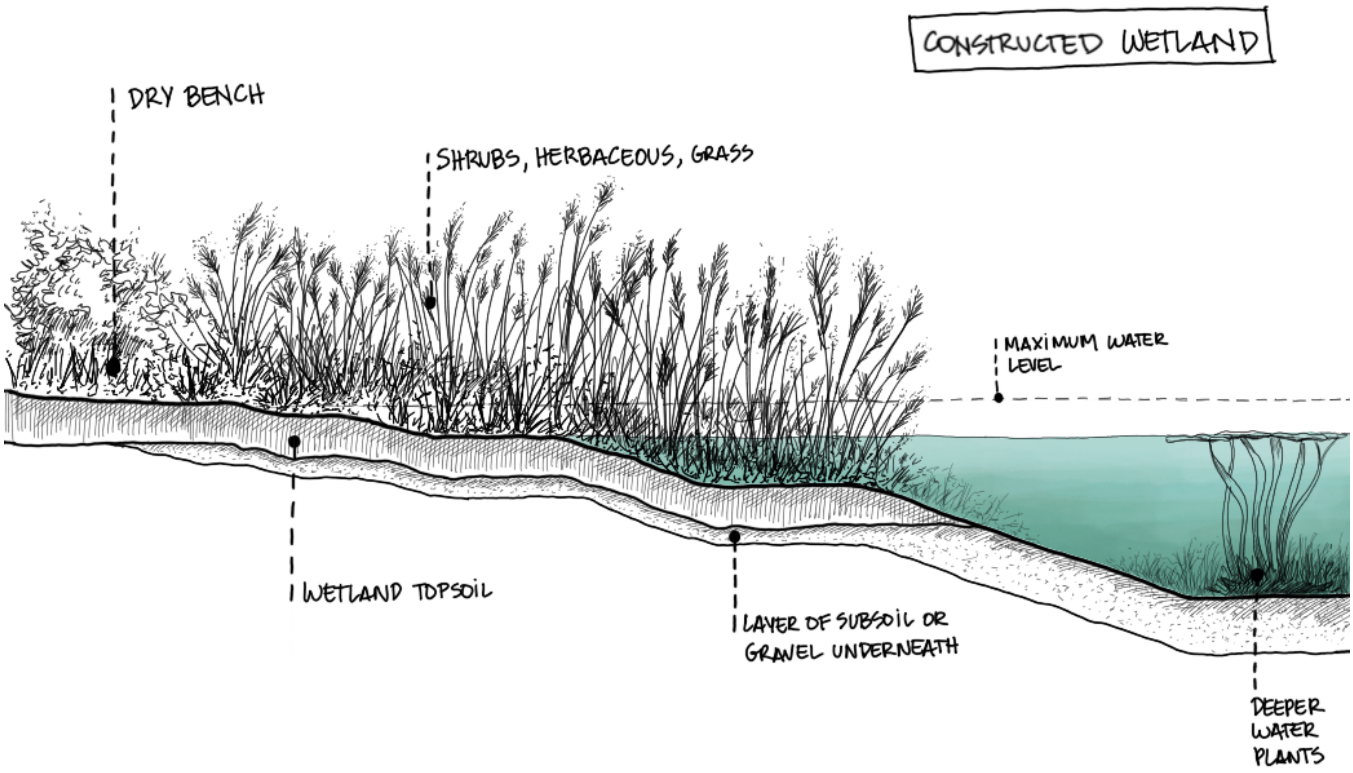


Figure 1.23. Wetlands. *Source: Image by author, adapted from Woods Ballard et al. 2015.*

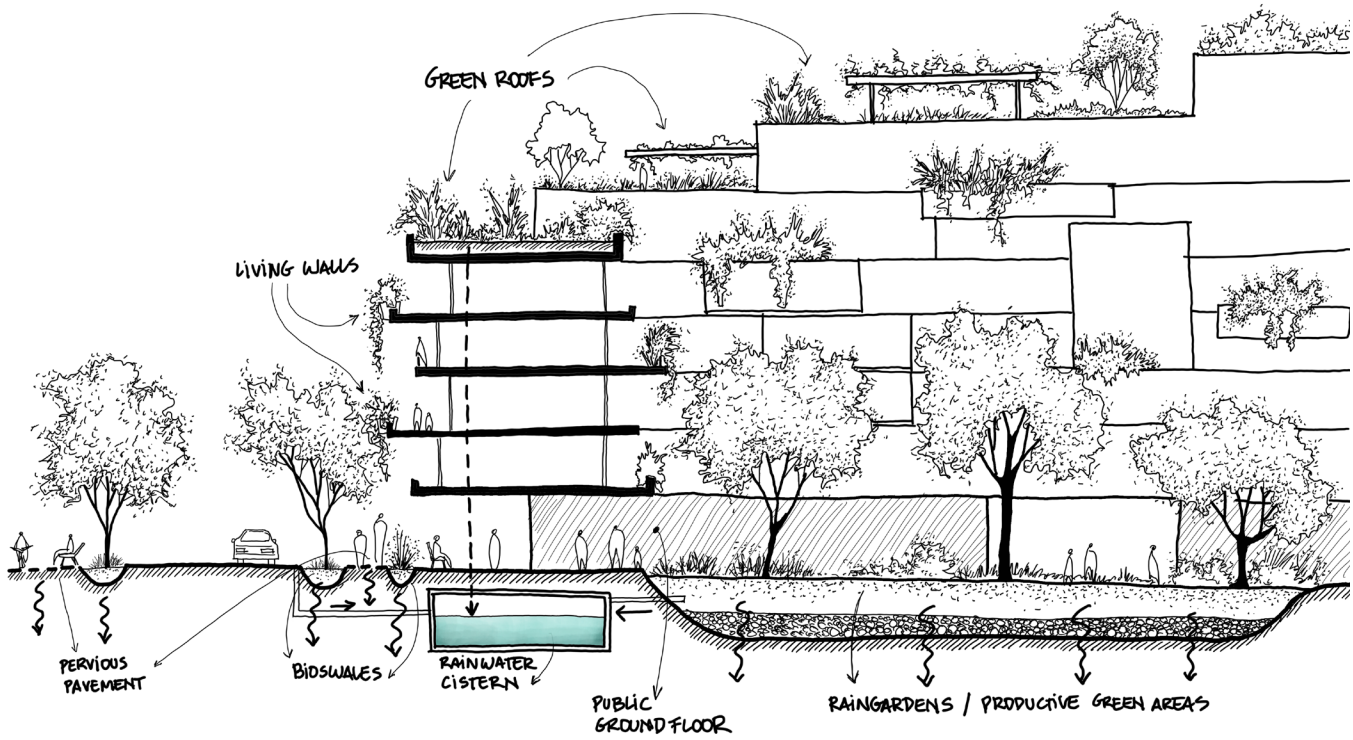


Figure 1.24. Green roofs and Rainwater harvesting and reuse in the building.
Source: Image by author, translated and adapted from Lotufo, 2020.

In addition, urban blocks can play a fundamental role in achieving the living-with-water strategy: if designed or rearranged to be more open and less programmatic, opening up space for green systems and public use together with private use, they offer a great potential to increase soil permeability and, thus, reduce floods. At the same time, they can increase the quality of life and sustainability by sequestering carbon, enhancing ecological services within an urban area, increasing biodiversity, improving public health, offering more recreational and gathering spaces, and reducing the heat island effect (Lotufo, 2020).

The segregation of the block by using the individual lot as a fundamental unit in urban design generates reduced space for green areas and, thus, for soil permeability, besides rendering more underutilized space. By densifying the block and rearranging the concentration of built areas and mix of uses on the ground floor, it is possible to increase the space dedicated for collective and public functions while being more permeable: a room for people and nature. Lotufo (2020) sees the integrated design for the block as a strategy to enhance its social and environmental qualities, which is more optimized, offers less space loss and more collaborative opportunities.

The "unified block" uses the center of the block as integrated space for multiple uses, fostering social interactions, collective activities, and more soil permeability. Promoting the continuity of ecological services by using decentralized green systems on each scale will increase natural stormwater storage and reduce floods, ultimately generating resilience (Ottoni and Britto, 2020). Parts of urban blocks could be appropriated to implement sustainable and productive systems that involve community management, such as collective urban agriculture, and by incorporating alternative and sustainable sewage treatment on-site, which could also be managed and maintained by the community (See figure 1.25). These could be low-cost social technologies that use plants and local materials, require community engagement, and not only treat sewage but produce safe food to be consumed at the same time. The living-with-water strategy can be extrapolated to encompass alternative sewage treatment for complex contexts like the Roncador River surroundings. Because the region does not have any sewage treatment plants, dealing with floods also means addressing the issue of sewage; otherwise, the solution will not be effective in this context.

A regulated conventional solution to treat sewage on-site, very common in small communities and rural regions, uses underground septic tanks connected to anaerobic filters, an individual solution already partly in use by some households in the area (See figure 1.26). Usually, the homes that apply this solution only build septic tanks but do not have the anaerobic

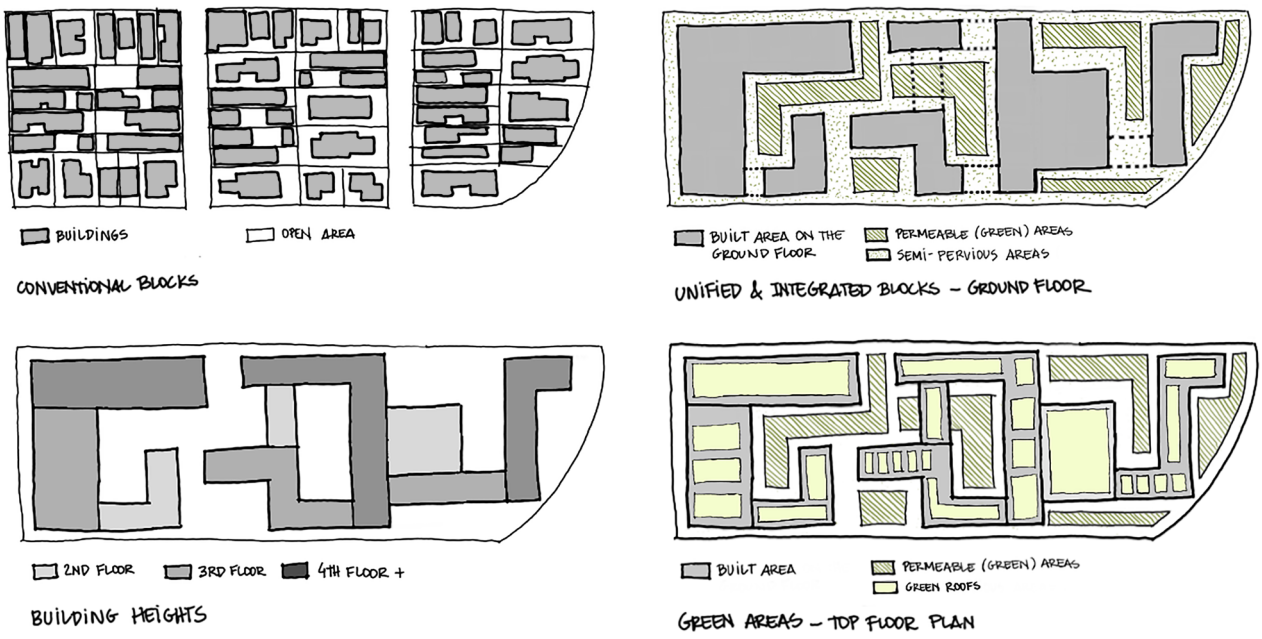


Figure 1.25. "Unified and integrated urban block" concept by Lotufo (2020).
Source: Image by author, translated and adapted from Lotufo, 2020.

filter, which is insufficient to treat sewage properly. The septic tank is an underground container made of reinforced concrete that receives sewage sludge and lets it settle, physically treating black waters. The byproduct of the septic tank goes to the anaerobic filter, which is composed of a layer of gravel, where the bacteria digest the organic matter and treat sewage through biologic decomposition (Ávila, 2005). Wetlands could be attached to this system to receive the surplus from the anaerobic filters and refine the sewage treatment.

Figueiredo and Tonetti (2019) present the "green septic tank", or "evapotranspiration basin", as a valuable alternative to treat black waters on-site. This system was created and developed by the American permaculture practitioner Tom Watson, who applied this technology in Brazil in the 2000s (Figueiredo and Tonetti, 2019). Some researchers have disseminated it throughout the country over the years and experimented with it in Duque de Caxias. This system uses anaerobic digestion to treat sewage and also generates food – such as banana, taioba (a vegetable), and papaya - that do not offer any risk to health if consumed (Benjamin, 2013; Pires, 2012). This technology requires that toilets have separated plumbing from the remaining plumbing in the bathroom. According to Figueiredo and Tonetti (2019), the green septic tank must be rectangular or oval, with the depth ranging from 1.2m to 1.5m. The area must result from the number of residents multiplied by two square meters. The system must be located in a well-ventilated and illuminated area and positioned on an even surface distant at least 1.5m from trees and buildings. Its construction comprises digging a hole with these dimensions and compacting the soil, then pouring a 10-centimetre layer of concrete, with walls made of masonry laid with cement and sand mortar. Both walls and floor must receive a 1-centimetre layer of waterproof mortar. Then, the PVC pipes are installed into a tunnel made of a line of car tires slightly spaced out with debris in between. The next layer is filled with a 50-centimetre

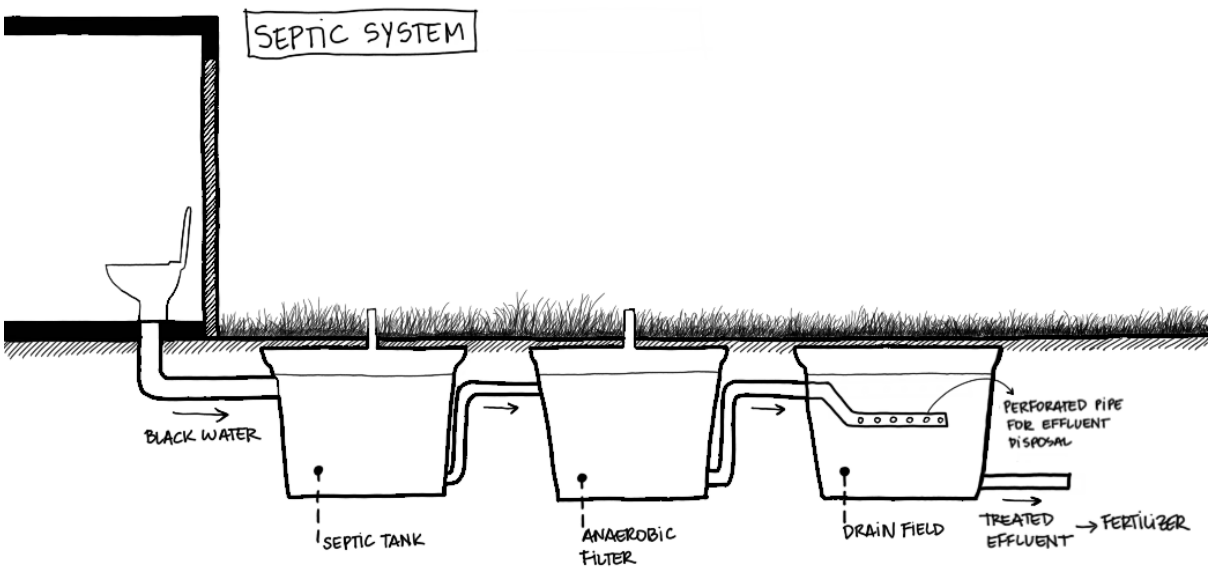


Figure 1.26. Underground Septic Tanks.
Source: Image inspired by Green Initiative, 2015. Image produced by the author.

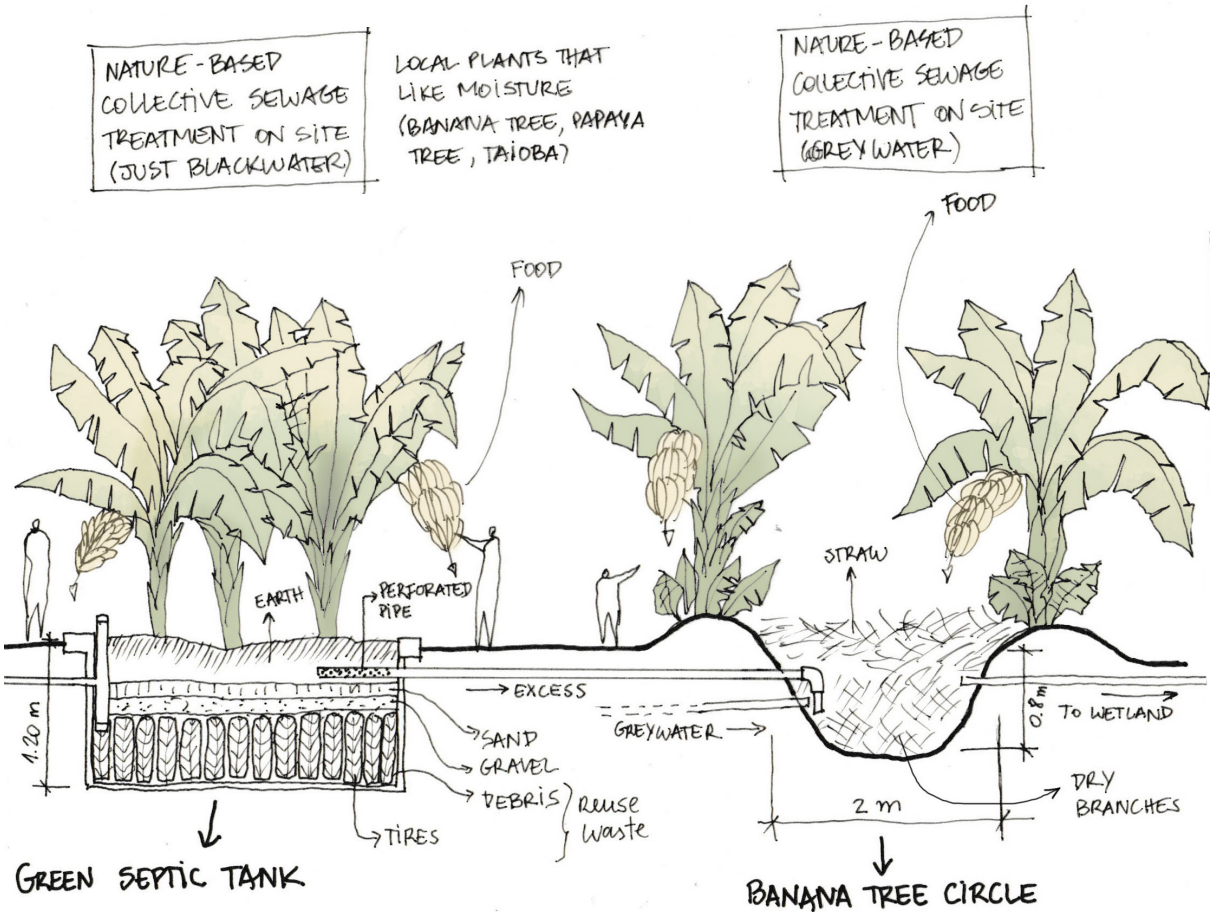


Figure 1.27. Green Septic tank connected to Banana Tree Circle.
Source: Image inspired by Figueiredo and Tonetti, 2019. Image produced by the author.

layer of clean rubble such as chunks of concrete, parts of bricks or larger stones, old clay tiles, etc. The above layer is composed of 20-centimeter of fine gravel or coarse sand and a 30-centimetre layer of earth on top of it. Finally, banana trees, taioba, or papaya trees can be planted (Figueiredo and Tonetti, 2019). It is also important to install a drilled PVC pipe before earthing the system, so the surplus can be directed to another treatment system called "banana tree circle".

After leaving the green septic tank, the next step consists of redirecting the treated waters to banana tree circles, which treat grey waters. To this end, each household should have from one to three banana tree circles. Figueiredo and Tonetti (2019) documented that this system must have a 2-meter diameter and be excavated at 80-centimetre depth. The excavated soil is placed on the system's edges creating a small hill where people can plant taioba, banana or papaya trees. The hole should be filled with branches, straw, and banana leaves, which receive the sewage from a pipe (Figueiredo and Tonetti, 2019). Figure 1.27 illustrates the green septic tank connected to the banana tree circle. The surplus of this treatment is clean water that can be safely directed to the rivers or redirected to wetlands or living machines for a more refined treatment before being conducted to rivers or could be reused for garden irrigation.

Another alternative to treat residential wastewaters is by using living machines. A living machine is a biological wastewater system developed by John Todd, composed of a series of ecosystems assembled in tanks. These tanks contain various species of bacteria, plants, snails, and fish, among others, which imitate natural processes to cleanse and purify water, as seen in figure 1.28 (Browning, 2000). It is a landscape design strategy that can be applied in public or collective spaces to improve aesthetics while treating wastewater.

An additional low-cost and nature-based technology treating residents' grey waters is by applying "Filtering gardens". Wilson da Silva, a researcher at the Brazilian Agricultural Research Corporation/EMBRAPA (Green Initiative, 2015), explained that the system requires an underground container for decantation or settling to separate solid materials. A grease trap box should follow it to intercept most greases and remove grease excess. The surplus residue is redirected to a pond composed of a gravel layer at the bottom, with another layer of sand on top of it. Some aquatic macrophyte species are planted, looking like a garden, as seen in figure 1.29 (Green Initiative, 2015).

Williams (2009) proposed a floating evolutionary community in Miami based on the Aquatecture concept and addressed grey and black water treatment and reuse on-site in a circular approach. The greywater is treated

and reused for irrigation. At the same time, black water treatment was done by utilizing living machines and connecting to an artificial wetland filtration system that returns the treated water to the source (Williams, 2009).

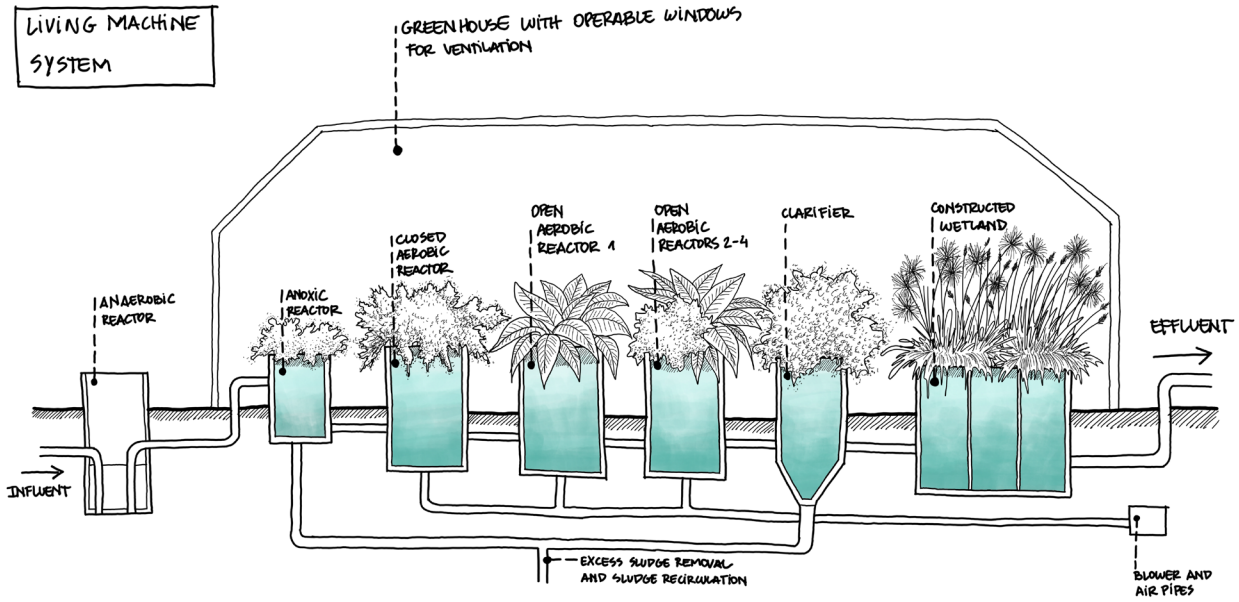


Figure 1.28. Living Machine system for sewage treatment.
Source: Image by author, adapted from Organica Ecotechnologies.

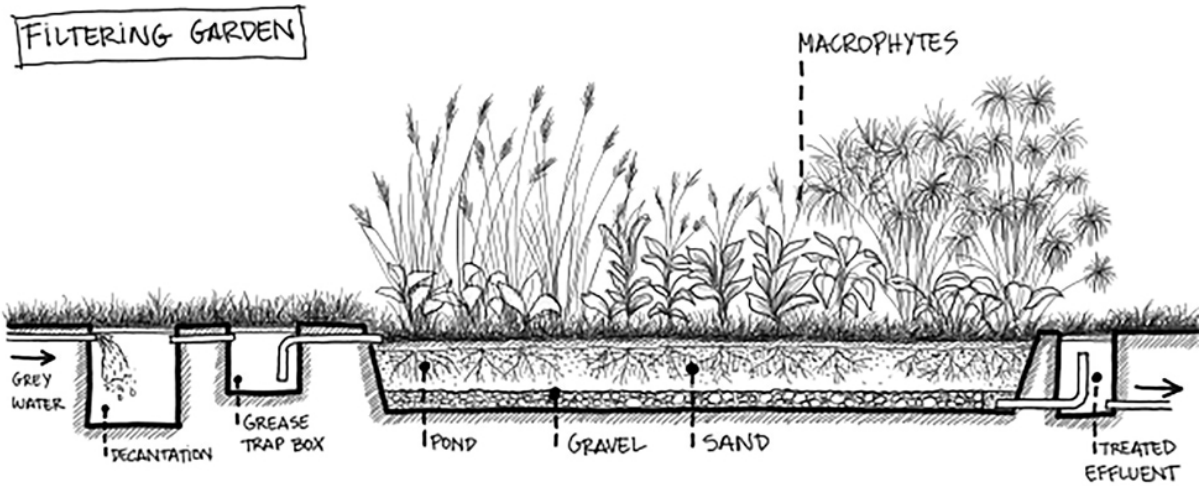


Figure 1.29. Filtering Garden for sewage treatment.
Source: Image by author, adapted from EMBRAPA, Green Initiative, 2015.

Aquatecture design strategies in the building scale
Eco-design strategy

At a building scale, hydroscapes help mitigate flooding, reduce water consumption, recycle water and provide cooling through evapotranspiration (Barker & Coutts, 2016). According to Lotufo (2020), eco-friendly buildings must contribute to biodiversity flow and urban water management. By adopting the eco-design strategy provided by the LifE concept, the housing scale and the lot also play an important role in mitigating floods and creating an eco-town environment. Barker and Coutts (2016) point to water-sensitive strategies on the lot, such as the use of SuDS to slow the runoff and on-site energy generation, but also in the architectural dimension, including green roofs, low carbon materials, local techniques, and building strategies for flood-proofing. They identify five flood-proof architecture typologies: (i) elevated buildings (flood avoidance); (ii) wet-proof buildings (flood resistance); (iii) dry-proof buildings (flood resilience); (iv) floating architecture (floating all the time); (v) amphibious homes (can-float). By being a middle ground between land-based houses and floating architecture, Amphibious architecture has the benefits of both: being flexible to adapt to floods while presenting a ground floor accessibility and security (Barker and Coutts, 2016).

Nillesen and Singelenberg (2011), in the context of the Netherlands, also identify water-dwelling typologies and categorize them as being: floating dwellings, amphibious house, pile dwelling, terp dwelling, dike house, and waterside living. These categories presented by Barker and Coutts (2016) and Nillesen and Singelenberg (2011) are generally applied to the contexts of Global North. Similarly, Januchta-Szostak and Karaskiewicz (2020) identified five types of buildings that adapt to floods (see figure 1.30): (1) buildings on artificial hills or embankments; (2a) buildings with individual flood barriers; (2b) real estates with individual flood barriers surrounding the plot; (3a) water-penetrable buildings: penetrable ground floor; (3b) water-penetrable buildings: open ground floor on stilts/posts; (4) amphibious buildings: placed in foundation docks, which can rise and float during floods; (5a) floating buildings: anchored in ports and at the quays; (5b) residential barges. In figure 1.29, the building type (4) can also be subdivided into two categories: (4a) amphibious buildings placed in foundation docks or pits, and (4b) amphibious buildings on flat ground, without a pit.

Amphibious architecture has been highlighted as an attractive option from all the above building types compared to expensive flood-control structures (Januchta-Szostak and Karaskiewicz, 2020). Because climate change and population growth to urban settlements are increasing pressure on natural systems and posing larger areas at risk of flooding,

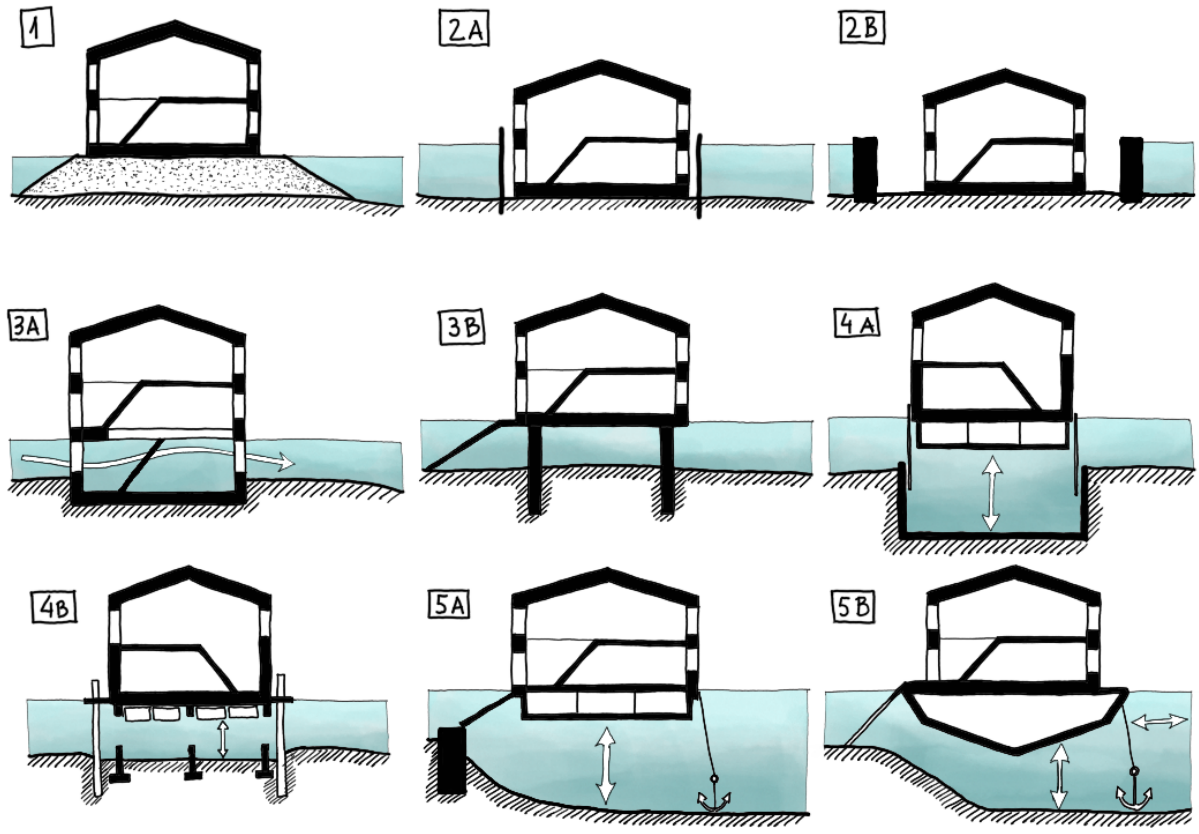


Figure 1.30. Building types that adapt to floods. *Source: Image by author, adapted from Januchta-Szostak and Karaskiewicz, 2020.*

amphibious architecture becomes a potential solution for adaptation to an increasingly uncertain future (Penning-Rowsell, 2020). As Elizabeth English pointed out, it is an innovative way of turning flood risk and threat into an opportunity to implement a resilient design to improve adaptive capacity in communities (Watson and Adams, 2011).

The research and work done by Elizabeth English at the Buoyant Foundation Project and the University of Waterloo have been applying the amphibiation technique in design and practice not only to Global North but in the Global South contexts, such as Vietnam, Bangladesh, Nicaragua, and Jamaica (English, 2016). The first examples of engineered amphibious buildings were produced in the 1980s in south Louisiana, US (English, 2009; Barker and Coutts, 2016), and have proven to work well for over forty years. English's work is pioneering in developing design, prototypes, and construction of amphibious retrofits as an alternative solution for flood adaptation, as seen in figure 1.31 (English, 2009).

The amphibious architecture approach presents strategies that allow the house to float and adapt to varying levels during floods, reflecting an intention to accept and interact with the water rather than deny it (Watson and Adams, 2011; English et al., 2016). It is considered a proactive solution, capable of immediately adapting to dry or wet conditions and, thus, protecting the building from flood damages (Barker and Coutts, 2016; English, 2009). In addition, the building in dry condition has almost no difference from a land-based structure, besides the vertical

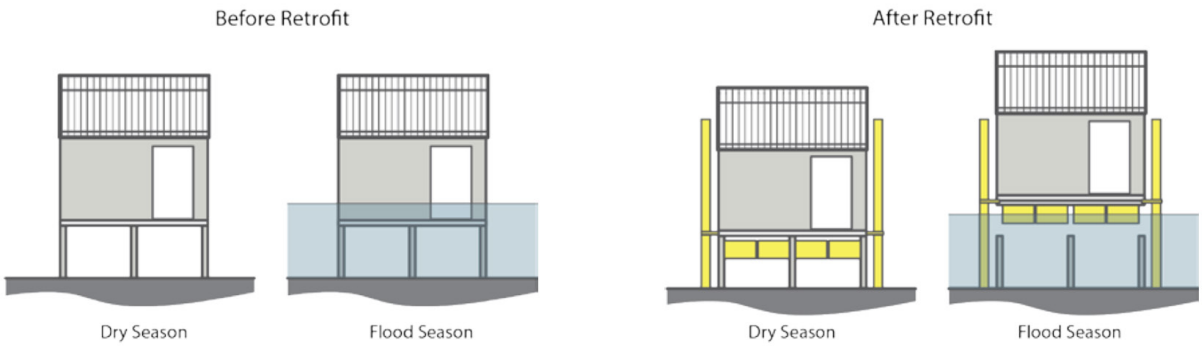


Figure 1.31. A building retrofitted with buoyant foundation. *Source: Bullough, Khokhar & English, 2019.*

guidance posts (Barker and Coutts, 2016; English, 2009). For both new constructions and retrofits, amphibious construction is an inexpensive, low-impact, and innovative response that fosters the preservation of local architecture and the use of local materials, as well as avoids forced evacuation due to flooding and preserves the relationship of the building with the street (English, 2009). Hence, this flood adaptation solution is also sustainable and fosters local practices. Other advantages include social benefits, such as enabling greater accessibility, as it does not require long stairs to access, besides being more cost-effective when compared to static elevation (English et al. 2016; Januchta-Szostak, 2020). Furthermore, amphibious architecture reduces livelihood disruptions and financial losses caused by floods (Barker and Coutts, 2016; English et al., 2016). Accordingly, amphibious architecture not only minimizes the threats of damages caused by floods but contributes to fostering a positive relationship with water, seen as an ally instead of a barrier that needs to be controlled (Barker and Coutts, 2016; English, 2016). Therefore, the amphibious architecture approach used by English (2016) is more appropriate to this thesis since it works well in a context of a Global South country. It also interconnects with the holistic Aquatecture approach, being complementary when applied as flood adaptation measures in multiple scales.

Barker and Coutts (2016) recommend amphibious architecture to areas with high flood risk and uncertainty in future flood levels, sensitive landscape settings, and water depths at least one meter high in wet conditions. They are also ideally suited in flat regions, where floodwaters slowly rise and recede. However, they are not indicated in areas with natural phenomena that generate waves such as hurricanes or tsunamis. Their design must guarantee stability to avoid tipping over (Barker and Coutts, 2016). Barker and Coutts (2016) also point to the importance of considering the neighbourhood context when designing amphibious homes.

The system of an amphibious retrofit building is composed of: (i) a structural subframe that ties all the parts together, attached to the underside of the building to support the buoyancy elements and connect it with the vertical guidance posts. The structural subframe is usually made of steel or wood; (ii) the structural subframe attaches to the vertical guidance posts, localized near the corners of the house, to provide lateral resistance and allow the house only to move up and down. Generally, they could be attached by rope sleeves or steel collars; (iii) the buoyancy blocks or flotation elements. In solutions applied to developing countries, the buoyancy blocks can be made of plastic jugs or barrels, but could also be composed of a set of recapped and recycled plastic bottles tied together; (iv) long and coiled "umbilical" lines (water and electrical) or self-sealing breakaway connections (gas and sewer lines) on the utility lines, to disconnect gas and sewer lines when the building is lifted by floodwaters and accommodate the elevation changes (English 2009; English et al. 2016). See figure 1.32.

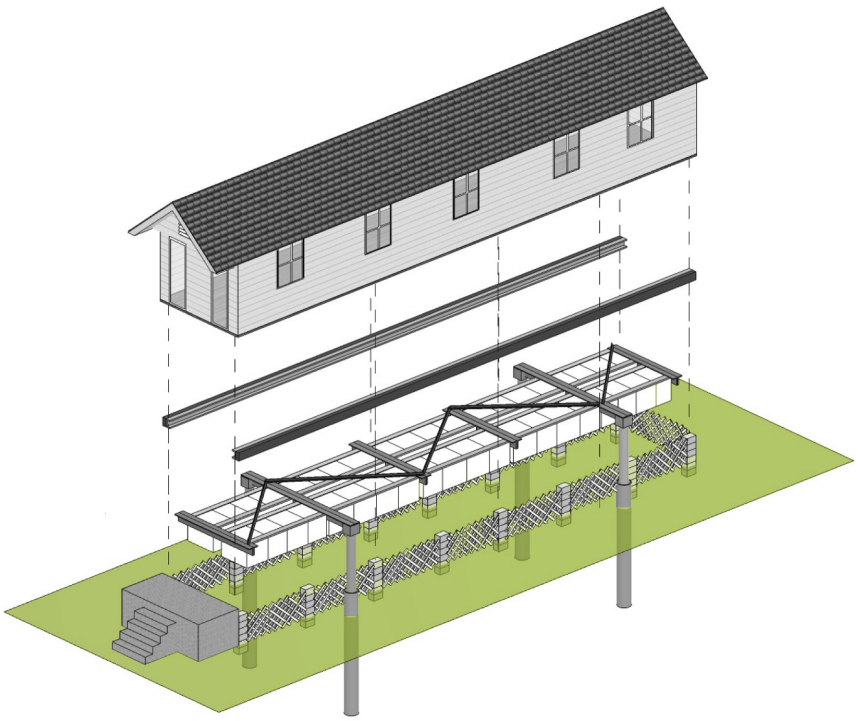


Figure 1.32. Amphibious Architecture system. *Source: English et al. 2016, drawing by BFP.*

However, amphibious architecture still faces significant challenges that hinder its more extensive implementation, limiting amphibious solutions to small-scale projects. Although it is proactive, low-cost, and adaptable to place-specificities, the industry in many countries still lacks specific skills and knowledge to disseminate it in design and construction. Accordingly, training professionals is fundamental to achieving its acceptance on a larger scale (Baca Architects, 2019). The progress in this type of construction is hindered by a lack of knowledge in planning, permitting, and construction, making municipalities hesitant to issue building permits for amphibious structures (Penning-Rowsell, 2020). The lack of standardization in building codes and regulations for this type of construction and the absence of professionals that dominate this technique can also generate issues with liability, which increases hesitancy in adopting amphibious architecture (Penning-Rowsell, 2020).

Watson and Adams (2011) highlight the importance of designing for flood resilience, to create buildings, communities, and regions capable of restoring and improving ecosystem services and reducing the effects of climate change, including intensification of flooding, storm surges, and sea-level rise. In terms of eco-design at the building scale, "it involves harnessing natural resources and sustainable building methods to create low energy, low environmental impact developments and reduce carbon emissions" (Barker & Coutts, 2016). An integral part of eco-building interventions is bioclimatic design, which focuses on biological and climatic aspects for thermal comfort. It includes passive design strategies, such as thermal mass, enclosure materiality, solar orientation, and passive cooling and heating systems (Košir & Krainer, 2008). However, it is more challenging to apply environmental-friendly and bioclimatic design to low-income informal settlements since their residents generally face daily problems at the survival level. Environmental comfort and ecological practices are, thus, considered a luxury or inessential, besides being more expensive and difficult to build than conventional practices (Brunetti, 2018). The modern informal vernacular type that usually defines an "international style of the poor" (characterized by ultralight density, ultra-low-cost, and ultra-small sizes) is almost not being addressed by bioclimatic studies currently. In many cases, the general public considers informal settlements incapable of being improved in situ due to their precariousness (Brunetti, 2018). The hyper-high densities, hyper-small size and hyper-low cost of typical informal settlements around the world are usually the barriers to implementing a posteriori bioclimatic practices since many of them require planning in advance to achieve an adequate size or quality, such as courtyards (Brunetti, 2018). Alternatively, Harnish (2018) sees informal settlements' incrementality as a valuable resource to be absorbed by architectural design in terms of adaptability, seen as a "method of development born of the opportunities and capabilities of local residents".

This ever-evolving incrementality process in informal settlements presents direct relationship between the user and the process since they are self-constructed and implemented spatially by residents, with self-evolving economies and self-informed politics (Harnish, 2018).

Complementary to English's discussion on amphibiation, Barker and Coutts (2016) bring the concept of hydroscapes which work in different scales to achieve flood mitigation. At a building scale, hydroscapes also reduce water consumption, recycle water, and provide cooling through evapotranspiration, such as in rain gardens, green and brown roofs, permeable paving, pools, ponds, bioswales, and rainwater harvesting (Barker & Coutts, 2016). Watson and Adams (2011) also discuss practical strategies for flood-resilient design at the building scale, including foundation types, structure, exterior walls, roofing, and services.

…

All the above practical solutions could minimize the degradation of urban rivers in low-income and vulnerable communities while enhancing public and community lives, including applying mechanisms to avoid the potential gentrification (See page 57 for more details). To effectively regenerate river systems, nature indispensably needs to become the priority, being balanced, integrated, and aligned with the community's needs and aspirations. To this end, it is fundamental to raise awareness of the importance of watershed preservation and to have people engaged as its stewards for long-term success. It is paramount to focus on healing the whole, not just some parts of it. This thesis's proposal affirms my position of applying decentralized, holistic, multi-scale, multifunctional, integrated, collaborative, and interdisciplinary solutions to achieve resilience and community empowerment in the urban space. It is about reflecting and acting on the present and prospecting a better future that, although uncertain, has the proper support to adapt to unknown circumstances that require flexibility to transform.

Part 2 | Community

Adaptive Living

2.1. Social problems in the Roncador River surroundings

Formation of the Metropolitan Region of Rio de Janeiro (RMRJ) peripheries as a process of displacement

The occupation of Duque de Caxias City, like the other cities in the Baixada Fluminense, started at the beginning of the 20th century, when working classes began to occupy inexpensive lands closer to railways (See figure 2.01). Since its first colonial settlements in the 16th century, Duque de Caxias was essentially a rural area, providing important polyculture agricultural products to supply Rio de Janeiro, the capital city. Some of its major plantation cycles over these centuries included sugarcane (16th), coffee (19th), orange (19th), and other food production. However, its agricultural production became stagnant by the end of the 19th century (Simões, 2007). By 1894, the Sanitation Committees were created to solve flooding and epidemic issues under the hygienist principles (preparing the way for future occupation), and were responsible for river channelization interventions (Simões, 2015; Raulino, 2016), as outlined in chapter 1. The start of the urbanization process at the Baixada Fluminense lands was favoured not only by the stagnant agriculture, cheap lands, and mass railway transportation but also by the high prices and scarcity of land in the Rio de Janeiro city (Simões, 2007; Magalhães, 2016). Additional investments in infrastructure, such as roadway, sewage, and energy systems, were implemented as of the end of the 1920s, coinciding with the end of the orange plantation period, heralding the transformation of this rural region into an urbanized space (Lima and Souza, 2014).

As happened in the largest Latin American cities, rural migrations, economic development, and cheap land availability triggered rapid (and uneven) urbanization and demographic growth processes (Sánchez-Calderón, 2017). The capital city of Rio de Janeiro was no exception and highly influenced the urbanization and growth of Duque de Caxias City as its most important peripheral city. However, the significant development was marked by intense socio-spatial segregation, typical of many Latin American cities (Sánchez-Calderón, 2017). As of the mid-twentieth

Figure 2.01. Start of occupation of Duque de Caxias City in the beginning of 20th century, usually settled adjacent to railway tracks or riverbanks edges. *Source: Duque de Caxias que passa, 2017.*

century, a massive process of industrialization started to be installed in Duque de Caxias territory, which, in parallel with the development of the railway and highway systems, began to attract people from other regions seeking jobs (Raulino, 2016). However, this population growth process lacked urban planning to control it and the land occupation became characterized by being disordered (Raulino, 2009; Silveira and Ribeiro, 2017).

By the 1940s-1950s, the allotment process (based on parcelling the former rural lands) intensified the rapid urbanization of Duque de Caxias. Migrants (from the Rio de Janeiro state and other regions) were mostly attracted by their low-cost price and the relative proximity to the capital city (Lima and Souza, 2014; Simões, 2007; Silveira and Ribeiro, 2017; Magalhães, 2016). The farther the lands from Rio de Janeiro, the cheaper they were (and less infrastructure they had). Many of these migrants were workers evicted from low-income tenements and slums in the capital. During this decade, the government implemented a displacement policy in the city's central areas toward urban renewal, dispossessing many impoverished people (Lima and Souza, 2014; Silveira and Ribeiro, 2017). The lowest-income groups started to occupy the peripheral Caxias lands by mainly producing their houses through self-construction[8] (Simões, 2007). During this rapid Duque de Caxias urbanization process, the private capital and the State were not responsible for the housing production for the lowest-income groups. Indeed, both the government and the private capital fostered the process of peripheralization, by what Harvey (2003) names as "accumulation by dispossession" (See Section 2.2); However, this process was done without providing housing for the displaced low-income groups. The government removed the slums from central areas in the capital and allowed urban land speculation by keeping vacant lands in valued areas. Likewise, real estate developers also contributed to this gentrification process (Pacheco, 1984). By bringing and building amenities in the central areas, they increased the urban land's value, thus accelerating the dispossession of impoverished groups residing there.

8 Simões (1993, 51, translation by the author) defines self-construction as the "process by which the worker and his family, alone or with the help of others, performs all or most of the task of building their own home", using non-capitalist and collective social relations for this end (Simões, 2007).

Accordingly, the housing production process for the poorest groups in Duque de Caxias and Baixada Fluminense was characterized mainly by self-construction as their only alternative. This last resource was, in fact, cheaper and efficient, thus feasible in conjunction with factors such as the railway and the allotment process during the 20th century (Simões, 2007). In Brazil, self-construction has already been practiced in rural areas since colonial times and the 19th-century urban slums (Simões, 2007). It was done incrementally, according to the residents' needs, budget, and time availability (Simões, 2007). Generally, the houses produced under this model in Duque de Caxias had wooded backyards as a common element, where social gatherings and parties took place, as the streets were usually violent (Simões, 2007).

Additionally, Simões (2007) stresses that self-construction in the Baixada Fluminense was a collective process, whereby residents build together houses and collective infrastructure facilities. This urban occupation model adopted in the city represented a "cleansing" practice, which allowed for the low-income classes and their social problems to be transferred from the capital city to this peripheral region, securing a "better place" for the highest-income groups (Silveira and Ribeiro, 2017). Yet, these new allotments still lacked culture, leisure, health, and education infrastructure, due to the government's omission (Silveira and Ribeiro, 2017). As Millington (2018) stressed, self-construction in Brazil is the hallmark for uneven access to land, which is a reaction to the government's neglect.

The district of Imbariê, where the Roncador River is located, started to be occupied from the 1960s to 1980s, as shown in figure 2.02. Because Imbariê is more distant from Rio de Janeiro city than other more central Caxias districts, its lands became occupied some decades later (Silveira and Ribeiro, 2017). The exception is Parque Paulista, adjacent to the Roncador River; this neighbourhood had its first occupation in 1948 (Silveira and Ribeiro, 2017). One major factor contributing to the urban expansion to these more distant areas was the construction of several highways. They included the Washington Luiz Highway or BR-040 in 1928, the Avenida Brasil expressway in 1946, and Presidente Dutra Highway or BR-116 in 1951. In addition, the installation of the petroleum refinery industry (Reduc) in 1961 also escalated the occupation toward these more remote areas as a significant employment source (Abreu, 1987).

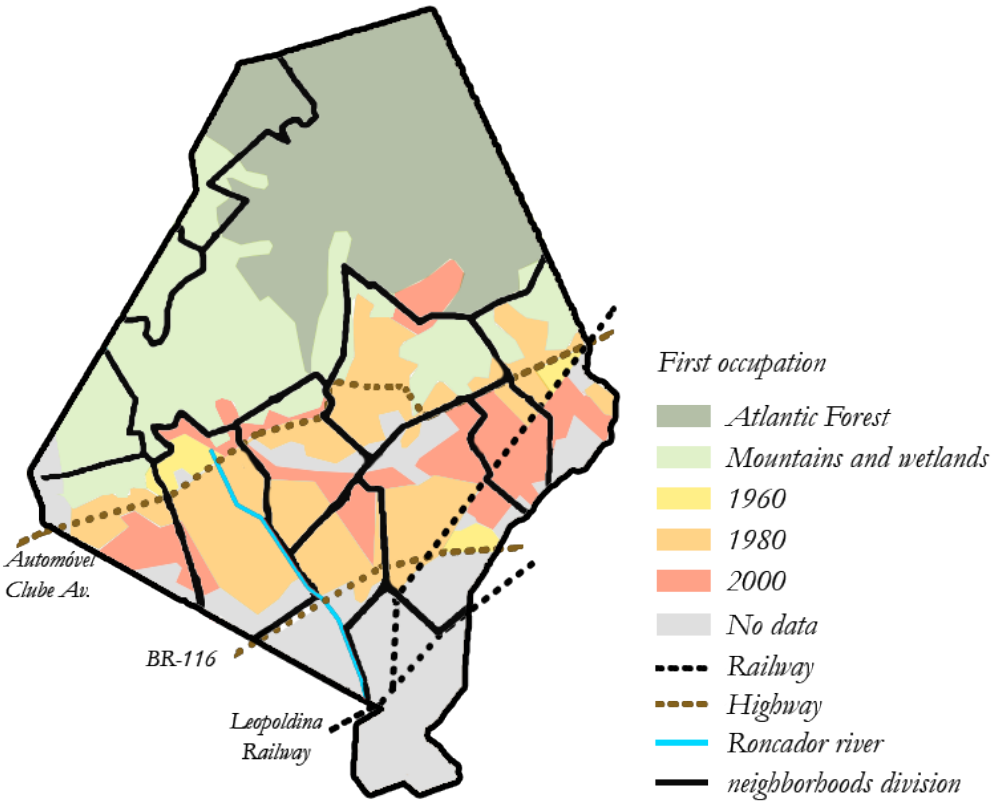


Figure 2.02. Urbanization process in Imbariê district, in Duque de Caxias city.
Source: Adapted from Silveira and Ribeiro, 2017. Image produced by the author.

The housing deficit in Brazil and Duque de Caxias

In 2012, Brazil accumulated over 5.7 million of housing deficit, concentrated in the lowest-income families, which resulted in the increase of informality in peripheral zones and at-risk areas as their only alternative to access housing (FJP, 2000). In 2015, this number increased to 6.4 million households, with almost 90% of them being located in urban regions and affecting over 19 million people, corresponding to nearly 10% of Brazil's population (FJP, 2018). Around 93% of families that compose the housing deficit in the country cannot afford decent housing and are particularly dependent on public support to access homeownership (MC, 2010). On the other hand, vacant properties, which could be used to reduce the massive housing deficit, totalized almost 8 million, the majority in urban areas, highlighting a contradiction propelled by property speculation (Campos and Martínez, 2020). According to the Local Social Housing Plan (PLHIS), in 2010, the housing deficit in the city of Duque de Caxias reached almost 33,000 units, and this number is projected to increase to nearly 45,000 units in 2023 (Placido et al., 2019; da Silva et al., 2015). Most of this demand for housing is directly related to the need to relocate people living in precarious conditions on the rivers' edges and floodplains (da Silva et al., 2015). In 2016, more than 50,000 people subscribed to the MCMV program (the active national social housing program that year), demonstrating that the housing deficit could be higher than what was accounted for. Therefore, Brazil has an urgent need to make access to affordable and adequate housing a universal right, also reaching the lowest-income groups (Lamounier, 2017).

Failure of the social housing program in Brazil and Duque de Caxias

The housing issue in Brazil has been a challenge faced by public policies, having been neglected and lacking investment for decades, which provoked an accumulation of the nationwide housing deficit concentrated within the most impoverished classes (Placido et al. 2019; da Silva et al., 2015). Accordingly, the major challenges for the housing policy to achieve universal access to housing lie in overcoming the housing deficit. This can be done by building decent, affordable dwellings and urbanizing precarious settlements in peripheries with proper infrastructure and services (Pedro, 2013). Previous social housing programs in Brazil failed to address the housing shortage of the poorest classes and significantly contributed to the increase of informality in peripheral regions and spatial segregation (Placido et al., 2019; da Silva et al., 2015). Thus, there is an urgent need to prioritize these most vulnerable groups within Brazil's housing and social policy (MC, 2010).

The most relevant and large-scale social housing program in Brazil's history, which received the highest investment so far, was called "Minha Casa Minha Vida" (PMCMV). This social housing program was created in 2009 under the law 11.977/2009 and was managed by Caixa Econômica Federal (Brasil, 2009). PMCMV provided a subsidy to rural and urban low-income individuals to purchase housing and, thus, access homeownership (MC, 2010; Campos and Martínez, 2020). However, it was not considered any better than the previous social housing programs in Brazil in terms of architectural design (Lamounier, 2017). In January 2021, PMCMV was replaced by the most recent housing program named "Casa Verde e Amarela" or Green and Yellow House. This housing program was created under the law 14.118/2021, which aims to broaden the reach of PMCMV and provide housing to 1.6 million low-income families across the country by 2024 (Verdélio, 2020). GT Habitação e Cidade (2020) criticized that the "Casa Verde e Amarela" program maintains continuity with the mechanisms used by the MCMV program. It promises to increase the proximity between the real estate sector and the interests of the financial market, but ending up treating home ownership as a commodity instead of fostering the universalization of the right to housing. Before PMCMV, the most important social housing program was Banco Nacional da Habitação (BNH), created in 1964 and terminated in 1986 (Placido et al. 2019).

Because the demand for housing is much higher than the supply, the different needs of various families were usually not adequately considered

in past social housing projects, either in planning, design, and construction (Lamounier, 2017). Previous national public housing programs in Brazil have provided low-quality, homogeneous, and poorly designed housing units to the residents, located in distant lands that lack urban infrastructure and accessibility, which disrupted these populations' livelihoods and their community bonds (da Silva et al. 2015; Placido et al. 2019; Pedro, 2013, Campos and Martínez, 2020). Usually, PMCMV's condominiums are located in peripheries far from urban centers, where the land is cheaper, thus, far from employment sources, hospitals, and schools (Placido et al. 2019; Pedro, 2013; Campos and Martínez, 2020). Therefore, people's lives became more precarious, and the government had their costs increased as the further the housing is from urban centers, the more public investment in infrastructure and urbanization is needed (Placido et al., 2019; da Silva et al., 2015). Yet, the government allowed the construction of most MCMV condominiums in peripheral regions lacking infrastructure, often in flood-risk lands and did not invest in urbanization (Placido et al. 2019).

Research indicates that the previous and current social housing programs in Brazil provide housing as a commodity and financial asset, instead of guaranteeing universal access to the right to housing and to the city, as advocated in the Federal Constitution of 1988 (GT Habitação e Cidade, 2020; Placido et al. 2019; da Silva et al., 2015; Lamounier, 2017). Cardoso (2013) criticizes the MCMV program for excessively favouring private capital, which seeks to maximize profit, including choosing less expensive lands – usually in peripheries that lack urban infrastructure and accessibility - for building the housing projects (da Silva et al., 2015; Lamounier, 2017). Moreover, this disordered urbanization model has contributed to air pollution and, thus, climate change due to its heavy dependence on road infrastructure (Rolnik e Nakano, 2009). Therefore, the past housing projects under the MCMV program were criticized for not articulating with any urbanization program or public policies to build infrastructure locally (da Silva et al., 2015; Cardoso, 2013; Pedro, 2013; Campos and Martínez, 2020). Pedro (2013) adds to this discussion that MCMV developments also offered unfriendly pedestrian and bicycle paths and poor connection to local streets, disregarding persons with special needs as the focus lies on standardization.

Consequently, the low-income residents become more vulnerable and impoverished since they cannot keep a job living far from the employment source. Most of them also lose the source of income they had in their original communities. Their new, and often verticalized housing type,

is inappropriate to support their local informal economies, which usually occur horizontally. By intensifying the expansion to the peripheries, the MCMV program has been increasing social inequalities and worsening the quality of life of the poorest classes (Pedro, 2013). Although the MCMV housing program had produced around 4 million dwellings for all income groups until 2016, it still was not considered effective in addressing the actual housing deficit, especially for the poorest groups (Lamounier, 2017). Ultimately, the MCMV program not only did not reduce the housing deficit but also compromised the right to the city of lower-income groups (Campos and Martínez, 2020).

Additionally, the MCMV standardized housing design, due to its rigidity and limited plan, does not support flexibility to convert a room into a source of income, as usually is possible in self-built homes in informal houses. Lamounier (2017) considers the major chronic issues in public housing production as the lack of the resident's participation in the decision-making process and the absence of spatial flexibility, as opposed to informal self-built settlements in Brazil. The standard units provided to all residents across the country were end-products ranging from 39 to 44 square meters for a household of 4 people on average, with a rigid and standardized programme, located in a building type that was the same for all regions in Brazil (Lamounier, 2017). The needs and demands from different socio-cultural backgrounds and income groups across the regions in Brazil are clearly varied; yet, the public housing production has been neglecting this very basic fact, creating monofunctional spaces that do not work well. Basic activities such as playing, socializing, drying clothes, selling as a significant source of income, working, among others, were not included in the MCMV housing design programme.

The housing design has disregarded the local practices of housing production, delivering a top-down and rigid solution for homes that did not adequately address the residents' needs nor allow them to keep evolving their houses over time as they were used to (da Silva et al., 2015; Pedro, 2013; Lamounier, 2017). Considering that around 70% of the housing production in Brazil is self-built, which increases to 85% if we include renovations and expansions (Lamounier, 2017), it is fundamental to consider the user participation and ability to change its house on the social housing production. These numbers also reflect that the lowest-income residents in Brazil prefer self-building to public housing production because at least their needs are better addressed, and they are the decision-making agents (Lamounier, 2017). Cardoso (2013) stresses the poor design

and low-quality construction that the MCMV program has delivered. Because the housing design in the current social housing program is not planned to be modified over time (treated as an end product instead of an evolving process), it is a more expensive solution for the government or developers who will build them, making homeownership less accessible and less affordable. It gets expensive because the government must invest in the house as the completed end-product, which is more expensive than providing, for example, half of a good house, which could be doubled over the years by the residents. Instead of providing housing as an end-product, it would be more efficient and cost-effective to see it as a process by giving the residents a basic starter unit they can afford, which could be expanded and improved over time when needed. Pedro (2013) discusses the drawbacks and opportunities of previous social housing programs in Brazil and points to the importance of designing social housing to be more flexible and adaptable to future changes. Lamounier (2017) demonstrates that the different needs of diverse families who will live in social housing must not necessarily be predetermined and controlled. Still, they must be taken into consideration in the planning and design processes.

These issues faced by the Brazilian government with the MCMV program and previous social housing programs are not exclusive to Brazil. Gattoni (2009) pointed out that land, development standards, and public housing are usually the three most common issues governments must deal with to house low-income groups. The more lands are consumed in the urban sprawling, the more expensive central plots get, and more investment is needed to provide infrastructure to new peripheral settlements. Most governments use standardized and homogenous models for public housing to keep prices the lowest as possible, albeit compromising the house's capacity to respond to the occupants' unique needs in the present and the future (Gattoni, 2009). Gattoni (2009) blames the implementation of homogenous models as the culprit for most public housing programs' failure. Alternatively, sites-and-services was a successful housing model for the lowest-income groups (Gattoni, 2009). In this model, the government provides the land with essential utilities (clean water, flood protection, and sanitation) and sanitary cores in the starter house. The residents were, then, responsible for building the rest of their houses incrementally (Gattoni, 2009). Therefore, it allowed them to increase their control on housing production at a low cost (Gattoni, 2009). However, this model requires a housing policy that fosters equitability, incrementality, and land availability to properly work for affordable housing (Gattoni, 2009).

Social housing provision alone will not solve the housing problem; it is paramount to integrate it into other policies to guarantee access to the city and urbanity (Balbim, 2011; Lamounier, 2017). Many past public housing interventions, especially in peripheral areas, were not successful in Brazil because they ignored infrastructure provision and job creation (Placido et al., 2019). Construction initiatives toward housing, sanitation, transportation, public health, recreation and other sectors should be part of an integrated planning and management agenda that prioritizes the collective welfare, reducing social inequalities and spatial segregation and increasing access to the land (Balbim, 2011; Lamounier, 2017). In Duque de Caxias, the lack of sanitation, the increased urban floods, and river degradation are intertwined with housing issues and must be addressed together (da Silva et al., 2015; Placido et al., 2019). The provision of sanitation services integrated with housing policies and urban water management is still a significant challenge that hinders urban space democratization and watershed preservation in Duque de Caxias and other peripheral Brazilian cities (Raulino, 2016). In the past decades, the functionalist urbanism practiced in Brazil has encouraged the separation of sectors (sanitation, housing, education, recreation, circulation, health), contributing to the challenge of territorial integration of urban policies (Balbim, 2011).

For social housing to be successful, housing projects should be located in vacant lands within urban areas with consolidated infrastructure or on their borders, which would provide more quality of life to residents and reduce costs with public investment in urbanization (Placido et al., 2019). However, this is a challenge in Duque de Caxias city because of the high prices of land in urban centers, which will reduce the developers' profit under the social housing program (Placido et al. 2019). Silva et al. (2015) stress the need to think more holistically to address the housing issues by focusing the efforts on building more equitable neighbourhoods and cities. Lamounier (2017) adds that the public housing production must prioritize building small-scale and low-rise projects, encompassing an average of 300 to 500 units. Balbim (2011) advocates that cities must be spaces for integration. This comprehensive way of dealing with the housing issues presents the challenge of structuring a housing policy integrated with other infrastructure demands to qualify the territory (da Silva et al., 2015). It is imperative to address the housing problem in the Roncador River region in relation to its river and the lack of other services and seek comprehensive responses that integrate both housing and water issues.

The need for an adaptable home in the Roncador River surroundings

The housing provision should ultimately aim to create healthy, sustainable, diverse, and vibrant communities, incentivizing the generation of a sense of place by appropriately connecting to the local context (Pedro, 2013). For local communities to thrive in social housing developments, it is paramount to seek housing quality, not only quantity. Housing quality includes providing an appropriate level of intimacy, space, security, lighting, ventilation, and infrastructure within a location close to employment and essential services at an affordable price (UN, 2002). A quality housing must respond to its users' needs at the present and future, "aligning individual and society needs and integrating priorities and collective values determined by the context, all in a generative process", being vital to the society development (Pedro, 2013, p.5). In the city scale, quality communities would be composed of citizens who are incentivized to collectively change themselves by changing the city according to their needs and desires over time, thereby exercising their right to the city (Harvey, 2008).

Quality housing must allow internal adaptations and expansions over time to be efficient and durable, fostering flexibility during its lifetime (Pedro, 2013). It is about creating the conditions to support healthy community growth. Thus, for offering a good quality of life, a house must be sustainable, affordable, foster users' participation and empowerment, supporting a variety of uses and socialization opportunities, and responding to the local identity and context (Freitas et al., 2002).

Consequently, the surrounding areas will experience direct positive results, such as reduction of criminality, improvement in public health, increase in property value, and positive environmental return (Pedro, 2013). Diversity of building types and mix of incomes, uses, and family types are also key factors for generating thriving communities (Pedro, 2013). Hence, adaptability, flexibility, and incrementality are invaluable features for achieving quality housing design and vibrant communities. Those three elements allow diversity to happen and highlight the role of the users as active participants and decision-makers in the housing production throughout its lifetime (See Section 2.3). They are particularly relevant in impoverished and neglected contexts, where there is an urgent need to produce more numerous and better housing, capable of adapting and responding to local specificities and issues.

Uneven access to land and housing in the Roncador River community

Unplanned and unserviced occupations, typical of informal settlements such as Roncador River surrounding communities, became the predominant model to house the poor in developing countries (Rolnik, 2014). Informality became a response to the government's neglect and inability to solve the massive housing deficit, especially for the poorest, and avoid conflicts and protests while keeping economic growth (Gilbert, 2020). The government and decision-makers in Brazil have prioritized the private capital interests over the communities' needs (Campos and Martínez, 2020). Accordingly, the urbanization process in Duque de Caxias city reflected an economic development model that concentrates wealth and is socially and spatially excluding by nature. When added to the lack of housing policies for decades, it leaves no options for the most disadvantaged groups but to inappropriately inhabit precarious settlements in risk areas, such as riverbanks (Raulino, 2016).

Self-built squatter occupations of vacant land are frequent in Brazil, usually in public lands and tied to social movements that question the government's neglect in addressing housing injustice and increased speculation (Campos and Martínez, 2020). Usually, these marginalized populations start to inhabit inappropriate, precarious, and at-risk lands (riverbanks, mangroves, and wetlands) not because they prefer or ignore the risks of living there, but because those are of low speculative interest, thus their only option (Costa, 2012, Raulino, 2016). Often, informal occupations transform riverbanks in "slum rivers" (Sánchez-Calderón, 2017). It is essentially a result of social inequalities in the urban space, influenced by political, economic, and social factors (Raulino, 2016). The process of informal occupation entails buying cheap and unbuilt land plots in peripheral regions, usually without access to urban public services, building the house by self-construction, hoping that an eventual formalization and installation of public infrastructure will occur over time (Sánchez-Calderón, 2017).

Many people, especially in South America, live informally in at-risk, environmentally protected areas and precarious settlements that lack basic infrastructure (Nunes, 2015; Rolnik, 2014). The informal housing production reflects the deeper problem of spatial segregation, uneven access to urban land, and structural inequalities embedded in housing policies (Silva et al., 2015; Campos and Martínez, 2020). Accordingly, peripheral regions grow without proper structure and pose flood and health risks to

their increasingly vulnerable residents, who were induced to occupy these improper areas (Lima and Souza, 2014). Rolnik (2008) stresses that the segregating development model applied in the Baixada Fluminense has generated issues related to land use and the lack of proper housing and environmental policies, which have been particularly impacting the lowest-income residents.

The poorest groups' rapid and unplanned urban expansion to degraded and vulnerable peripheries form uneven spaces, characterized by environmental injustice (Lima and Souza, 2014). The vulnerability of these marginalized groups increases due to social, economic, environmental, political, and sanitary factors (Richemond and Veyret, 2013). Consequently, the illness related to contaminated water by sewage is directly related to poverty (Lima and Souza, 2014). Rolnik (1997) names this process of occupying precarious lands that lack basic public infrastructure and services by an impoverished portion of the population as Risk Urbanism, meaning that they do not have access to proper housing and the minimum services a city must provide. Several Duque de Caxias residents live under the Risk Urbanism, lacking sewage treatment system, adequate housing, and access to proper education, transportation, and health services (Lima and Souza, 2014). Lima and Souza (2014) discuss the socio-environmental issues grounded on the concepts of risk, vulnerability, and environmental justice in Duque de Caxias.

Although the term ‘slum’ may not be the most appropriate one, Gilbert (2020) stresses this term as a negative stereotype that may undermine and stigmatize people already marginalized who live in impoverished settlements. The terms slum and squatter settlement usually refer to temporary occupations related to precarious infrastructure, materiality, and legal status (Williamson, 2020). The common characteristics of informal housing include self-built and self-help incremental dwellings inhabited by impoverished people. They are located in a peripheral and underserviced land that usually lacks title, is public, is of low economic value, and is inappropriate to build on, such as riverbanks, hillsides, and mangroves. Sanitation, electricity, transportation, recreation infrastructure, and education and health facilities come later depending on the private sector or government investment (Gilbert, 2020; Sánchez-Calderón, 2017).

On the other hand, Williamson (2020) highlights the unique qualities of long-time slums and other informal communities, which should not be undervalued since they present important lessons on community living.

Their residents usually have a strong bond and sense of togetherness, reflected in a greater sense of belonging, besides showing high levels of solidarity, creativity, and adaptability capacity to deal with difficult situations, making them more resilient (Williamson, 2020). By exercising the practice of commoning, many individuals in informal communities benefit from working together, maximizing resources to reduce risk (Williamson, 2020). Therefore, Williamson (2020) advocates that property possession should not be considered a basic human need, but safety and affordability in land tenure, as seen in Community Land Trusts, to promote more inclusive, diverse, spontaneous, resilient, and sustainable communities. This instrument provides individuals with housing rights to buy and sell while the land becomes the community's property forever. It eliminates the possibility of land speculation since the land is collectively possessed and cannot be sold together with the houses. Hence, invaluable qualities acquired in the incremental process of informal community-building get to be preserved in this model (Williamson, 2020).

Demographic information in the city of Duque de Caxias, and the relationship between people and the watershed

Duque de Caxias is the third most populous city in the Rio de Janeiro State and one of the most populous in the country, comprised of over 882.000 inhabitants (IBGE, 2015). However, its economic indicators conflict with social indicators (Silveira and Ribeiro, 2017). It has the second-highest Gross Domestic Product (GDP) in the Metropolitan Region of Rio de Janeiro, the third-highest in the State of Rio de Janeiro, and one of the highest in the country (IBGE, 2015). Nonetheless, this richness is not evenly distributed, presenting a low Human Development Index (Silveira and Ribeiro, 2017). On the one hand, the city possesses one of the most important commercial and industrial centers and the most relevant space for petroleum derivatives production of the State. Moreover, Caxias is localized close to Rio de Janeiro (an important consumer market) and well-connected by a robust roadway system (Silveira and Ribeiro, 2017).

Conversely, the lack of institutions to train the skilled workforce and the insufficient primary education in the city reduce the opportunity for evenly distributed salaries, meaning that wealth is concentrated. When compared to the average household income in the city, very low, this uneven wealth distribution gets clearer (Silveira and Ribeiro, 2017). The low household income drastically influences the low quality of life of Duque de Caxias

population, indicating why this city has the highest number of people inhabiting slums in the entire Baixada Fluminense and the second in the State of Rio de Janeiro (Silveira and Ribeiro, 2017). Costa (2012) also points out that Duque de Caxias being close to the Rio de Janeiro city and its abundance of vacant lands of low speculative interest favoured the growth of slums close to rivers and floodplains in the region mid-20th century. When considering that the city historically lacks sewer infrastructure, especially in the central and northern zones prone to expansion (Placido et al. 2019), it is clear why Duque de Caxias presents a high rate of its population living in very precarious conditions. The sanitary issue gets exacerbated due to the illegal and hazardous occupation of riverbanks by low-income residents (Placido et al., 2019; da Silva et al., 2015). The center-periphery model applies to Duque de Caxias, whereby the central regions concentrate services, infrastructure, employment, and high-quality housing, while impoverished peripheral portions of the city lack those (Silveira and Ribeiro, 2017).

The Imbariê district, where Roncador River is located, has a population of 161,853 residents, of which 99% of this population lives in urban areas (Magalhães, 2016). However, the remainder 1% are responsible for supplying organic food to the local public schools. People who currently live in this region, and Duque de Caxias city overall, are primarily migrants who came from the Northeastern Brazilian region in the mid-twentieth century, attracted by new sources of employment in factories, cheap land, and proximity to the city of Rio de Janeiro (Magalhães, 2016). Thus, most of its residents have traditional habits of organizing weekly or even daily food and artistic markets on the streets, very common in the Northeastern parts of Brazil, to display handicraft products and local food (Magalhães, 2016). The most common architectural type of residence is the detached single-family house up to three stories, representing 88% of the dwellings in the district landscape (Magalhães, 2016), mainly produced by self-construction, especially in informal settlements.

About 76% of Duque de Caxias residences are connected to a sewage system that mixes wastewater and stormwater. There is no sewage treatment before being discharged into the rivers, while almost 9% use individualized septic tanks to treat their sewage on-site (IBGE, 2010). Hence, the lack of proper sewage treatment becomes one of the major socioenvironmental issues the local populations face, especially during frequent flood events. Parque Paulista is one of the neighbourhoods adjacent to the Roncador River and constantly suffers from floods

and contamination by lack of sanitation. As stressed by Costa (2017) and Raulino (2016), Duque de Caxias, including the Parque Paulista neighbourhood, suffers from environmental injustice and inequality resulting from uneven distribution of environmental risks, environmental crimes and degradation by water, air, and soil pollution. Costa (2017) considers the Duque de Caxias Oil Refinery (REDUC) the main source of pollution and contamination of surface water, groundwater, air, and soil. When mixed with the impacts of recurrent floods, REDUC is responsible for indirectly generating several chronic diseases such as cancer, meningitis, hepatitis, tuberculosis, leptospirosis, heart diseases, viruses, skin diseases, and infections (Costa, 2017). In addition to increasing water quality issues in Duque de Caxias (and particularly severe in Parque Paulista), REDUC has raised water quantity concerns. It has been generating a chronic water shortage for supply. The refinery uses around 3,000 litres of water per second to refine the petroleum, which diverts water from the local people and generates more diseases (Costa, 2017; Raulino, 2016).

Water quality and quantity issues in the city, especially for those living closer to the rivers, increase their dependency on other water supply sources, such as water trucks, artesian wells, clandestine connections or counting on neighbours' solidarity (Raulino, 2016). Nevertheless, the government still does not punish the refinery for its environmental degradation crimes, neglecting people's claims, as mentioned in Costa (2017). Particularly in the Parque Paulista neighbourhood, the contamination of drilled wells, the primary water supply source, is an alarming issue generating many diseases in the residents. They are often forced to walk over one hour and a half to get clean water from the Environmental Protection Area nearby or pay for bottled water since the public water supply service does not supply the entire district (Costa, 2017). As Costa (2017) highlighted, some residents complained that the water shortage by public supply lasted over 20 consecutive days in a month, but no water was lacking for REDUC's industrial processes.

Additionally, almost 20% of its residents are under the poverty line, receiving up to half of the minimum wage as per capita income (Magalhães, 2016), as shown in figure 2.03. In Duque de Caxias, 5% of people are considered extremely poor, receiving less than a quarter of the minimum wage, while 65% of households in the city do not exceed the minimum wage as average monthly income (Magalhães, 2016). However, even when a significant proportion of people are poor or extremely poor (and many of them have recurrent health problems due to lack of sanitation), about 70%

of health facilities are owned by private corporations (Magalhães, 2016). This means that access to good public health services is also hindered, in addition to the precariousness of other public essential services and infrastructure (Magalhães, 2016).

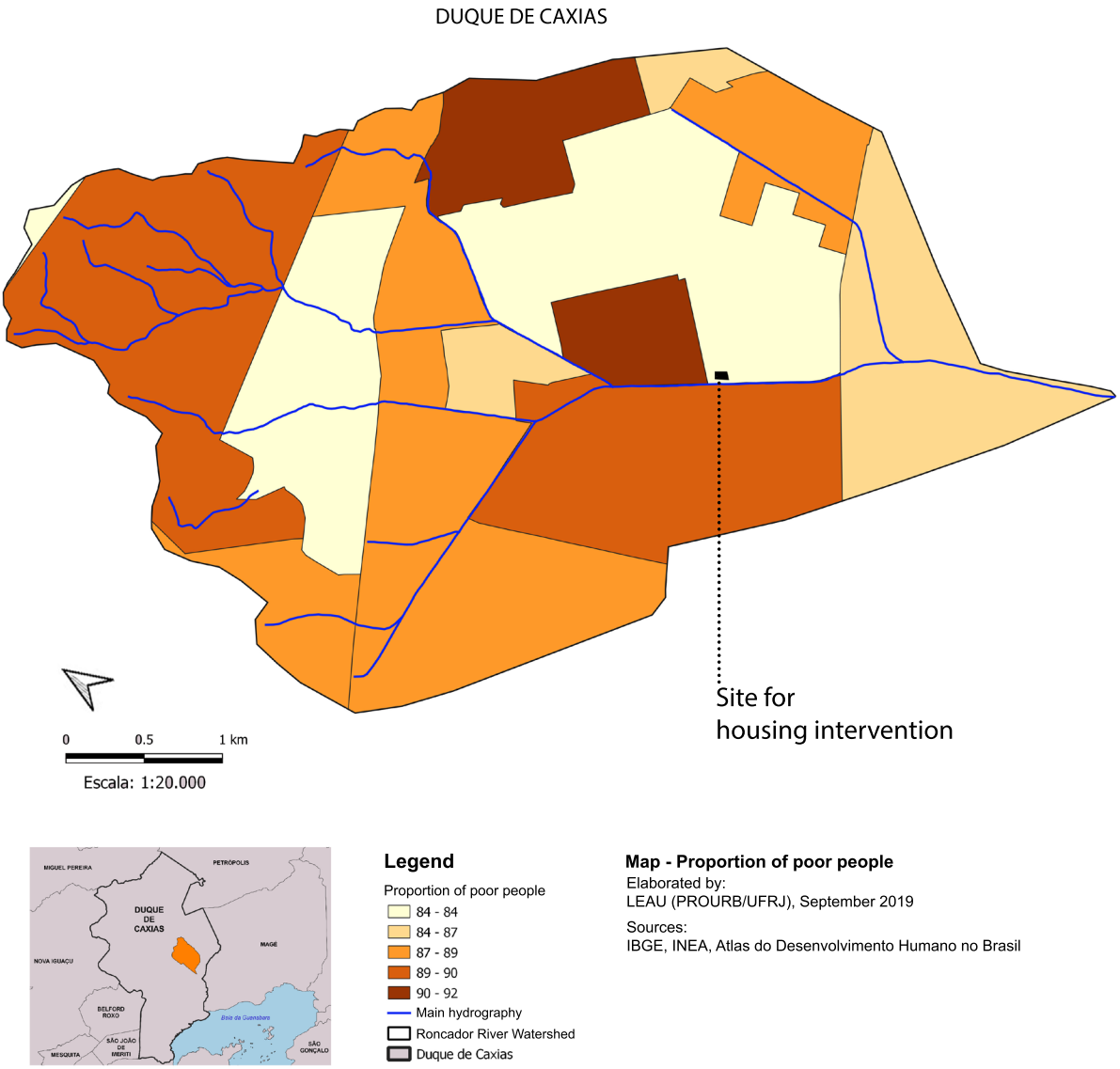


Figure 2.03. Proportion of impoverished people in the Roncador River surroundings.
Source: IBGE, INEA, and Atlas do Desenvolvimento Humano in Brazil. Elaborated by LEAU (PROURB/UFRJ), translation by author.

Figures 2.04 and 2.05 illustrate the irregular waste disposal on the soil and riverbanks and the precarious conditions of the informal houses on riverbanks. Figure 2.06 evidences the current expansion of informal dwellings on the banks of the Roncador River. A synthesis of the current socio-environmental problems faced by the residents in the region is represented in figure 2.07. The major identified issues were the informal and precarious occupation of river edges, the irregular discharge of garbage in the riverbanks and directly in the water, the lack of recreational spaces and parks, a small number of pedestrian bridges, and a considerable quantity of vacant and abandoned lands and lots of various sizes. Three areas were selected within the Roncador River watershed to highlight these problems on a closer scale, as shown in figures 2.08, 2.09, and 2.10. Figures 2.11 and 2.12 illustrate the opportunities and socio-environmental problems of Regions A and B on the pedestrian scale. These regions are not used only for analyzing the local issues but also to show the design proposal in this scale, considered a neighbourhood scale.

Figure 2.04. Irregular waste disposal in the Roncador River banks.
Source: Image retrived from Google Street view.

Figure 2.05. Precarious conditions of informal houses in the Roncador River banks.
Source: Photo by researchers at the Laboratoty of Urban Water Studies - UFRJ (LEAU / PROURB - UFRJ) in field visit on September 2019.

Figure 2.06. Expansion of informal human o
Source: Photo by researchers at the Laboratoty of Urban Water Studies

ccupation on the margins of Roncador River.
- UFRJ (LEAU / PROURB - UFRJ) in field visit on September 2019.

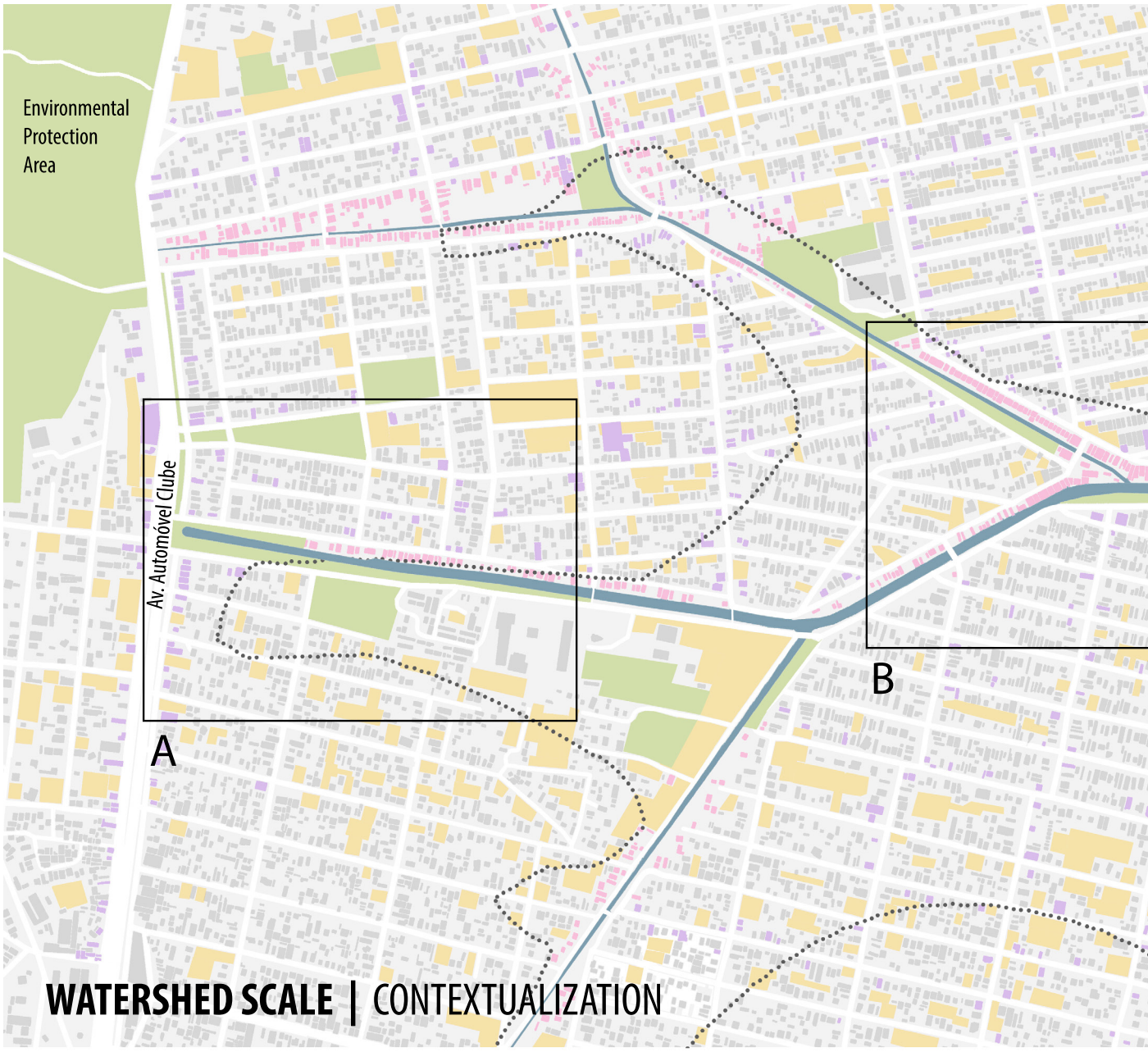


Figure 2.07. Synthesis of the socioenvironment
Source: Image prod

ousing on river's edges *Commercial ground floor* *Floodable areas*

al problems faced by the residents in the region.
luced by the author.

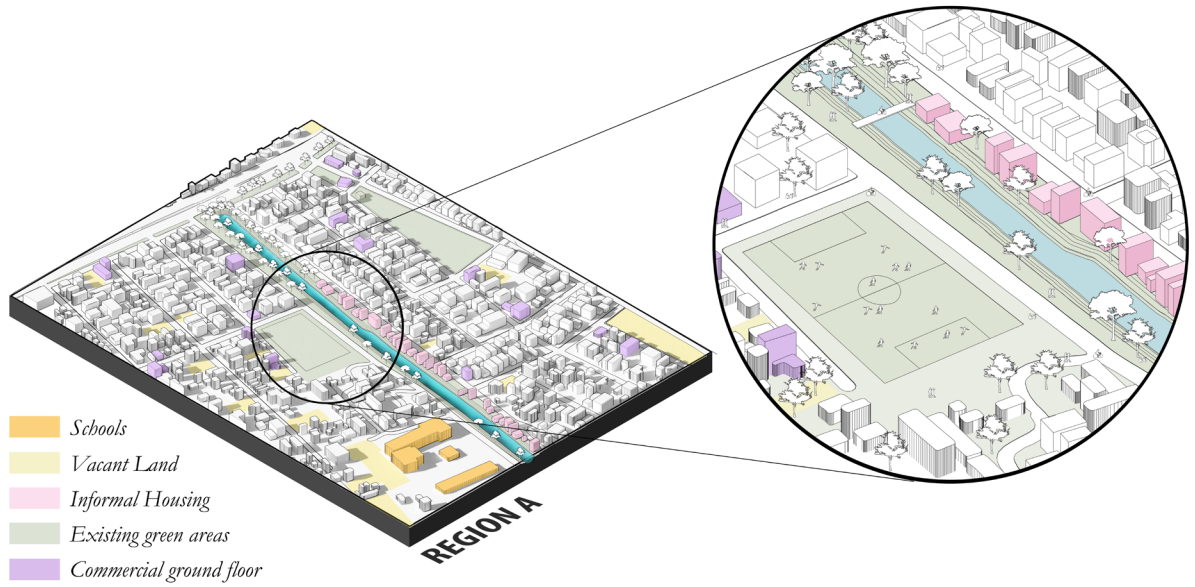


Figure 2.08. Contextualization and synthesis of opportunities and socioenvironmental problems in Region A.
Source: Image produced by the author.

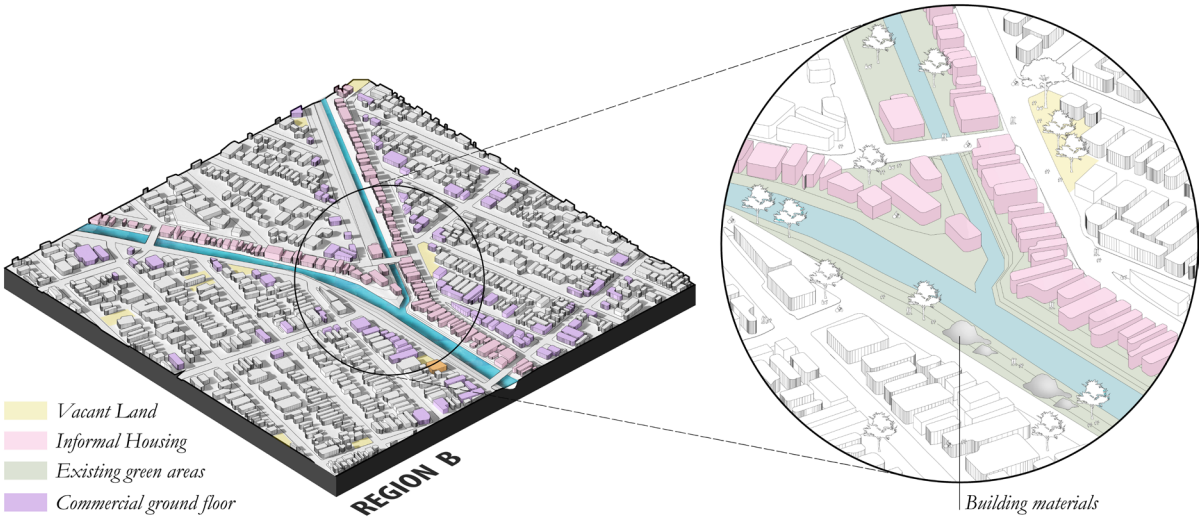


Figure 2.09. Contextualization and synthesis of opportunities and socioenvironmental problems in Region B.
Source: Image produced by the author.

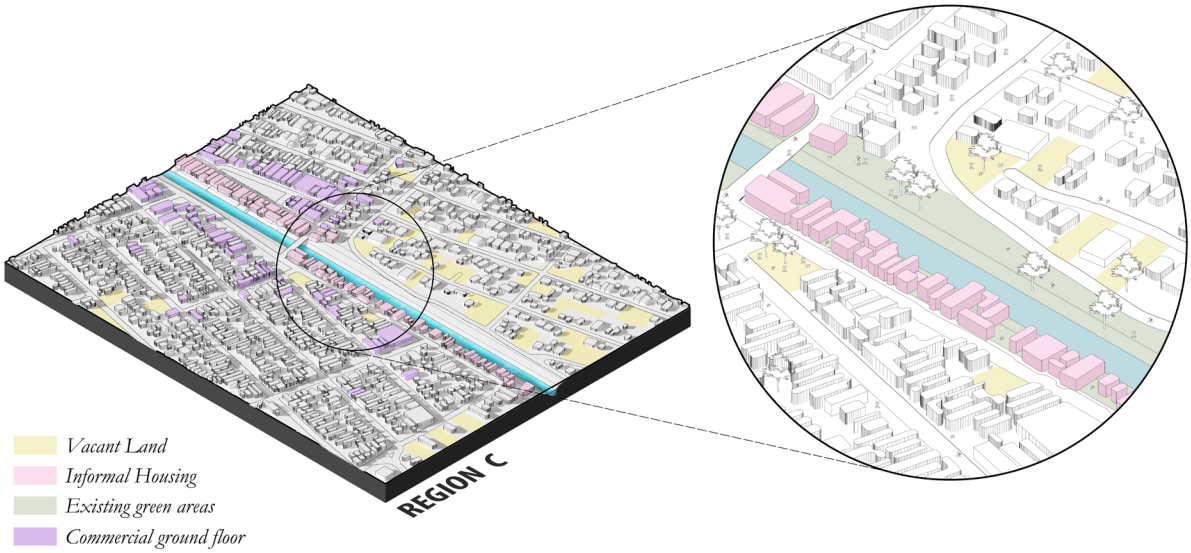


Figure 2.10. Contextualization and synthesis of opportunities and socioenvironmental problems in Region C.
Source: Image produced by the author.

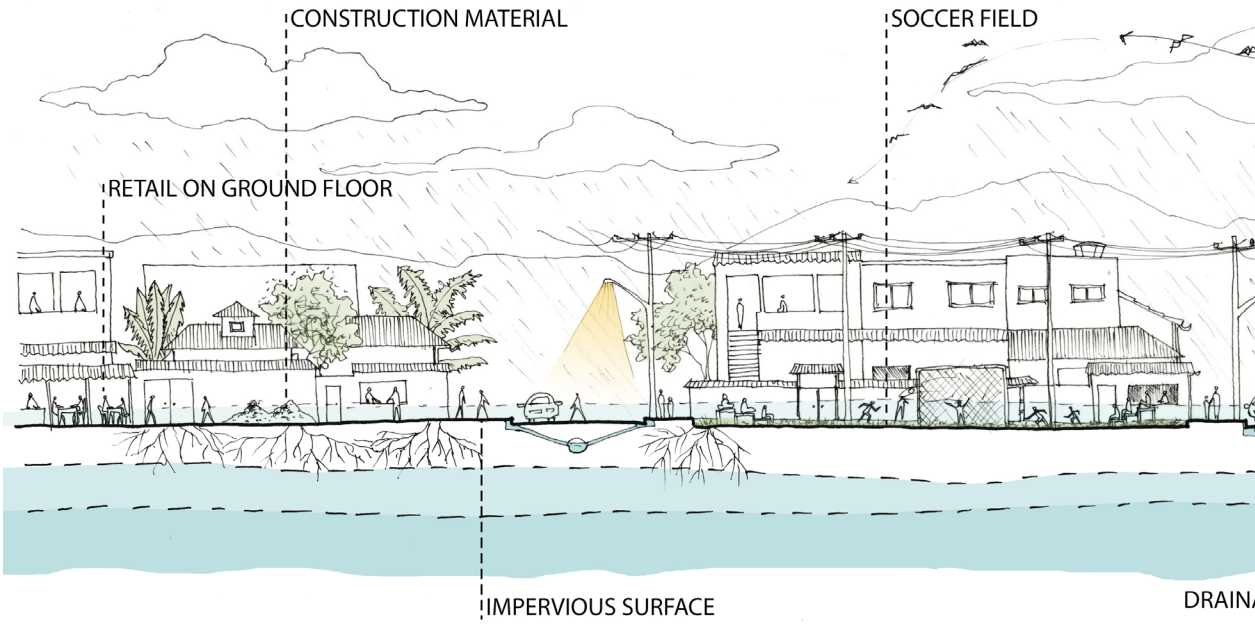


Figure 2.11. Section illustrating the context and synthesis of opportunities and soc

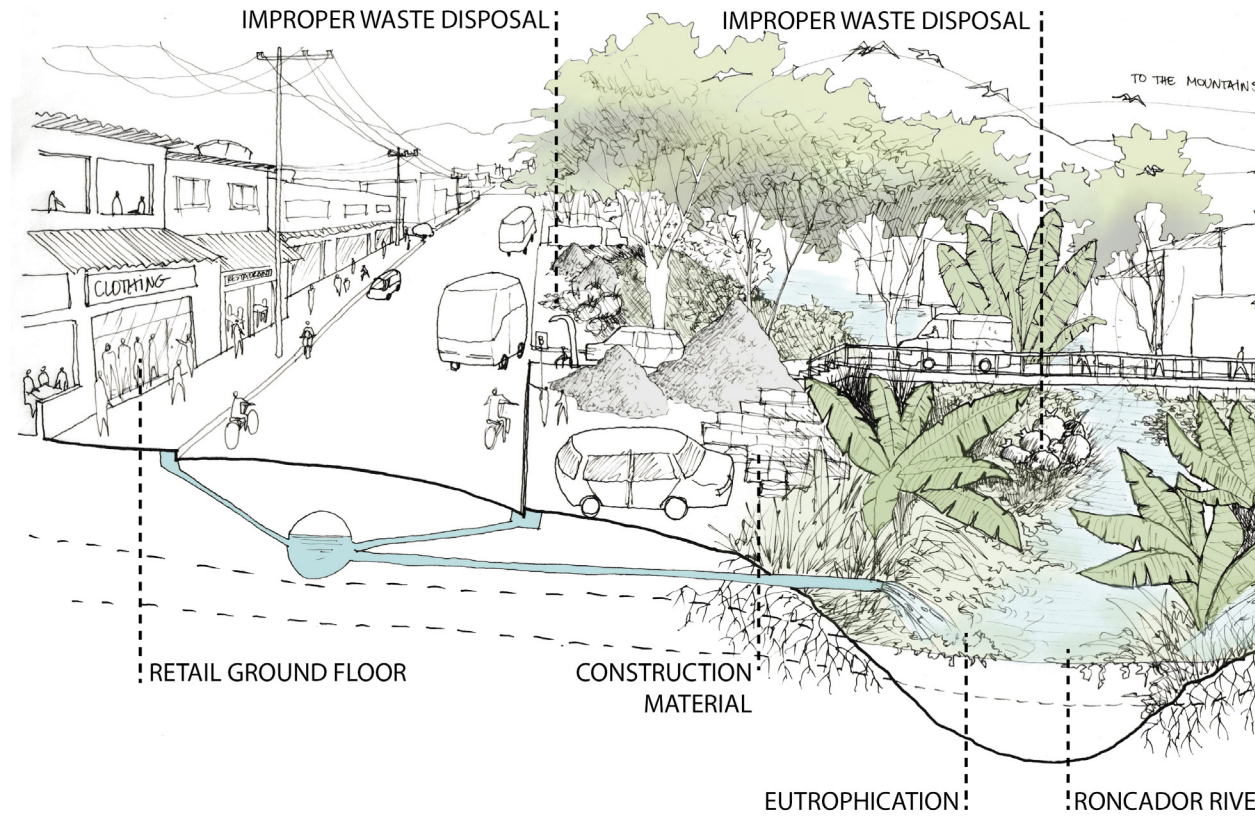
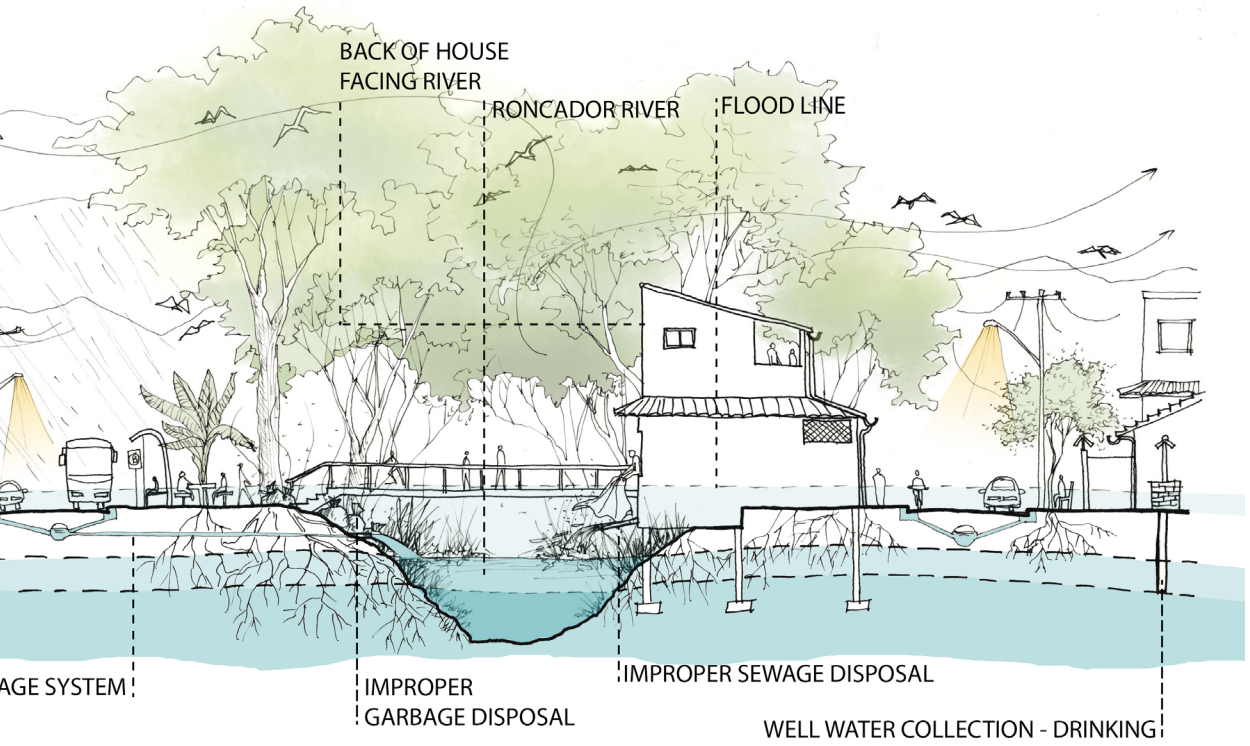
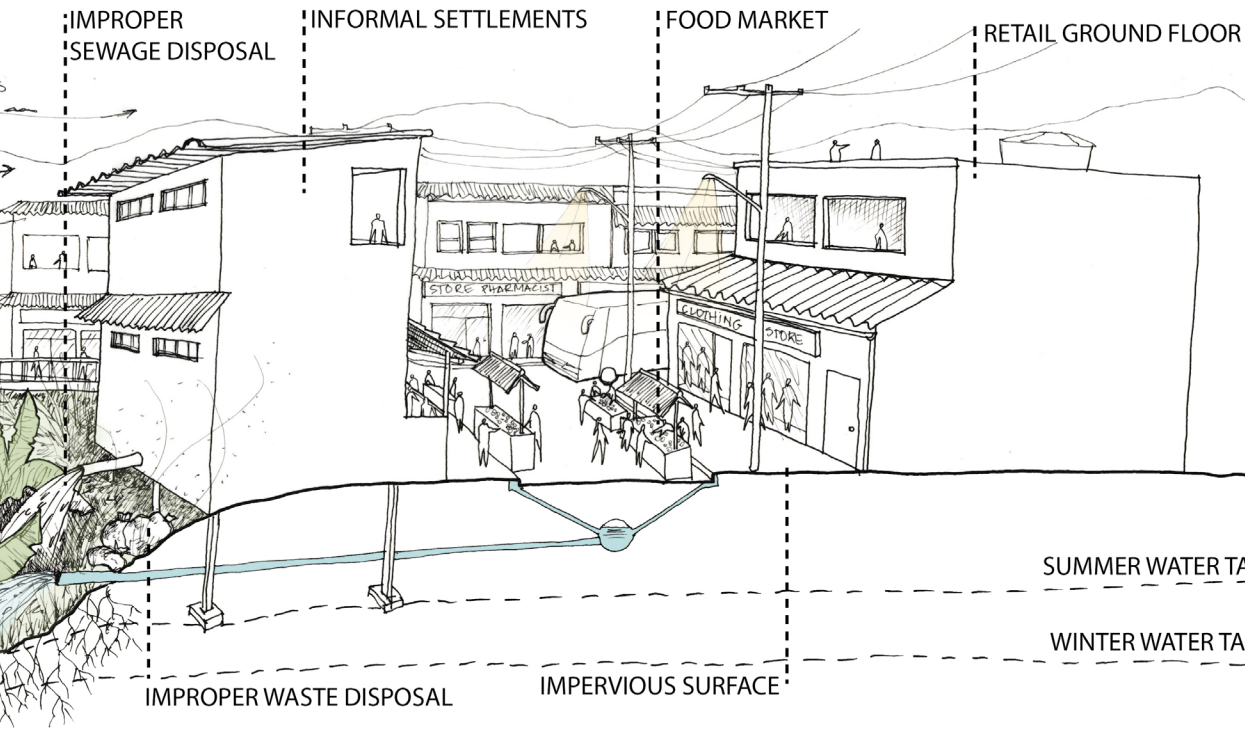


Figure 2.12. Section illustrating the context and synthesis of opportunities and soc



cioenvironmental problems in Region A. *Source: Ottoni, 2021. Translated by author.*



R

cioenvironmental problems in Region B. *Source: Ottoni, 2021. Translated by author.*

2.2. Repurposing vacant lands

Vacant land as a speculation strategy

In Brazil, the production of vacant urban lands, whether public or private, heralds a significant social imbalance process triggered by the lack of political will to apply the urban regulations (Conti et al., 2014). Because the government usually fails to take action and allows the existence of vacant lands within the cities, these parcels get exposed to the private capital interests and become spaces for real estate speculation, instead of working as spaces for the collective welfare that promote citizenship (Conti et al. 2014; Campos and Martínez, 2020). As pointed out by Smith (1979), the existence of abandoned lands or properties is necessary to trigger the gentrification process. Ideally, underutilized or unproductive lands in urban areas should be used to prioritize collective purposes, such as leisure, social gathering, environmental preservation, fulfilling the social function of the land (Conti et al. 2014; Campos and Martínez, 2020).

According to Silva (2010), the social function of the land is exercised when there is integration between initiatives and policies towards housing, employment, recreation, and circulation, which contributes to the city's social functions. The existence and production of underutilized lands nurture spatial segregation and social inequalities and counter the land's social function, perpetuating contradictions between economic and social development and negatively impacting the quality of urban life (Conti et al. 2014; Campos and Martínez, 2020). Conti et al. (2014) stress the importance of rethinking the concept of private property if the social function of the city is to be practiced and insists that the government must be more proactive not to allow the capital to intervene in the uses of urban properties. The production of vacant urban lands for speculation and the increase in the housing informality process in peripheries have triggered the rise of social movements since the 1980s to fight for housing public policies and their right to the city (Conti et al. 2014).

Displacement on account of privatization & gentrification

The surrounding Roncador River neighbourhoods and many marginalized regions characterized by slum rivers in Duque de Caxias result from the process Harvey (2008, 2003) calls “accumulation by dispossession.” This concept, much more visible with the rise of neoliberalism by the 1970s, refers to:

> "commodification and privatization of land and the forceful expulsion of peasant populations (…); conversion of various forms of property rights (common, collective, state, etc.) into exclusive private property rights; suppression of rights to the commons; commodification of labour power and the suppression of alternative (indigenous) forms of production and consumption; colonial, neo-colonial and imperial processes of appropriation of assets (including natural resources); monetization of exchange and taxation, particularly of land; the slave trade (…); and usury, the national debt and (…) the use of the credit system as radical means of primitive accumulation" (Harvey, 2006, p. 43).

At the beginning of the twentieth century, there was a need for redeveloping, modernizing, and beautifying the hitherto capital city of Rio de Janeiro. For years, the high-value lands that sheltered low-income people in the city were forcibly captured from them to increase land value, pleasing the bourgeoisie with higher-order land use. The elimination of slums during the urban renewal projects shifted their impoverished residents elsewhere in the peripheries, mainly without any compensation, as slum dwellers could not prove their long-term residence on the land or private property rights since they were illegal. The poorest were forced to live in increasingly more distant locations, further from the central regions, where land was cheaper, which constitutes the gentrification process (Torres et al. 2019). Duque de Caxias had cheap and available land lacking proper infrastructure and a railway system that successfully enabled this resettlement process. Guatarri (2000) criticizes how the capital maneuvers toward redevelopment of urban centers generate displacement of poverty-stricken families and creates homelessness as it increases the rents and impoverished populations cannot afford them. In the Global South, the capital logic negatively impacts local cultures, languages, climate and habitats, sometimes destroying them.

The right to the city and the right to housing

The current housing issues, which entail the differences in access to services, products, and socially produced infrastructure, are defined by Henry Lefebvre (2001) as the right to the city. For David Harvey (2008), the right to the city refers not just to the right to access resources

embodied in urban areas; more fundamentally, it entails the agency one has to transform the city and participating in place-making, ultimately changing oneself in this process. It represents a collective power to change the urbanization method (Harvey, 2008). It is about having the right to co-produce the spaces in a city and, thus, generating a sense of belonging (Aalbers & Gibb, 2014). Furthermore, it essentially integrates the right to education, housing, work, leisure, and health towards empowering people rather than contributing to their exploitation (Aalbers & Gibb, 2014). The right to the city counters privatization efforts and commodification of the property, as they are excluding mechanisms triggered by profit (Aalbers & Gibb, 2014). The right to the city refers to establishing an egalitarian control over the capital surpluses by urbanization in opposition to the current concentration of the right to the city on the elite's hands, seeking to promote social justice and empowerment (Harvey, 2008; Aalbers & Gibb, 2014). It directly relates to struggles for accessing housing and against displacement originated by gentrification and privatization forces (Harvey, 2008; Samara, Sinha, & Brady, 2013; Aalbers & Gibb, 2014; Campos and Martínez, 2020). Since the 1960s, most Brazilian cities started to massively receive rural migrants, who could not afford to live in the formal city. Hence, they occupied the public and private vacant lands in the peripheries, usually inadequate to be inhabited (Conti et al., 2014). This process formed the communities surrounding the Roncador River.

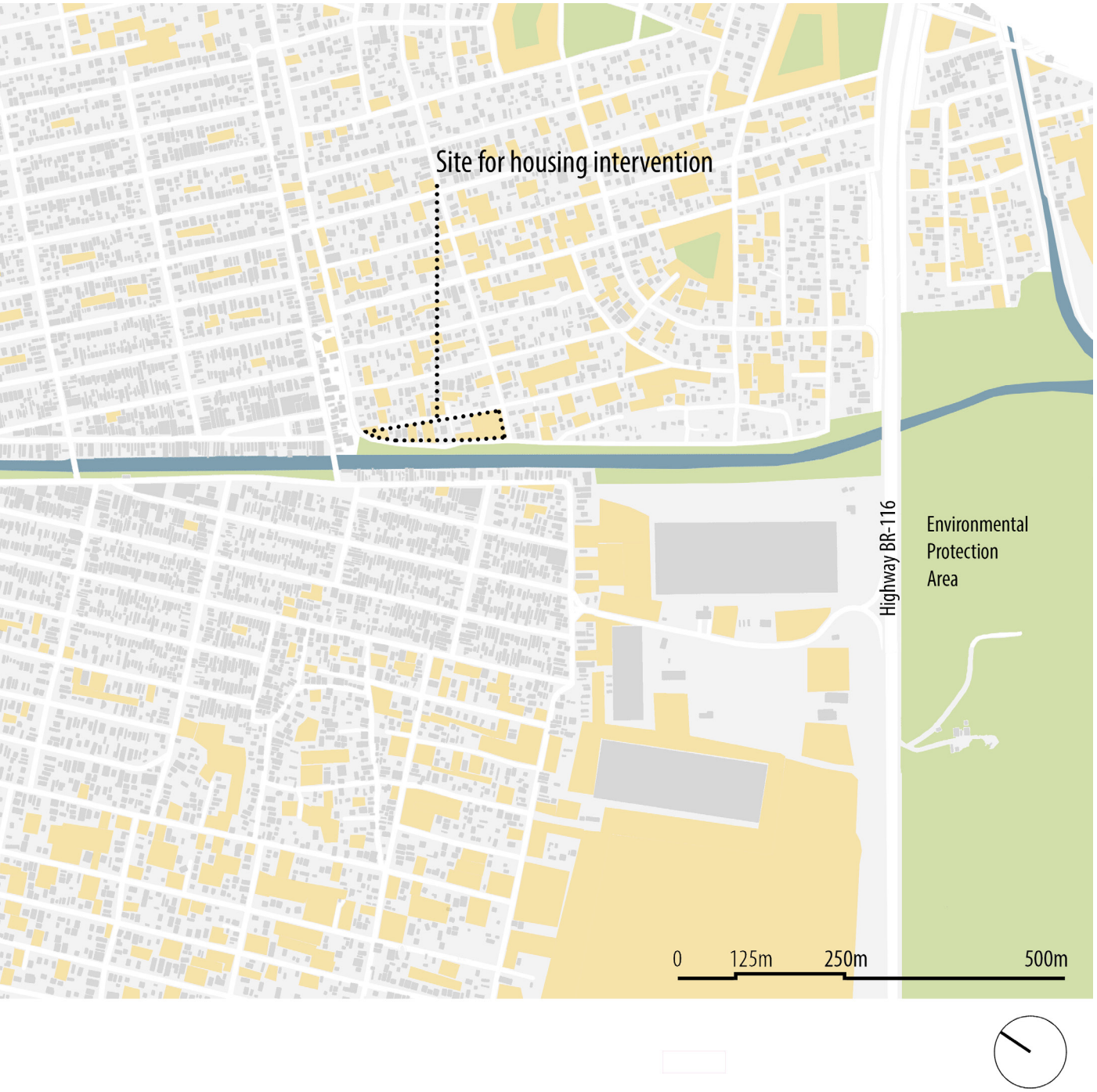
In 1948, ONU declared the right to housing as a universal and fundamental right (Placido et al., 2019). In Brazil, an amendment of Article 6 of the Constitution, enacted in 2000, made housing a constitutional right for the first time (Campos and Martínez, 2020). Rolnik (2014) stressed that the right to adequate housing is part of the right to the city and needs to be understood more broadly since it represents a claim for integration in the city. It encompasses protection against evictions and natural threats; access to land, infrastructure, essential services, work, and environmental resources; the right to use appropriate materials to guarantee a good housing quality; and the right to participate in the decision-making process of housing production (UN E/1992/23, Annex III at 114., 1991). In a broader sense, the right to housing is not only to have access to a physical structure to live and to property rights, but the articulation with a variety of related policies that guarantee the right to the city, access to its services, and ensure the exercise of belonging (Balbim, 2011; Rolnik, 2014). Therefore, the exclusion of access to adequate housing also implicates the lack of access to be part of and enjoy the city (Rolnik, 2014). For Harvey (2008), it is paramount to seek the democratization of the right to the city through the construction of a social movement, where excluded populations can take back control of the city and the urbanization process. However, Aalbers & Gibb (2014) stress that the right to the city is not a utopia but a constant struggle to make it more

democratic.

Reappropriating underutilized urban land becomes a strategic mechanism that allows vulnerable communities to regain the right to the city. In Brazil, the 1988 Federal Constitution, the City Statute enacted in 2001, and the Ministry of Cities created in 2003 are laws and tools that reinforce the social function of the city and the land. In theory, they guarantee access to the city's services and benefits to all citizens (Conti et al., 2014; Placido et al., 2019; Campos and Martínez, 2020). The City Statute, elaborated with the participation of civil society social movements, shed light on and regulated the constitution's articles on the social function of properties within the city and imposed limits to speculation (Rodrigues, 2004; Campos and Martínez, 2020). It questioned the hegemony of the right to private property (toward capitalistic interest) over the fundamental right to adequate life and collective production of the city. As stressed by Rodrigues (2004) and Conti et al. (2014), for the city to fulfill its social function, the private property must be relativized to guarantee the use of properties and lands toward the collective welfare and environmental equilibrium. However, Campos and Martínez (2020) point to the questionable efficiency of the City Statute since regulation instruments become useless if speculation is uncontrolled and housing provision is insufficient.

Adding new collective functions (work, recreation, housing, culture) to abandoned lands in Duque de Caxias is a way to reduce speculation and increase equality. It fosters local practices and economies and provides residents with more agency over their spaces, empowering them to be more resilient. However, Rodrigues (2004) points to the challenge of identifying and quantifying the actual vacant lands and properties left for speculation, mainly because it requires site survey, completion of preliminary research, and criteria definition on underutilization of lands and properties. Figure 2.13 shows in yellow the distribution of vacant or abandoned lands in the surroundings of the Roncador River. In the Roncador River informal context, relocating residents living precariously on riverbanks to safer lands (formerly vacant) within their neighbourhood would be beneficial, as it would reduce their flood risk and increase the river's environmental qualities.

Figure 2.13. Distribution of vacant or abandoned lands in the surro



undings of the Roncador River. *Source: Image produced by the author.*

2.3. Theories and design strategies for adaptability in scales

Neighborhood scale

When proposing interventions on the urban scale, it is crucial to reflect on the landscape and urban elements and simultaneously integrate with the housing scale. The proposed settlements for people relocated from riverbanks need to be strategically positioned in the urban fabric, harnessing underutilized lands to provide collective benefits for local communities. At the same time, the housing design must provide strategies for different families to adapt to their routines and address their various needs and desires over time. In addition to considering housing provision for people who need to be relocated due to flood risk, it is fundamental to think about how the new housing types will relate to the surrounding environment and how they will dialogue and respond to the context of a river revitalization project.

Adaptability in architecture and urban planning is directly related to understanding and accepting the context. One strategy that helps achieve adaptability in the neighbourhood scale is by adopting bioclimatic and passive design strategies. In this case, the local climate must inform the best strategies to be used, as well as solar orientation to situate the building accordingly. Since Duque de Caxias is located in a hot and humid climate, it is fundamental to design buildings that have minimized solar exposure and heat retention and maximized natural ventilation. Some of the passive design strategies that could be properly applied to Duque de Caxias include: the use of large roofs with overhangs that provide shading to the walls; shading devices such as fins, louvres, and brise-soleil; the use of operable windows and openings to induce stack effect; and the application of lightweight materials that do not retain heat inside them for a long time. These are simple strategies that help reduce the cooling requirements in hot and humid regions (Lechner, 2015). In addition, planting trees nearby help with blocking part of solar incidence on buildings' external walls and providing natural shading, besides increasing soil permeability (Lechner, 2015).

Adaptability can also be addressed not only by applying design strategies that are climate responsive but also by using locally available materials and by adopting local construction techniques and methods. A community-centred design must prioritize local resources, construction knowledge, and practices instead of importing them to minimize costs, generate jobs for local people, reproduce the construction culture and vernacular

architecture, and reduce carbon footprint. These strategies become even more critical when designing evolutionary housing for low-income groups, in which self-construction will be part of the housing process.

Housing scale

Harnish (2018) points out valuable lessons learned related to incrementality by observing informal settlements in the city of Johannesburg. Even in an unintentional and ingenuine way, local people produce their houses by being responsive to their context, applying low-cost solutions that use local resources, and addressing a phased construction approach. These strategies also foster community engagement and produce multifunctional spaces that allow them to be more flexible to accommodate different uses. This happens, for example, when one transforms a room into retail on the ground floor as a source of income. However, the challenge lies in providing a more flexible structural grid for dwellings in low-income communities to allow future spontaneous modifications and incorporate bioclimatic design improvements in the future.

Schmidt & Austin (2016) affirm that to live sustainably, it is fundamental that all stakeholders involved in the building process and environment maximize the building's life by providing a setting for allowing changes to accommodate future needs in the community. It requires flexibility to adjust to the social context specificities and should be seen as a long-term process, which provides infrastructure stability that encompasses infill changes (Schmidt & Austin, 2016). Adaptability is defined as the building's capacity to adjust or to be adjusted to effectively suit new situations and accommodate the evolving demands of its context to maximize its value during its lifetime and minimize costs. Examples include responsive structures, adaptive reuse, inclusive and accessible design, increased user control, and climate adaptation (Schmidt & Austin, 2016). Among the five different interpretations of adaptability presented in Schmidt & Austin (2016), this thesis focuses on the strategies that maximize user control with customization and adaptation to the local climate and context toward resilience.

"Accepting" time becomes a fundamental design gesture to achieve adaptability and, thus, durability. This means that buildings must be designed considering future modifications and additions, not as static

products, but as dynamic creations that constantly change over time. The relationship between form and context shapes the building over time, enabling predictable and unpredictable forms. This type of design is about being under-specific, increasing the building's capacity of intuitively allowing several or still unknown activities to happen. However, it cannot be designed also as a 'too loose' space, as it would become unable to accommodate the users' immediate needs. That is why it is crucial to understand how people may use the space and plan for that. It is about providing options to the user over time, which makes the housing process dynamic. Schmidt and Austin's main points reiterate the importance of seeing housing not as a completed and stationary product but as evolving and experimental building processes that must be able to change to respond to its users' needs over time within a specific context. Hence, an adaptable housing should constantly negotiate modifications to be redefined in space, function, time, and size as "a result of the user-building relationship" (Schmidt & Austin, 2016, 31).

Schmidt & Austin (2016) categorized six types of adaptability to understand how they could be accommodated in the future and make explicit the nature of the adaptability desired in each case (See figure 2.14). The six types are: adjustable (change of task/user), versatile (change of space), refitable (change of performance), scalable (change of size), convertible (change of use), and movable (change of location), as shown in figure 2.14. The versatile type comprises a mix of fixed and flexible areas to enable various functions. This type uses a planning grid, open plan and framed structure that allows joinable or divisible rooms, besides having movable furniture and wide circulation. The scalable type generally has extendable circulation, framed structure to allow expansions and shrinkage according to the users' needs, and extra spaces that could be utilized in the future. The refitable type consists of shell and core construction, with unfished spaces that allow custom finishes. Schmidt & Austin (2016) identified 12 design strategies for adaptability (modularity, design in time, long life, simplicity and legibility, loose fit, spatial planning, passive techniques, unfinished design, maximize building use, increased activity, aesthetics, and multiple scales) associated with 60 building characteristics and 135 design tactics.

Nevertheless, there are some barriers to adaptability. Cost is one of the main obstacles for some adaptable strategies compared with non-adaptable techniques, although Schmidt & Austin (2016) point out this is not always true. In addition, short-term development methods, valuation practices and funding initiatives are other obstacles to achieving large-scale adaptability.

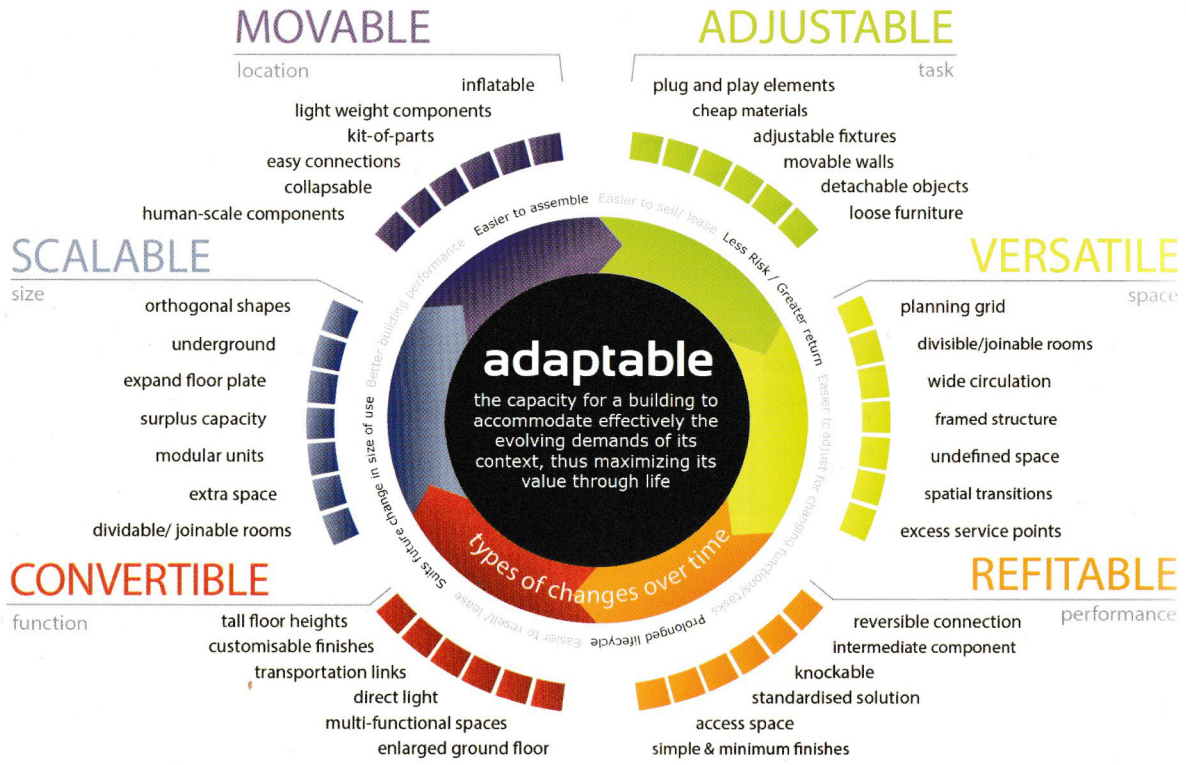


Figure 2.14. The six types of adaptability: adjustable, versatile, refitable, scalable, convertible, and movable.
Source: Schmidt III and Austin, 2016.

The Open Building Movement (OBM):
Benefits, drawbacks, and design strategies

Many of the design strategies and tactics for achieving adaptability and flexibility outlined above are also mentioned by the Open Building Movement (OBM) established by John Habraken (Kendall and Teicher, 2000). The OBM approach proposes to adopt a logic for project practice considering spatial attributes open to possible or desired transformation of space in time and the presence of the resident in the decision-making processes of housing production. By adopting this approach in housing design, the focus lies on the inhabitant, in which architecture provides the support for the user to be the agent of change. Thus, the house becomes more suitable to respond to the individual's needs, fostering unpredictability, unfinishedness, and a sense of ownership (Schmidt & Austin, 2016). To include the resident in the decision-making process of housing production (design, construction, and post-construction), Habraken proposes two separate categories that constitute the house: the support and the infill. The theory of support and infill was developed as a critique of the 1960s' mass housing boom, which aimed to increase users' empowerment in the housing process, and currently constitutes an international phenomenon (Schmidt & Austin, 2016; Kendall and Teicher, 2000; Lamounier, 2017). The support represents the building elements that have long-term durability, being the fixed, permanent, and general elements, such as common services (Lamounier, 2017; Kendall

and Teicher, 2000; Habraken, 2002). These include the plumbing and electrical facilities and installations, the structural system, usually open frame structure, and the vertical circulation. Kendall and Teicher (2000) define support as a finished and permanent part of the building, in which the layout and size of individual occupancies are not pre-determined, ready to be occupied by the infill. The infill refers to the elements that are changeable, dissociable, detachable, have short-term durability, are composed of lightweight components, and are under the residents' control. Therefore, the infill category allows for customization of the indoor space, such as the furniture, partition walls, doors, windows, finishing, and decoration (Lamounier, 2017; Kendall and Teicher, 2000; Habraken, 2002). Both elements are beneficial if applied to social housing because they make housing production more affordable. Van Nostrand (2000) explains this progressive process as "grow-as-you-go" in his approach called "Pro-Home" to increase access to affordable housing in Canada.

Therefore, adaptability can be more easily achieved by having a framed structure as one layer separated and independent from the space plan (composed of internal partitions) and the envelope layers (Schmidt & Austin, 2016). This disentangling of subsystems aims to minimize conflicts, facilitate replacement and renovations, and allow more freedom to customize the space. As pointed out by Kendall and Teicher (2000), the Open Building initiatives, focusing on designing for more durable and flexible buildings, contribute to more sustainable architecture. Buildings that are more flexible, responsive, customizable, and efficient also contribute to sustainability, as currently has been happening with the use of assembly and disassembly design and manufacture. Another point in the Open Building approach that contributes to sustainability is that adaptability also relates to applying local materials, construction techniques and recognizing the local culture and traditional architectural character (Kendall and Teicher, 2000). In addition, the cost per area for implementing Open Building strategies by using the support structure (framing systems) is reduced compared to conventional construction methods, especially when the infill is produced by the users (Lamounier, 2017).

Therefore, OBM solutions result from a balance between individual freedom and collective decisions. Actions are taken in different and clearly defined levels, by various stakeholders, and with different lasting periods (Kendall and Teicher, 2000). This approach presents design strategies that provide residents with control to adapt and modify their spaces over time, which is an important feature that contributes to a high quality of life and sustainability. Figure 2.15 shows the support and infill elements within the Open Building approach, and figure 2.16 synthesizes the decision-making levels in the Open Building. The flexibility is achieved

mainly due to subsystems' disentanglement, which facilitates changes in layout, renovations, shrinkages or expansions. The level separation allows for flexibility through the use of scaffolding or framed structure and modularity (Schmidt & Austin, 2016). This also contributes to giving residents more independence from the government's assistance, which usually neglects their needs and aspirations for a better future. As a result, Open Building "(…) enables an architecture of coherence coupled with variety in dwelling form, income and household make-up." (Kendall and Teicher, 2000, 57).

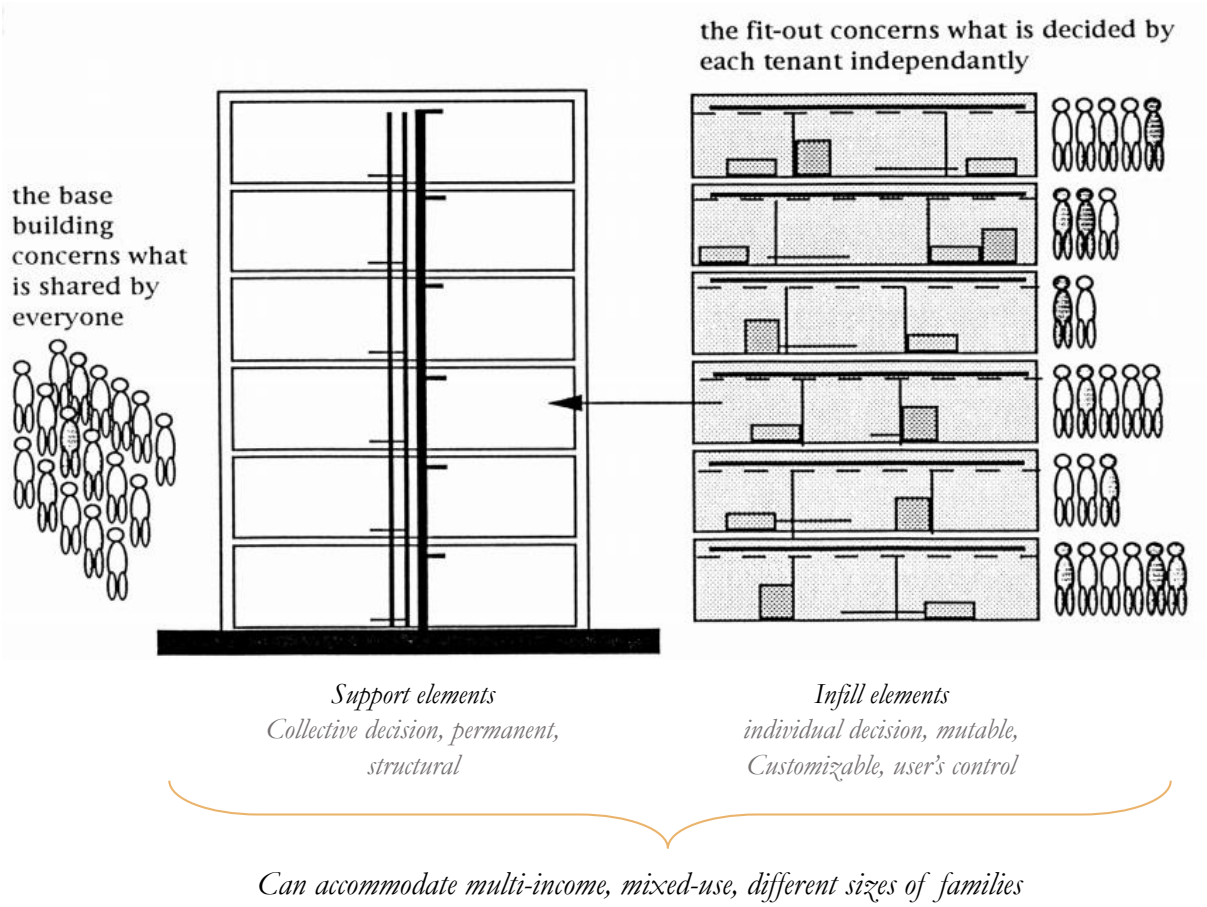


Figure 2.15. Open Building: Support and Infill elements. *Source: Adapted from Kendall, 2003.*

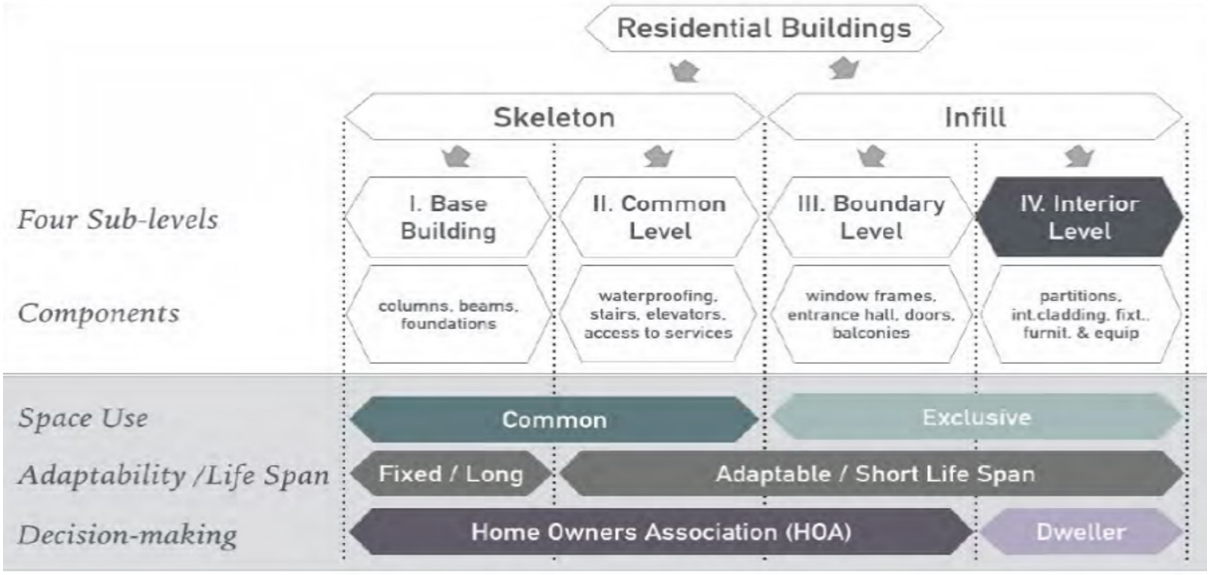


Figure 2.16. Decision-making levels in the Open Building approach.
Source: Kobayashi & Fujimoto, 2003, translated to English by Costa, 2016.

The infill elements allow the residents to become the agents of change in their dwelling, igniting the individual's creativity and imagination to adapt the indoor environment to its needs and desires, defined by social and technical criteria (Lamounier, 2017; Kendall, 2000). Kendall (2000) explains that the transformation in the uses of a building happens according to social, technological, demographic and market changes during the building's lifetime. For Habraken (2011),

> *"A support structure is built knowing that we cannot predict what will happen to it. The more varied dwellings there can be in the support structure, the better. Therefore, it is not an unfinished construction, but it is not a complete building. A support is not merely a skeleton. It is not neutral, but it enables architecture. It is more than service, than a built environment inserted in a landscape: a support is a physical configuration that offers space and the possibility of producing houses with the fewest restrictions possible, requiring the least amount of work [italics added]".*

The OBM approach presents several practical strategies to achieve adaptability and flexibility, on a long-term and a short-term. A combination of techniques that consider adaptability, flexibility, and incremental design approaches seen in informal settlements' contexts could be precious to create a proposition for low-cost housing. In the context of the Baixada Fluminense and Roncador River, applying the Open Building approach can help minimize the issue of a housing deficit and provide more accessible and adequate housing to low-income populations. The OBM strategies are better developed and have its benefits maximized in smaller-scale social housing condominiums since they offer greater interaction between the users for the decision-sharing process (Lamounier, 2017). Lamounier (2017) stresses the importance of expanding access beyond private property, and the OBM approach provides strategies that facilitate other ways of accessing affordable housing that is more responsive to the different needs of various families.

Design strategies for adaptability

Schmidt and Austin (2016) provided tools and practical strategies for designing more adaptable buildings. One of these strategies is opting for operable windows. They offer the user with more control over the indoor temperature and more contact with the external environment. They also allow for natural ventilation and daylighting while providing views and being a simple, energy-efficient, and cheaper solution than conventional mechanical systems. Additionally, opting for designing a shallow plan depth, preferably rectangular plan, and high ceiling (around 2.9 meters or more) also contribute to increasing natural ventilation and daylight penetration, improving energy efficiency, and providing flexibility. Another design strategy that fosters adaptability and user empowerment is the use of familiar and simple construction methods. Using concrete, brick, and stone is familiar, durable, and they consist of low-maintenance materials that transmit confidence to the users to adapt their space. Longevity can also be improved by opting to use efficient services, including rainwater collection and energy production on site.

Modularity and use of planning grid are strategic for facilitating adaptability. According to Schmidt and Austin (2016), grid systems in residential design usually range from 1.2m-2.4m-3.6m to 1.5m-3m-4.5m. Finding a balance between open plan and enclosed spaces also allows for adaptability in housing design by having clear spans generally ranging from four to eight meters (Schmidt and Austin, 2016). Adaptability and flexibility are also promoted when providing a mix of standardized rooms with a diversity of room sizes, which allow for various uses. Designers should aim to provide support for a combination of functions, especially on the ground floor, to encourage a vibrant street and neighbourhood. Above all, Schmidt and Austin (2016) stress that one of the most used and efficient design strategies to achieve flexibility and adaptability in housing design is by concentrating fixed spaces, or the core (composed of services, kitchens and bathrooms, and vertical circulation) and leaving the remaining areas to be adapted by the user according to their needs.

Villa Verde: A case study for adaptability in social housing by expanding the initial volume

Villa Verde is an interesting case study that brings the concept of incrementality, adaptability, and flexibility into the affordable housing design. Located in Chile, it was built in 2010 and designed by Elemental, shown in figure 2.17. This project's core concept and goal are to provide "half of a good house" instead of a whole house that does not work well and is more expensive, as usually is done in social housing projects (Moore,

2016; O'Brien et al. 2020). A total of 484 incremental dwellings were built, consisting of an initial area of 42 m2 (two-storeys with an initial footprint of 3m x 7m) that could be expanded by its users over time, growing up to a limit of 85m2. The initial houses, or embryos, are two-storey row houses with a good quality interior finish.

The Chilean architect Alejandro Aravena provided an almost complete structural frame in lightweight timber framing, composed of shared party walls, pitched roof, and lower slab and beams. He set the conditions for the residents to build the rest of the house over the years if needed. They would only have to add two walls and a slab to expand their homes at the limit (O'Brien et al. 2020). The planned modifications were: no infill modifications on the pre-existing framework; partial infill, where the upper and lower floors are enclosed; complete infill with extensions in the front yard (O'Brien et al. 2020). The fixed components of one house provided by Elemental are the structure, roof, and core with services, wet areas, and staircase. The façade, interior walls, and finishes are mutable and self-built. Therefore, Villa Verde provided a structure consisting of the basics of plumbing and shelter that allows the residents to live well initially but enables them to expand the house using their own labour, skill and according to their budget and needs (Moore, 2016).

People have been living informally in this region for more than 30 years. Incrementality was embedded in their savoir-faire since they built their informal houses themselves. Accordingly, Aravena accepts and appropriates this habit and knowledge of building incrementally from the residents to deliver a home that fits into the community life, adapts to their practices, and supports them to be agents of change in their routine. This project also proposes a more effective and less expensive land use by building structures that went up two-storeys instead of one-storey (as was practiced in the

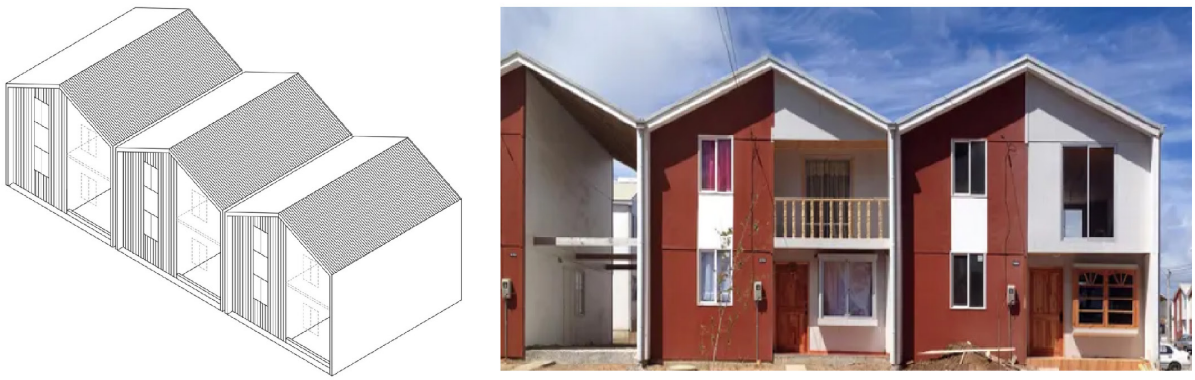


Figure 2.17. Incremental design in Villa Verde, Chile. *Source: Moore, 2016.*

region before). It, thus, provides better conditions to live in affordable housing. This project responds to the mission of Aravena of "fulfilling human desires, from respecting the single individual to taking care of the common good, from efficiently hosting daily activities to expanding frontiers of civilization" (Moore, 2016).

However, a post-occupation analysis conducted by O'Brien et al. (2020) revealed issues with site planning and the occurrence of informal additions beyond what was envisioned and planned by Elemental. In some cases, individual expansions for private use were carried out by appropriating collective open spaces, jeopardizing the quality of public areas. This unplanned over-development also decreased the indoor quality by reducing the natural light and ventilation of spaces because of the expansion to inappropriate areas (O'Brien et al. 2020). The authors question what could prevent these settlements from becoming slums since the freedom to build in a formal framework has already proven to generate over-development, which perhaps points to the need to reinforce a limit to potential expansions.

Future design must find a solution that could allow for user participation and customization of the housing production, but under a controlled limit to avoid decreasing the collective quality of life. As Mulyono & Hidayati (2019) stressed, it is essential to have control of the expansions to avoid escalating to a slum-like situation of overcrowding. At the same time, it is crucial that the house allows for a gradual, incremental process safely and with collective coherence. Osman (2016) also criticizes Elemental for not providing design solutions for a mix of incomes and uses in their projects, although the firm has been successfully exploring the concept of capacity.

468 James Street North: A case study for adaptability in affordable housing within a fixed envelope

The 468 James Street North development in Hamilton, Ontario, designed by JvN/d, offers valuable lessons on internal flexibility and the potential for future expansions by the user. This mixed-use, mixed-income, multi-family building has a key design strategy of providing 250 square-foot "lots" on each floor, which can be purchased and combined to increase the unit's size. The individual 250 square-foot lot can accommodate a bachelor's apartment. Each of them is separated by a partition wall, which can be removed to add two units together and transform into a 1-bedroom apartment of 500 square feet. If the homebuyers want to have more space, they can add one more lot and have a 2-bedroom apartment of 750 square feet or add one more and expand it to a 3-bedroom apartment of 1000 square feet (Burda et al. 2019).

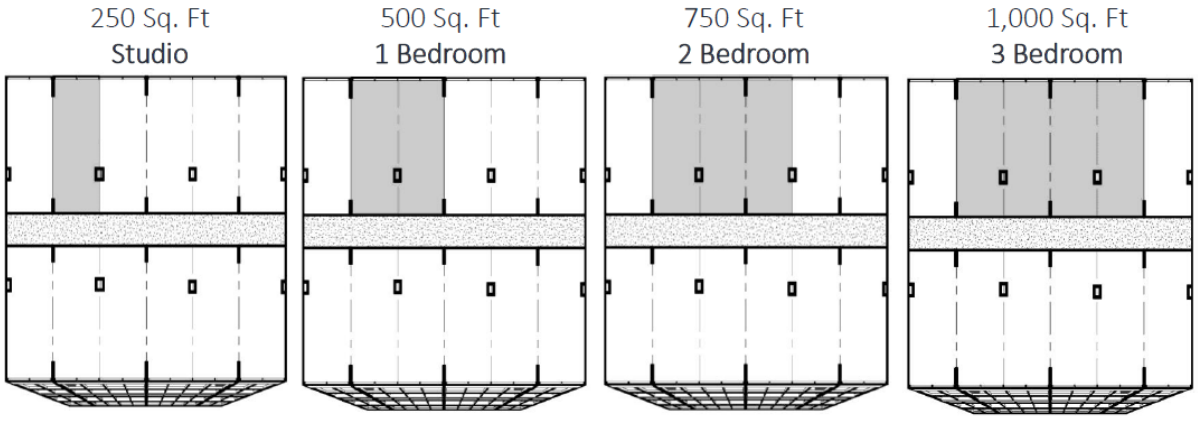


Figure 2.18. Working with flexible lots in the 468 James Street North development in Hamilton, Ontario, Canada. It provides opportunity for horizontal expansion of units. *Source: JvN/d, 2018.*

Figure 2.18 summarizes how the unit's evolution and expansion can happen in this building. This strategy gives the homebuyer the option of receiving an extra income with renting the units, ultimately enhancing their financial progress and increasing their quality of life. The units can also be provided either fully or partially completed, giving the homeowners the option of completing them with their own resources over time, making the apartment more affordable. Using a structural frame independent from other systems and concentrating services and wet areas maximizes the internal space to be used and customized according to the different user's needs over time. It combines flexibility in tenure and space and provides financing support to make homeownership more affordable and accessible to the lowest income groups (Burda et al., 2019).

Adaptation in the housing scale for resilience

The concept of adaptability is also discussed in the context of social-ecological systems in the Resilience Science field. It is defined as "the capacity to harness collective action to 'bounce back' after threat and re-establish some kind of stable condition, whereas transformability is the capacity to 'bounce forward' and 'create a fundamentally new social-ecological system when ecological, political, social or economic conditions make the existing conditions untenable'" (Gibson-Graham et al., 2016). Gibson-Graham et al. (2016) resituate humans within ecological communities and non-humans in ethical terms, advancing that the idea of community economies must be encouraged to sustain life in Anthropocene times. They question how built environments can deal with instability and unpredictability of change and still provide flourishing habitats for humans and other living forms. Therefore,

they propose a non-capitalocentric perspective for situating human economic activity within extra-human communities' ecologies to build resilience, integrating ecological, economic and social science theory based on systems thinking (Gibson-Graham et al., 2016).

Guatarri (2000) also advocates that it is paramount to start thinking transversally and in systems to holistically comprehend the interactions between ecosystems, societies, and individuals. I agree with Gibson-Graham et al. (2016) vision, which acknowledges that "human economies are interdependent with other living forms' economies, and the future depends on building the capacity to live together in flourishing ecologies that work with disequilibrium complexity and instability". Guatarri (2000) proposes ways to adapt and find new ways of living on this planet that focus on the three ecologies (socius, environment and psyche). For him, innovative and radical practices are needed to revert the damage caused by hegemonic capitalistic forces. Alternative solutions should foster a continuous process of "resingularization" and more relational experiences that prioritize collective well-being, diversity, and adaptation (Guatarri, 2000).

The OBM approach responds to the psyche and social levels defined by Guatarri. It proposes interventions focused on adaptability and flexibility in the housing strata, thereby increasing the users' freedom and autonomy, which is also an economically beneficial strategy on a long-term basis. Additionally, adaptability and flexibility come with a degree of pre-established and fixed items equal to all houses, thus being equitable in the collective realm. The ecological and social layers are added to this equation when incorporating the local construction knowledge and materials into this theory. The local culture is not being erased but instead prioritized, generating less carbon footprint by applying local materials and being more adaptable to the local climate. It is not about importing western knowledge and using it to different climates but learning how to provide a quality house at a low cost from the local construction techniques. The quality comes with thermal comfort, flexibility to change in time by its residents, and being mindful of natural resources. Applying OBM strategies in the housing intervention and focusing on using local knowledge responds to Guatarri's three ecologies, generating a more sustainable housing production. The concern with siting is paramount since location could make a community thrive or be destroyed. In this discourse, local vacant lands play an important role as they present the possibility of a community to continue living in their neighbourhood.

Part 3 | Water and Community

Interweaving Water and Community: a design proposal for Roncador River

3.1. Interventions in phases

It is essential that the Aquatecture interventions, in the context of the Roncador River region, be integrated with a more adaptive housing strategy. Planning phased interventions is crucial to guarantee that local people will have their human rights protected during the implementation of the proposed strategies in this large-scale project (see figure 3.01). This design proposal has four phases of implementation: (1) Identifying vacant and underutilized lands in the region that could fulfill their social and housing functions; (2) building new low-cost and incremental houses on nearby vacant lands, adaptable to floods and integrated with a holistic Aquatecture system in the watershed scale; (3) relocating the impoverished residents from the riverbanks to the new nearby houses, which will enhance their capacity to adapt to floods and increase their agency and control over the housing space; (4) Implement an Aquatecture system in three scales to mitigate floods. This thesis focuses on applying adaptable design strategies to achieve better quality residential and public spaces. In the Roncador River context, the proposal approaches adaptability concerning floods, flexibility to accommodate changes in the housing layout and form, and responsiveness to local climate and culture. Land redistribution and land use reorganization compose the key strategy for a watershed restoration project combined with social housing provision in the same neighbourhood, prioritizing collective uses.

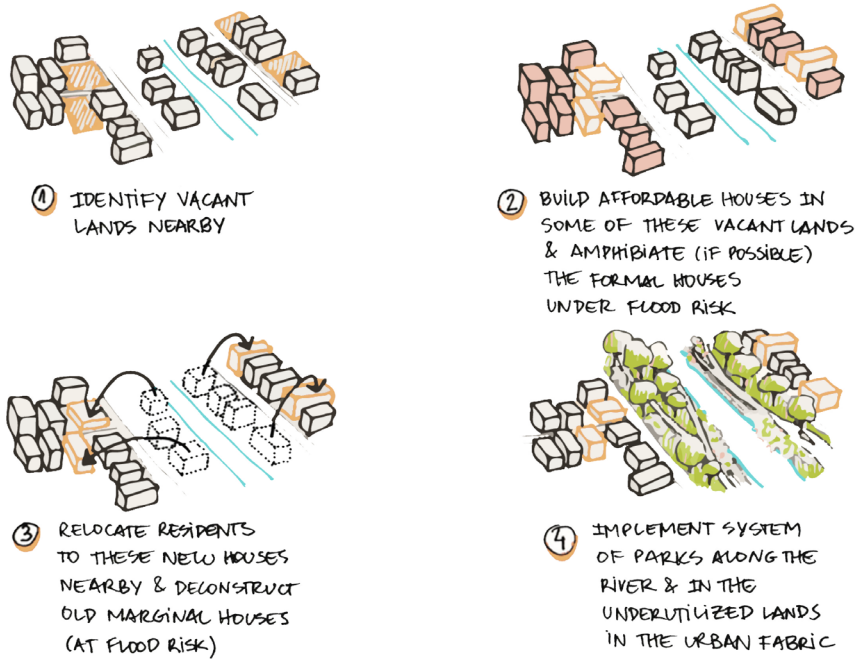


Figure 3.01. Proposed four phases of intervention in the Roncador River region. *Source: Image by author.*

3.2. Interventions in scales

Watershed Scale

This study proposes the integration of nature-based parks along the river and within the urban fabric with amphibious evolutionary housing, which allows the residents to safely stay and grow over time in their communities and achieve flood mitigation and adaptation. The Roncador River watershed was selected to propose these interventions given its location within a metropolitan periphery with precarious informal settlements on its riverbanks. Water and community are the key elements for the design proposal and will be approached in this project on multiple scales. The intervention will be done in three scales (watershed/macro, neighbourhood/intermediate, and housing/micro), based on the LifE concept, within the Aquatecture approach, brought by Barker & Coutts (2016). Figure 3.02 shows the demarcation of the limits of each scale. In the watershed scale, which corresponds to the watershed boundaries and area, the strategies will be based on the 'making space for water' principle (see figure 3.03).

The strategy for the watershed scale encompasses the creation of a nature-based riverside park, bringing more permeability by restoring the riparian vegetation and adding more green areas to the system within the watershed's boundaries by repurposing vacant lands. The proposed riverside park intervention combined with a system of parks will mitigate floods by increasing soil permeability and enhance environmental qualities by allowing the continuity of ecosystem services (See figure 3.04). In order to set space free for implementing the riverside park, the at-risk informal settlements on the riverbanks will need to be removed, and their residents will be relocated to new affordable housing within the neighbourhood, addressed in the micro-scale intervention.

However, this strategy's challenge lies in the potential to generate riskier lives for these displaced residents. Millington (2018) discusses the extensive displacement originated from implementing the largest Linear Park in the world, the Tietê River Valley Park in São Paulo (Brazil), presenting the potential to increase the risk for low-income residents living in precarious settlements on river edges. Ecological initiatives toward more sustainable urban space can often generate the need to relocate. This may increase insecurity and safety issues since usually people are relocated to public housing, which in Brazil are often low-quality condominiums in distant and unserviced lands, and may lose their sources of income and connection to their community (Millington, 2018). It is paramount to have a robust resettlement plan that considers the resident's immediate

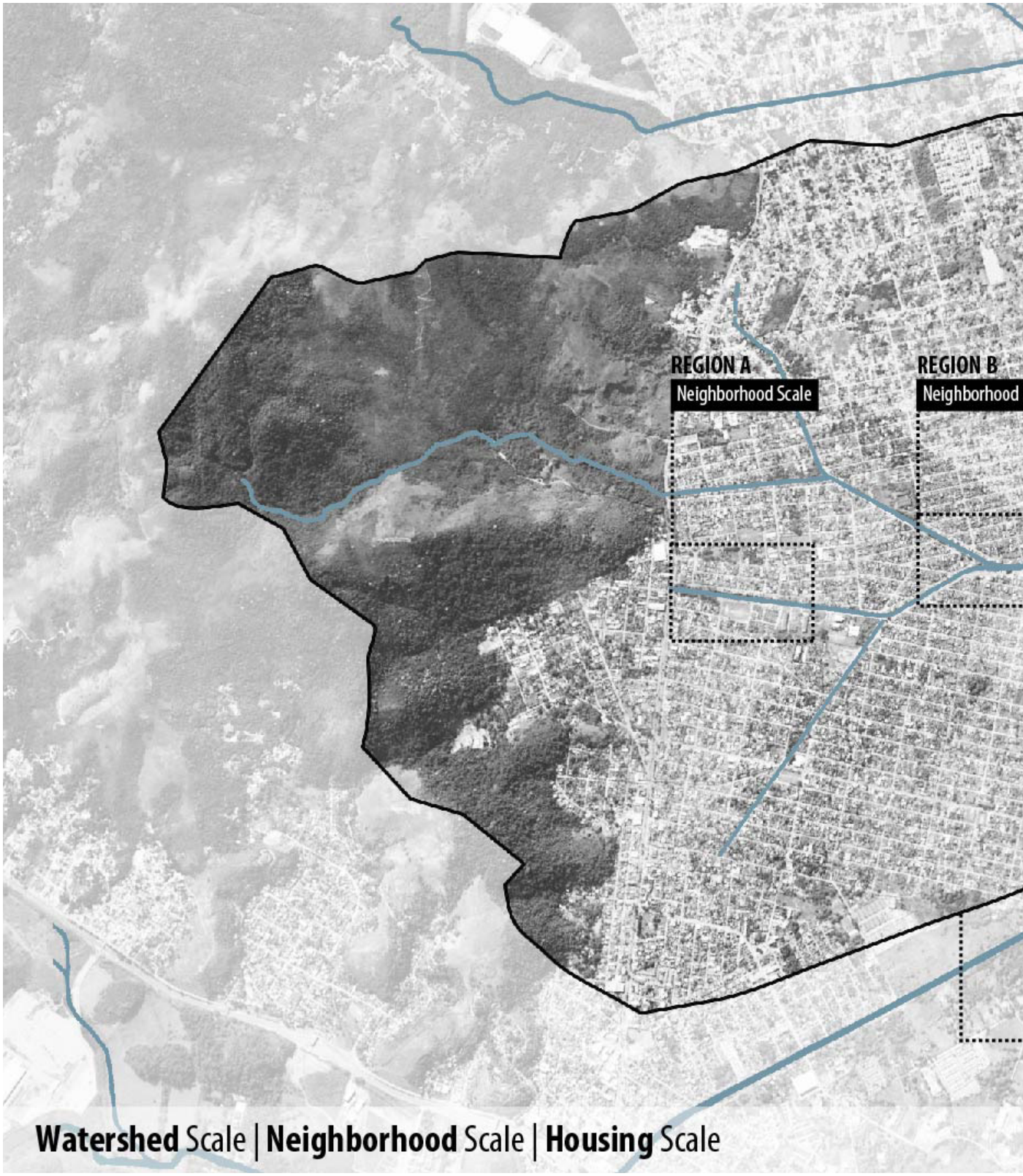
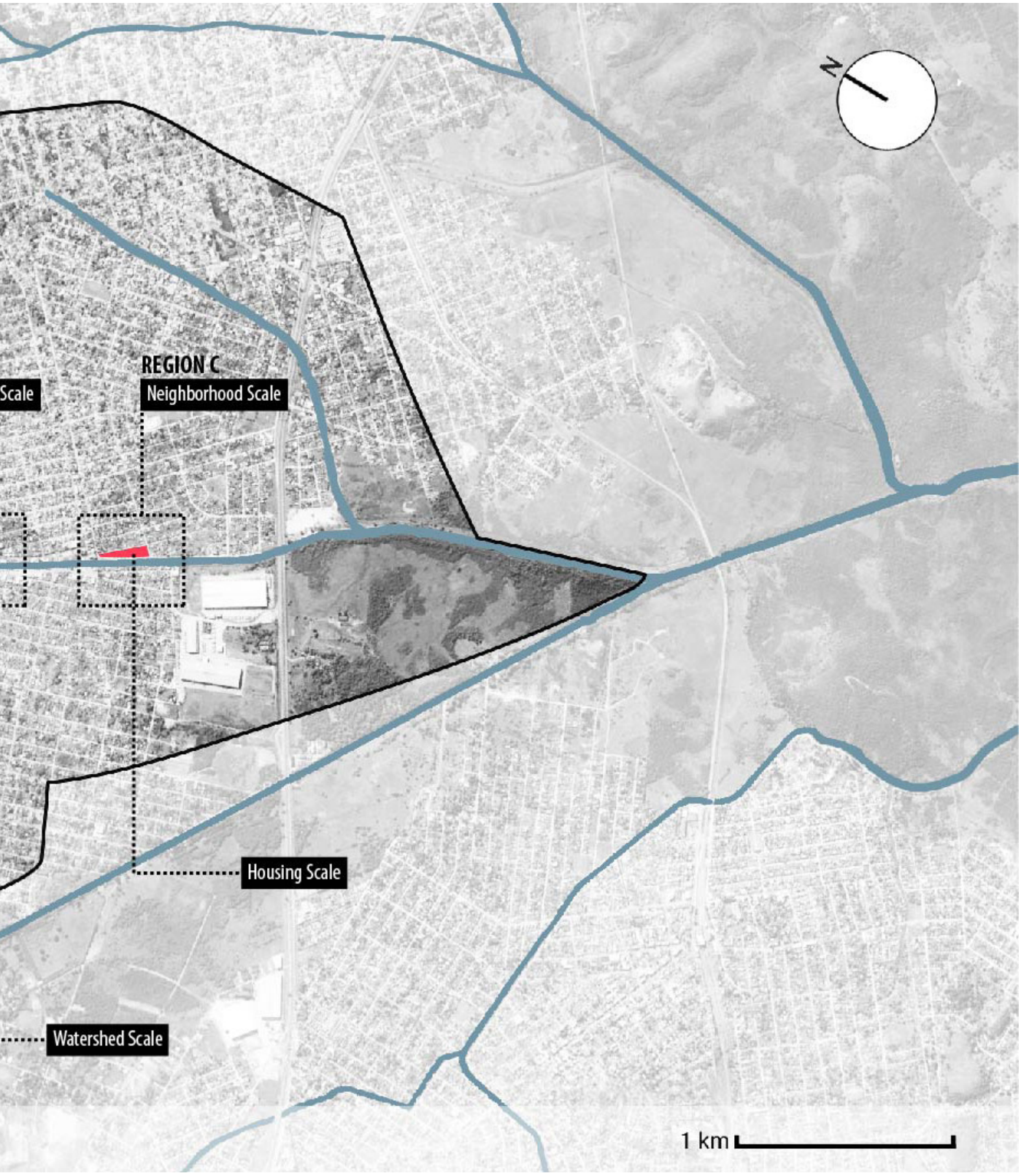


Figure 3.02. Three scales for intervention: W
Source: Imag



Watershed, neighborhood, and housing scales.
ge by author.

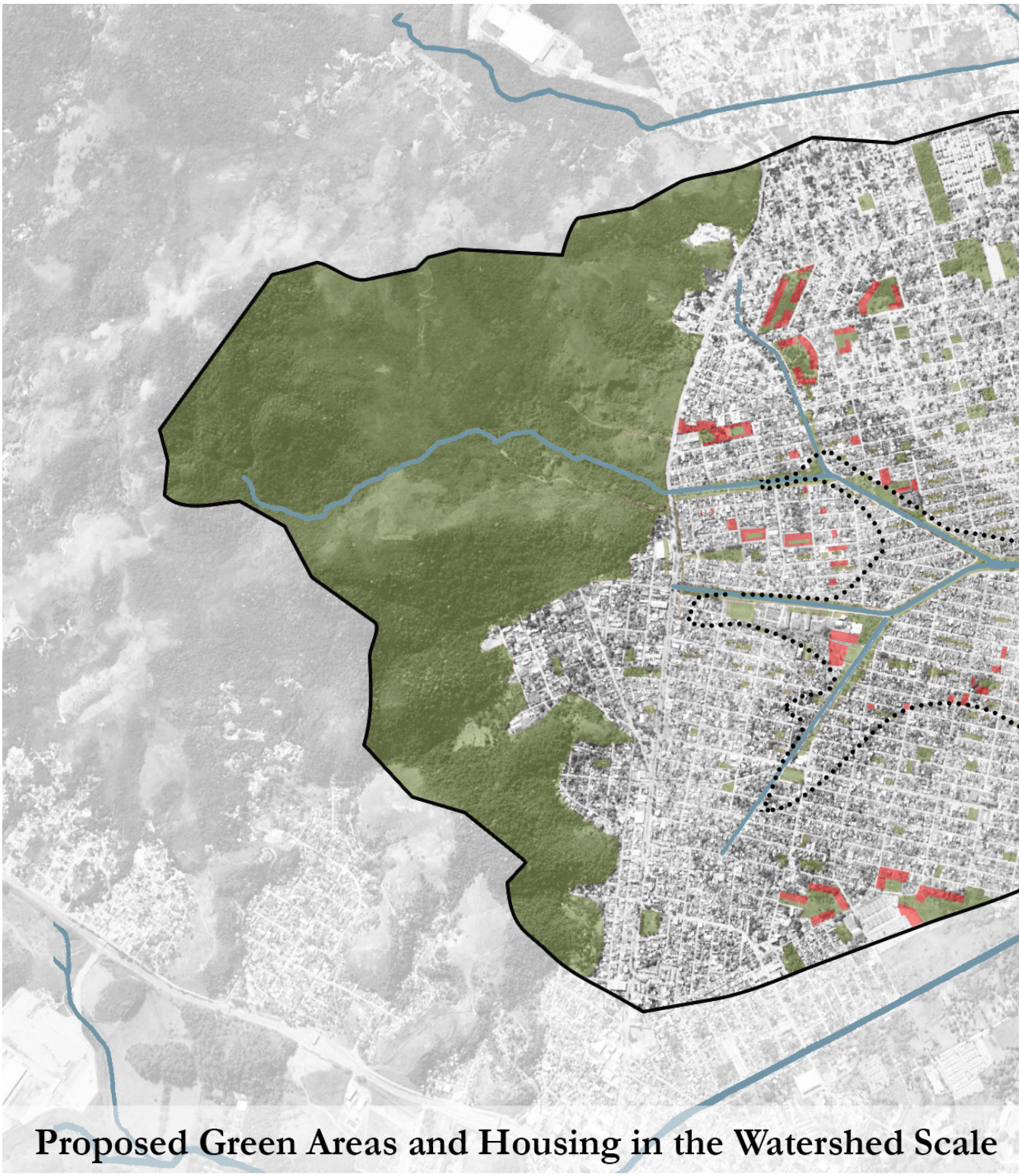
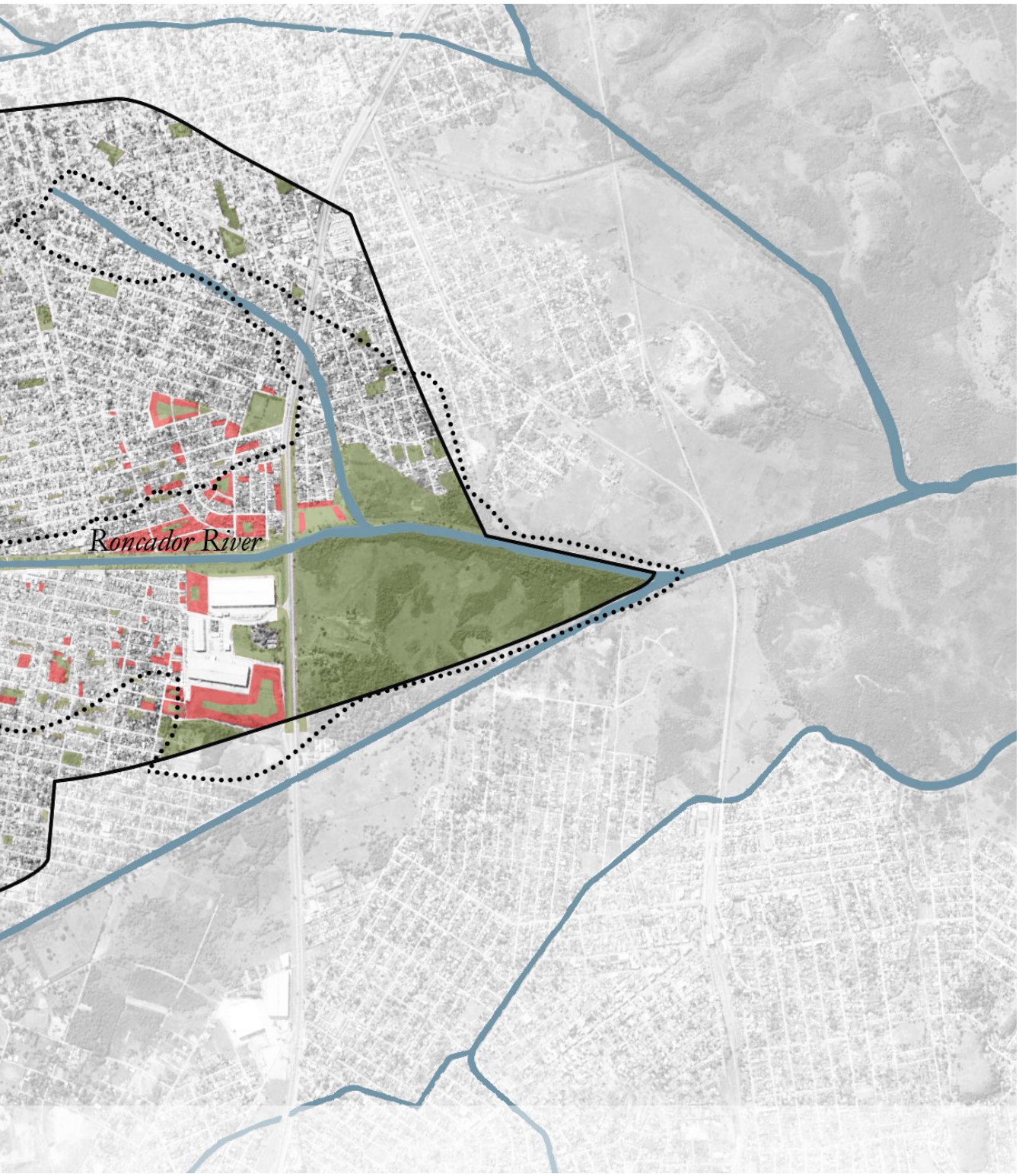


Figure 3.03. Strategy 'Making spac
Source: Imag



Proposed new Green areas / reinforcement of existing green areas

dary *Proposed areas for Housing*

ce for water' in the watershed scale.
ge by author.

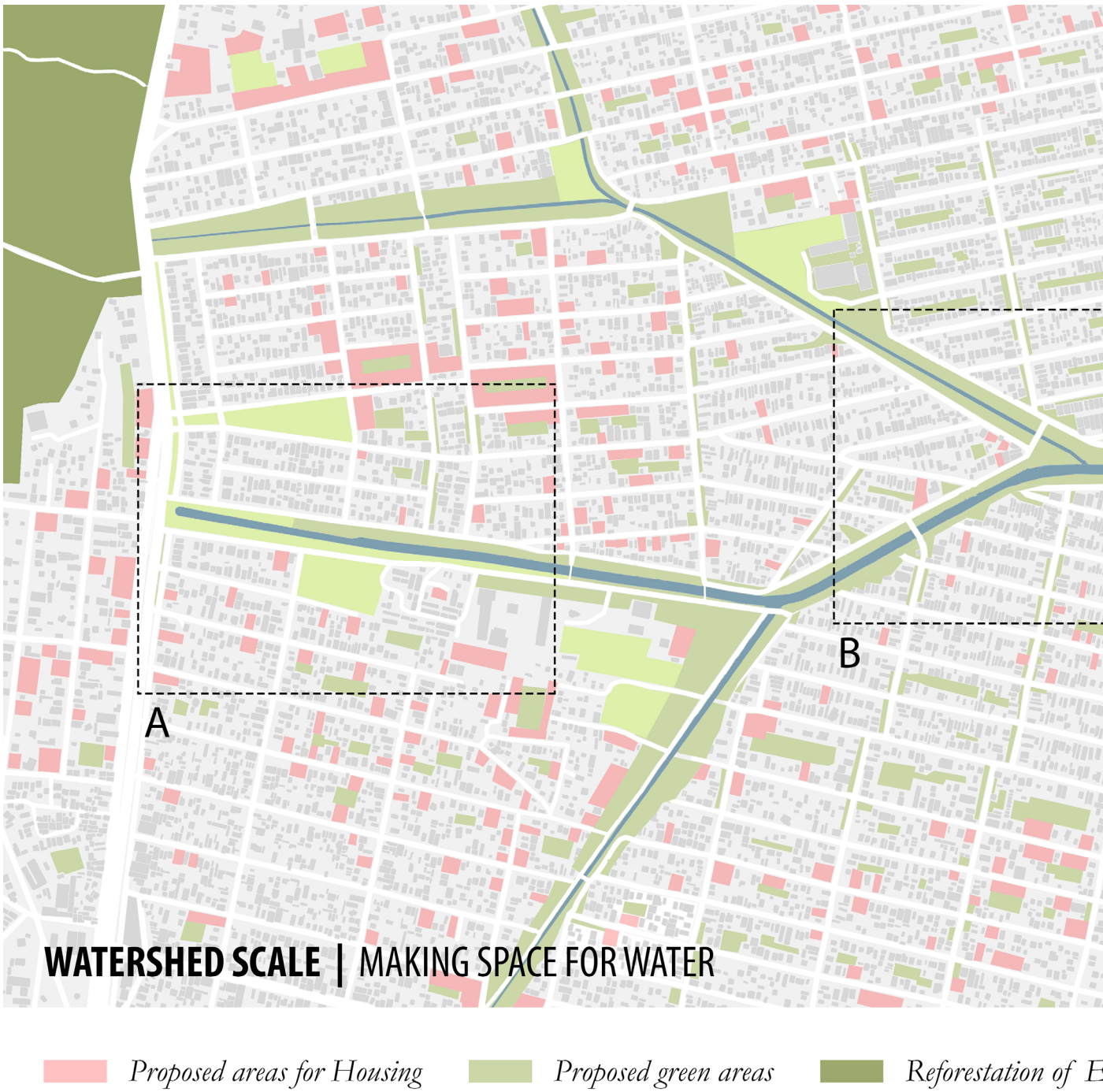


Figure 3.04. Strategy in the watershed scale
Source: Imag

Environmenatl Protection Areas *Existing green areas*

e: 'Making space for water (and for people)'.
ge by author.

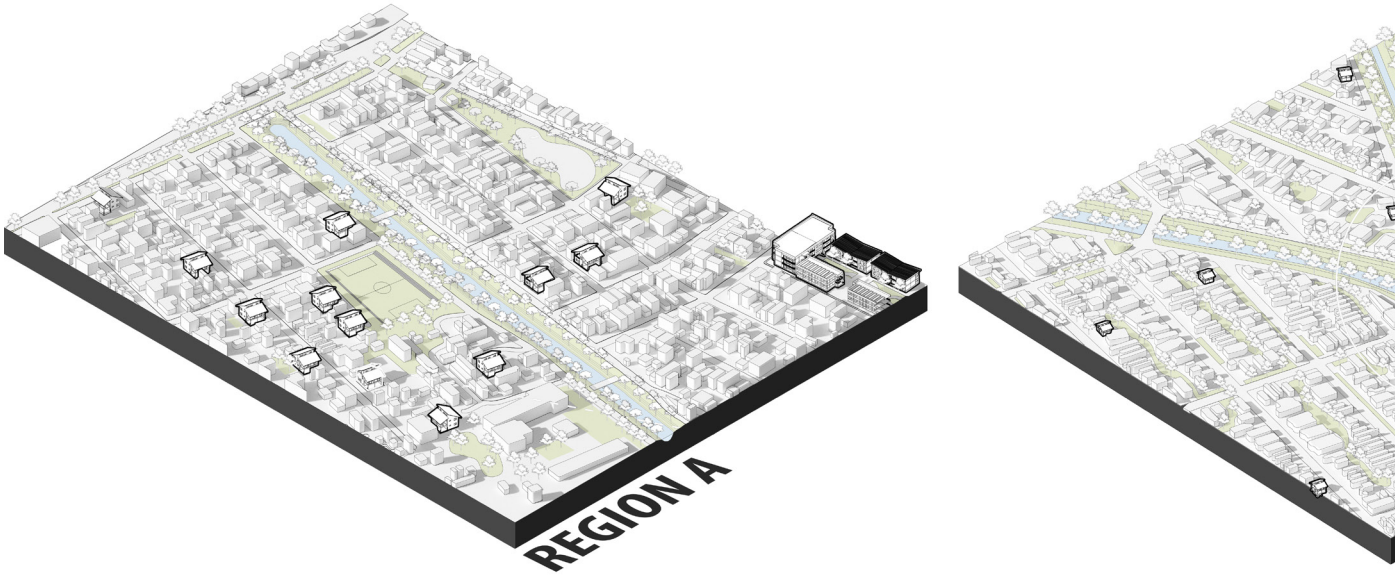


Figure 3.05. Strategy in the Neighborhood scale:
Source: Imag

needs (Millington, 2018) to avoid creating potential risks. In this context, the new housing must be adapted to floods and on safer ground, built and accessible before the resettlement occurs. According to Millington (2018), "Breaking the link between social displacement and environmental upgrading requires that we take seriously the intimate, banal ways in which urban landscapes are made and remade by those who inhabit them." (p. 876). In addition, it is vital to apply mechanisms to avoid green gentrification[10] from happening, especially in places such as Duque de Caxias, where there is a chronic lack of nature-based recreational areas. The risk is that the proposed network of parks increases the lands and properties prices, which can potentially generate the dispossession of the lower-income groups who could no longer afford their houses. Torres et al. (2019) stress the importance of active community participation and collaboration in the planning, design, and implementation phases of environmental initiatives, making sure they are part of the decision-making process to avoid green gentrification, especially in more impoverished regions.

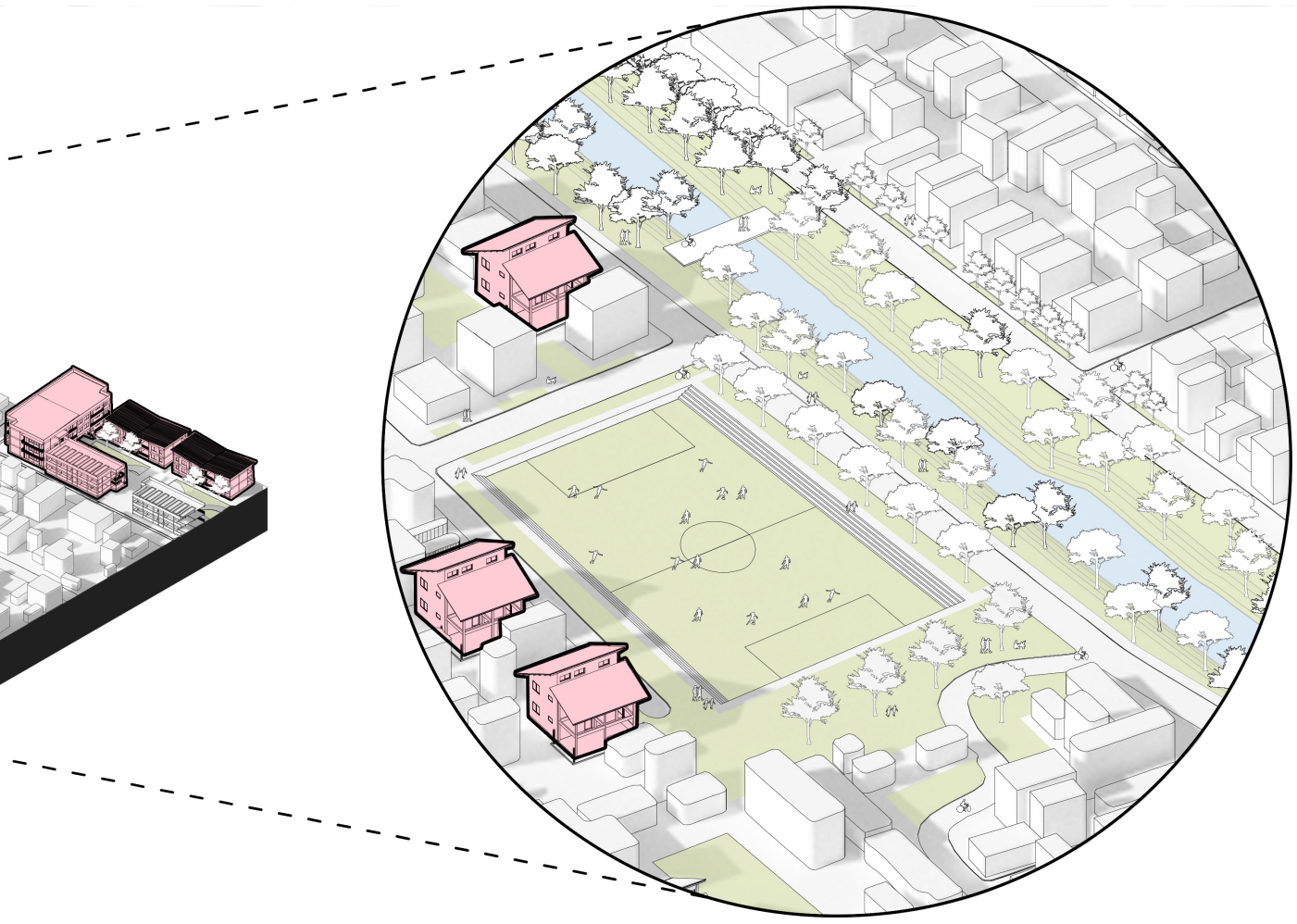
10 As explained in more detail in Part 1 subsection 1.3

'Living with Water', in the Regions A, B, and C.
ge by author.

Neighborhood Scale

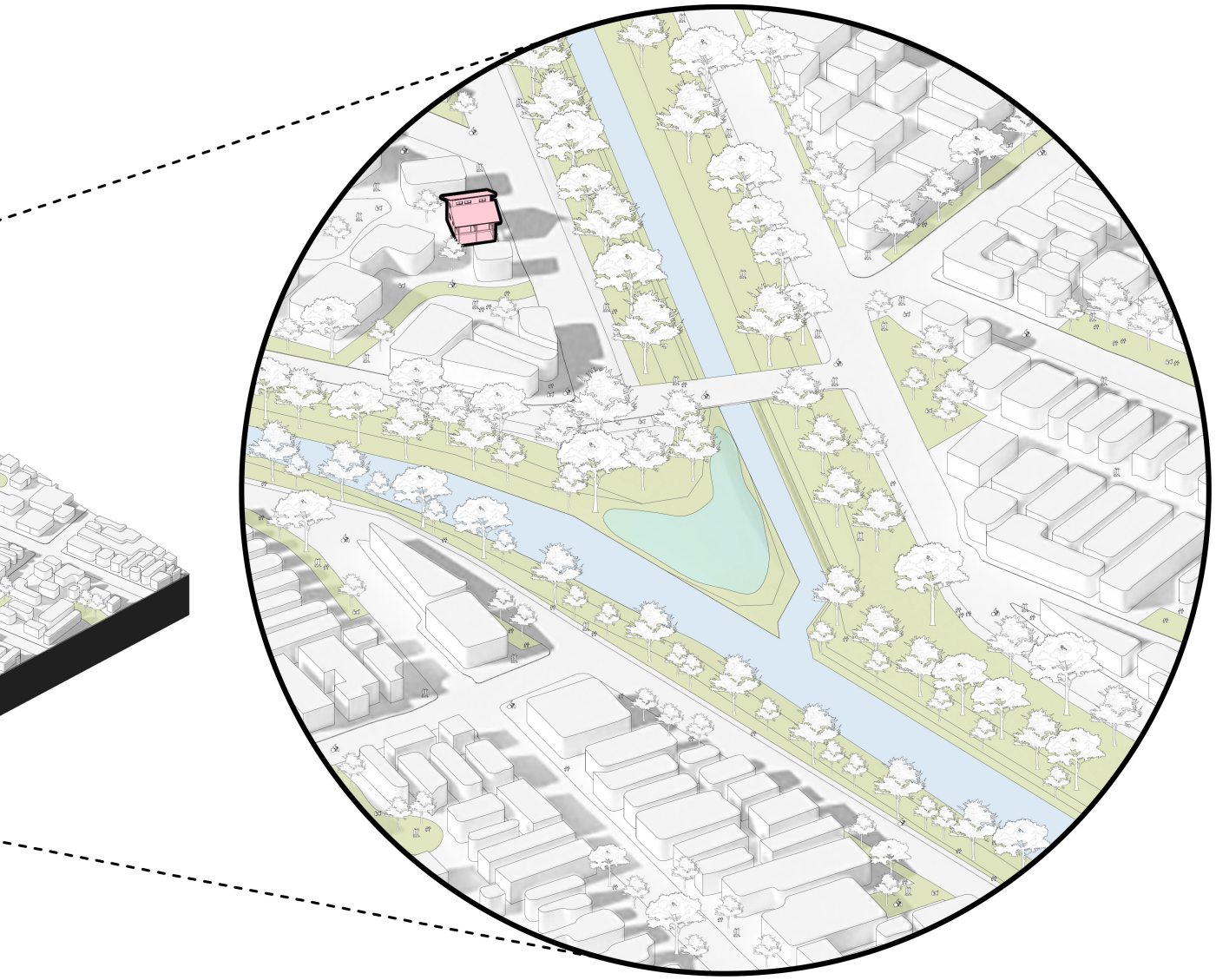
In the neighbourhood scale, the principle of 'Living with water' will guide the strategies adopted (see figure 3.05). The design strategy in this scale includes identifying abandoned and vacant lands in the surroundings of the Roncador River. Some of these lands are to be repurposed for building new social housing, while others will be used to provide new green areas (increase permeability and recreational areas) in the region, based on the Aquatecture approach. Figure 3.06 shows the strategy for intervention in Region A, including lowering the existing soccer field and providing permeable squares and skateparks to retain stormwater and reduce runoff, thus mitigating floods. Figure 3.07 illustrates the strategy for intervention in Region B, with fewer vacant lands since it is a more central area. Therefore, in Region B, the plan is to work with green streets and to incentivize green spaces in the center of occupied blocks. The intention with the green areas is to provide places for recreation and contemplation and act as collective productive spaces, generating income for the local communities. For instance, community gardens for urban agriculture, floriculture, and fruit farming foster the local economies by selling products in food markets, besides green streets composed of rain gardens and bioswales. This strategy is more applied in Region C, where there is more available land to propose productive green areas, as shown in figure 3.08.

Figure 3.06. Strategy in the Neighborhood
Source: Imag



scale: 'Living with Water', in the Region A.
ge by author.

Figure 3.07. Strategy in the Neighborhood
Source: Imag



scale: ‘Living with Water’, in the Region B.
ge by author.

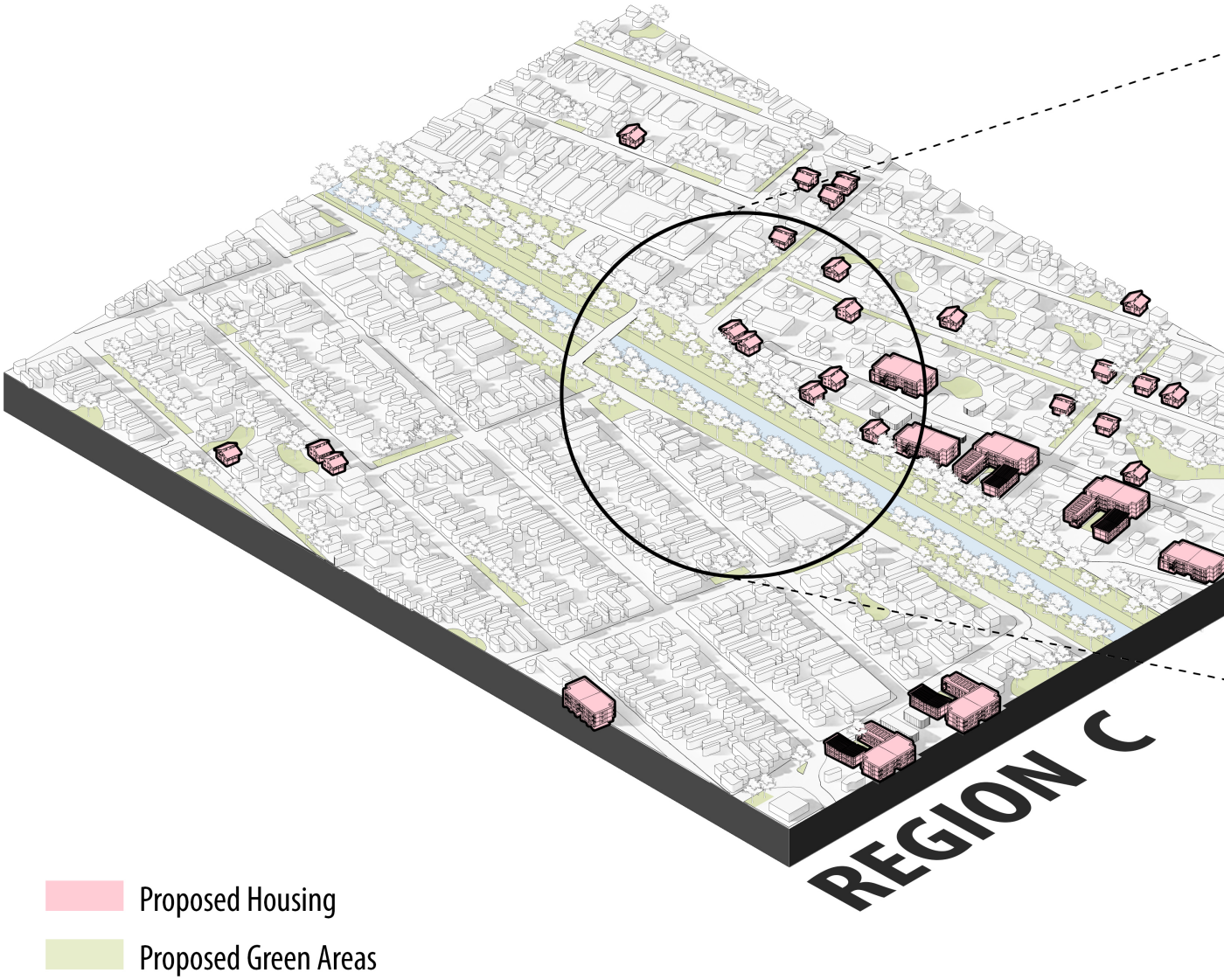
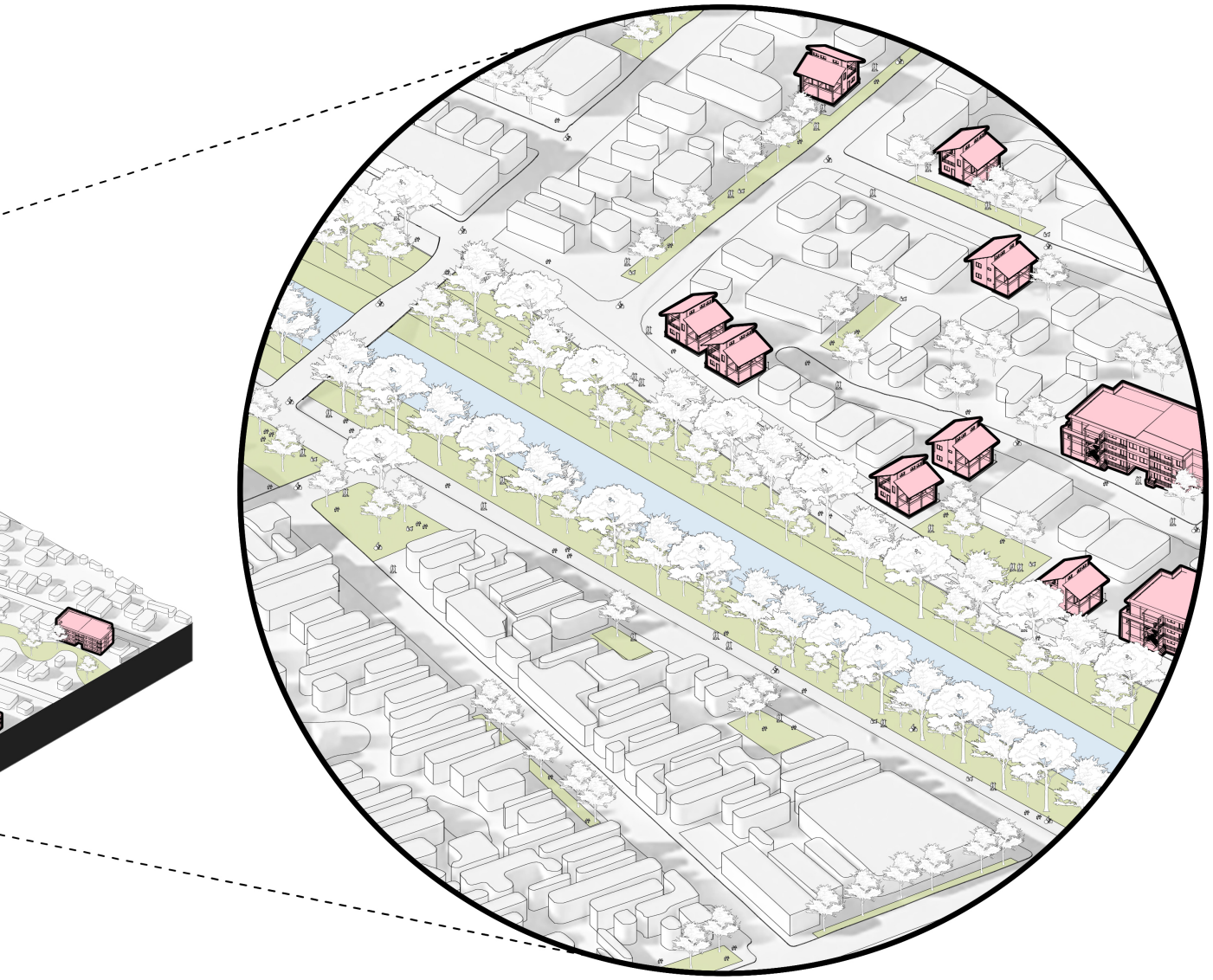


Figure 3.08. Strategy in the Neighborhood
Source: Imag

Figures 3.09 and 3.10 illustrate the "Living with water" strategy applied in Regions A (figure 3.09) and B (figure 3.10). The solutions include restoring the riparian vegetation and incorporating more permeable solutions to increase water storage and reduce runoff (such as green streets made of bioswales and rain gardens), lowering existing recreational areas, and using them as retention detention ponds during the flood season, and applying pervious pavement. Only then is it possible to mitigate floods and bring more nature-based recreational areas to the neighbourhoods.



scale: ‘Living with Water’, in the Region C.
ge by author.

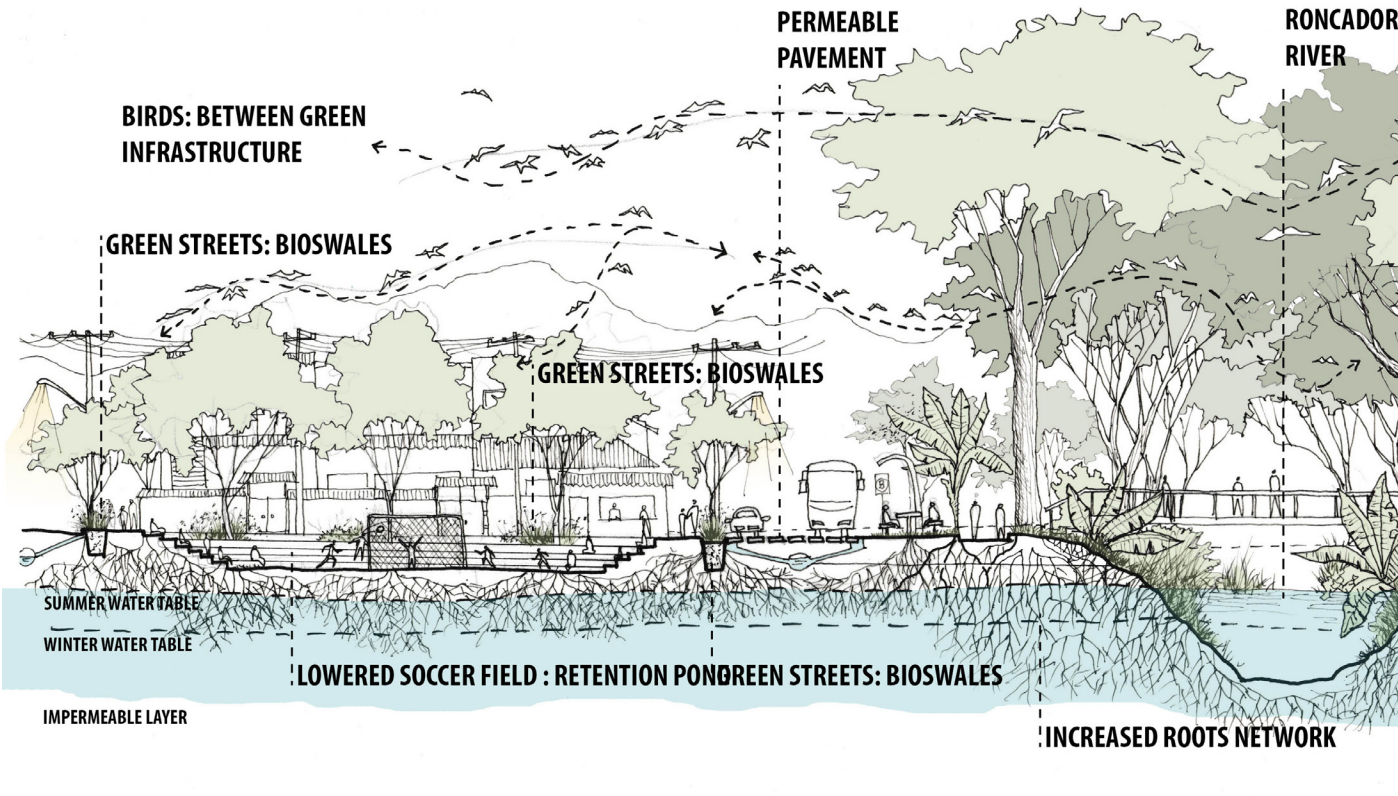
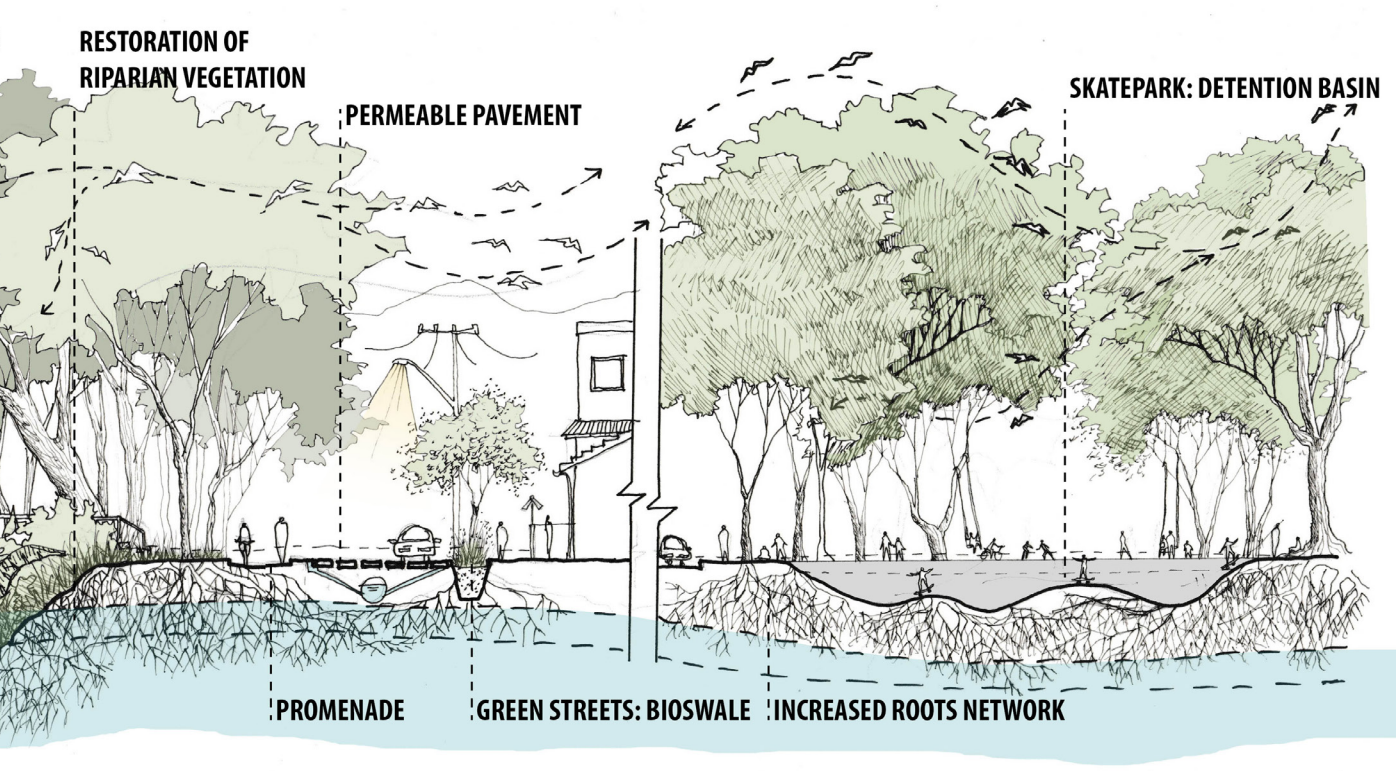


Figure 3.09. "Living with Water" Strategies in the Regi



on A. *Source: Adapted and translated from Ottoni, 2021.*

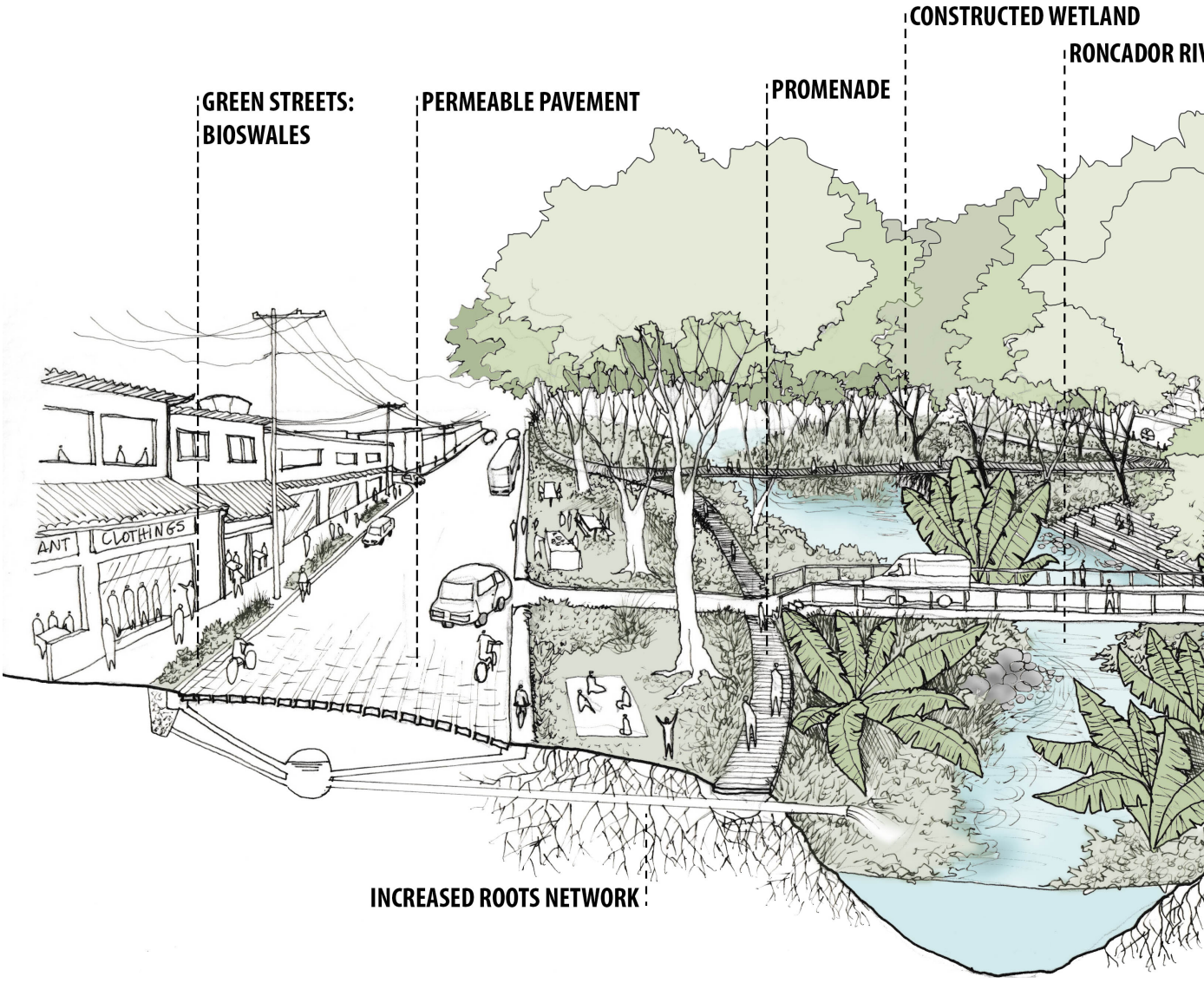
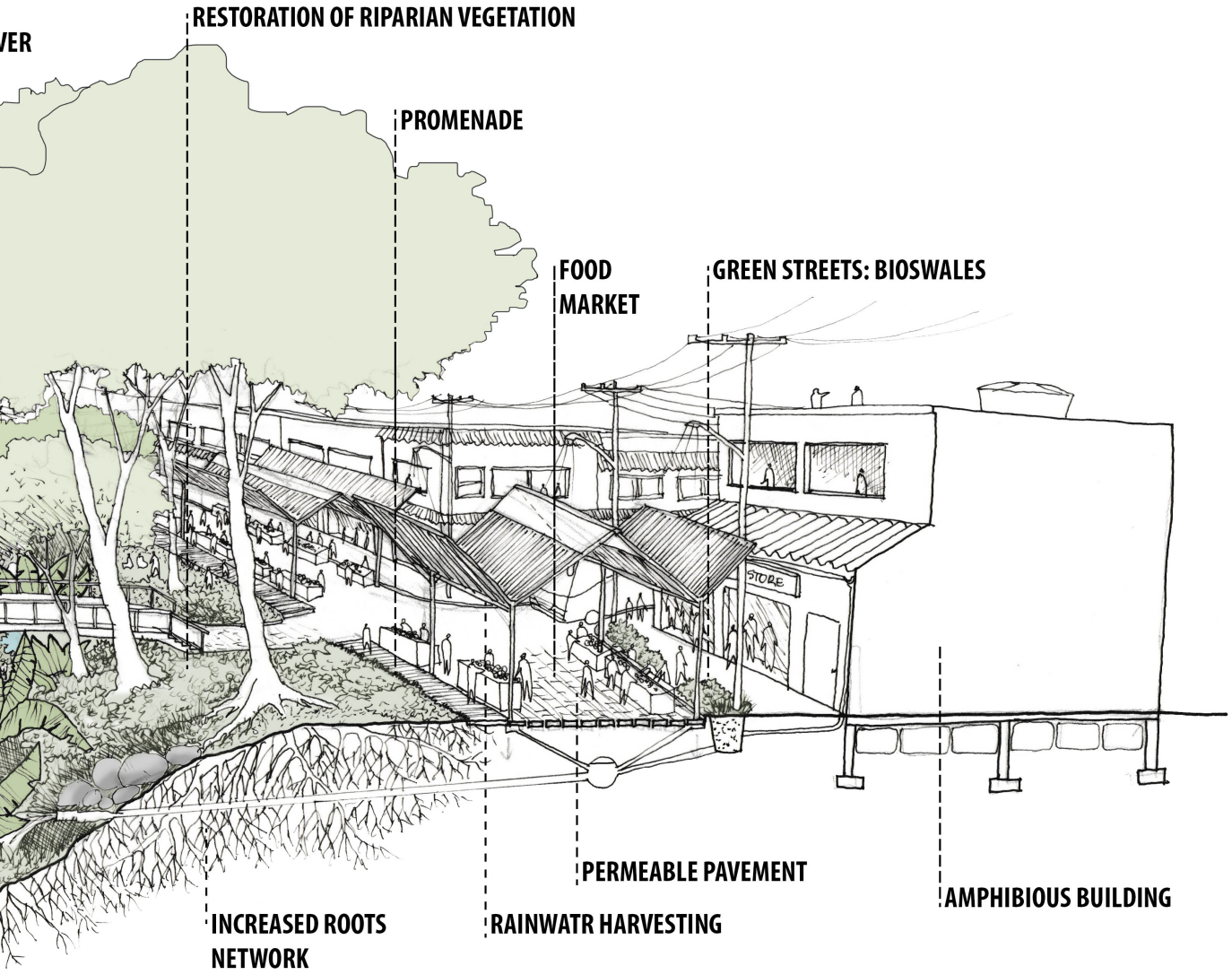


Figure 3.10. "Living with Water" Strategies in the Regi



on B. *Source: Adapted and translated from Ottoni, 2021.*

Housing Scale

The design strategies in the housing scale will respond to the 'Eco design' principle of the LifE concept but focus on water systems. The solutions correspond to the affordable housing intervention, thought to be evolutionary, adapted to floods and to the local architecture (materials and construction techniques), which provides a sustainable architecture. Rooftop rainwater harvesting and reuse for non-potable uses is another strategy to achieve water sensitivity that integrates with the other scales in reducing floods and contributes to sustainability. This thesis will not focus on the energy side of the Eco-design principle since it is more complex to address in an impoverished context and becomes out of scope. It will be built more upon the conceptual framework for sustainable design idealized by Guatarri (2000), which sees sustainability in a broader sense. Sustainability can, then, be achieved by focusing on the interdependent relationship among the three ecologies (communities, individuals, and environment) thought as intertwined systems that are adaptable to each other.

To properly address the housing shortage caused by the removal of riverine settlements and the significant local housing crisis, the intervention will entail building new quality affordable housing units in underutilized vacant plots within the same neighbourhood. This intervention aims at maintaining their community life and repurposing underutilized spaces to fulfil their social function (Rodrigues, 2004). The intervention will focus on the units' design quality by approaching it through the lens of incrementality and adaptability brought by the Open Building Movement (Kendall & Teicher, 2000). This approach presents design strategies that increase residents' control to adapt and modify their spaces over time, facilitating changes in layout or expansions. Increased control over housing production over life stages is considered an important feature that contributes to a high quality of life and sustainability.

Two housing types will be proposed in the Roncador river's expansion zone: a single-family housing type on Site 01 (a common practice in the region) and a multi-family low-rise building on Site 02. Figure 3.11 indicates the location of Sites 01 and 02 within Region C. As an expansion zone, Region C has less dense occupation than regions A and B and has significantly more extensive and numerous vacant lands, which presents more opportunities for design experimentations. Site 01 is a small lot, with dimensions of 15m x 34m, and its area coincides with many other lots in the surroundings, appropriate for a single-family unit. Adaptability will also be addressed by making the houses protected from floods by adopting an amphibious architecture system. This system will provide flood-adaptability by working with the floodwaters instead of creating barriers, allowing the house to float when the flood hits and returning to the land when it subsides (English et al., 2016). This thesis's innovative

idea is combining adaptability strategies, both for incrementality and amphibiation, to provide low-income residents with more control over their houses and resiliency against floods. Figure 3.12 presents other vacant lands within Region C that could also be appropriated for the housing intervention. Because there are small and large sites within this selected region, the housing strategies used differ according to the lot size. Small lots are more suitable for single-family housing types, whereas large lots or entire vacant blocks can accommodate multi-family low-rise buildings to increase density over time. Figure 3.13 shows the site plan, with different housing types according to the lot size.

In addition, it is paramount to this study that the proposed design be integrated with its social and environmental contexts, resulting in an architectural response that utilizes local materials and construction techniques. Acknowledging local traditions by incorporating local knowledge in this evolutionary design proposition will allow the residents to expand their houses in the future by self-construction, which is already a local practice. Understanding the water layer in this housing intervention also connects to thinking about alternative solutions to address sanitation (not existent in the region) individually and collectively. This design proposition in the housing scale will also consider a low-cost and easy-maintenance wastewater treatment system that applies nature-based and local techniques strategies. These strategies, such as green septic tank interconnected with wetlands (as seen in figure 3.14), are low-cost sustainable solutions that not only treat domestic wastewater but can engage the community as a collective maintenance activity and generate food and sources of income for them (Figueiredo & Tonetti, 2018).

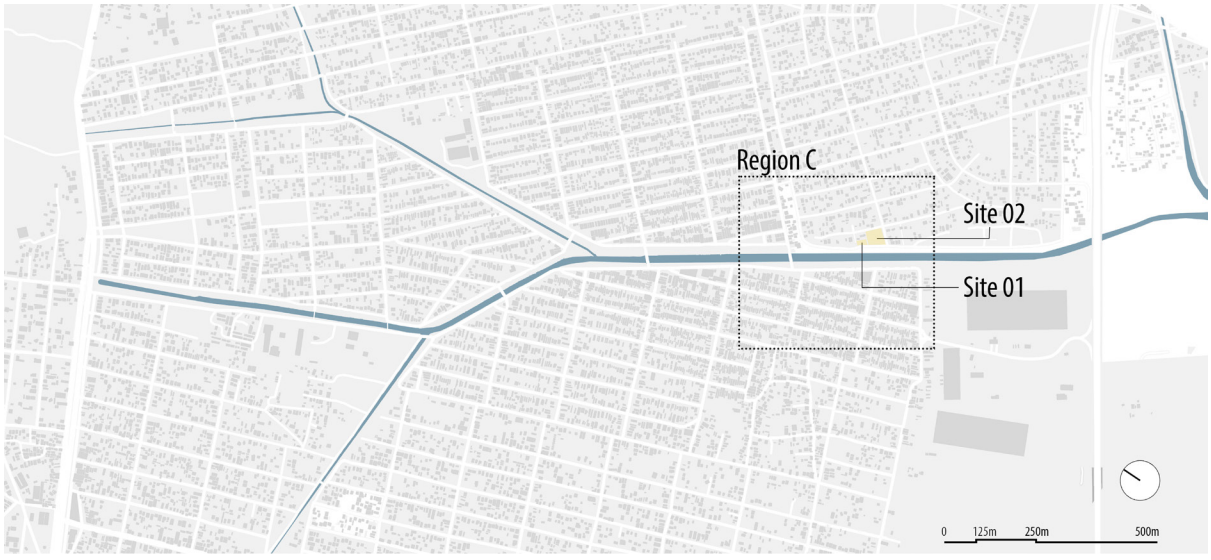


Figure 3.11. Location of Sites 01 and 02 within the Region C, for proposing housing interventions. *Source: Image by author.*

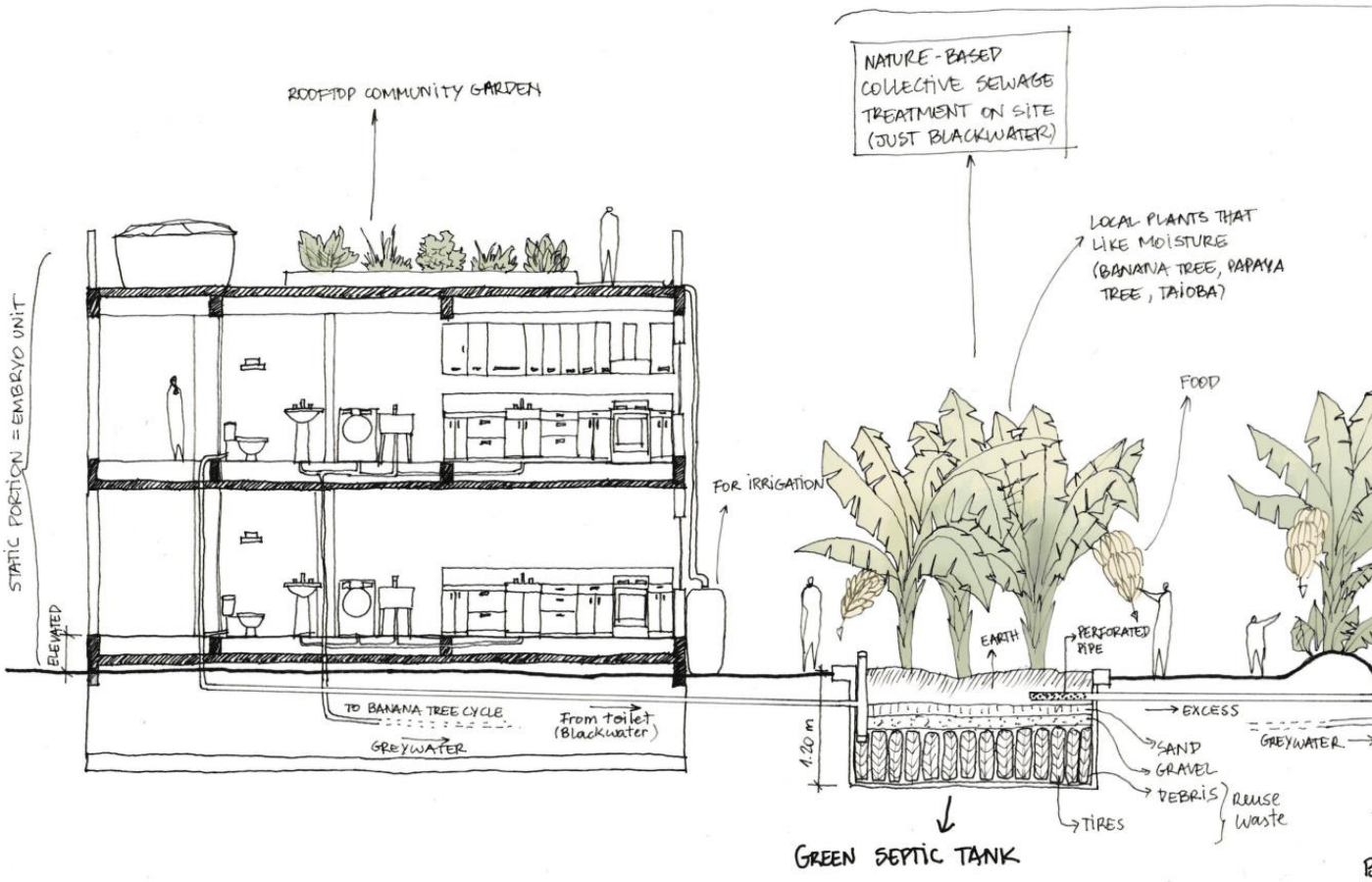
Figure 3.12. Location of Sites 01 and 02 and other vacant lands within th

e Region C, for proposing housing interventions. *Source: Image by author.*

Figure 3.13. Different housing types according to th

he lot size within Region C. *Source: Image by author.*

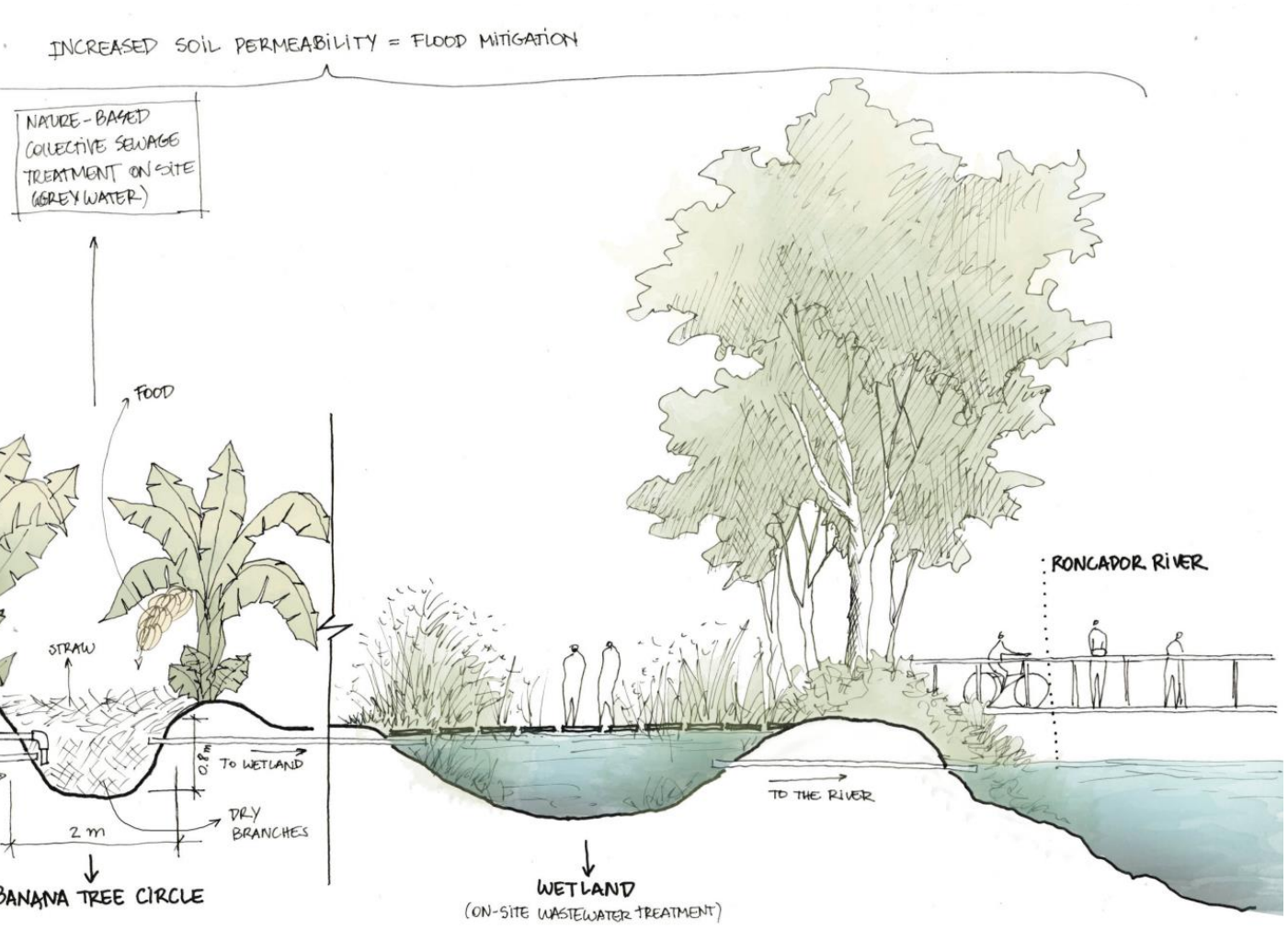
Alternative sewage treatment system



Scale	LifE Principle
Intermediate (neighborhood) Regions A, B, C	Living with water

Figure 3.14. Alternative sewage treatment system in the Neighborhoo
Source: Ima

Figures 3.14 and 3.15 show the transition between the system of parks and the housing intervention, using vacant lands to not only provide affordable housing but the alternative, low-cost, low-impact, and low-maintenance strategies to treat sewage on-site and to produce local food collectively. By using nature-based strategies, such as the green septic tank, banana tree circle interconnected with wetlands, the residents can improve their quality of life, reduce hazards and contribute to regenerating the river's environmental qualities (See figure 3.14). In addition, these transitional spaces in the neighbourhood scale can work as collective productive areas, such as community gardens. This collaborative food production system can generate food and fertilizer by composting, enhancing soil permeability,



Action

Non-defensive strategies: Use **vacant lands** for housing + green areas; productive **collective green areas** and streets

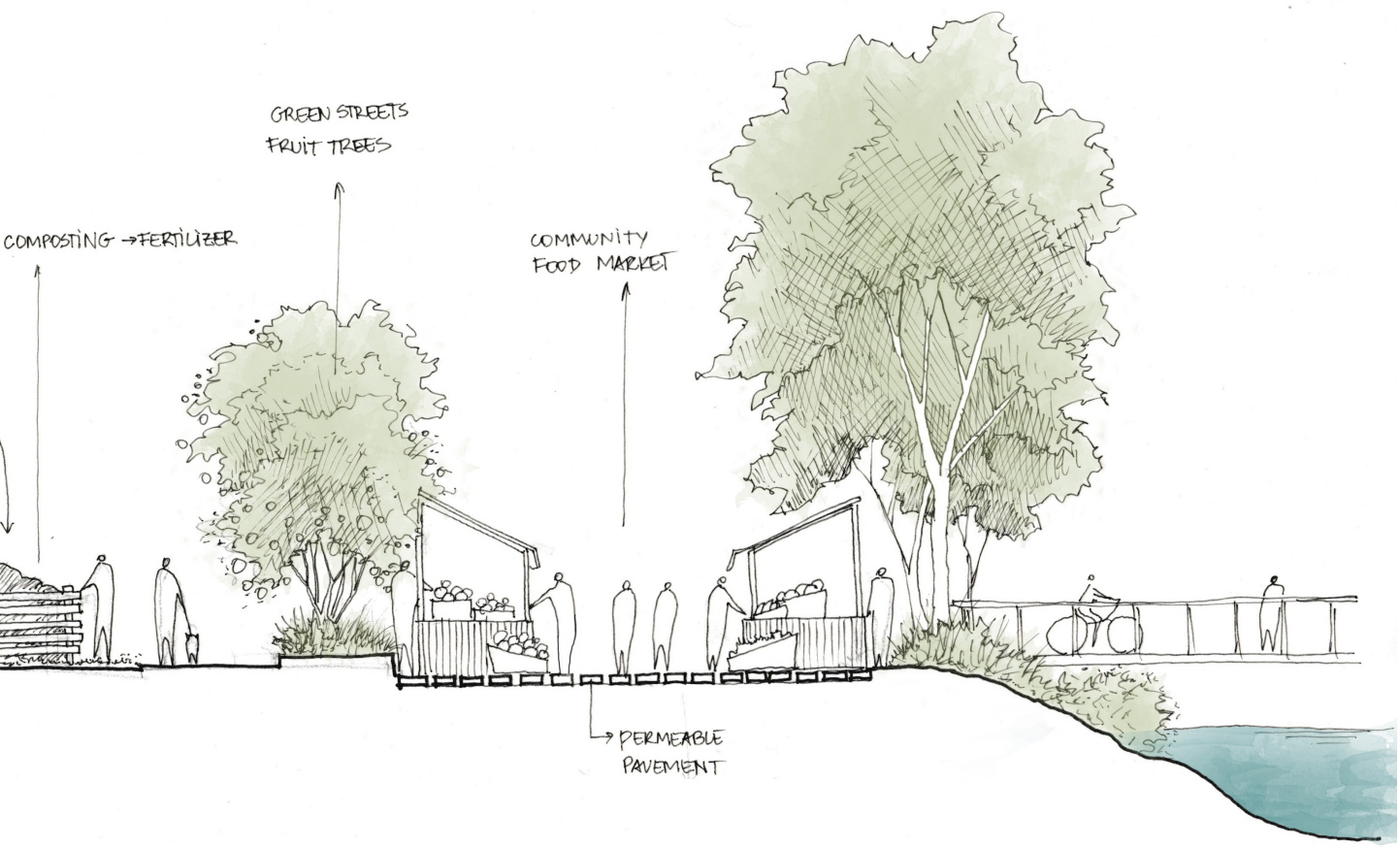
d scale: green septic tank connected to Banana Tree circle and wetland.
ge by author.

improving local economies, and reinforcing local traditions such as weekly food markets, in a circular way (See figure 3.15). Figure 3.16 illustrates the scenario where the house is relatively closer to riverbanks, with less space to develop a productive system strategy, and with a street separating the residential area from the margins. The transitional space would comprise solutions to increase soil permeability, like permeable pavement, bioswales and rain gardens for greenery, wetlands, and restoration of riparian vegetation, complemented by solutions in the housing scale such as rainwater harvesting and reuse, green roofs, and living walls.

Collective food production system

Scale	LifE Principle
Intermediate (neighborhood) Regions A, B, C	Living with water

Figure 3.15. Collective food production in the Neighborhood scale: transition be



	Action
	Non-defensive strategies: Use **vacant lands** for housing + green areas; productive **collective green areas** and streets

etween the system of parks and the housing intervention. *Source: Image by author.*

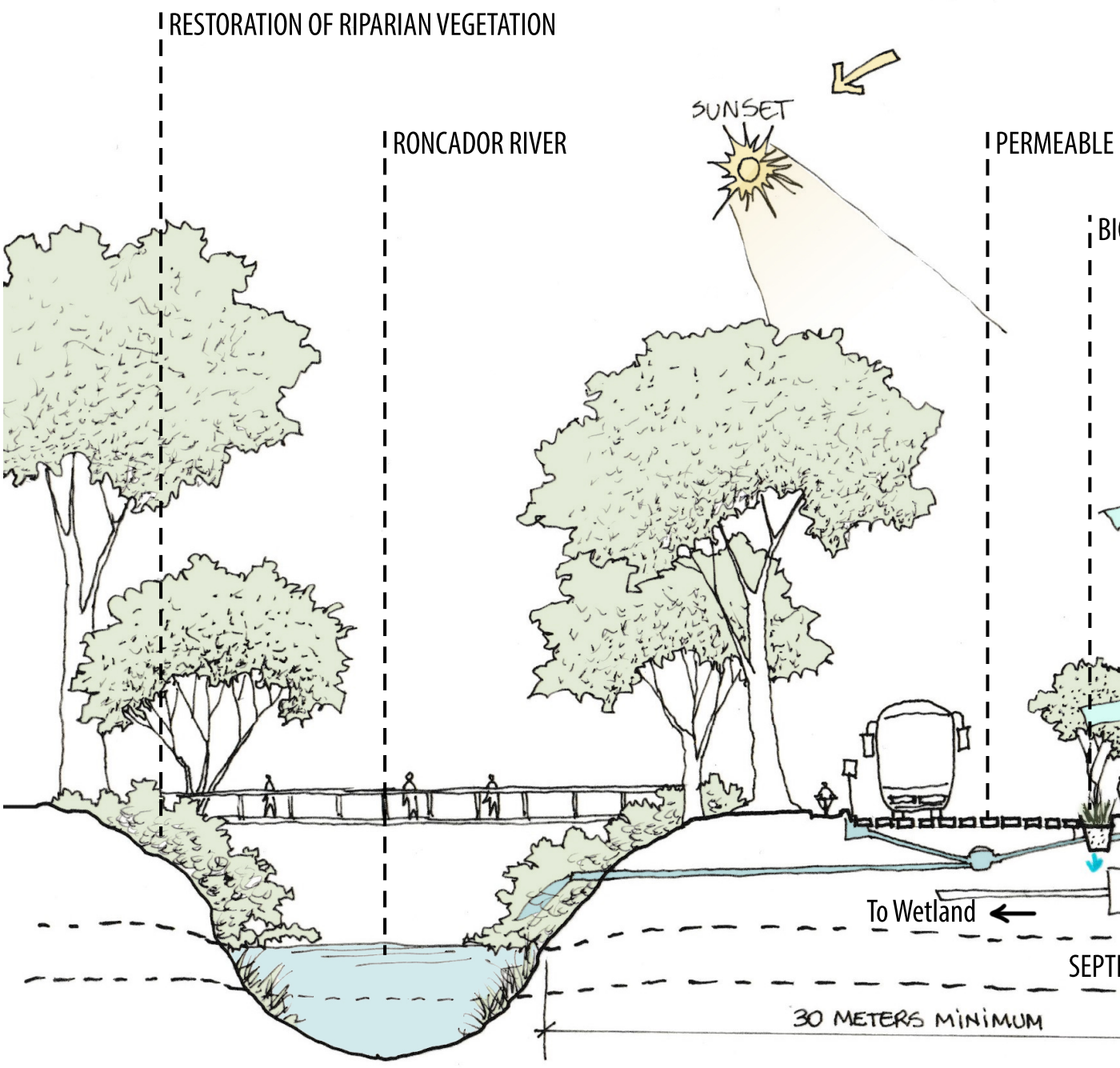
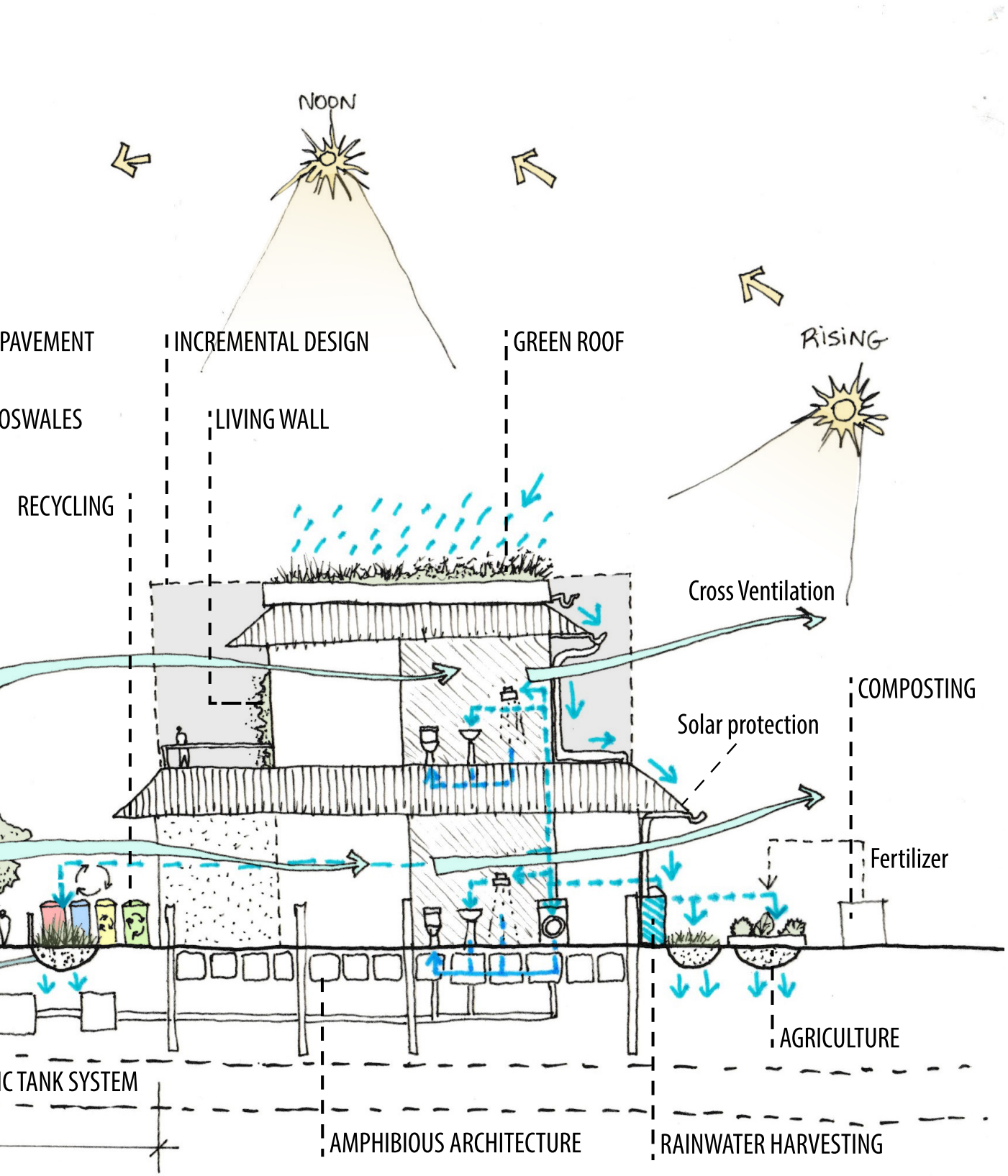


Figure 3.16. Strategies to increase soil permeability in the transition betw
Source: Imag



veen the riverbanks and the residential area with a street separating them.
ge by author.

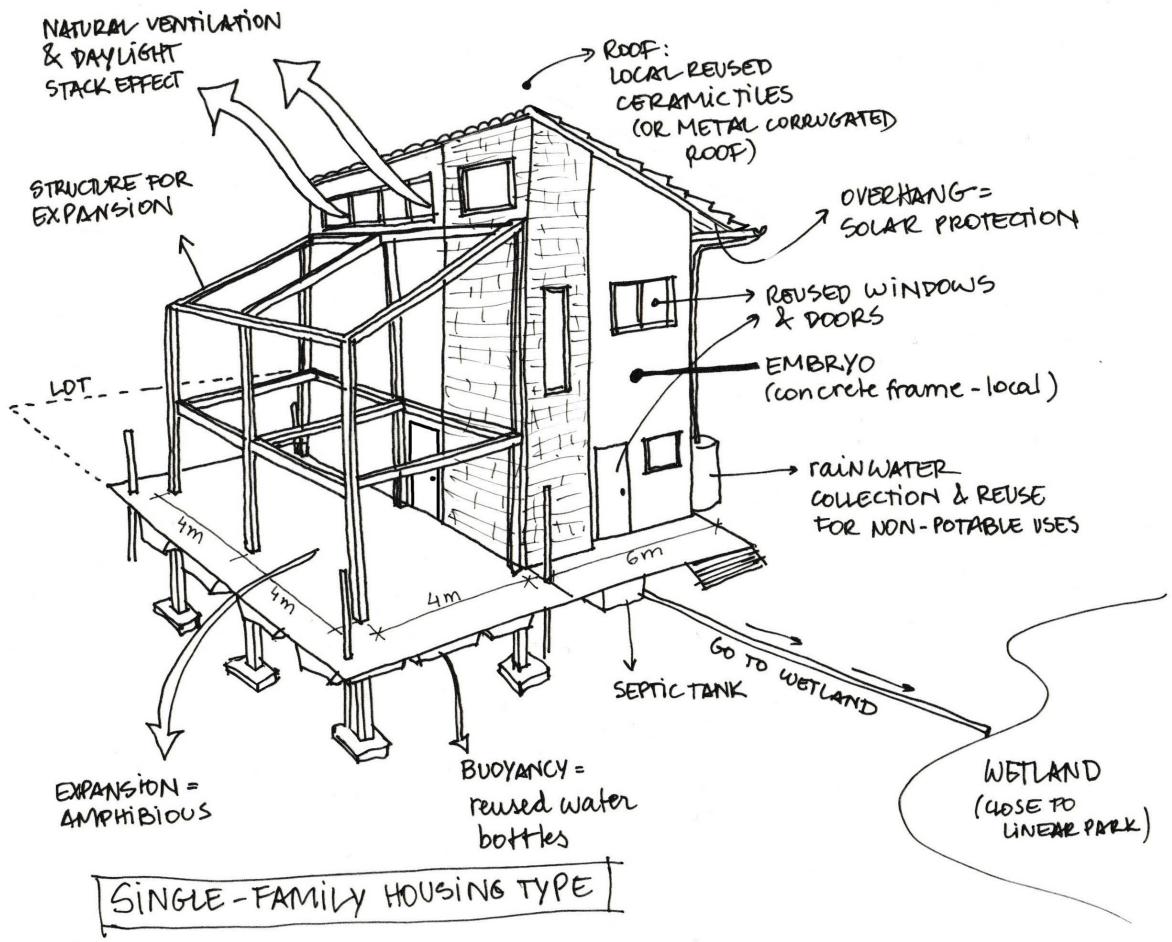


Figure 3.17. Parti for the single-family housing proposition on Site 01. *Source: Image by author.*

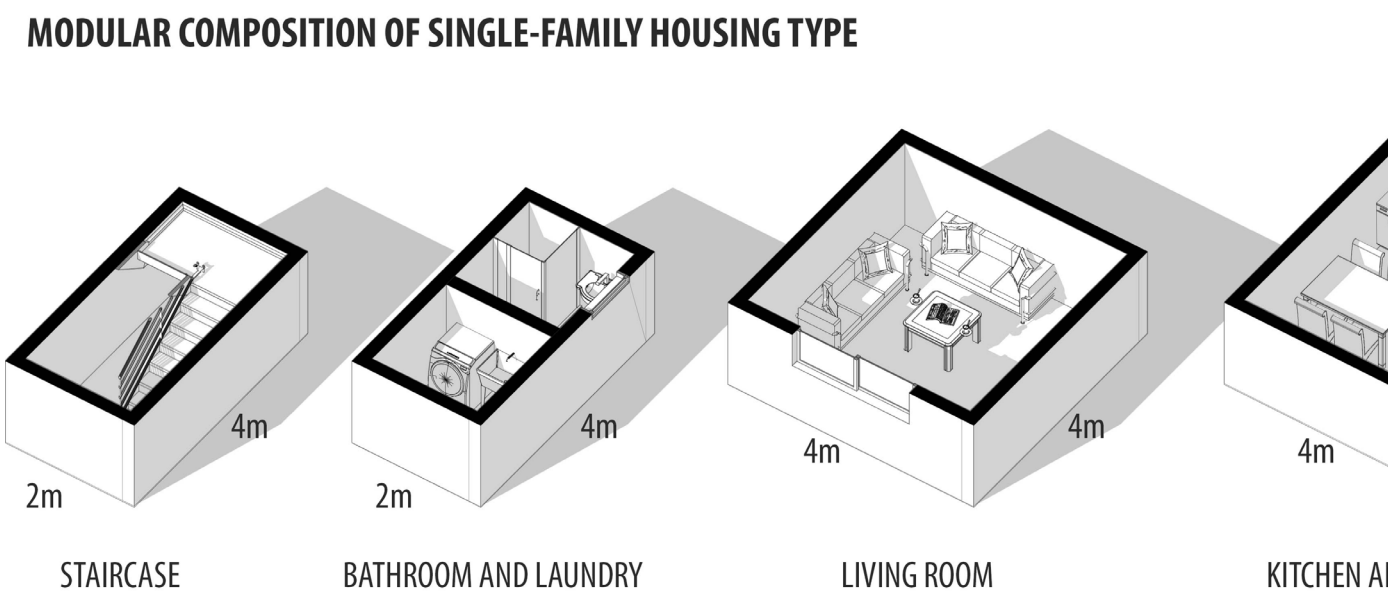


Figure 3.20. Modular composition of single-family ho

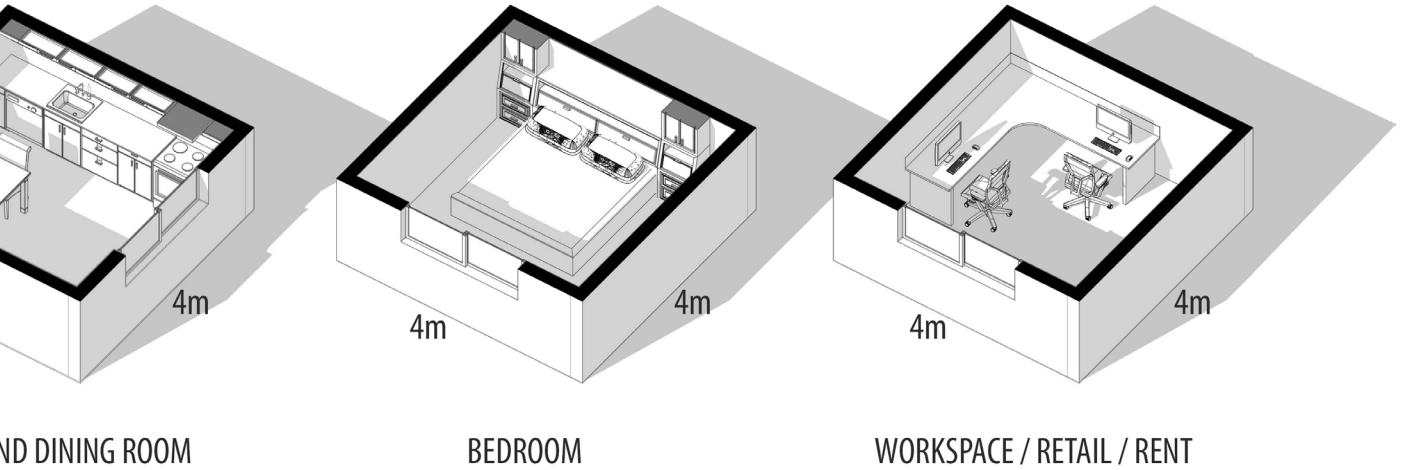
Accordingly, the single-family housing intervention on Site 01 will be approached by applying the design strategies from the Open Building approach combined with amphibious architecture and utilizing local materials and construction methods. Figure 3.17 indicates the parti for the single-family housing proposition, which considers the small lot size.

The parti represents the idea of providing a starter or embryo unit that is half of the potential final house area, as seen in Aravena's Villa Verde case study. It also shows the provision of a structural frame to support the expansion of the house over time (made of local wood) and the amphibious system to allow the starter house and the future expansion area to float during a flood event. It also acknowledges the importance of reusing local materials, such as reused ceramic tiles or corrugated metal sheets for the roofing system, and reusing windows and doors, if they are in a proper state. In addition, the buoyancy system elements can be composed of reused water bottles[11] (which are very commonly thrown away in the streets), contributing to reducing the waste irregularly discharged on the roads. Figures 3.18 and 3.19 illustrate a buoyant foundation made of reused plastic water bottles applied in Bangladesh (Prosun, 2011).

As shown in figure 3.20, the starter unit combines two modules of 4m x 4m (kitchen and living room), two sub-modules of 2m x 2m (bathroom and laundry room) and one sub-module of 2m x 4m (staircase) in the ground floor, having a final size of 6m x 8m. The starter second floor has one module of 4m x 4m (bedroom) and another module of 2m x 4m (bathroom). The expansion on the ground floor can also comport another module of 4m x 4m, 4m x 6m, or 4m x 8m to work as an extra bedroom, retail space, office space, or rental bachelor's unit (see figure 3.21). Figure 3.21 also indicates the fixed elements (support) concentrated on the center of the plan. Figure 3.22 shows the ground floor plan in the starter unit on Site 01, highlighting the single-family housing type interventions. Figure 3.23 illustrates the expansion on the ground floor over time, in which the red colour represents the expansion. The second-floor plan for this housing type in the embryo condition is displayed in figure 3.24, while the expansion scenario is indicated in figure 3.25.

11 The buoyancy system for amphibious housing can be composed of reused materials, as an affordable and sustainable strategy, specially relevant for impoverished contexts. In her Master Thesis, Prithula Prosun designed the buoyant foundation of the LIFT House in Bangladesh as composed of used water plastic bottles, placed inside a bamboo framing and hold together with nylon rope, as can be seen in Figures 3.18 and 3.19 (Prosun, 2011).

Figures 3.18 and 3.19. Preparation and testing of buoyant foundation composed of reused water bottles and local bamboo framing by local residents. Images by Prithula Prosun, 2011.



ousing proposition on Site 01. *Source: Image by author.*

Modular composition | ***Site 01***

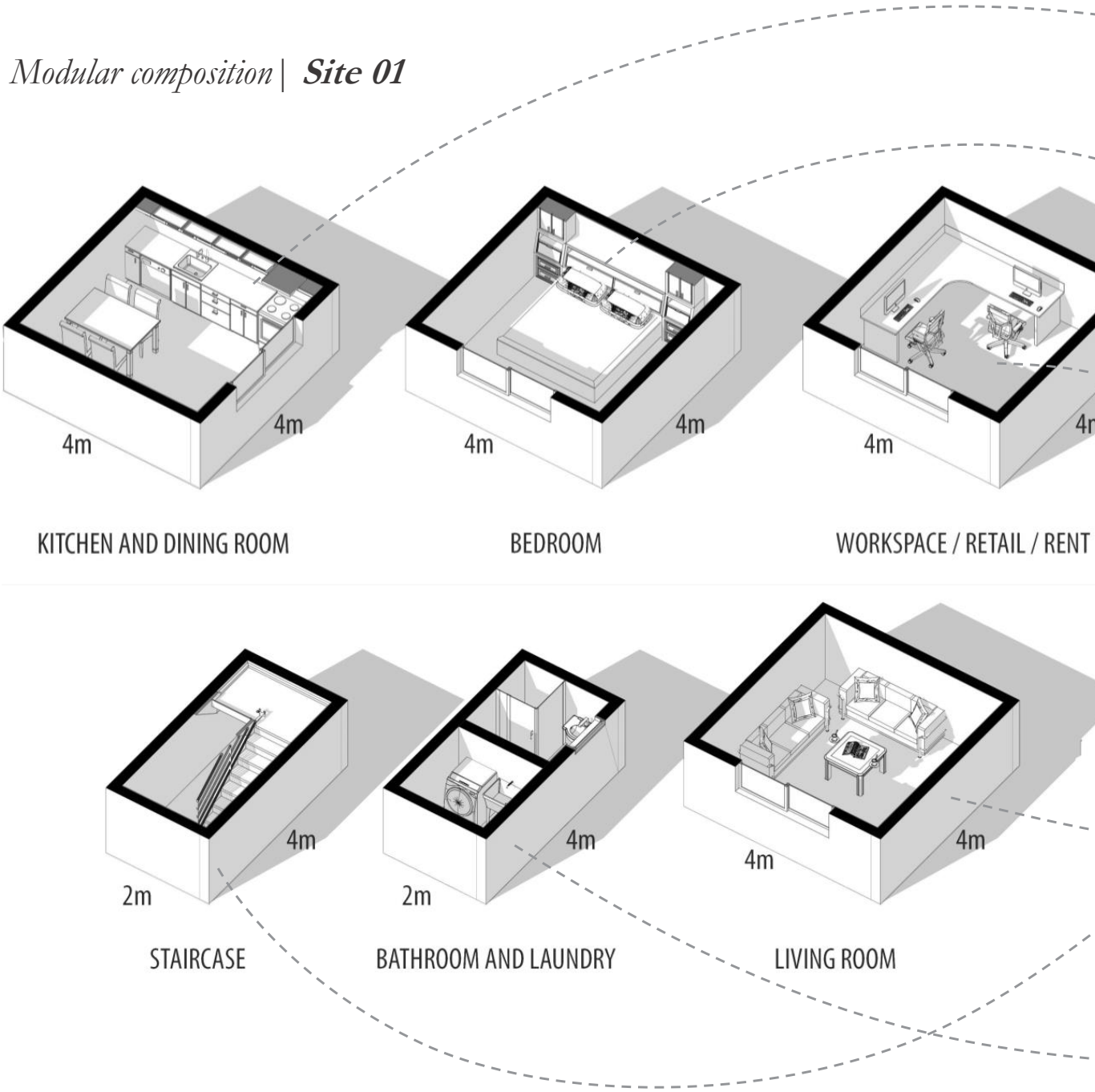
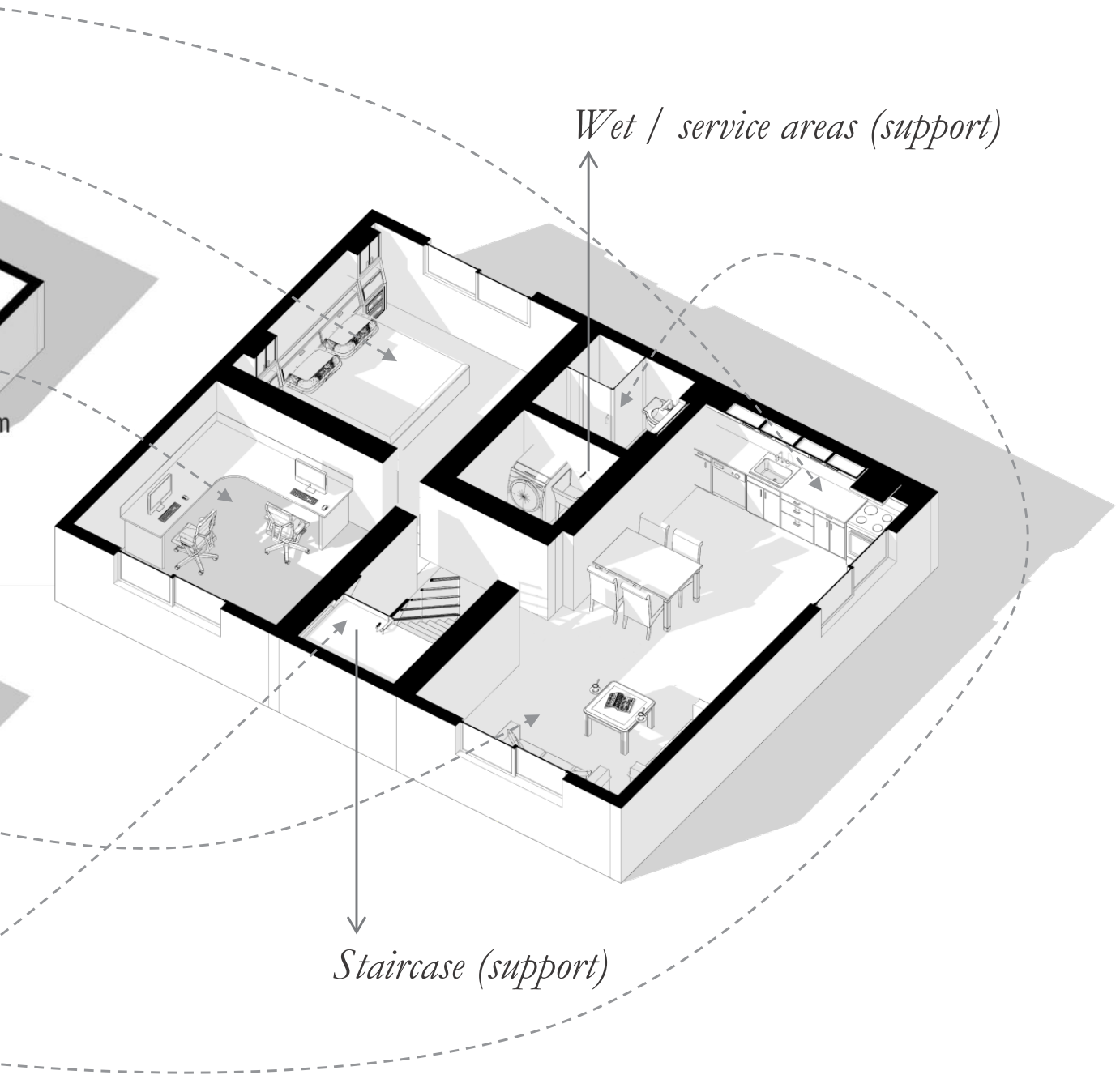


Figure 3.21. Modular composition of single-family housing proposition on
Source: Imag



n Site 01, with core or support elements concentrated in the center of plan.
ge by author.

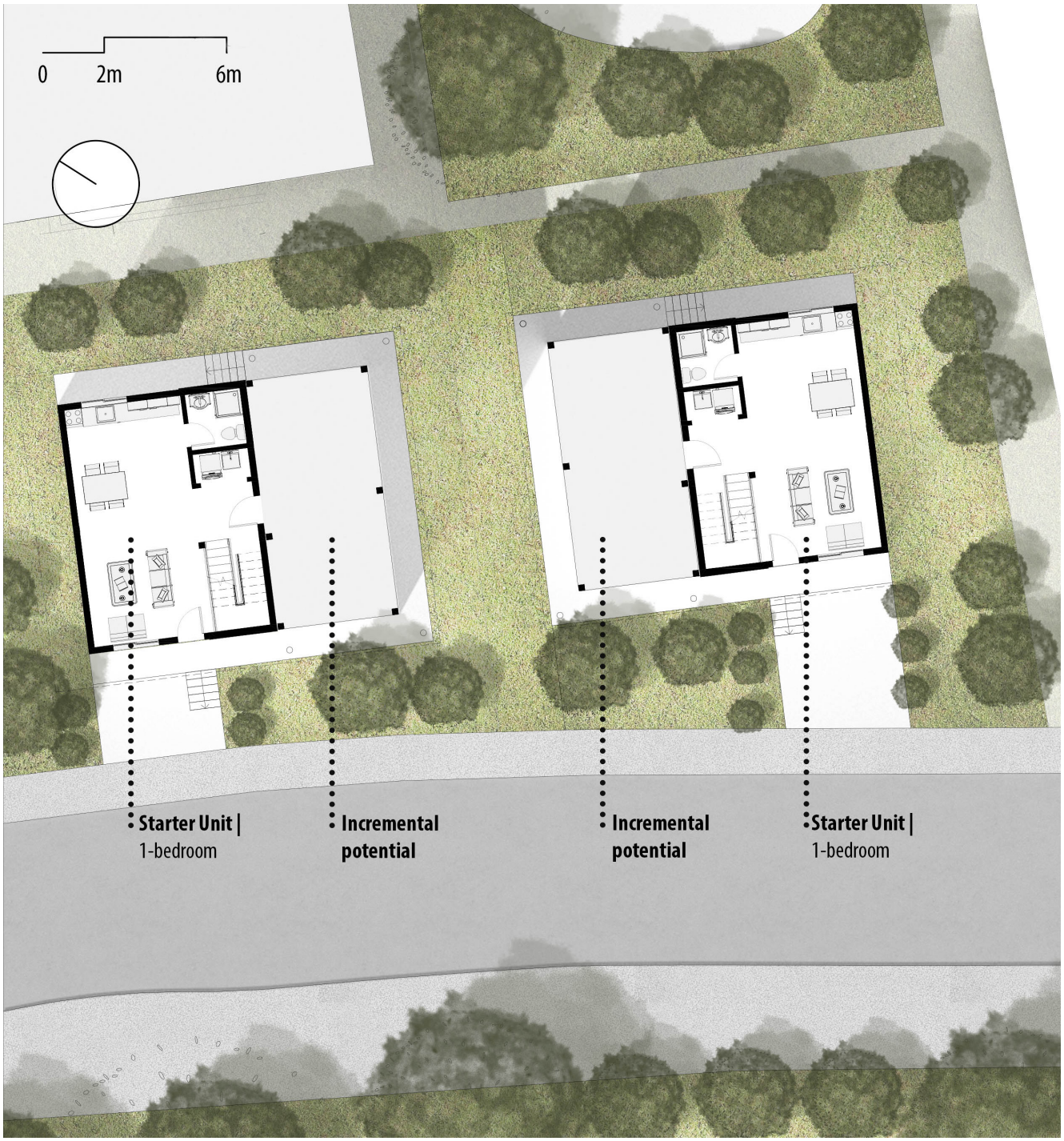


Figure 3.22. Ground floor plan of single-family housing type on Site 01 in the starter / embryo condition.
Source: Image by author.

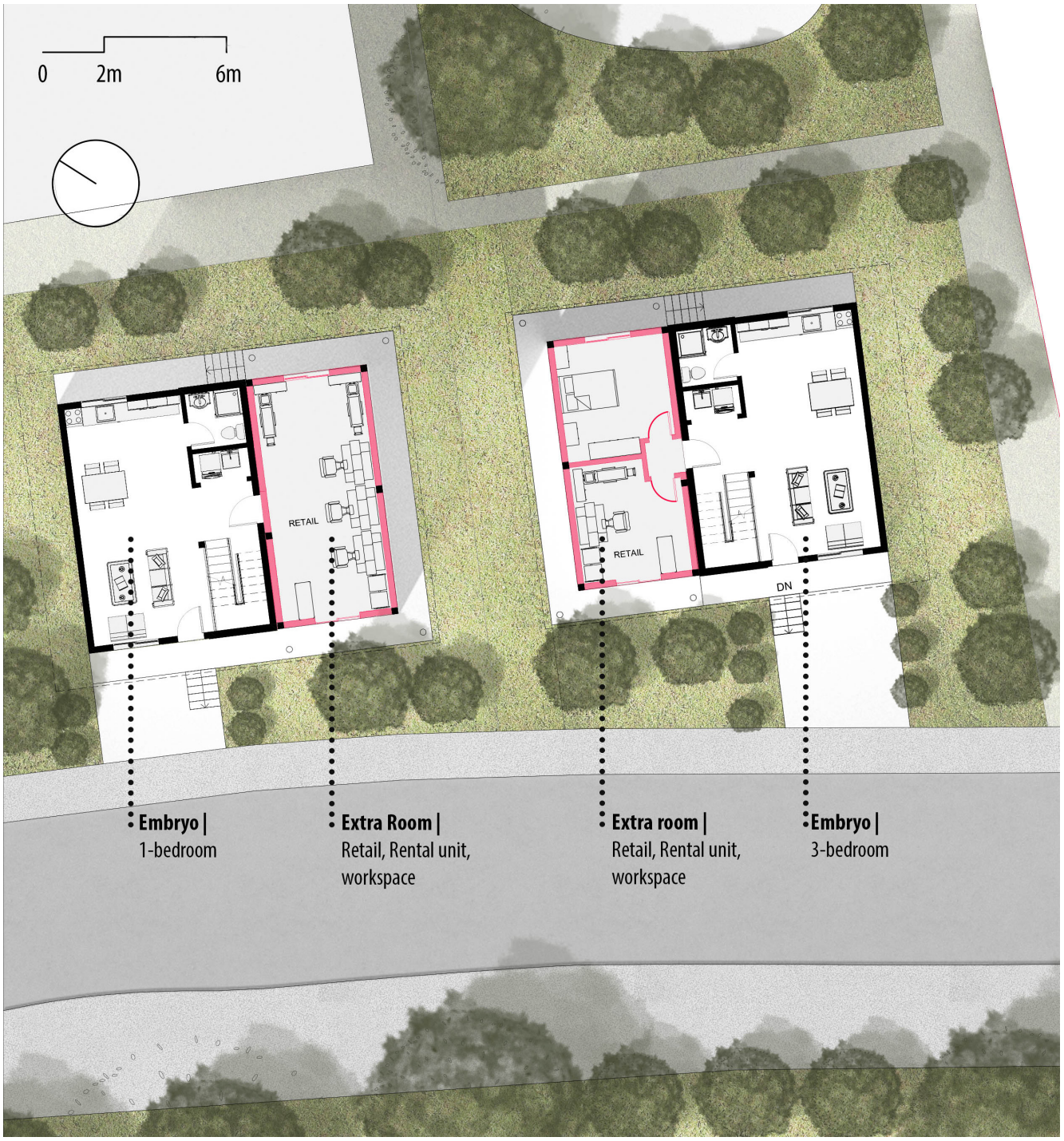


Figure 3.23. Ground floor plan of single-family housing type on Site 01 in the expansion scenario.
Source: Image by author.

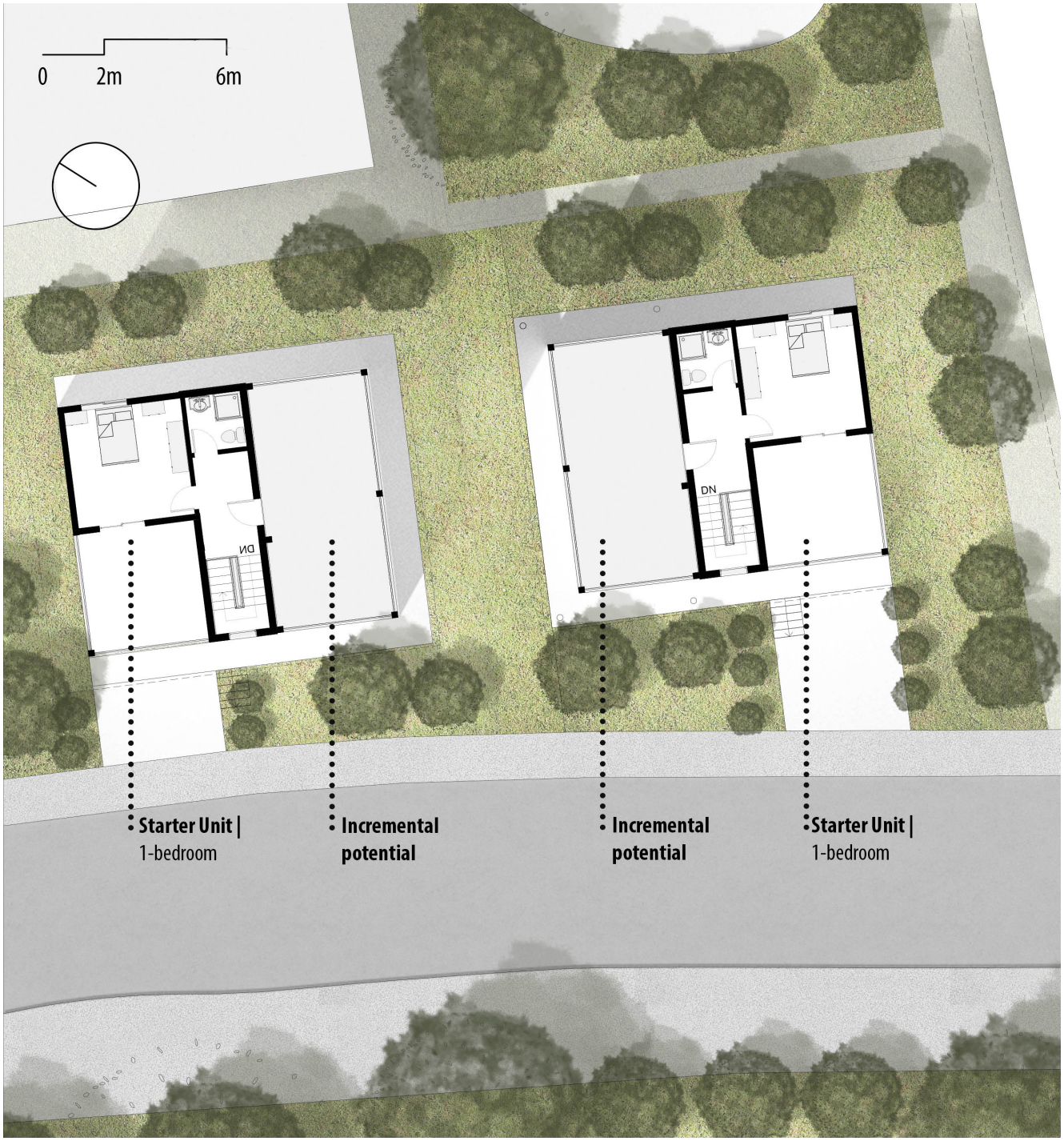


Figure 3.24. Second floor plan of single-family housing type on Site 01 in the starter / embryo condition.
Source: Image by author.

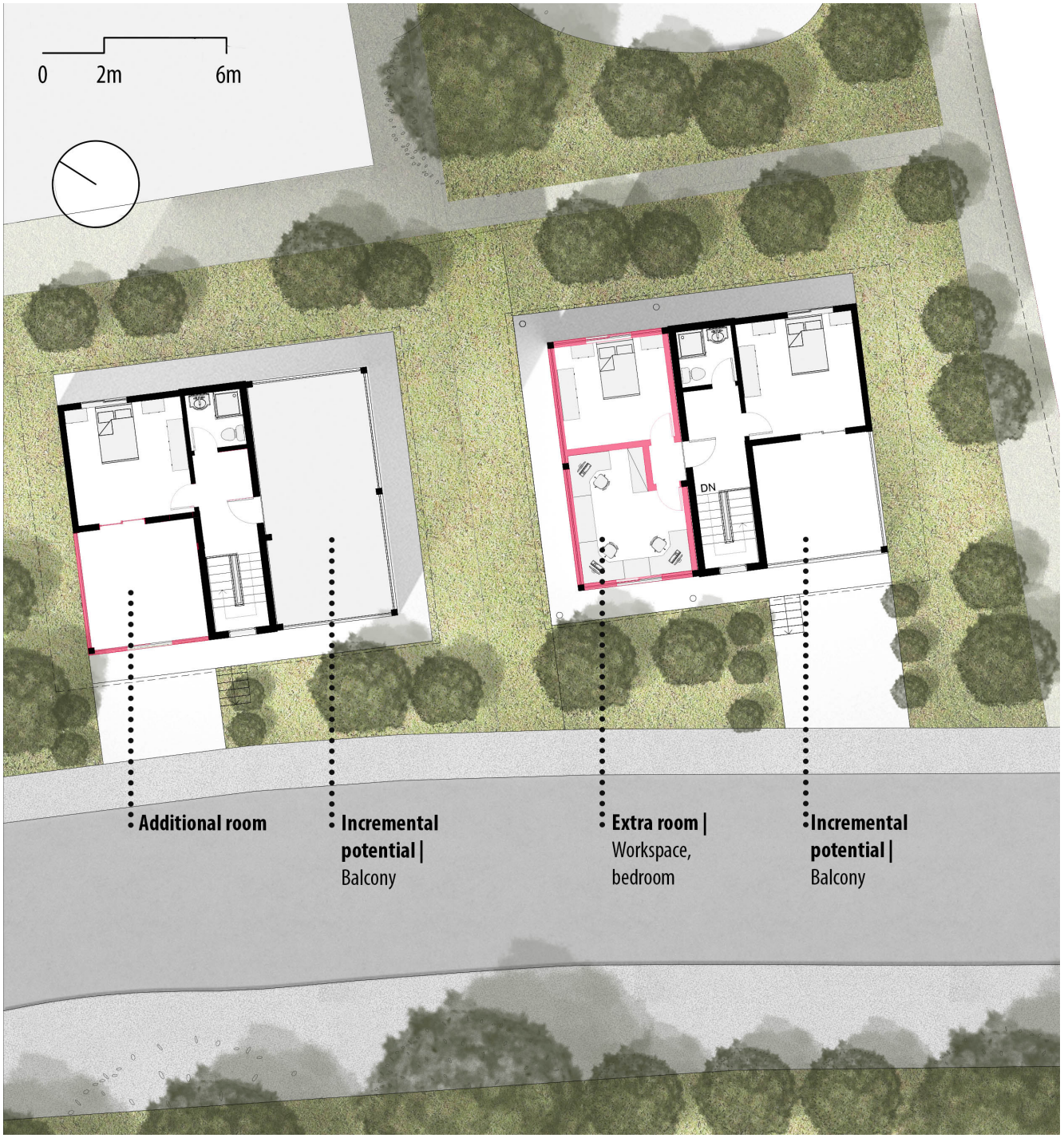


Figure 3.25. Second floor plan of single-family housing type on Site 01 in the expansion scenario.
Source: Image by author.

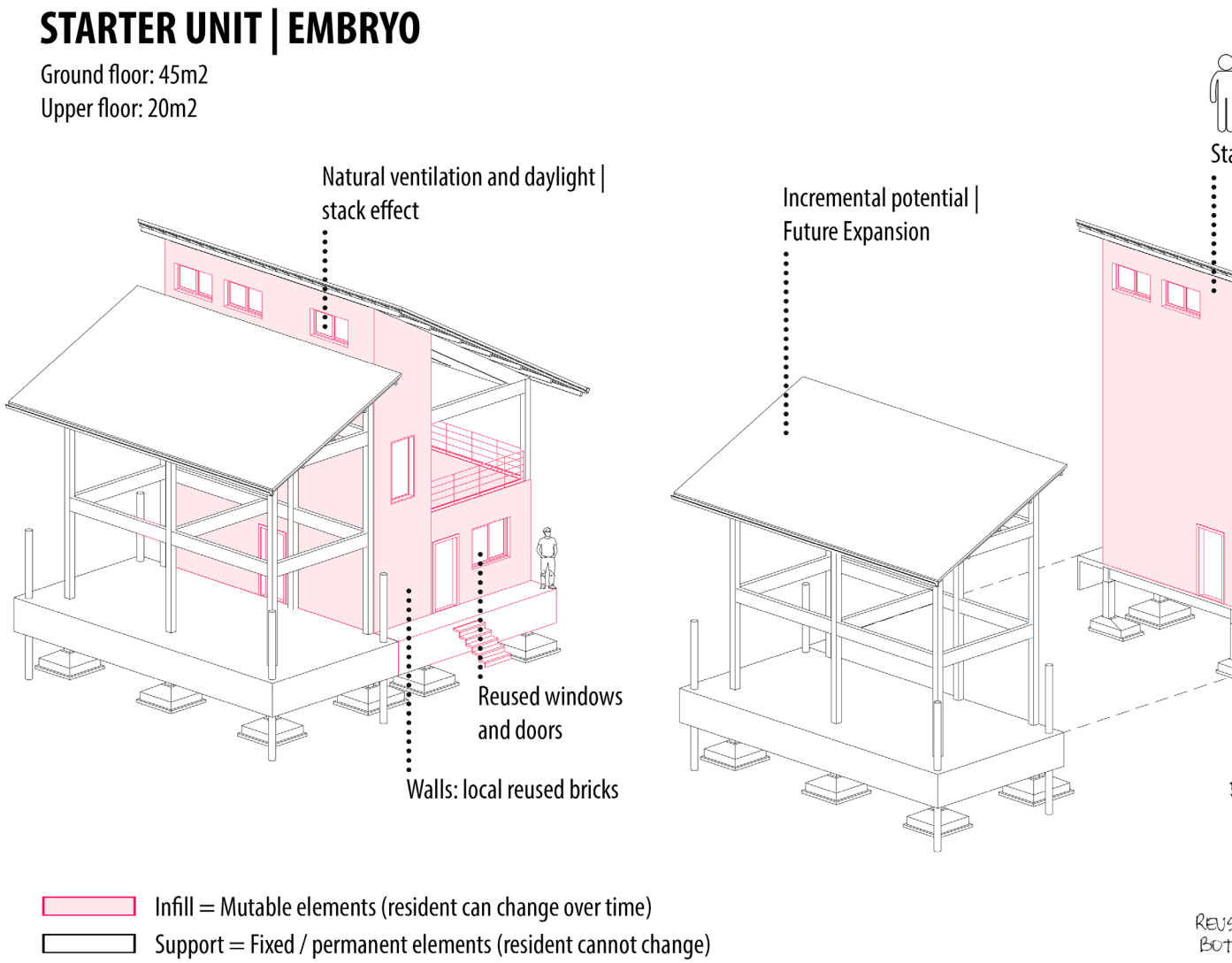
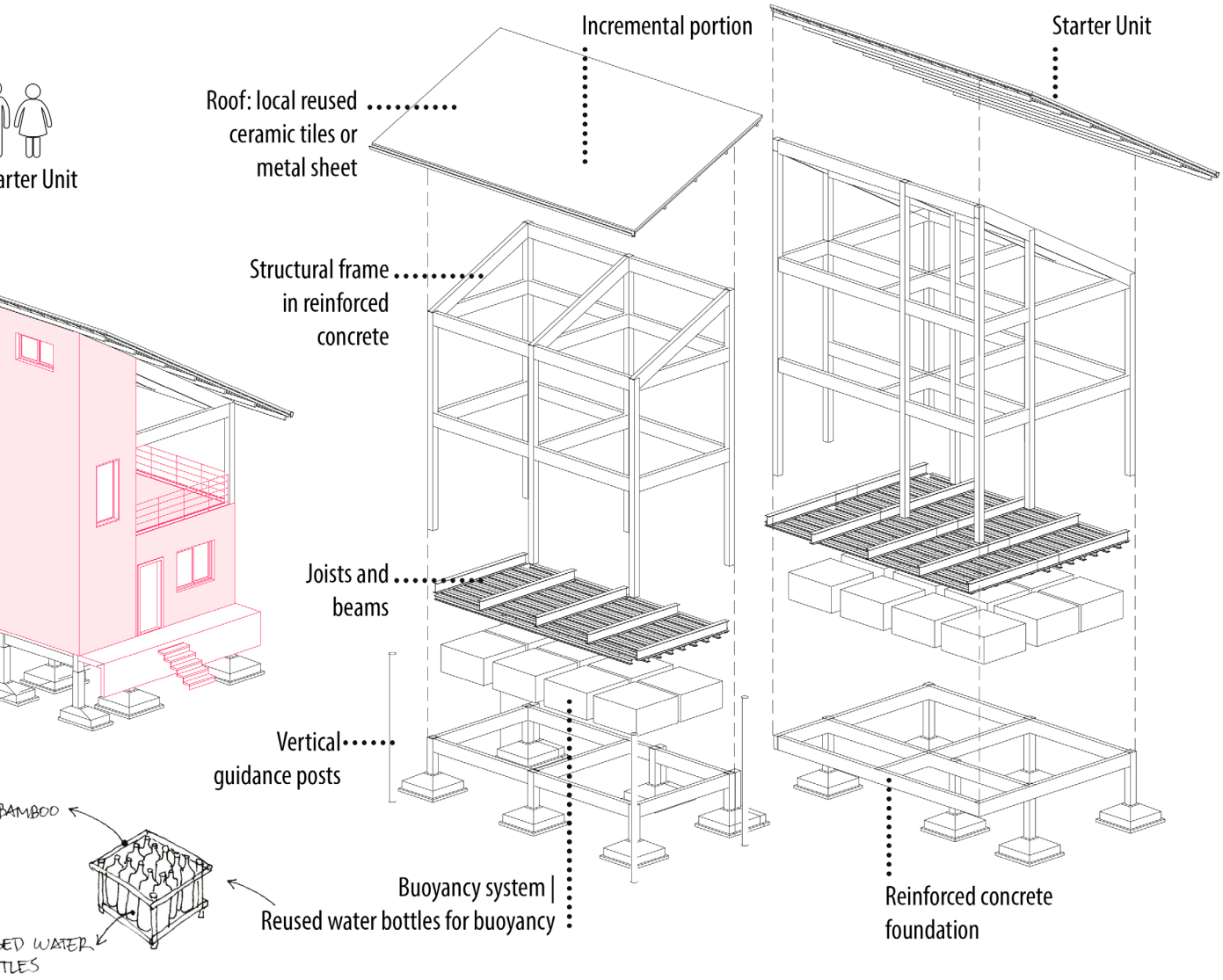


Figure 3.26. Single-family housing proposition on Site 01: incremental design strate

Figure 3.26 shows the parts that compose the starter unit, evidencing it is mainly made of infill and support elements. The residents are initially provided with support elements such as the structural frame and amphibious foundation for the starter unit and the future expansion portion, the roof (made of local reused ceramic tiles or corrugated metal sheets), the plumbing stacks, bathroom and kitchen fixtures, and services such as plumbing and cabling. The amphibious foundation (which provides buoyancy for flood adaptation) is composed of reused water bottles, fostering the collection and reuse of waste in the region and reducing pollution. The residents should not change the support elements over time since they are fixed and permanent building elements. On the other hand, the residents can change the infill building elements if needed or according to their desires and/or budget over the years. The infill elements comprise non-load-bearing brick masonry walls, as locally available materials, reused windows and doors, and handrails.

Figures 3.27, 3.28, 3.29, 3.30, 3.31, 3.32, and 3.33 show some of the



egy and amphibiation to achieve adaptation in various levels. *Source: Image by author.*

possible expansions the single-family housing intervention can have over time, done by the residents according to their needs, desires, and budget. They entail horizontal and vertical expansions, including the transformation from single-family to a multi-family building if needed over the years (figure 3.28). For future vertical expansions, it is important that the structural frame is oversized to support the expansion loads. The embryo unit has 65 square meters and is suitable for up to three persons. According to the household's stage of life, the expansions can occur in several variations and might include adding a rental unit or a workspace or retail to increase the residents' income in time. Due to its flexible design strategies, from the starter unit until the final expansion, the house can double its space to accommodate several uses in different stages. The use of large and generic rooms allows the accommodation of various functions to adapt to the users' needs, and the concentration of fixed elements such as wet areas and staircases in one compact area in the center of the plan help to better distribute the remaining space for unprogrammed or not specific uses.

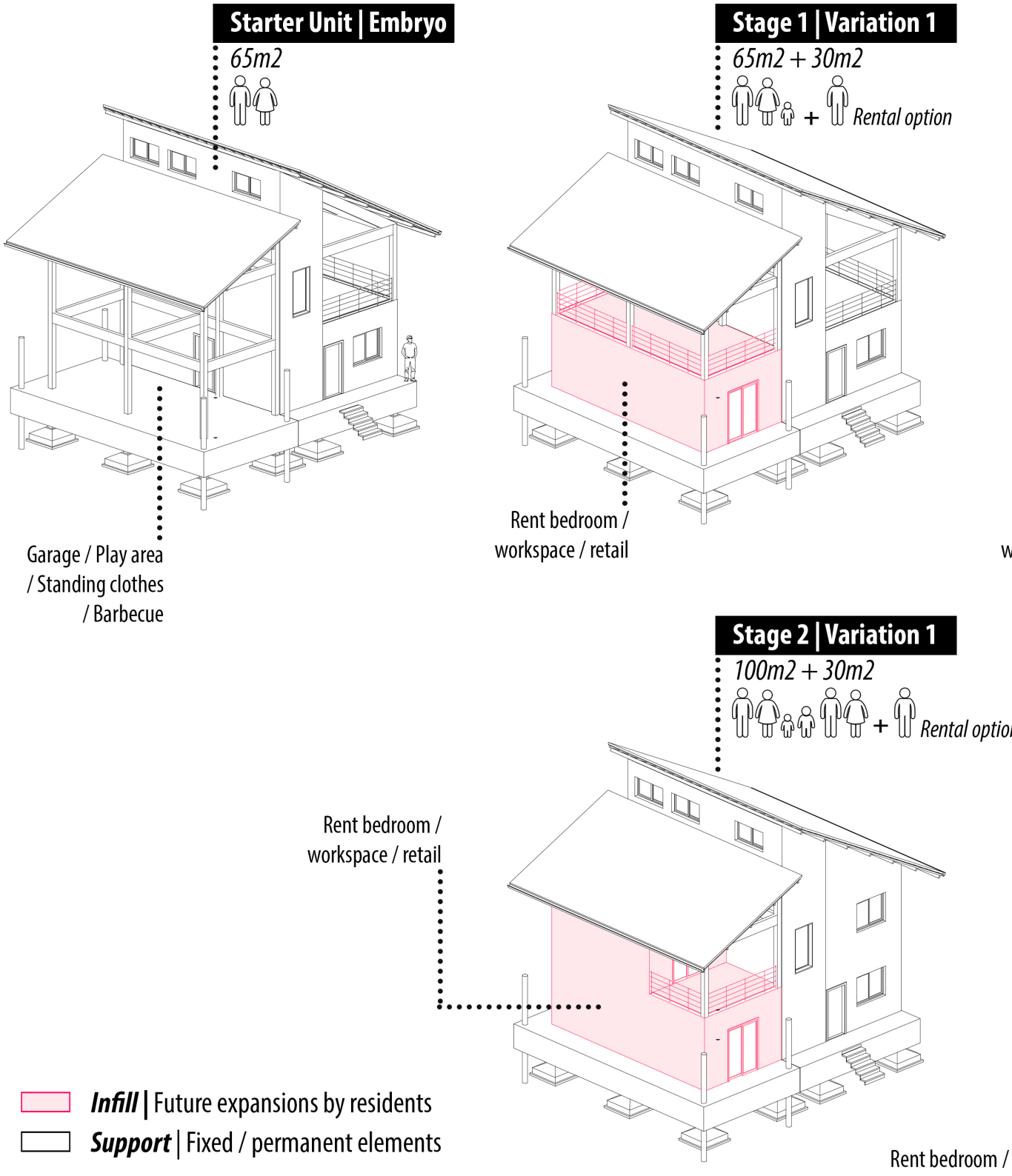
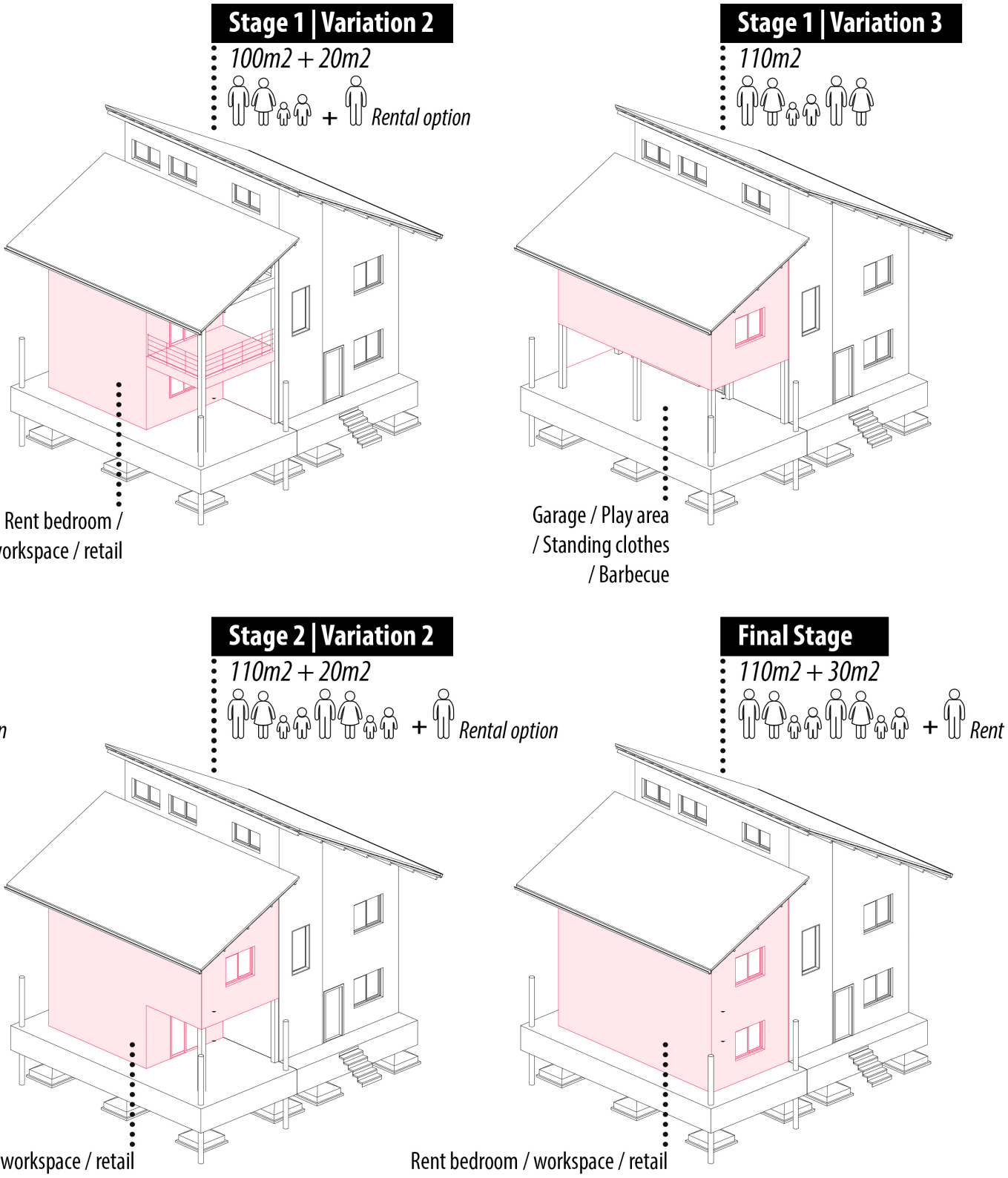


Figure 3.27. Single-family housing proposition on Site 0



1: possible expansions over time. *Source: Image by author.*

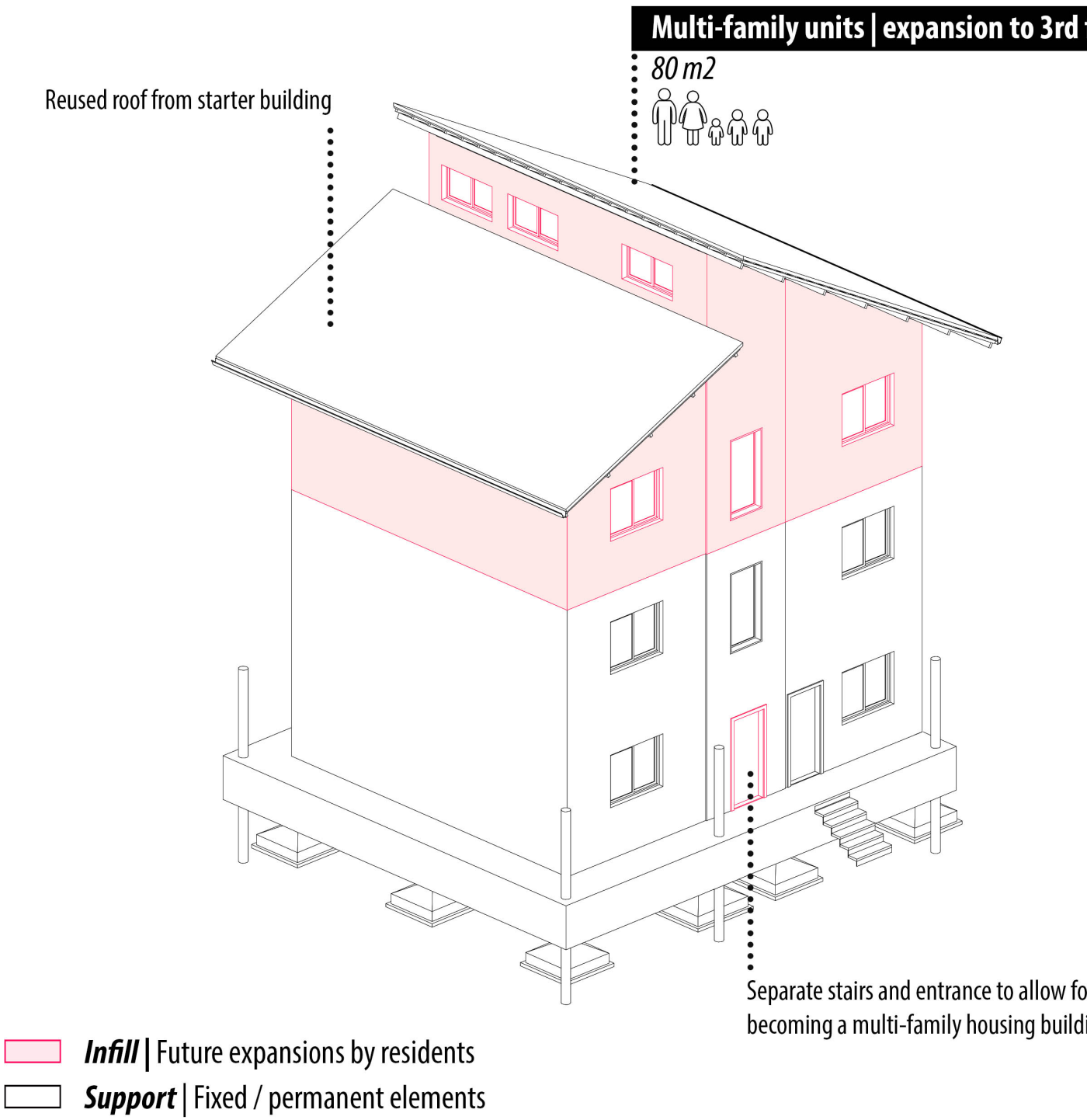
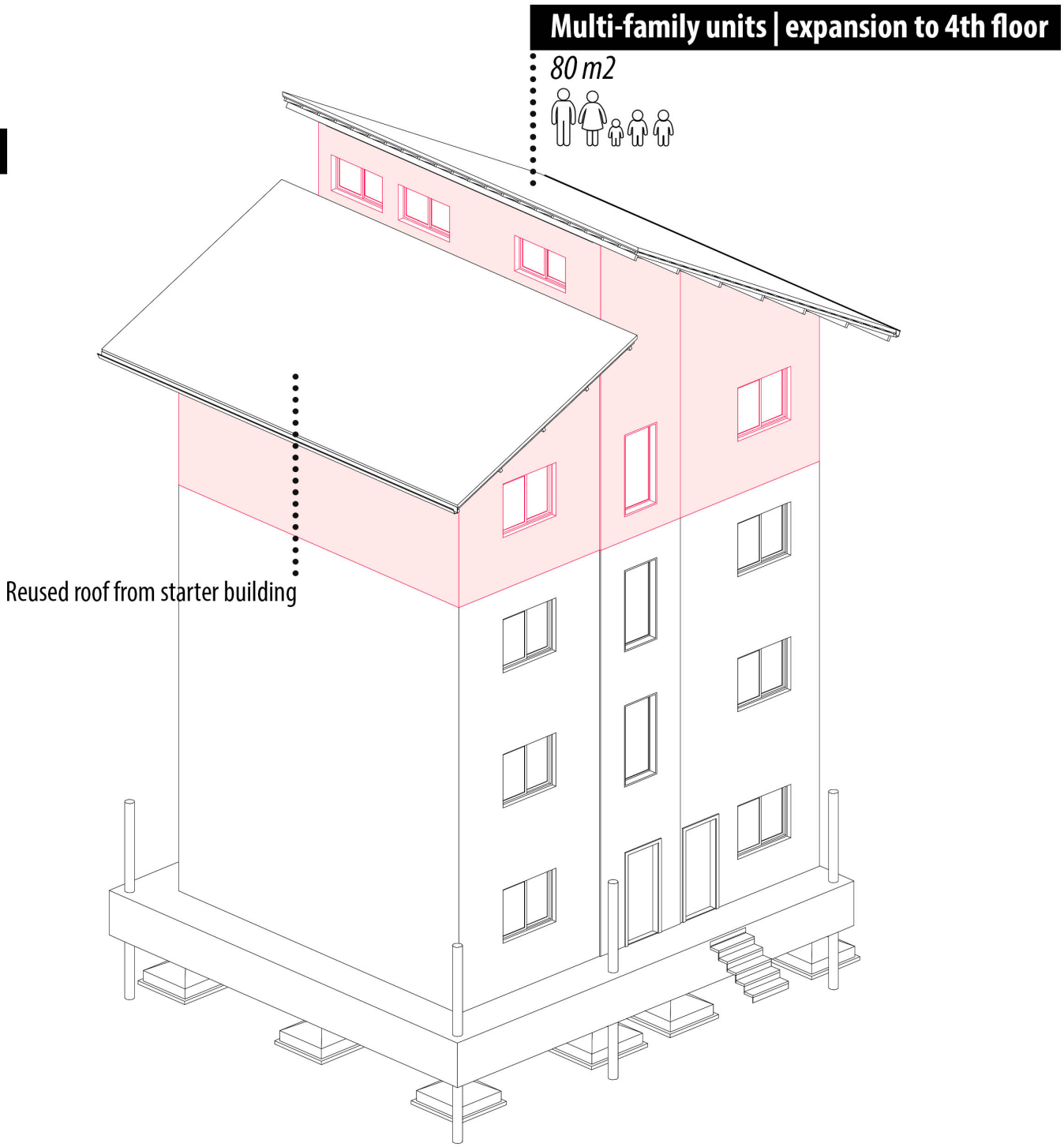


Figure 3.28. Housing proposition on Site 01: possible vertical expansion ov



er time, from single-family to multi-family building. *Source: Image by author.*

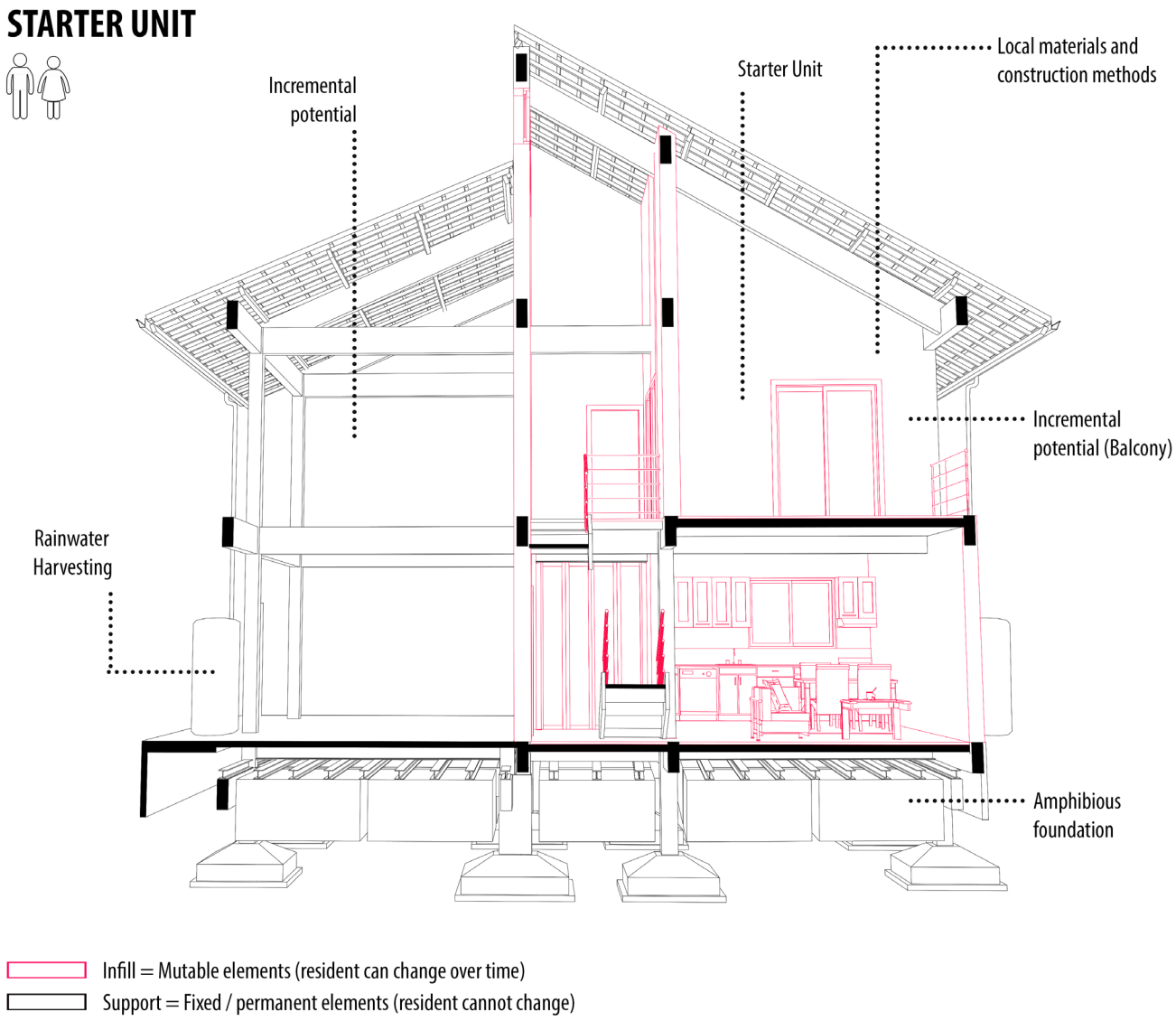


Figure 3.29. Single-family housing proposition: infill and support elements in the starter unit. *Source: Image by author.*

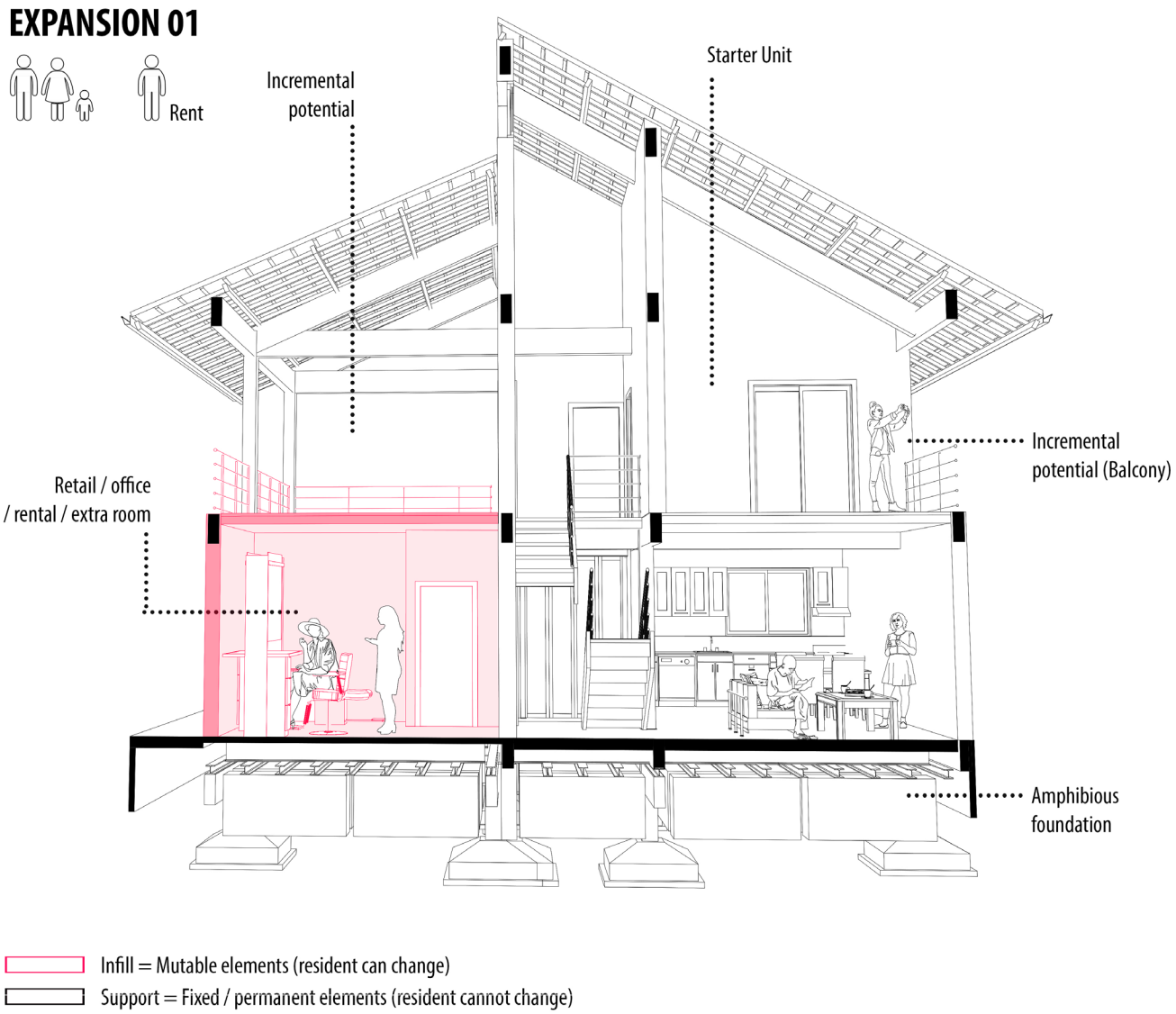


Figure 3.30. Single-family housing proposition: infill and support elements in Expansion 01. *Source: Image by author.*

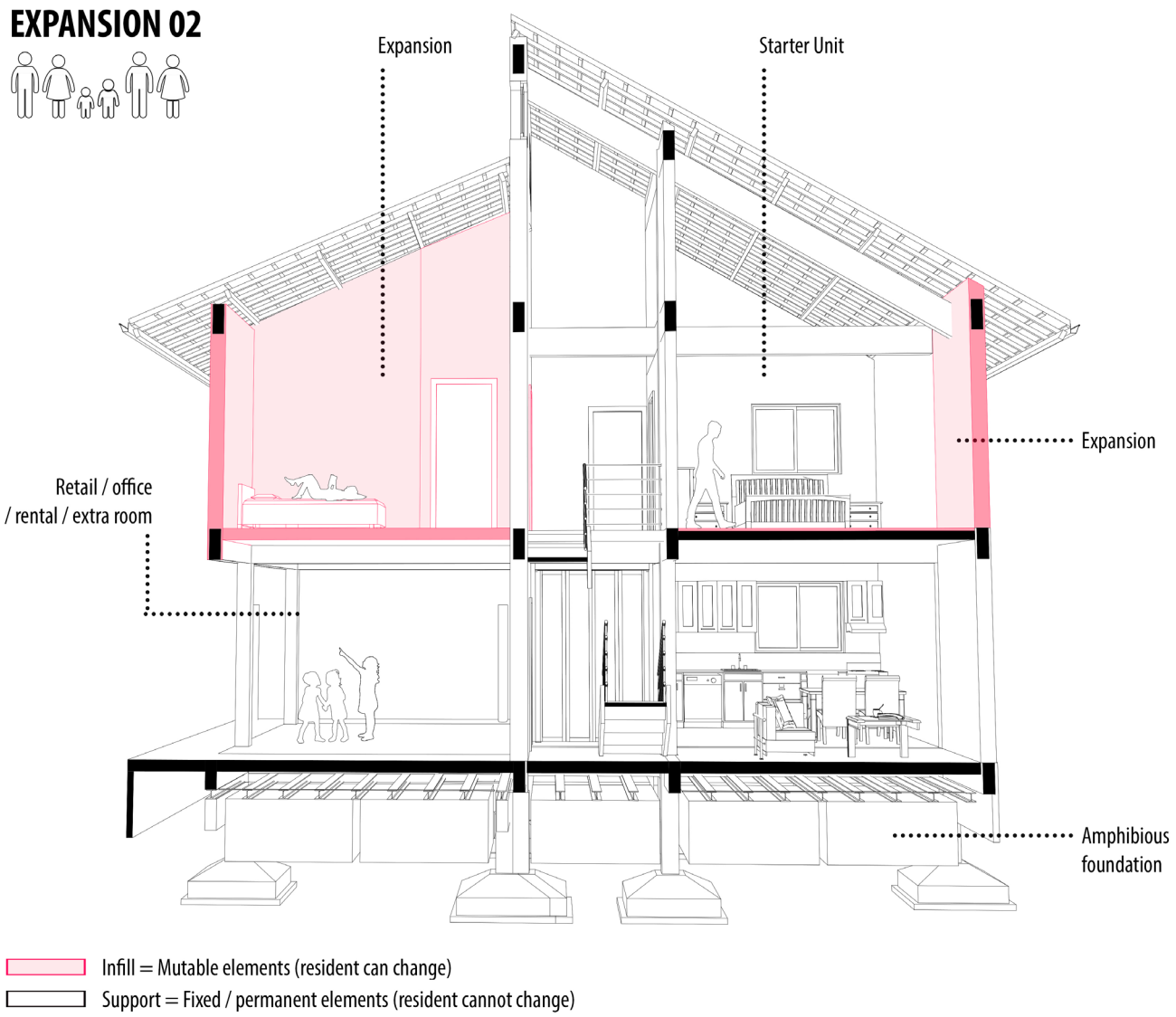


Figure 3.31. Single-family housing proposition: infill and support elements in Expansion 02. *Source: Image by author.*

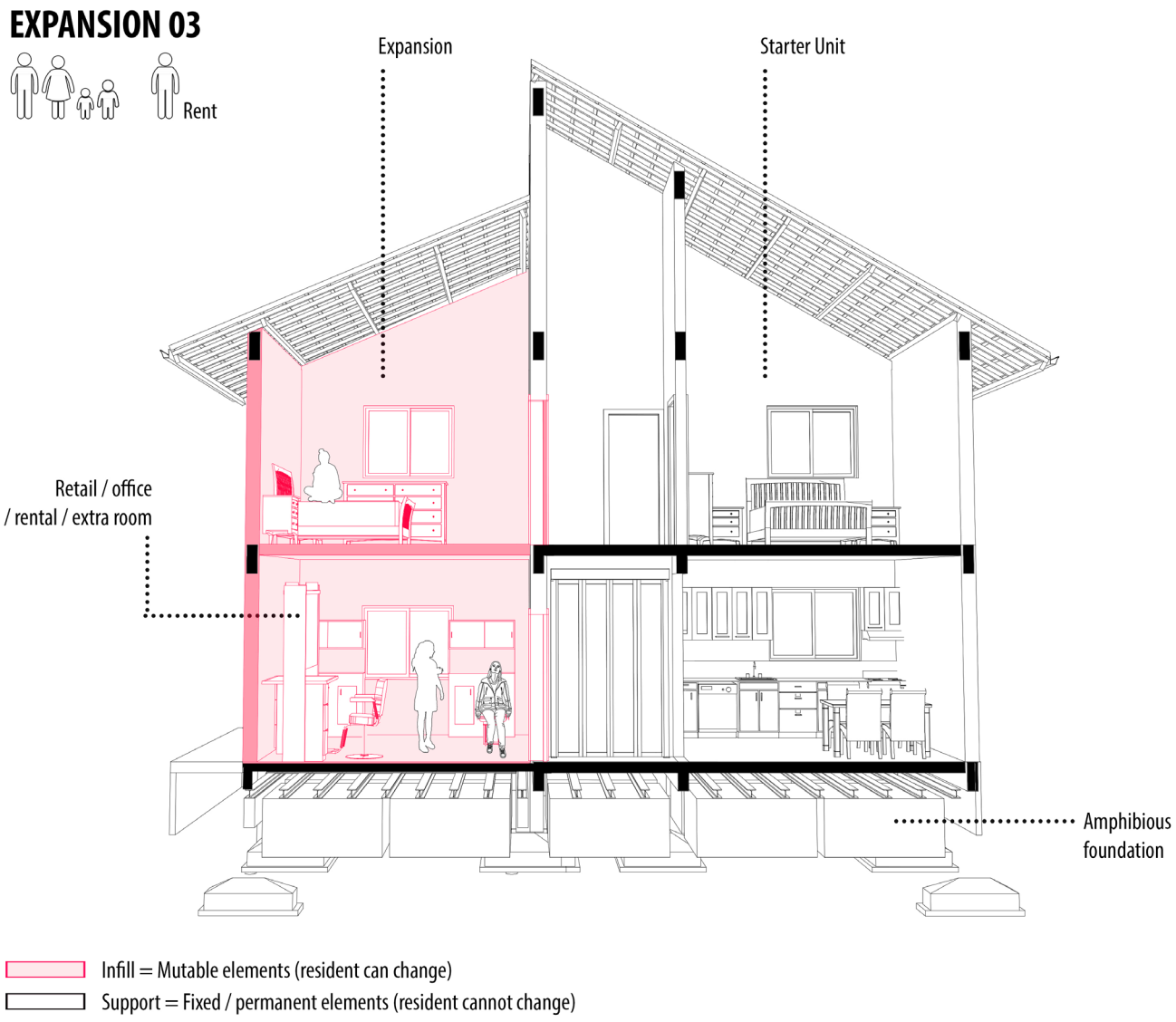


Figure 3.32. Single-family housing proposition: infill and support elements in Expansion 03. *Source: Image by author.*

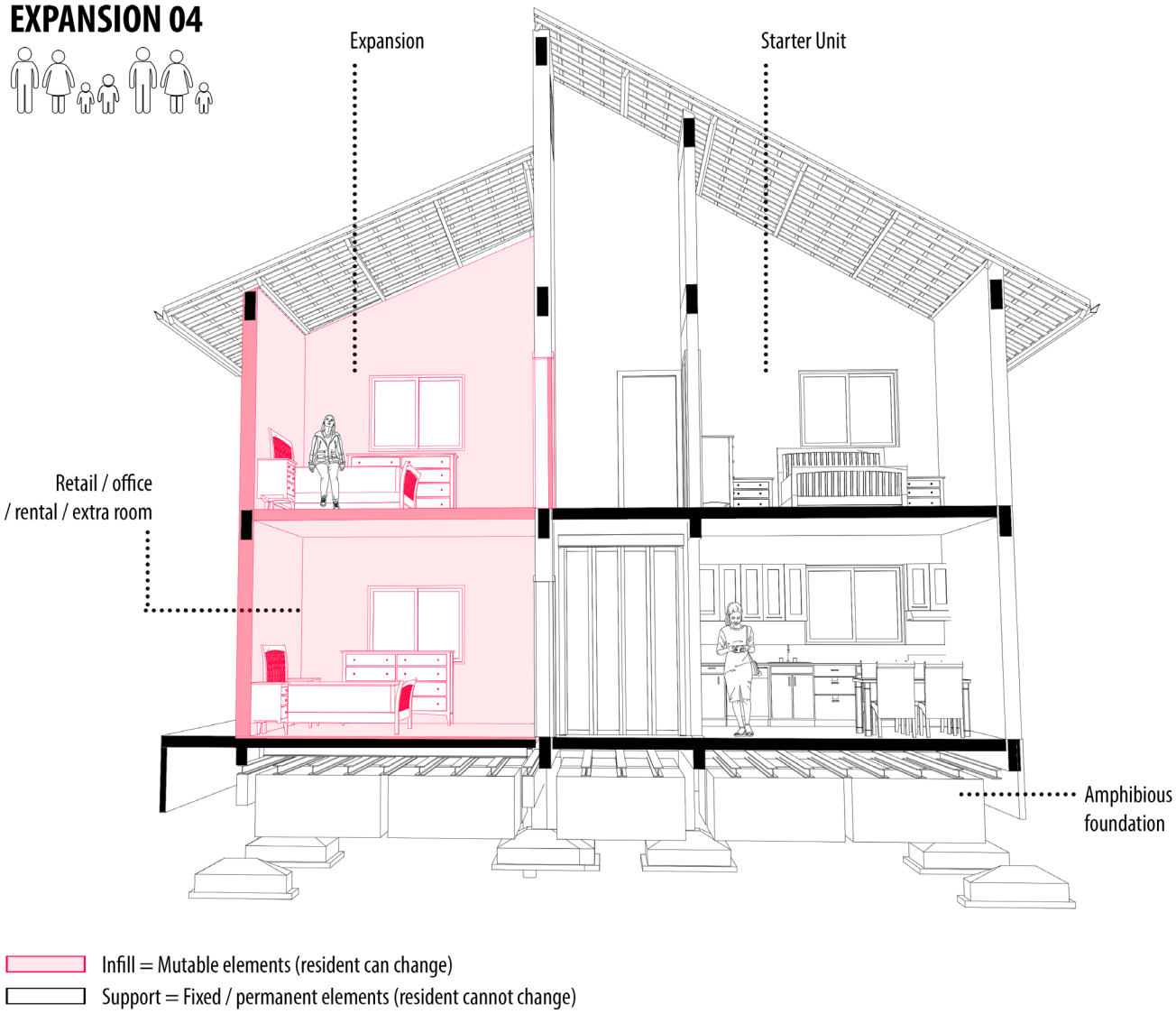


Figure 3.33. Single-family housing proposition: infill and support elements in Expansion 04. *Source: Image by author.*

On Site 02, there is more opportunity to experiment using the "block" as the design unit (under a more collective approach) instead of the "lot" (more individualized) as happens in the first site. In the case of planning the block to be unified and multifunctional, it could make the built areas more concentrated to free up space at the center of the block to be more permeable, green, productive, and of collective use (Lotufo, 2020). This way, there would be a transitional space between the housing and the riverside park. The courtyard connects to the green streets, therefore, interconnecting with the park system and making the green areas more fluid within the built environment (see figure 3.34).

The multi-family housing type intervention on Site 02, as a low-rise development composed of 3 buildings, also combines the strategies from the Open Building theory with the amphibious foundation to allow adaptation to floods and provide agency to the residents to expand and improve their houses over time. The starter stage on the ground floor plan is displayed in figure 3.35, and its expansion in figure 3.36. The second floor plan in its starter stage is indicated in figure 3.37 and its expansion scenario in figure 3.38. This proposal on Site 02 also gives homeowners the opportunity to generate extra income by allowing part of their units to be used for renting, workspace, or retail, making them improve their local economies and fight gentrification. Building 1 presents more compact apartment units compared to Buildings 2 and 3.

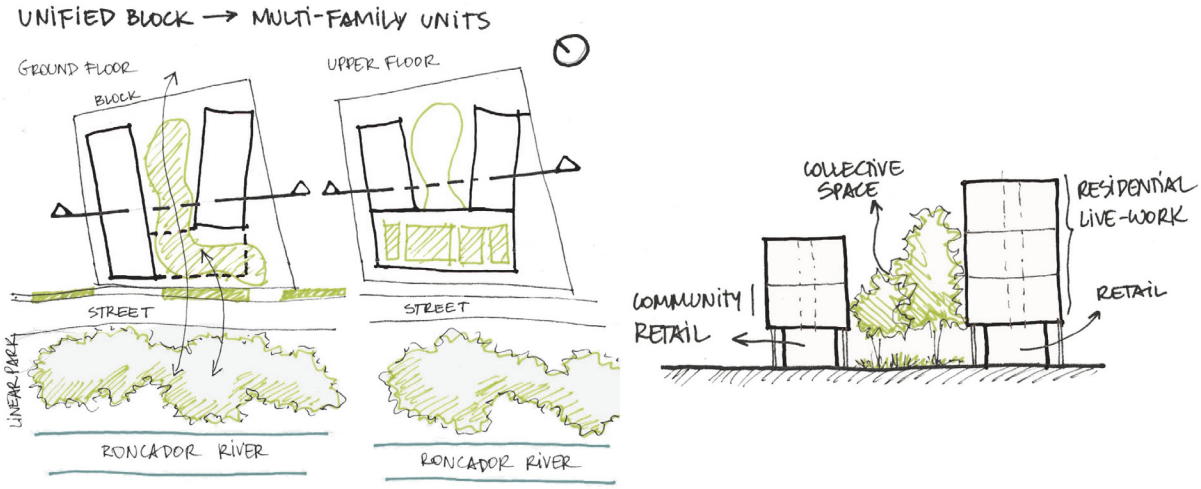


Figure 3.34. Parti of Multi-family housing proposition in a unified block with collective and green spaces in the center.
Source: Image by author.

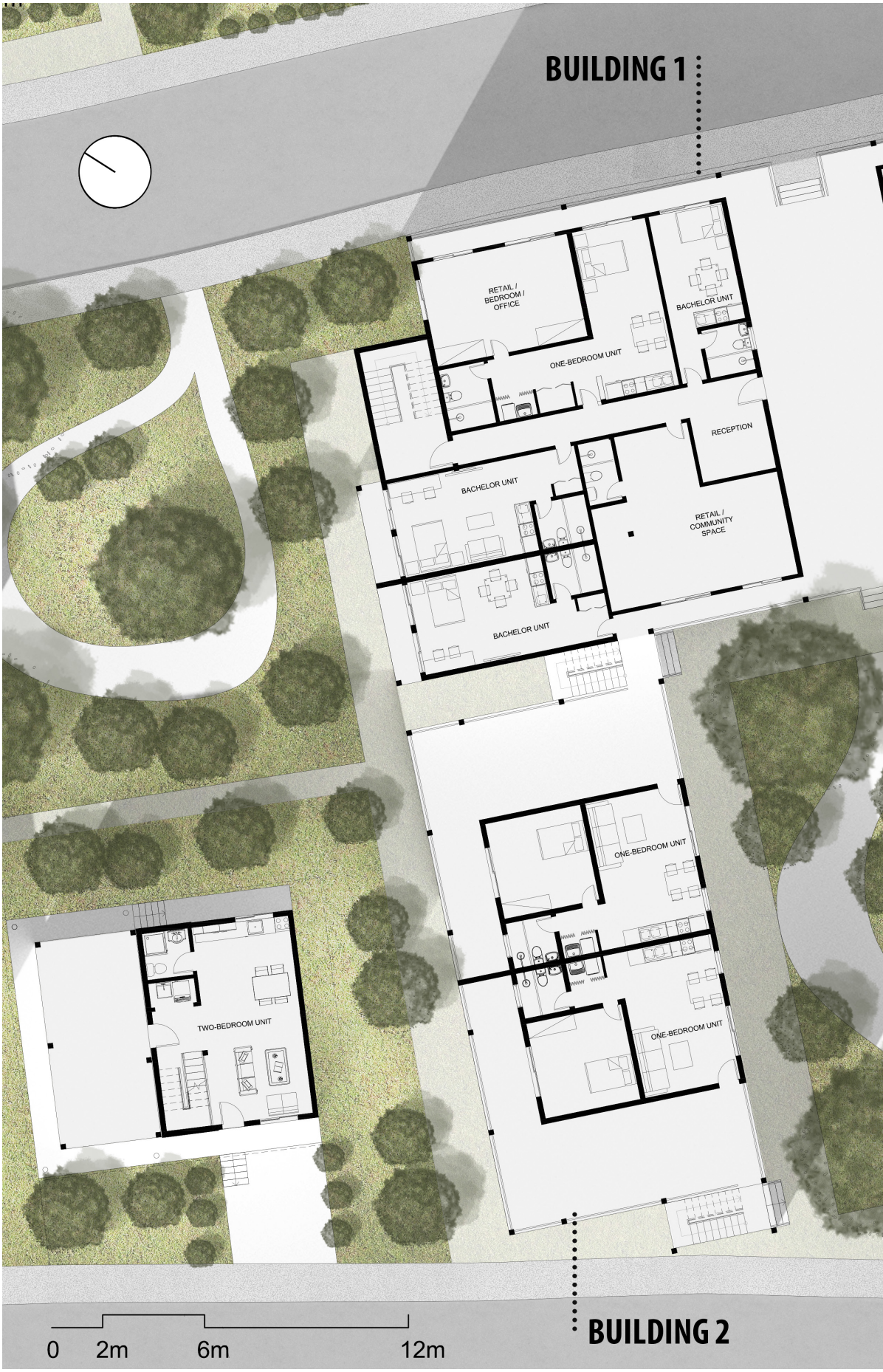


Figure 3.35. Multi-family housing proposition

on Site 02: starter units. *Source: Image by author.*

Figure 3.36. Multi-family housing proposition on S

Site 02: Expansion scenario. *Source: Image by author.*

Figure 3.37. Multi-family housing proposition

on Site 02: starter units. *Source: Image by author.*

Figure 3.38. Multi-family housing proposition on S

Site 02: expansion scenarios. *Source: Image by author.*

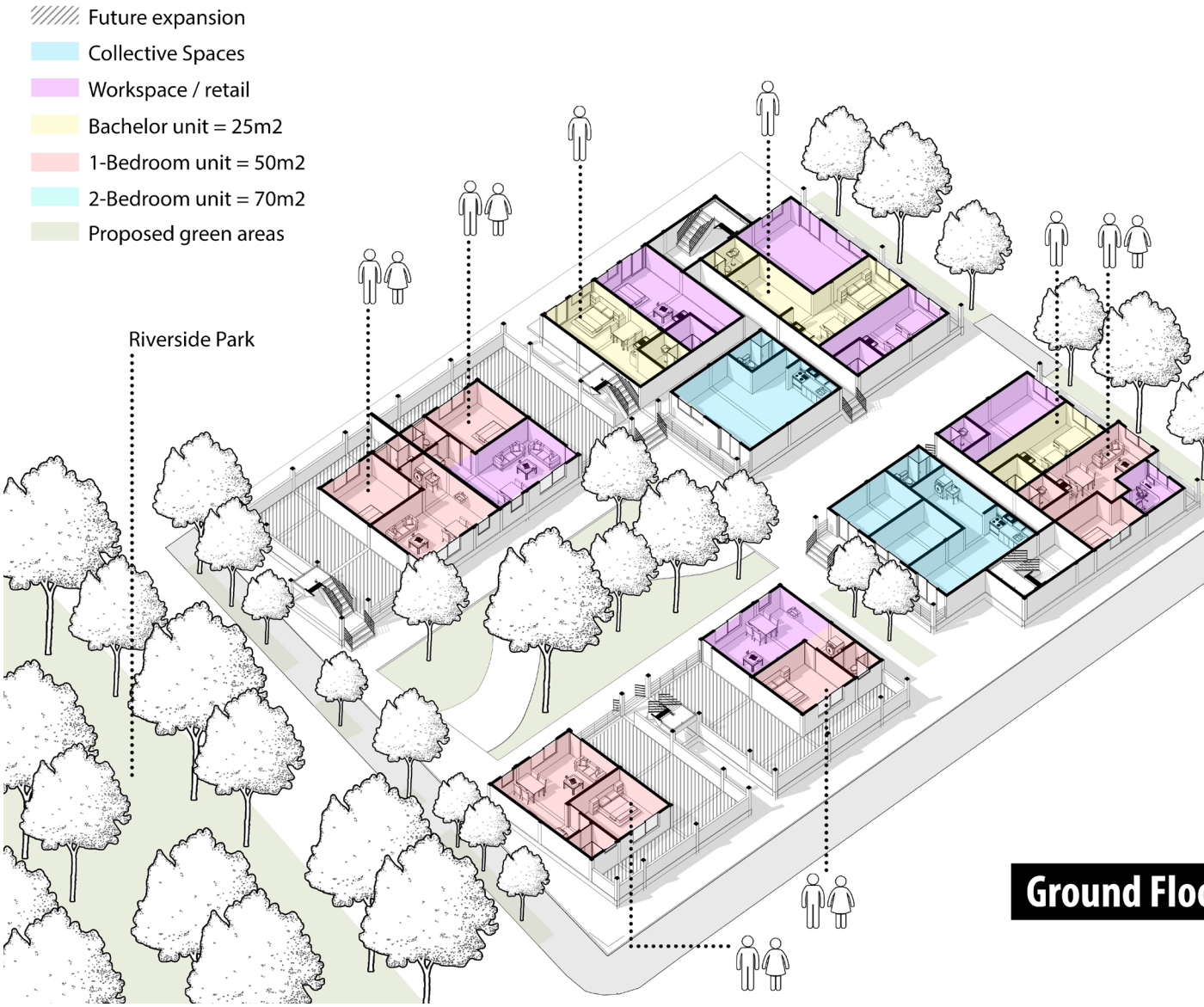
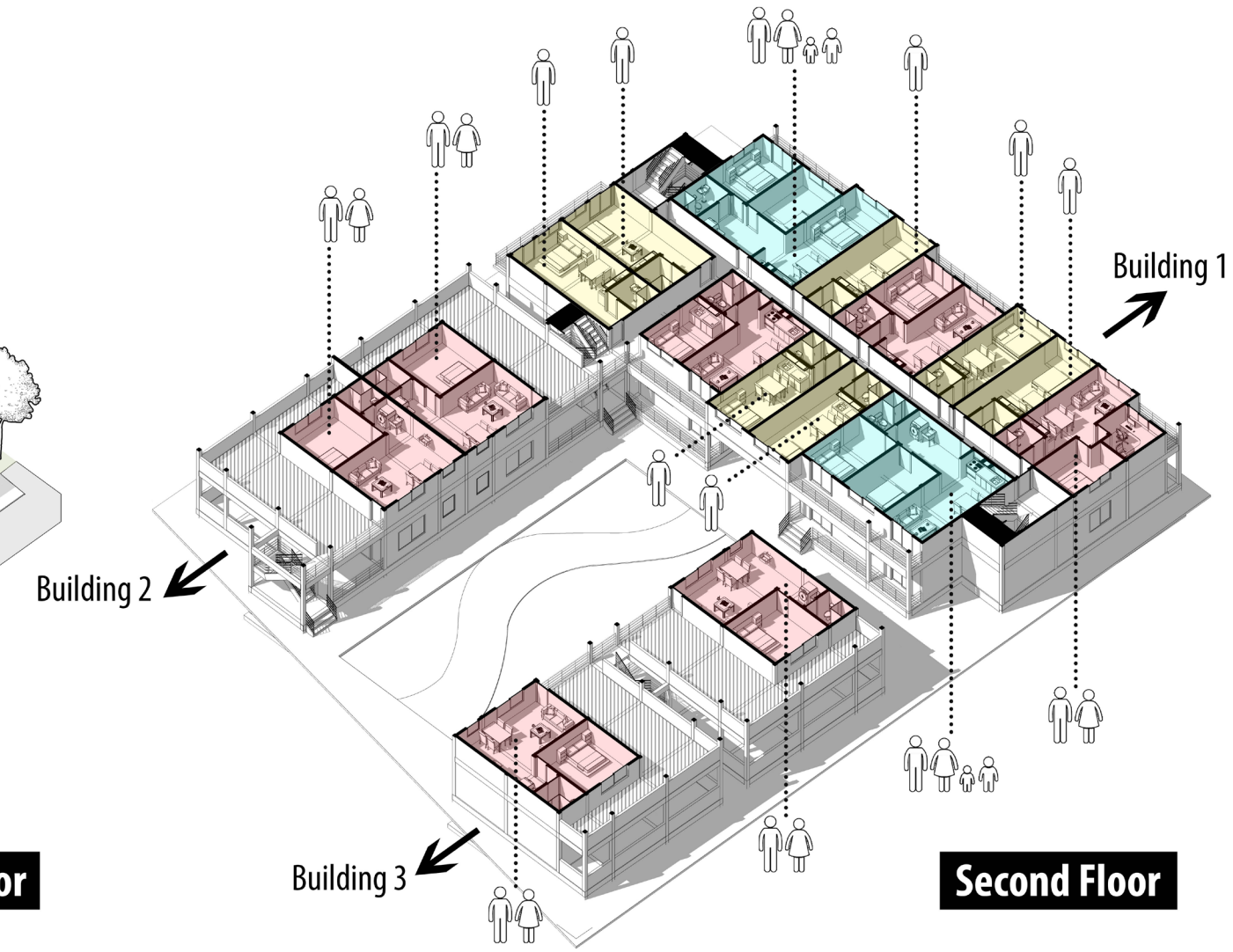


Figure 3.39. Multi-family housing proposition on Site 02: programme on th
Source: Imag

Figure 3.39 shows the programme in the multi-family low-rise buildings, comprised of residential, collective, work and retail areas within the ground, second, and third floors. Figures 3.40, 3.41, and 3.42 illustrate the strategies for evolution in each unit, allowing different levels of income and family stages and sizes. By working with a modular approach, Building 1 (See figure 3.40) is strategically designed to present the possibility of expanding one's unit by buying and incorporating an adjacent unit, thus doubling the original unit area, as happens in 468 James Street North development in Hamilton, ON (Canada), elaborated by JvN/d (see more detail about this case study on page 114). On the upper floors,



ne ground floor and second floor, and residential capacity in each starter unit.
ge by author.

the adaptability strategies allow for a mix of incomes and family sizes. The proposed three types for Site 02 are the following: Bachelor unit, 1-bedroom and 2-bedrooms. The bachelor units can be incorporated into the adjacent units and be converted into larger units according to the families' needs and budget. They can also generate income for the residents by renting the units or converting the spare rooms into office space or retail, enhancing the local economies (see figure 3.40).

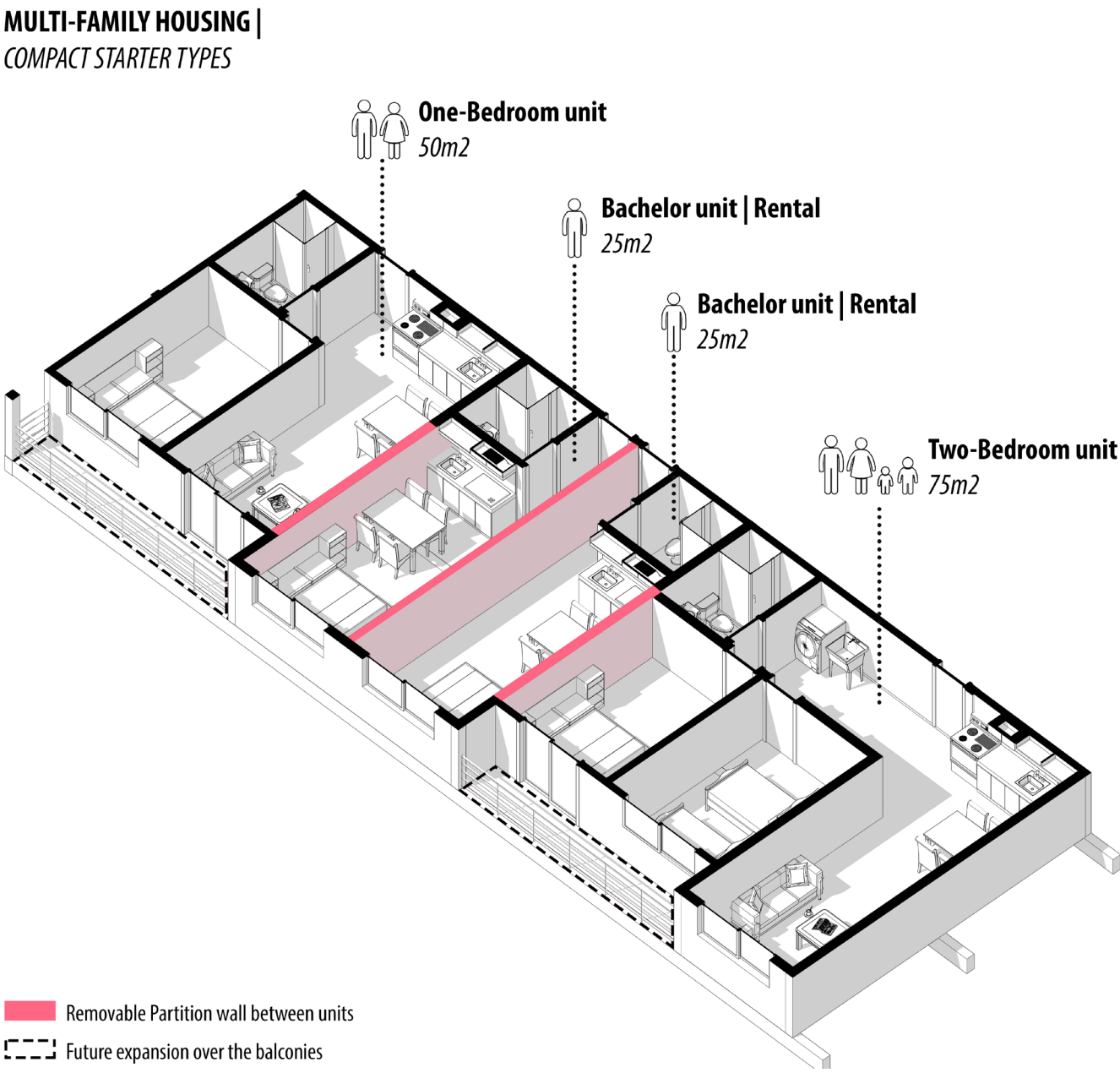
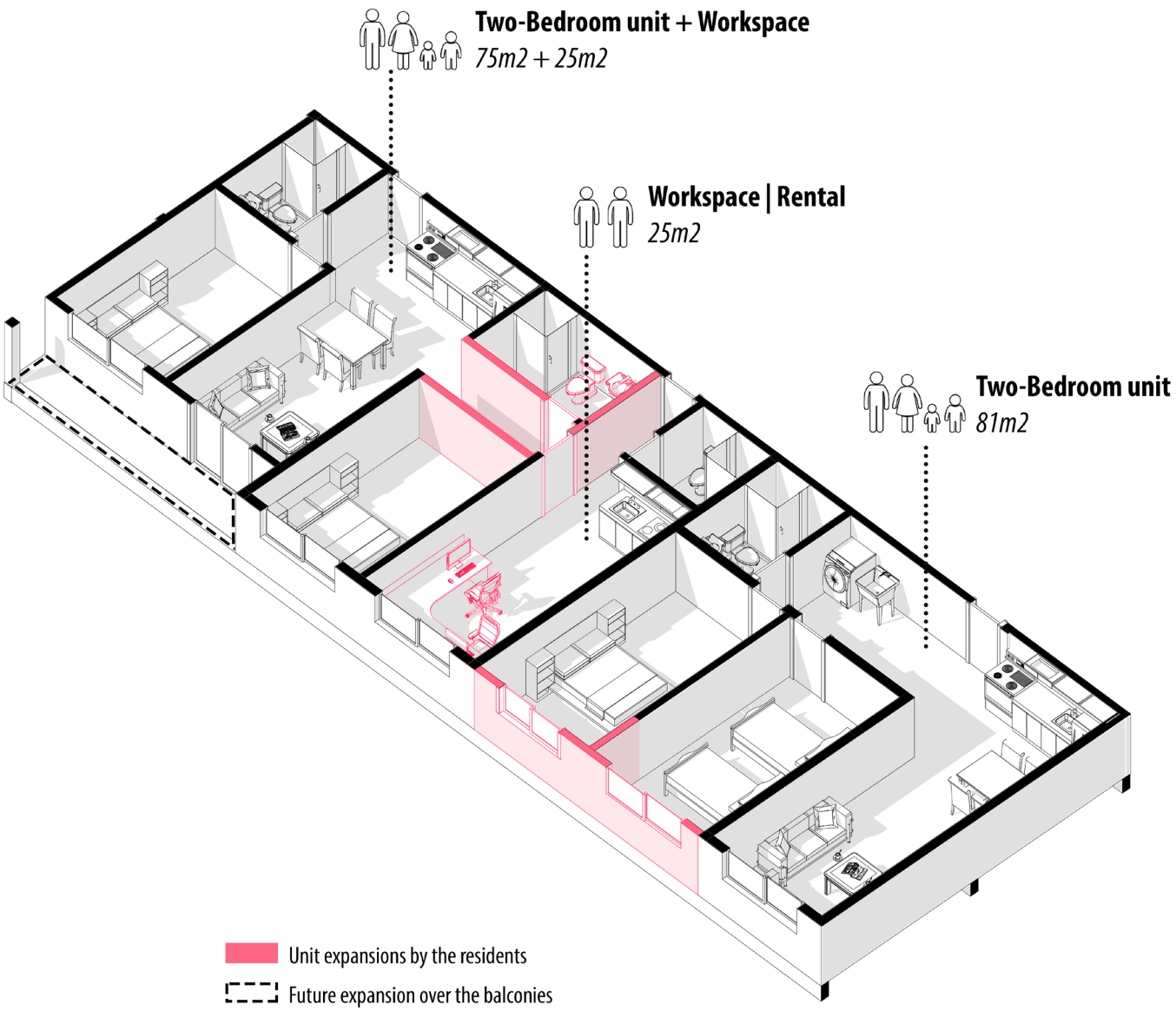


Figure 3.40. Flexible strategies for unit expansion and transformation
Source: Imag

Buildings 2 and 3 on Site 02 present the possibility of incremental expansion by providing an embryo unit with an unbuilt space in large balconies to grow horizontally, allowing the residents to double their unit area over time, as can be seen in figures 3.41 and 3.42. This is possible because the structure (made of columns, beams, and slabs) and the service core are separate from the other systems, acting as support elements, thus, leaving the remaining area free to be appropriated by the user over



over life stages in the Multi-family housing proposition on Building 1.
ge by author.

time, either by self-building or by contracting. The rooftops could also be productive by bringing community gardens or using the area to harvest rainwater and reuse it for non-potable uses, such as irrigation and toilet flushing (see figure 3.43). Figure 3.43 also illustrates that ground floor open areas can be used as collective and productive green areas, not only for alternative food production but for alternative sewage treatment on-site, becoming a multifunctional solution.

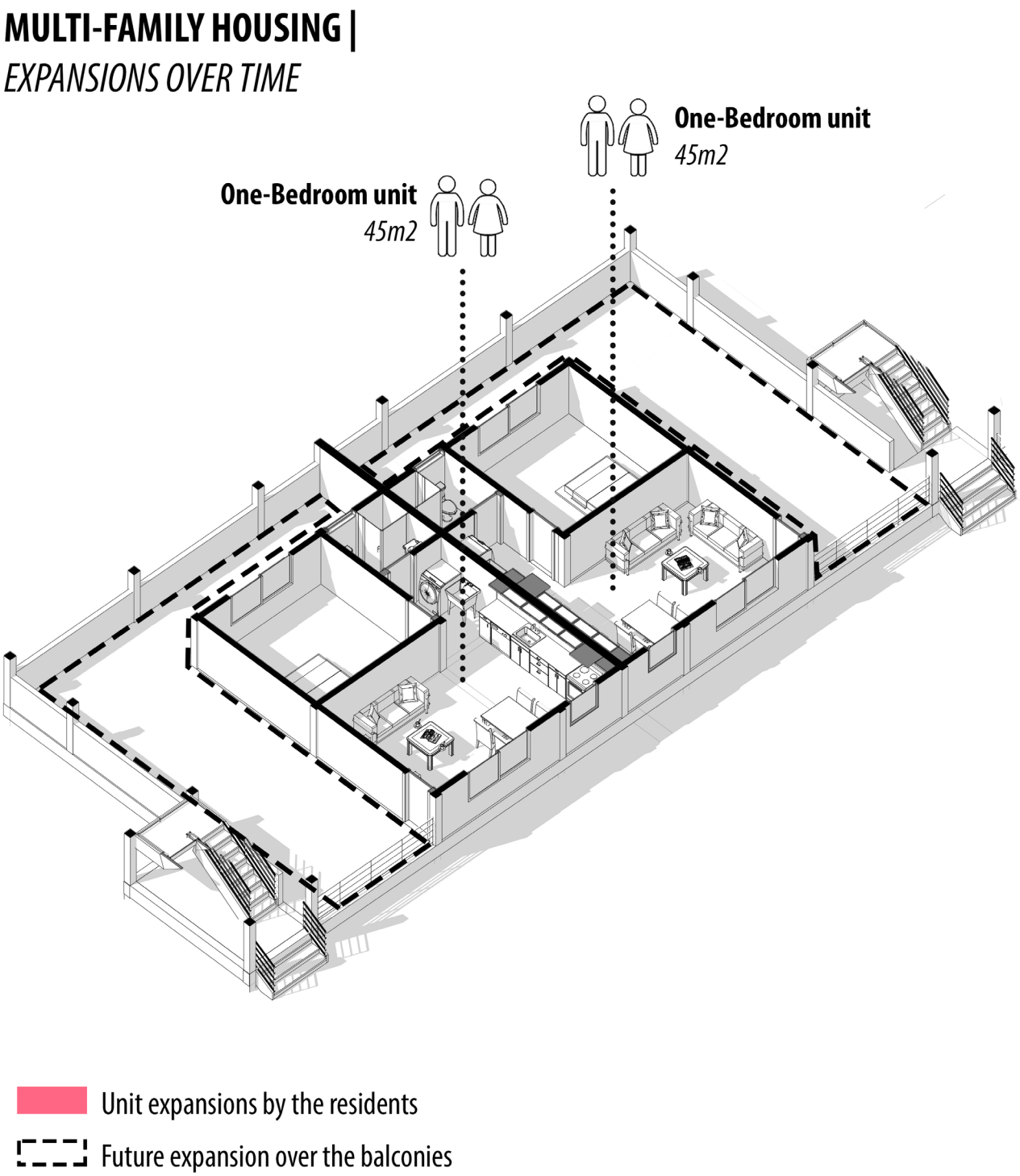
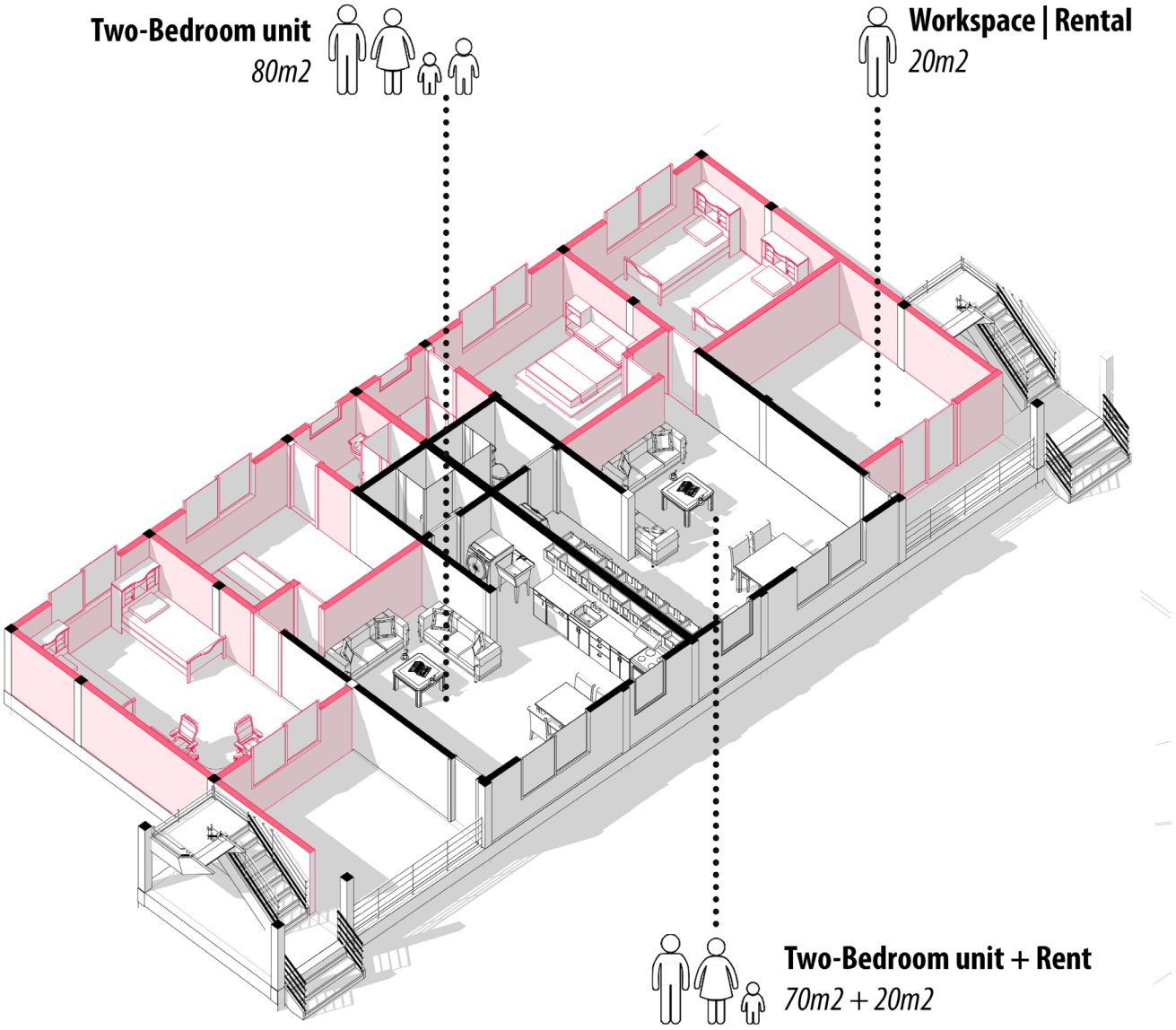


Figure 3.41. Flexible strategies for unit expansion and transformation
Source: Imag



over life stages in the Multi-family housing proposition on Building 2.
ge by author.

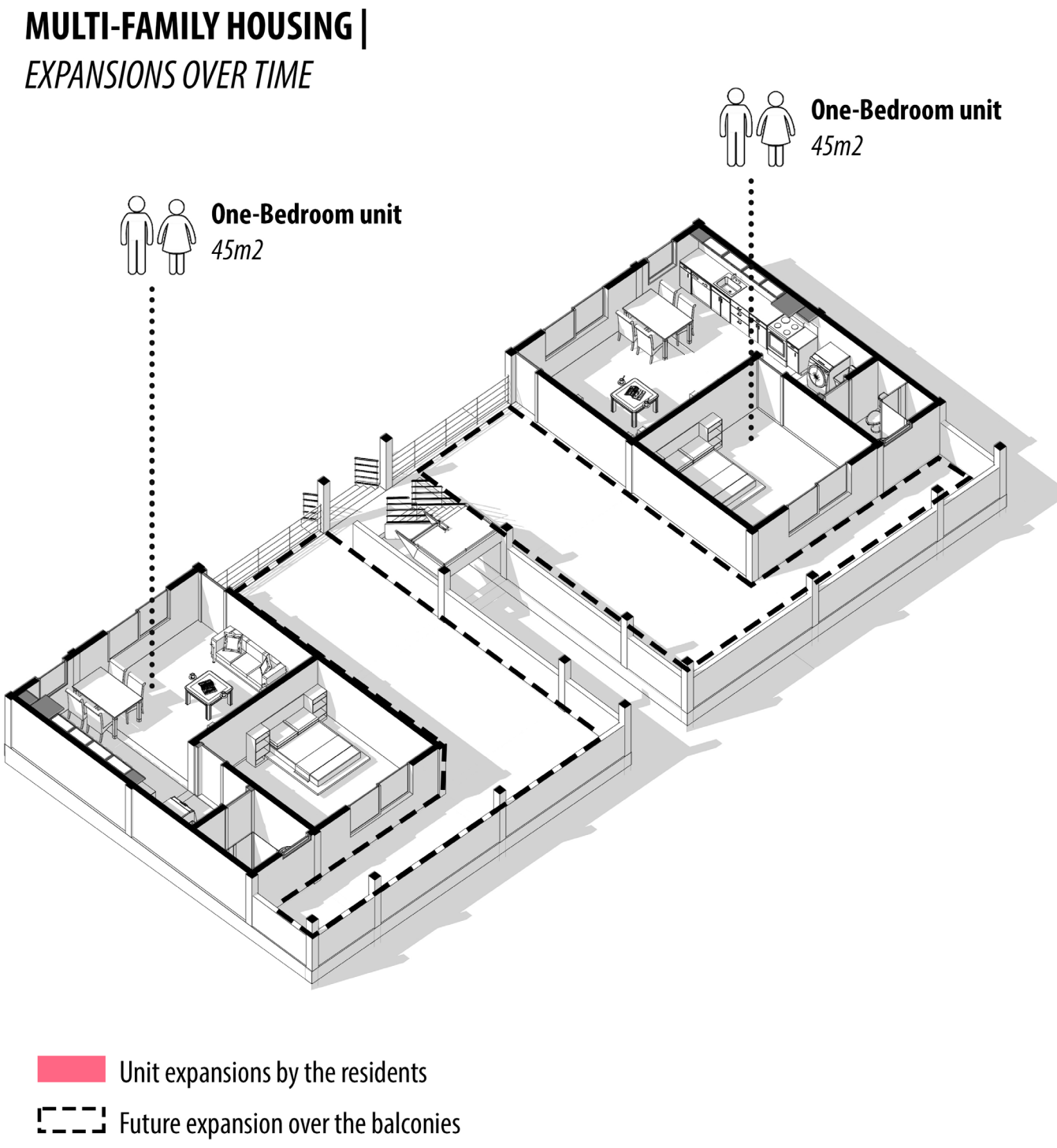
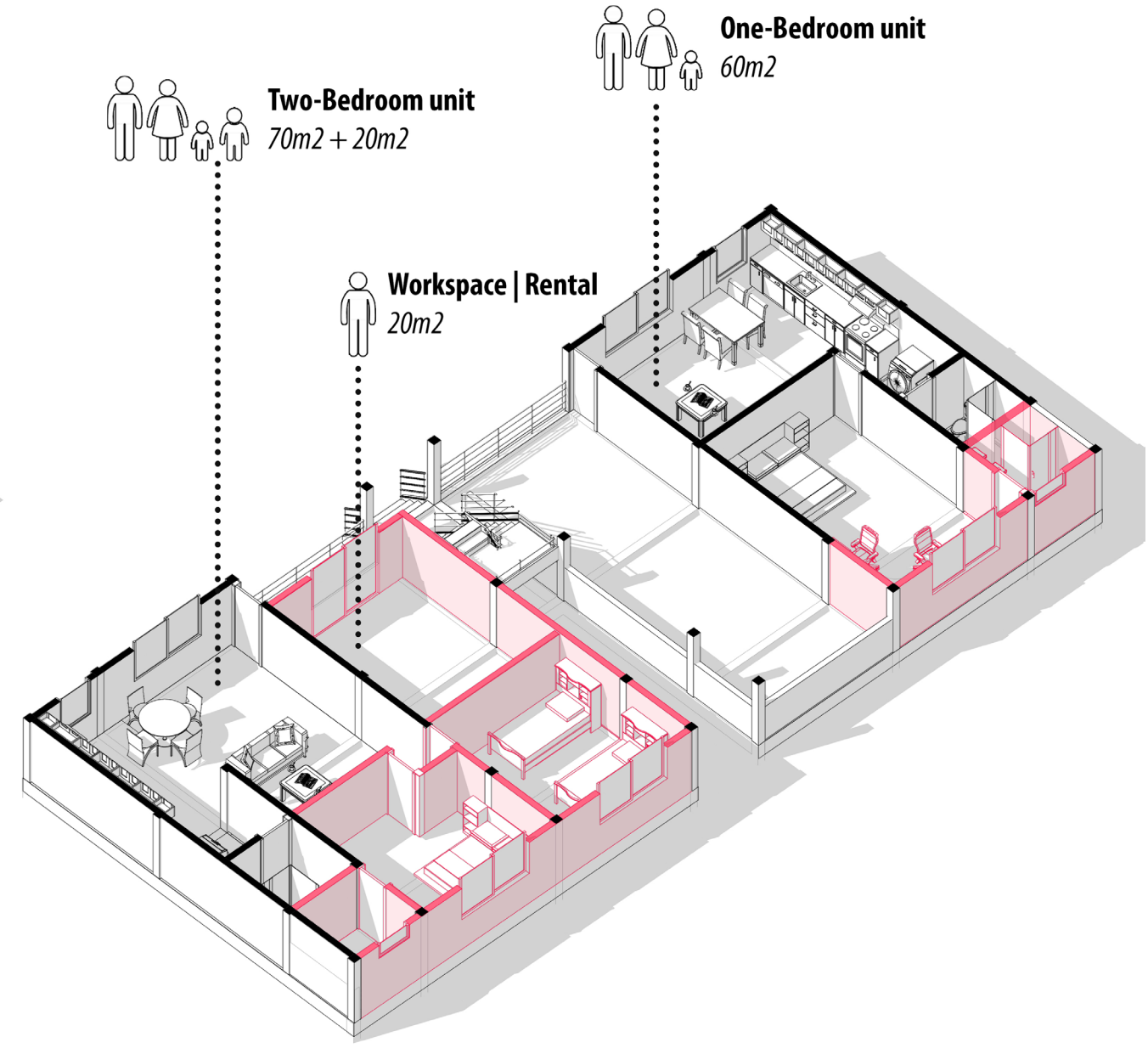


Figure 3.42. Flexible strategies for unit expansion and transformation
Source: Imag



over life stages in the Multi-family housing proposition on Building 3.
ge by author.

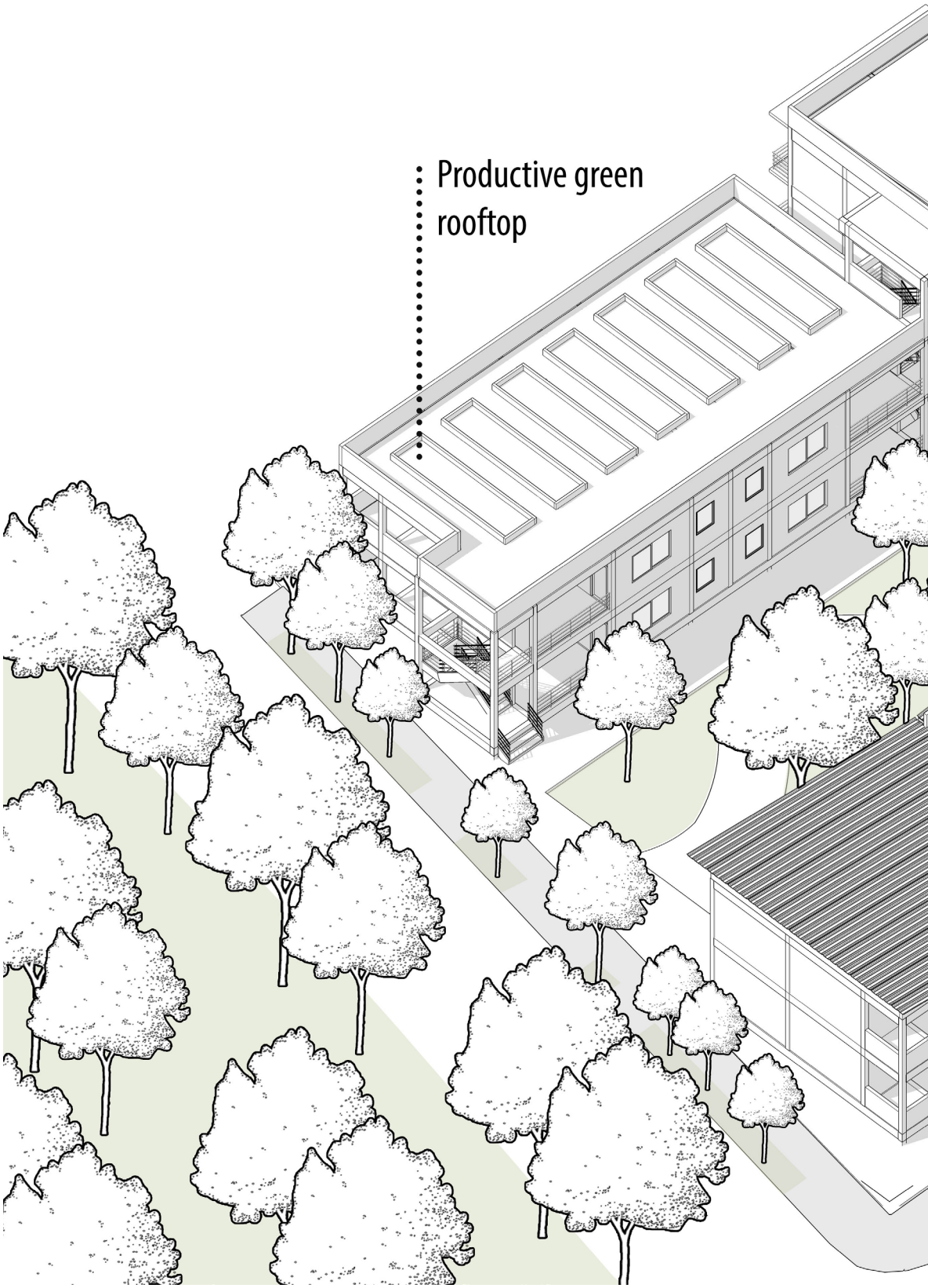
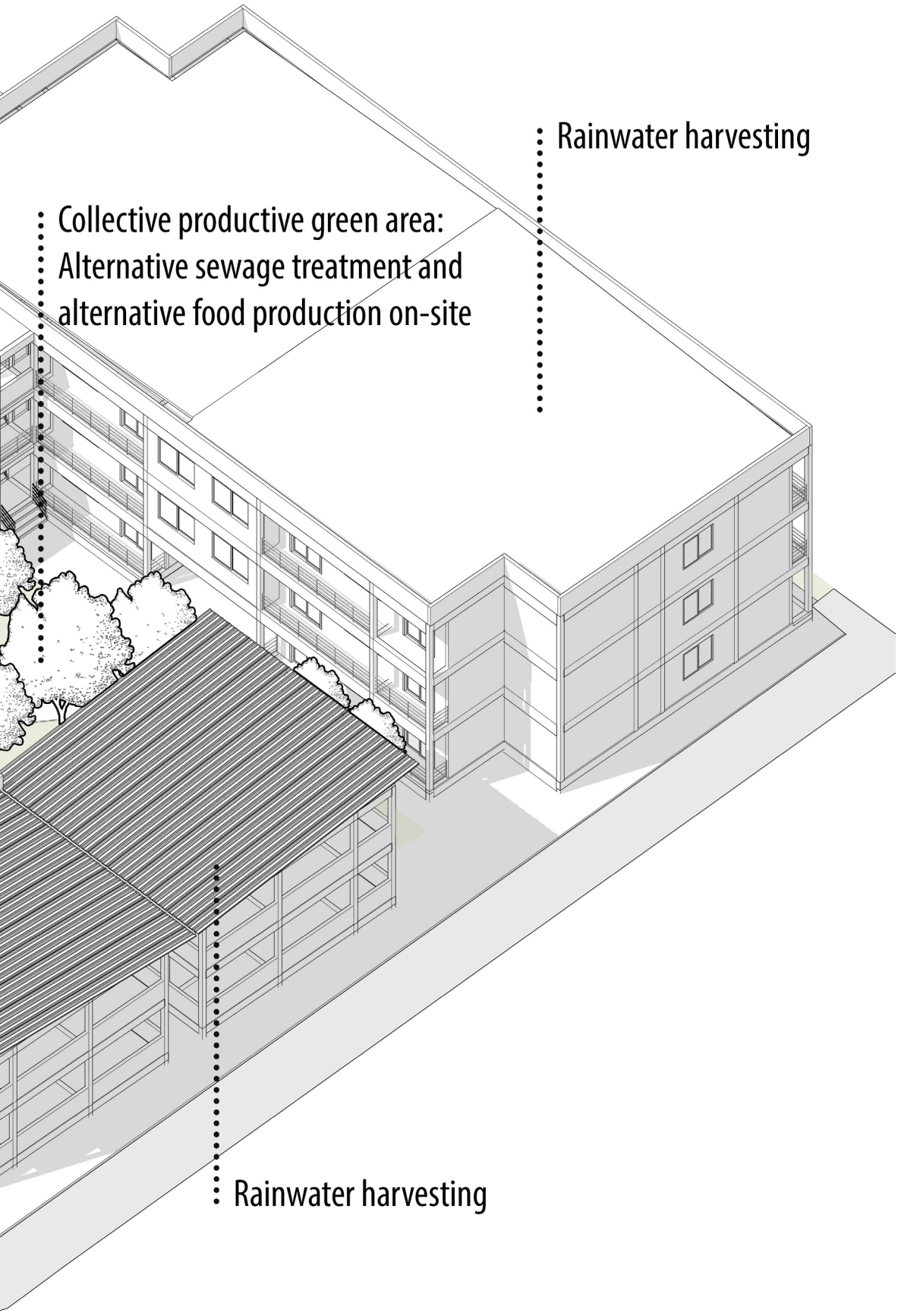


Figure 3.43. Productive rooftop and rainwater harvesting fo
Source: Ima



r non-potable uses in the multi-family housing intervention.
ge by author.

Figures 3.44 and 3.45 show the cross-section cutting both the single-family and multi-family interventions in the dry (see figure 3.44) and wet (see figure 3.45) conditions. Accordingly, when a flood occurs, the buildings float with the floodwaters. Figures 3.46 and 3.47 illustrate the longitudinal section for both proposed housing types, in a dry condition (see figure 3.46) and wet condition (see figure 3.47). Figure 3.48 illustrates the proposed scenario from a bird's eye view, with the proposed green areas on the margins of the Roncador River and within the urban fabric,

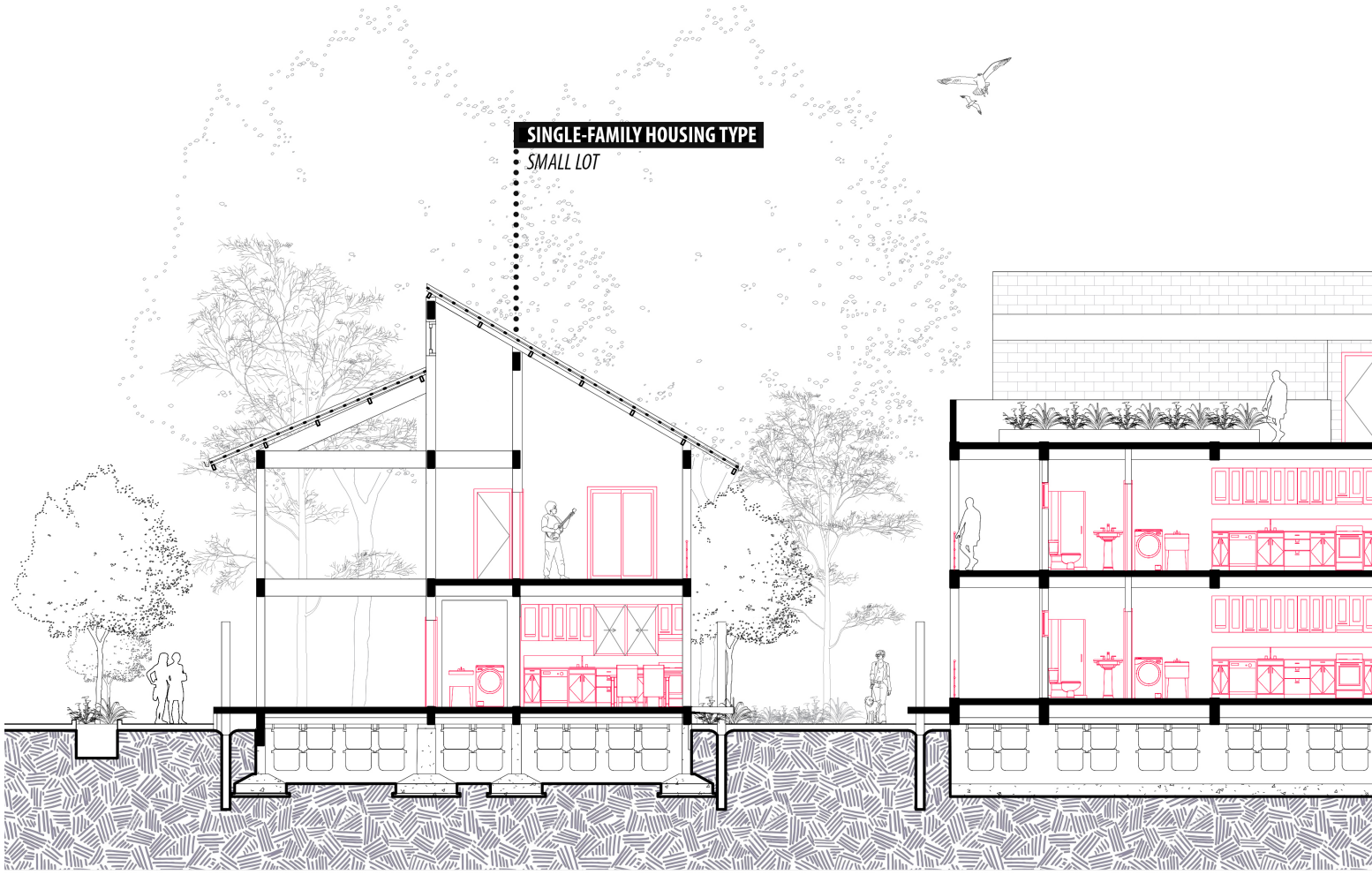
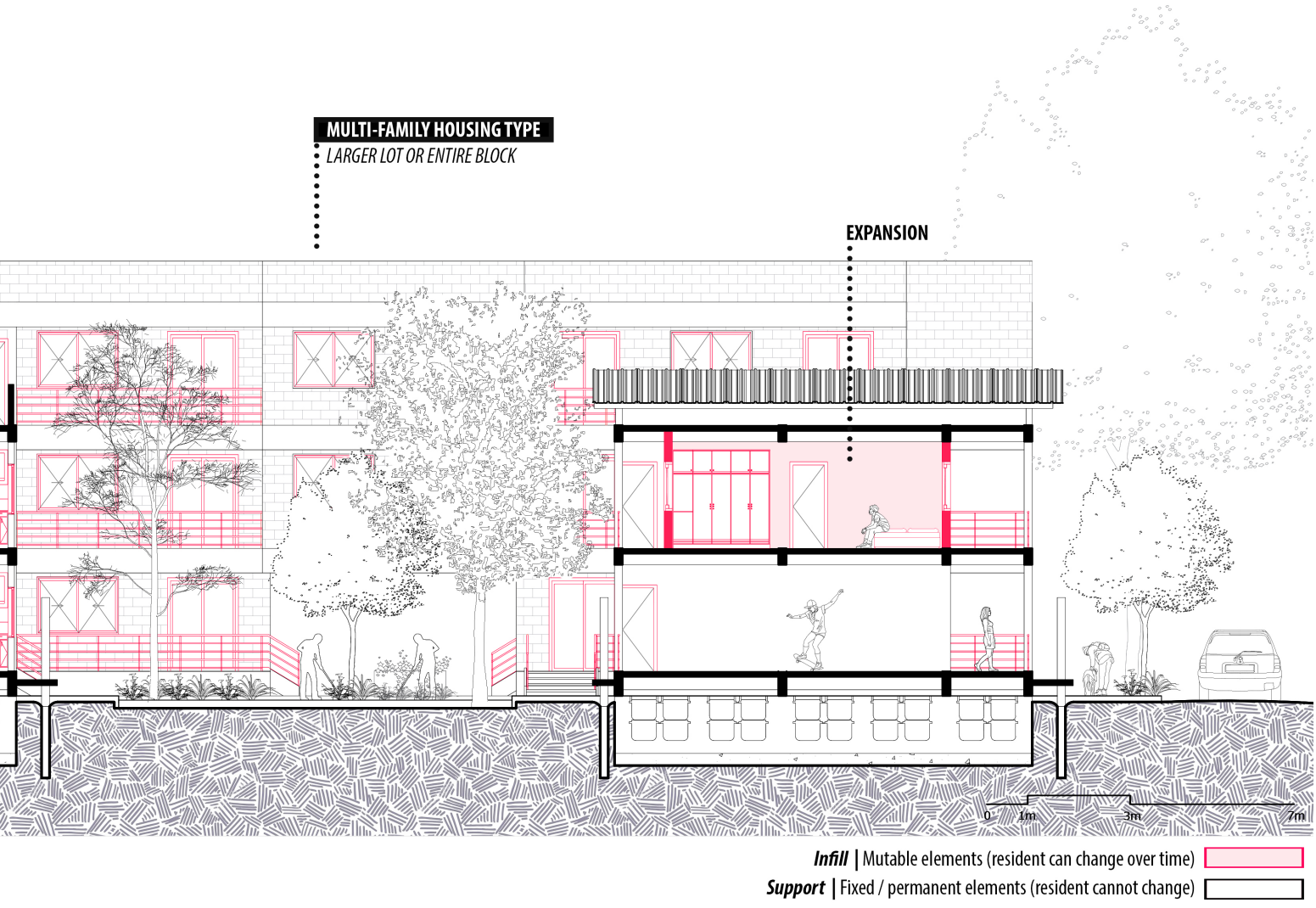


Figure 3.44. Cross section cutting the proposed single-
Source: Ima

by using the vacant spaces in the center of blocks and implementing green streets and wetlands distributed along the watershed. This figure also shows the proposed housing by appropriating the existing vacant lands in various sizes and planning an incremental evolution to allow the residents to live and grow in their neighbourhoods. Figure 3.49 displays the design proposal from the eye level's perspective, showing the proposed single-family and multi-family interventions. Figure 3.50 illustrates an eye-level perspective that highlights the relationship between the evolutionary housing interventions in Region C with the riverbanks revitalization.



family and multi-family interventions in dry condition.
ge by author.

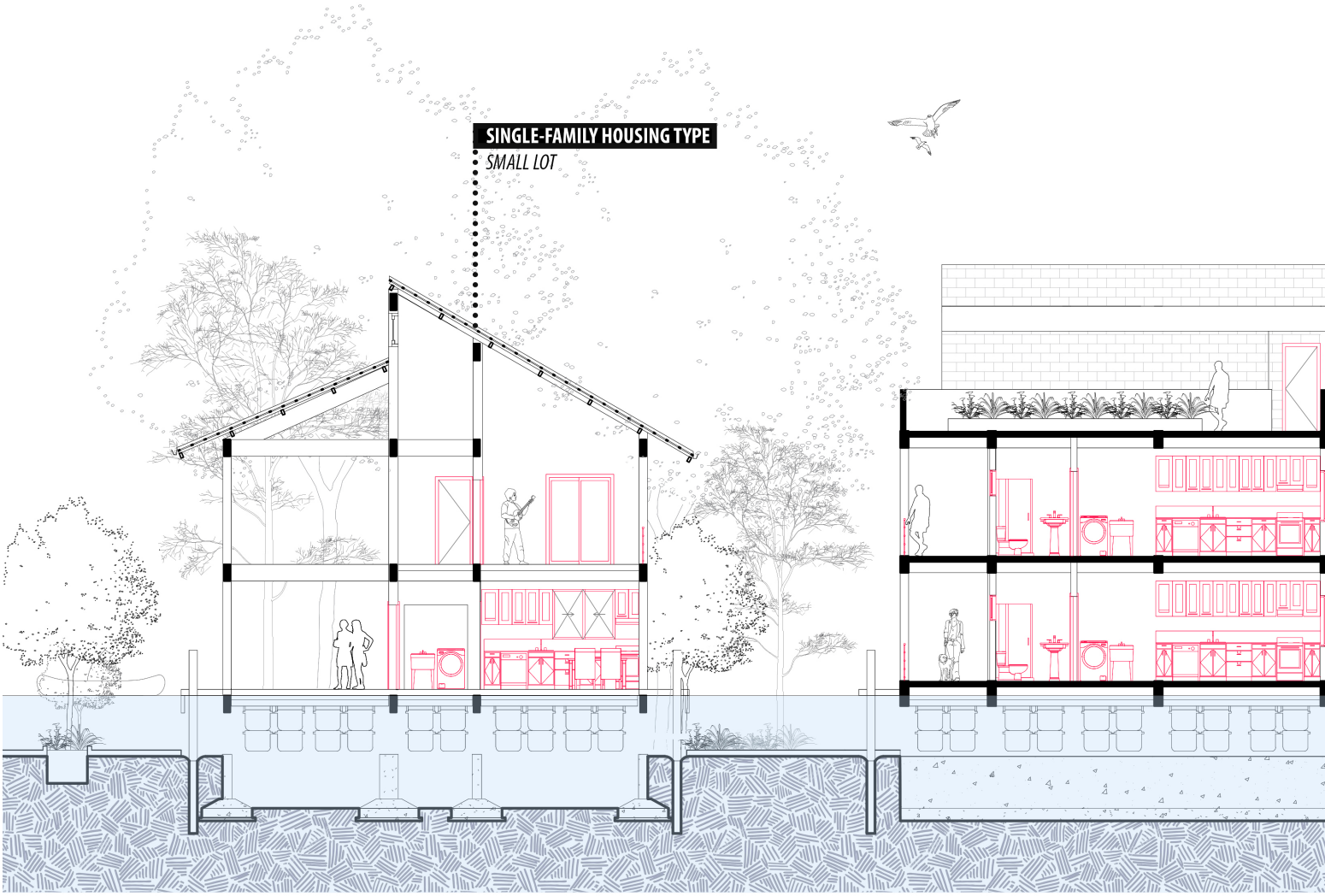
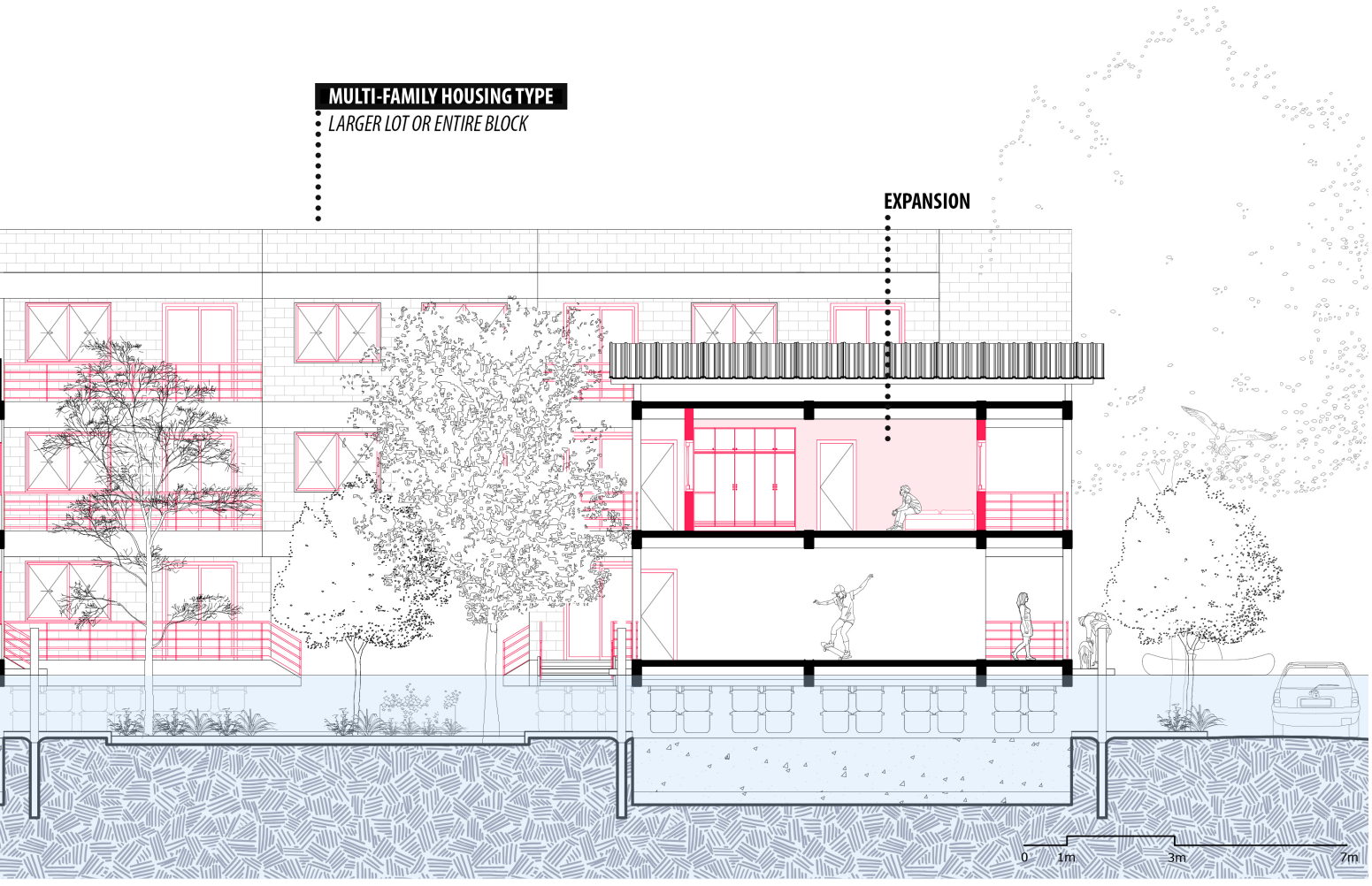


Figure 3.45. Cross section cutting the proposed single-fa
Source: Imag



amily and multi-family interventions in flood condition.
ge by author.

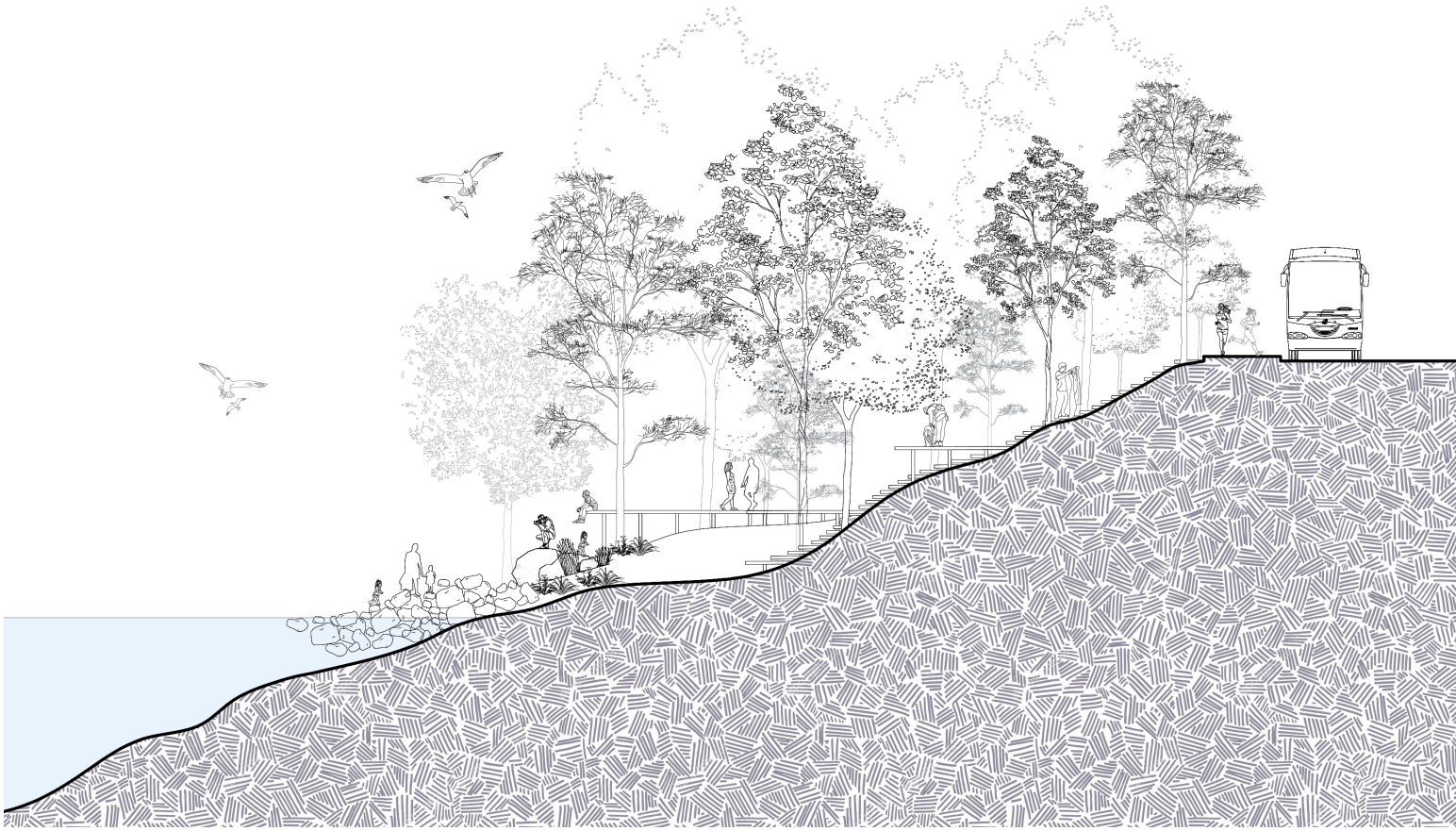
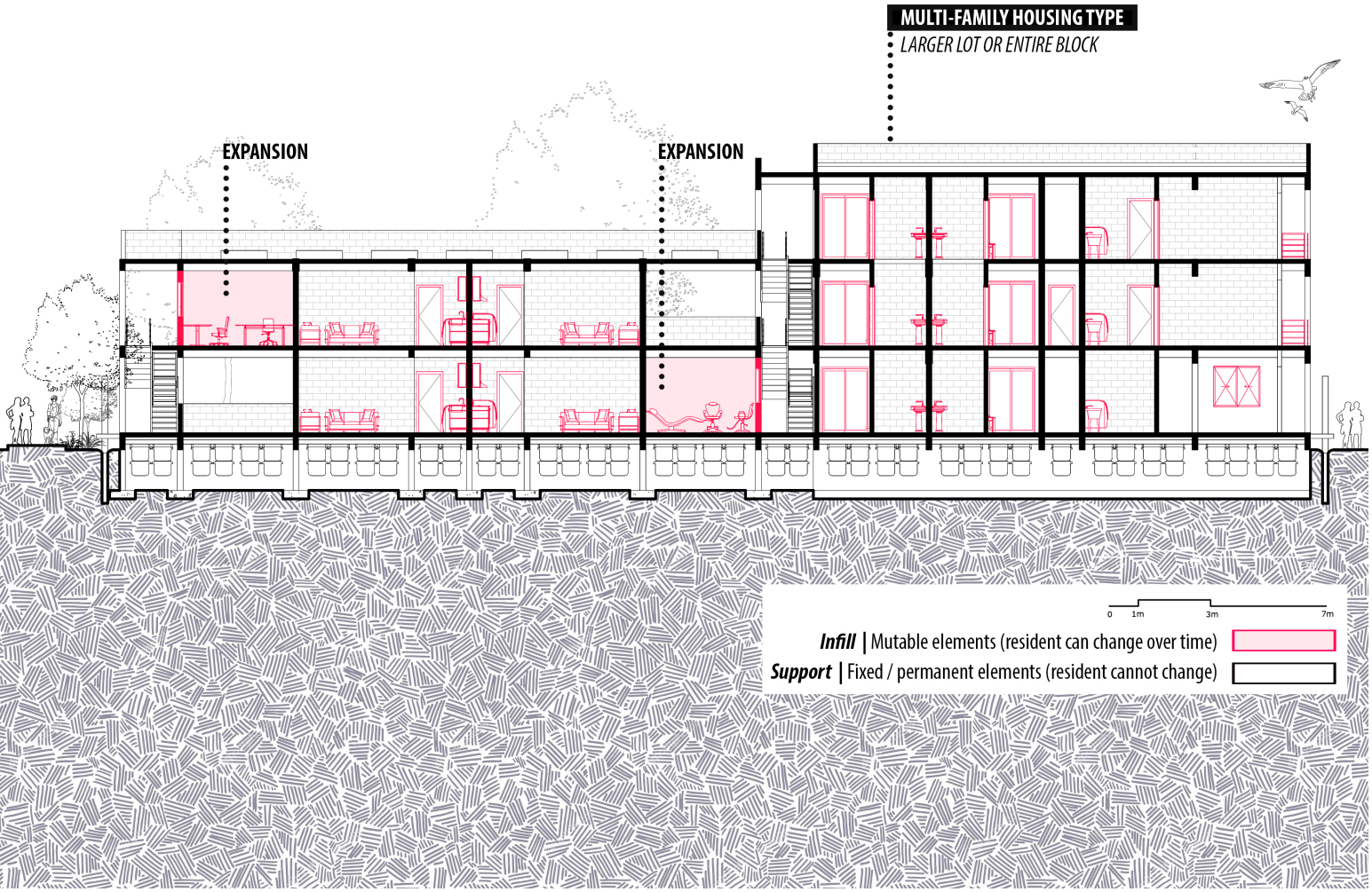


Figure 3.46. Longitudinal section cutting the proposed sin
Source: Ima



gle-family and multi-family interventions in dry condition.
ge by author.

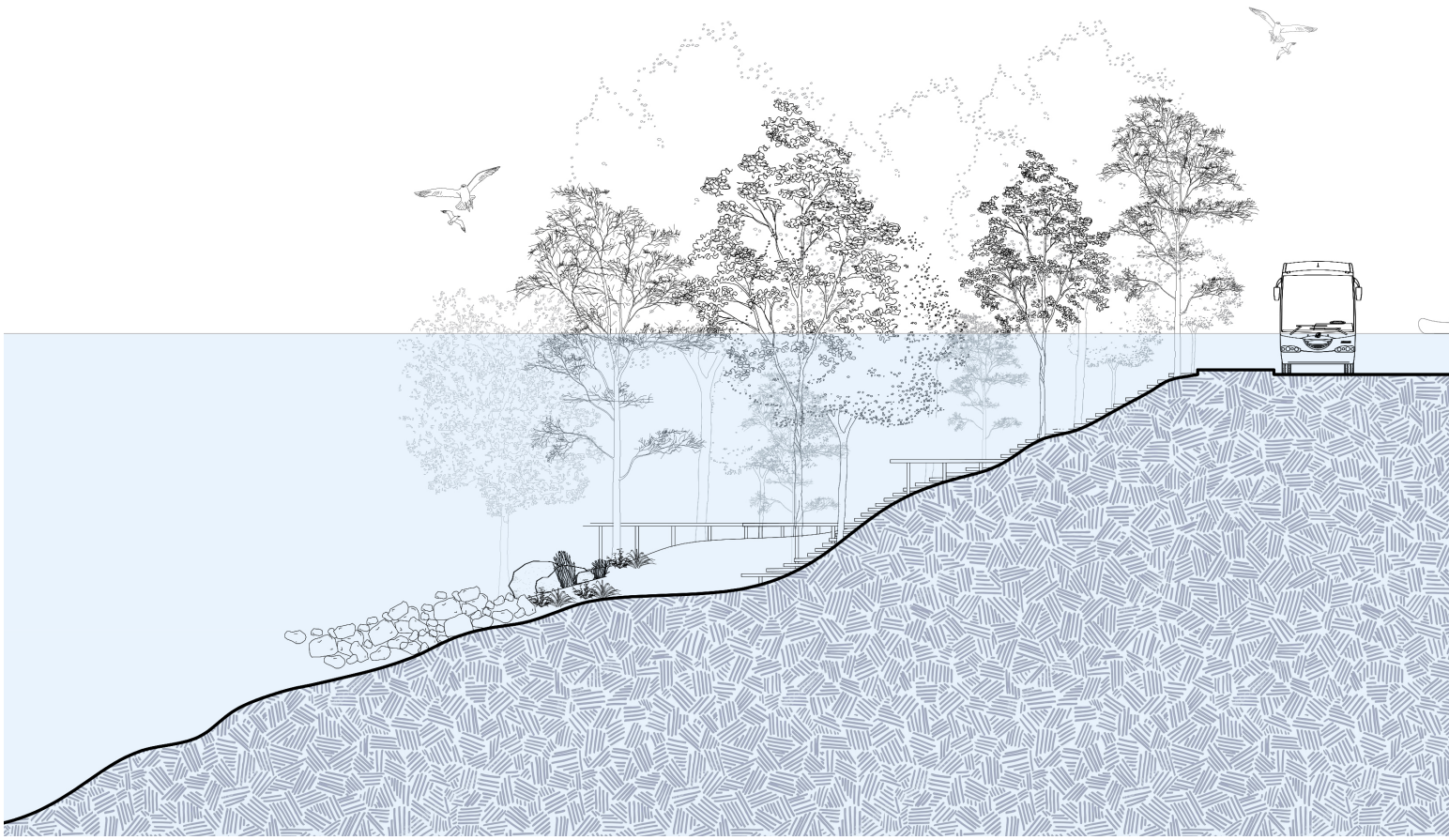
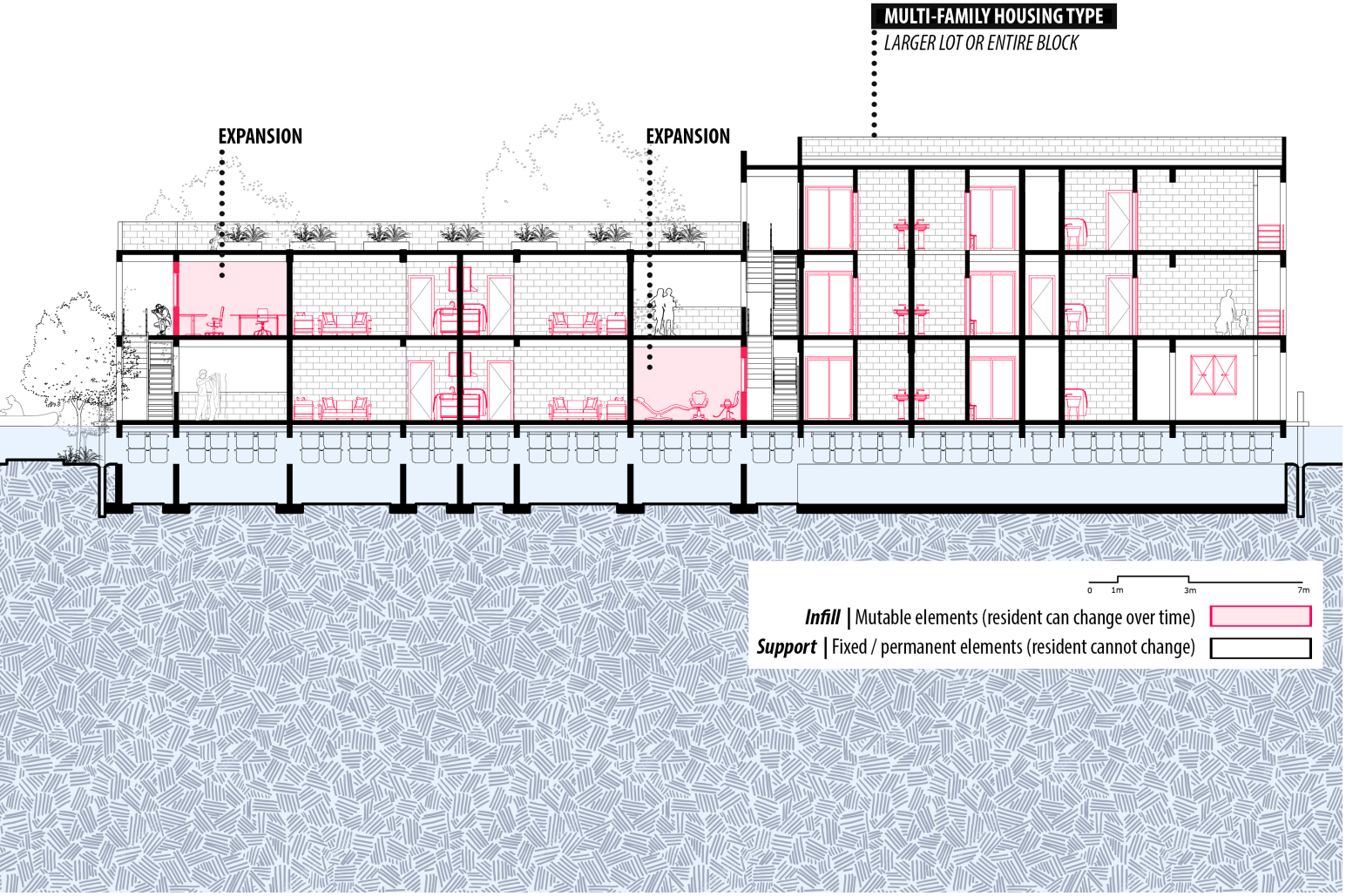


Figure 3.47. Longitudinal section cutting the proposed sing
Source: Ima



gle-family and multi-family interventions in flood condition.
ge by author.

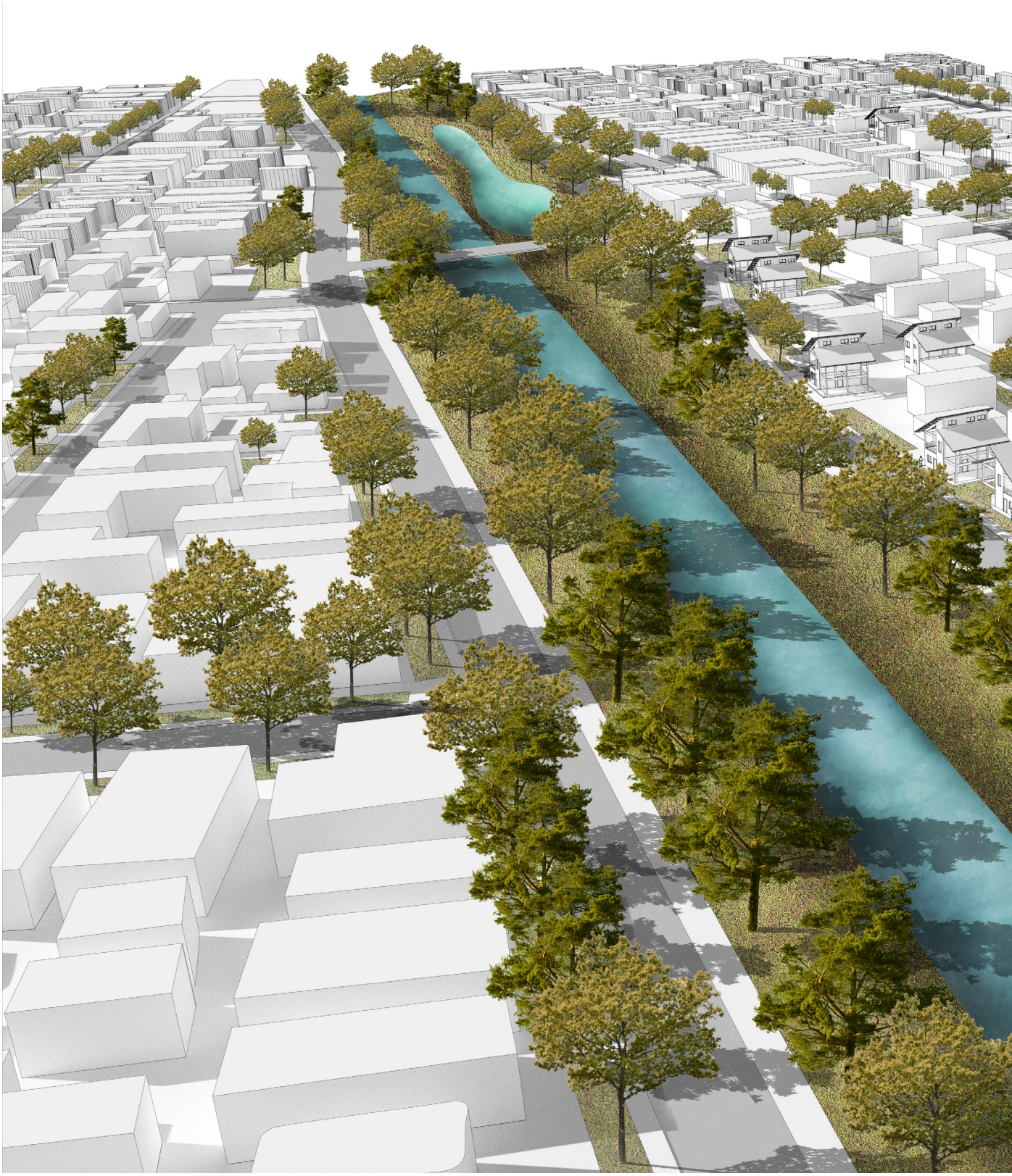
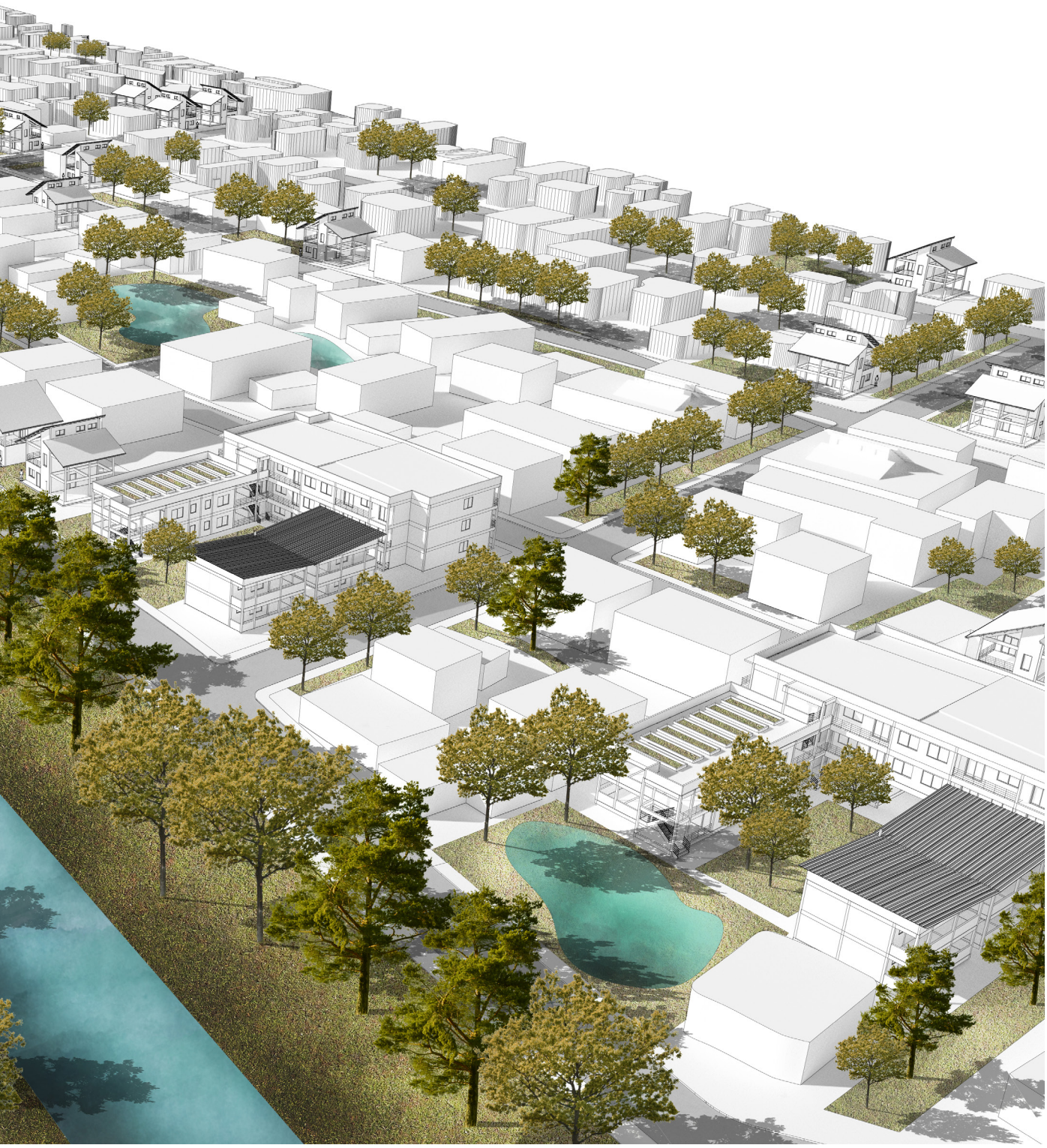


Figure 3.48. Bird's-eye view showing the proposed interventi
Source: Imag



ions in the Roncador River watershed, highlighting Region C
ge by author.

Figure 3.49. Eye-level perspective, showing the proposed interventions in the Roncador River watershed, highlighting the single-family and mu
Source: Image by author.

lti-family interventions in the Region C.

Hence, the outcome is a low-cost community- and water-centred housing design, strategically thought to be flexible enough to accommodate current and future changes, including being adaptable to variations of floodwaters. This proposition also aligns with the context of river restoration and a system of green areas by being adaptable to accept and work with water, fostering stormwater infiltration instead of being a barrier to it.

On the watershed/macro scale, the river margins are rehabilitated and returned to the river to accommodate the natural river dynamics and transformations, enhance the riparian ecosystem services, and connect to other green areas' systems within the urban fabric. In the neighbourhood/ intermediate scale, the concept of "margins" (or liminal, interpretable spaces that accommodate changes and transformations) is translated by utilizing the vacant lands in the region to create new meanings, both housing for the poor or new recreational, collective, and productive green spaces.

Finally, in the housing scale, the concept of "margins" provides extra space or an element that allows expansions and unit transformations to occur. Margins could be an empty, external, open space within the structural frame that could be encapsulated to extend the indoor area. They could also be a partition wall that divides two units, which could be removed to allow their combination and duplicate one unit.

Figure 3.50. Eye-level perspective, showing the proposed interventions in the Roncador River banks, relationship w

Source: Imag

highlighting the single-family and multi-family evolutionary interventions in the Region C and their
with the river.

ge by author.

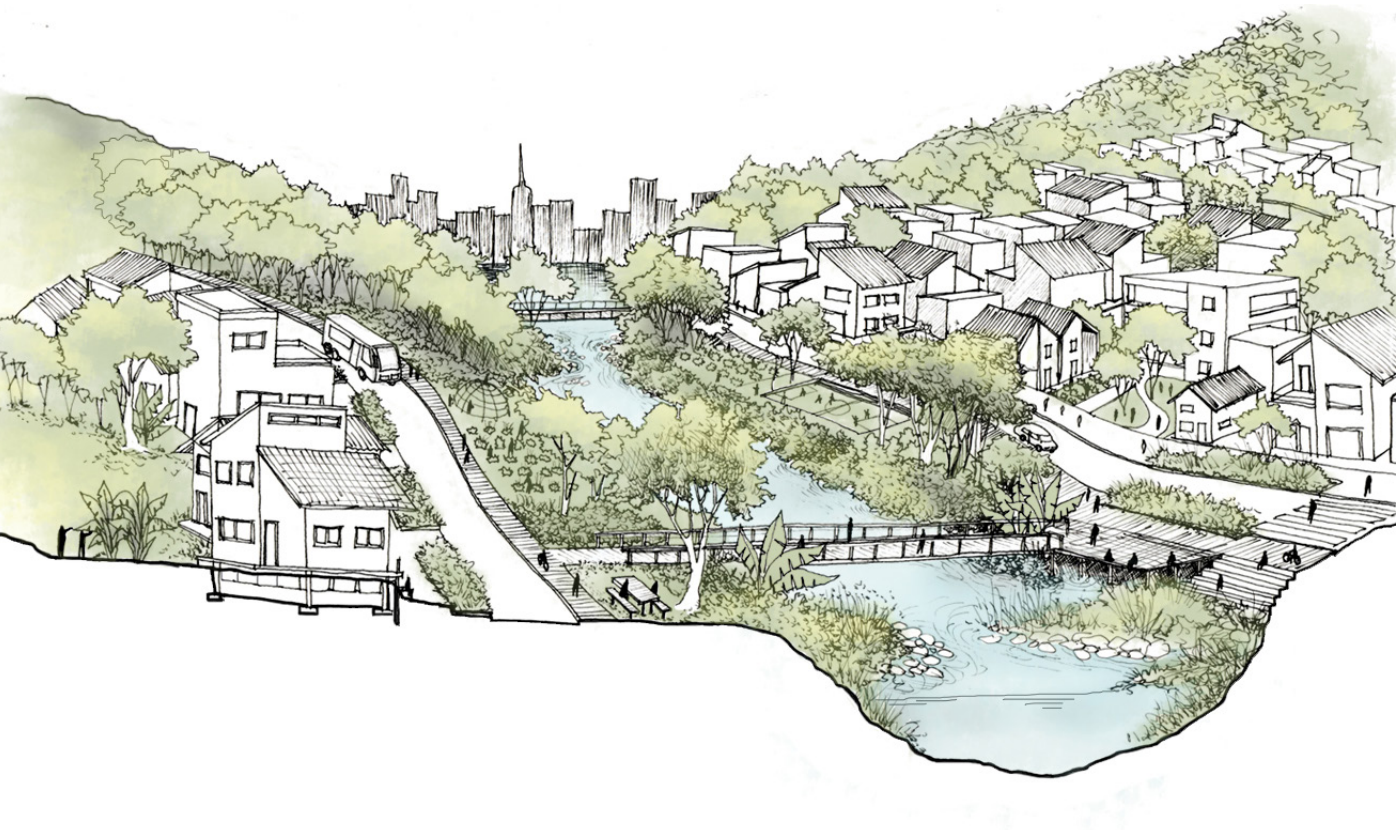
Conclusion

This thesis topic addressed the issue of informal settlements located on urban rivers' edges, which poses flood risks and health concerns to these low-income residents and represents a source of pollution and degradation to the watershed system. A central question that arose from this problem is how to transform these spaces and the relations among all actors involved in this context (including non-humans) in a more equitable, sustainable, collaborative, and holistic way of living among riparian ecosystems and urban periphery communities. This thesis sought to address questions such as: In the context of a degraded urban watershed characterized by informality, which actions could trigger a transformation toward a more sustainable way of living? What could be the architectural response that would support a harmonic urban growth, acting as the bridge that would dismantle the polarizing forces in this context, and foster a relational state in which water and community are interwoven and co-existing harmoniously? Which low-cost and low-impact design strategies would succeed in addressing the informal housing issues, from adapting to floods until empowering residents to reduce their vulnerability and increase their resilience?

Figure 3.51. Synthesis of design proposal, showing th

The discussion proposed in this thesis includes investigating flood mitigation and adaptation strategies in multiple scales, which would also improve the river's environmental qualities. Simultaneously, it is also essential that these strategies preserve and foster local community life and economies, considering a scenario of the future expansion of the city and the provision of affordable housing associated with resettlement and housing crisis.

The thesis provides integrated strategies in three different scales (informed by water and community as the key elements) to empower vulnerable communities to thrive in a healthier riverscape and increase their agency, adaptive capacity and flood resilience on a long-term basis (See figure 3.51). These strategies entail an alternative solution for urban flood mitigation and adaptation that prioritizes local knowledge (in terms of materials, construction knowledge, and traditional self-construction practices) and nature-based strategies, focusing on fighting gentrification and environmental degradation. The green spaces system applied to impoverished peripheries increases soil permeability and



he before and after scenarios. *Source: Image by author.*

mitigates floods, acting as a low-impact and low-cost alternative to treat the river's environmental qualities. In addition, the proposed design intervention focuses on addressing the housing issues generated by the implementation of the riverside park and responding to the local housing shortage, approaching quality in terms of location in the same neighbourhood and in bringing a more adaptable design. This thesis questions the current government responses and inaction to address social housing and urban flooding in Duque de Caxias City in Brazil, which disregards the existing problems and creates additional risks to the local population. Since the problems in the Roncador River surroundings are typical of metropolitan peripheries in Brazil, this method could also be applied to improve the quality of life of other riverine vulnerable communities in similar informal contexts.

The literature review comprises an analysis of the causes of the imbalance in urban river systems, understanding the acceleration of urbanization and the effects of climate change as significant threats to these systems. The acknowledgment of the rupture between nature and human beings is discussed as a result of the anthropogenic modifications on the natural environment. The negative human transformations on natural systems throughout the past decades can be reverted by changing the perspective and learning from the living systems how to reconcile the man-nature connection to achieve resilience. This thesis investigates what it means to be a sustainable community through the lens of Guatarri's three ecologies, subverting the neoliberal logic that prioritizes profit at the cost of collective well-being.

The review of literature also investigated widely known approaches for flood-risk reduction based on nature, such as the Blue-Green Infrastructure (BGI) and the Sponge City concept, which can improve environmental qualities in urban centers. However, this thesis is not following them as they are still very broad concepts. Similar to BGI and the Sponge City approaches, the British Aquatecture concept was also explored as a promising conceptual and practical framework encompassing strategies for living with water across scales to generate more flood resilient and sustainable communities. Thus, this thesis' design proposal was grounded on the Aquatecture approach because it brings a synergy between architecture, landscape, water, and people, which is a central point in this study. The intention is not to copy and paste the model into the peripheral context of a Global South country, but to incorporate its essence and adapt its strategies to fit into this context.

Focusing particularly on water, the interventions in the three scales are based on the Aquatecture principles to improve water infiltration, reduce stormwater runoff, and provide a multifunctional riverscape public space

for the surrounding low-income community and integrate them into amphibious housing solutions. The housing proposal is designed to be adaptable to floods and maximize exchanges (of surpluses) with the surrounding environment, a regenerative solution deeply interwoven with the park system, and internally flexible to accommodate a diversity of uses and functions (other than residential) in its lifetime. For this intervention to take place, it requires a collaborative and interdisciplinary approach. Because the proposed strategies are nature-based, their application in the Roncador River watershed context focuses on being integrated, decentralized, multifunctional, heterogeneous, collaborative, and regenerative (as nature is). It is hoped that this could be a valuable path to transform a 'slum river' into a vibrant and pulsing public space integrated with a housing system that is adapted to and fosters the local community life.

Investigating and applying the potentials of adaptability to the indoor space was also crucial to this study, as it proved that it could improve the quality of life for individuals and communities. Adaptability and flexibility are directly related to incrementality, and practical strategies can be found in the Open Building approach to generate a more flexible housing design that allows dwellers to modify their houses according to their needs over time.

However, combining Open Building strategies for adaptability with the amphibious architecture approach to flood adaptation presents a challenge related to practicality and limitation to expansions. Starting with a one-storey house that can expand horizontally and vertically up to four storeys makes it heavier and taller, which can compromise the building's stability during floods and the buoyancy if the expansions exceed their spatial and weight limits. The expansion needs to be guided by parameters that allow people to expand in a controlled way. The ideal scenario would be to have the control parameters for expansion within the building code, but this is a very distant scenario, as amphibious architecture does not appear in any building code anywhere in the world to date. The structural frame and buoyancy system need to be correctly sized to support the expansions' extra load over time. The taller and heavier the building gets, the less cost-efficient the buoyant foundation becomes. Thus, expansions are required to have a limit. One solution would be to oversize the flotation elements in the starter unit accounting for the maximum expansion scenario. Another strategy would be to provide the starter house with the buoyancy elements required only for the starter scenario, and train the residents to install more buoyancy elements when they expand their houses. In this case, the foundation would need to have enough space and height to accommodate more buoyancy blocks over time.

Another challenge faced by this study is related to achieving an integrated approach on multiple scales (urban, neighbourhood and housing) beyond the design stage, which largely depends on integration with the policy level, as well as achieving political will and community's acceptance. Because the majority of the proposed design work is infrastructural, it needs to involve the government, for both the riverside park intervention and the social housing proposal on safer ground. This work would entail the use of big machinery and public investment and resources, therefore, it requires political will to do it. The integration with the policy level must occur in a way that regulatory frameworks, such as the building code, provide guidance on how much space should be set aside for flooding, future development, parks and vegetation, recreation, retail, navigation, etc., so that the city can guide future developers in a very responsible way, to allow human beings to live in harmony with the natural environment. There is the need for incorporating control parameters that also allow for a multifunctional programme to happen where many functions, such as recreation, vegetation, and space for water can overlap.

A successful integrated and decentralized approach also depends on having a large-scale water management system mapped along the length of the river, encompassing not only nature-based strategies but also engineering structured solutions to help hold and manage the water and reduce flood hazards in the long term. This thesis focuses on providing a sectional strategy with a series of cross-sections alongside the river, combining landscape and architecture to resolve the cross-section. This sectional strategy is intended to be part of this larger integrated approach in the longitudinal dimension, from the headwaters until the river mouth, encompassing the entire watershed. Thus, this larger integrated stormwater management plan is pointed as a suggestion for future research in the Roncador River watershed, as a continuation of this thesis.

The difficulties in implementing the solutions proposed in the watershed scale lie in the need for budget and for a multidisciplinary team to work in different project phases, which could take a few years to be implemented. Because the government has a mindset that prioritizes profit and the private market interests, under a neoliberal logic, the proposed design for the region would subvert this logic, which would probably not be accepted as desirable by the government agents and decision-makers. For this project to be implemented and successfully last in the long term, it is paramount that policies be created to integrate with urban planning, sanitation, and housing policies. Investments in environmental education are needed to foster ecological awareness so that the local population can understand the importance of preserving and maintaining green technologies and be motivated to do so. In addition, the interventions on the macro scale propose a series of

solutions that work together in a decentralized way to achieve the goal of minimizing floods while creating recreational spaces based on nature.

Nevertheless, if they are applied in isolation, they will not effectively achieve their goals, demonstrating the need for a holistic approach. It is also important that the municipality prioritizes the river's cleaning and maintenance with frequency to guarantee and improve its drainage capacity. In addition, the potential negative consequences of implementing the proposed solutions on the watershed scale (such as green gentrification and conflicts with resettlement) can be avoided if the community is part of all the processes, from the planning and design conception, until the implementation and maintenance, being included in all levels of decision-making. When the community actively participates in these projects and collaborates in the decision-making process, also supported by public policies to guarantee that social equity is central to the project, it is possible to avoid green gentrification and build more inclusive urban projects that revert the neoliberal paradigm.

As presented in the neighbourhood scale portion of the design proposal, the solutions proposed by this thesis to address the lack of sanitation in the region were considered alternative solutions that are also low-cost, easy-maintenance, nature-based, and low-impact solutions, which utilized local materials and techniques. Ideally, they are considered sustainable practices. However, to properly implement them, the community must receive training to clarify how to maintain them properly, how much that will cost and their benefits. The residents must understand how these technologies work and why they are needed to accept them; otherwise, they will probably not maintain them correctly, generating issues for the entire community. It is also essential that the community is united and agree to maintain these solutions collectively and understand them as a long-term benefit that requires collective organization.

A challenge with the implementation of natural strategies for improving sewage treatment in the region is how to properly manage the wastewater treatment when flooding occurs, inundating these alternative technologies. The proposed alternative solutions for sewage treatment in the region, such as the banana tree circles, green septic tanks, and wetlands, work well for primary treatment if they are in a non-floodable area. In flood-prone regions, these solutions can be applied only for tertiary treatment, refining the effluent already treated in primary and secondary processes such as happens in the conventional septic tank. When the effluent comes from the primary and secondary treatment processes, it becomes rich in organic matter, which is beneficial for being applied to wetlands, banana tree circles and green septic tanks. Therefore, in floodable areas in the Roncador River region, these alternative solutions can be applied in addition to

safer sewage treatment solutions for black and grey waters, to guarantee they will not contaminate the soil and water bodies during a flood event. In the housing level, during flood events, amphibious homes become disconnected from sewer lines (as well as natural gas) when the house starts to rise with floodwaters by the self-sealing breakaway connections (English, 2009).

Notwithstanding, it is still crucial that the government implement a definitive sewage treatment system in the region, including a collector system separated from the stormwater drainage system to convey the effluents to sewage treatment plants, which do not exist in the city yet. Although the alternative solutions proposed by this thesis will help improve the sanitary situation for communities surrounding the Roncador River, they are small-scale and require considerable space to be implemented. Therefore, when the densities increase in the future, these solutions may not be sufficient, highlighting the importance of implementing a permanent and large-scale solution for sewage treatment in the region by the government.

Regarding the housing solutions proposed by this thesis, there are a few limitations to implementing the design strategies. Although they inform good practices for increasing adaptability in the housing realm, the barriers to implementing them include the political will to accept a more flexible design. This requires shifting the current inefficient mindset of rigid and homogeneous design to one that is more adapted to local specificities and provides increased control to the user to modify their homes according to their needs and desires. The possibility for expansions over time should also be incorporated in building codes, to allow people to expand their houses in a controlled way.

Additionally, social housing provisions alone will not solve the housing problem since it needs to be integrated into other policies, especially related to water. The housing deficit will only be permanently resolved if there is a considerable investment in housing policies and improving the public housing program. It is crucial to shift the current poorly designed, homogeneous, universal, and rigid architecture to a new logic that allows residents to have more control and opportunities to adapt their houses to accommodate their needs over time. Another challenge faced by this thesis on the housing scale includes applying the amphibiation technique[12] in the type of local construction in the Roncador River region, composed mainly of masonry and concrete materials. The amphibious architecture approach has a practical limitation on the structure's overall weight, as the system becomes more cost-efficient if the structure is lightweight. Thus, this could become a concern in future developments of this project and needs to be considered.

12 Amphibiation technique is a term coined by Elizabeth English (2016) to refer to transforming a building into amphibious, designed to temporarily float during floods, and rest again on the ground when the flood is over. See more detail on Section 1.3, page 68.

Although the design demonstrates that the proposed solutions are applicable and locally appropriate (especially with harnessing vacant lands as a major strategy), design actions are not enough for guaranteeing its practicality to be successfully implemented. Taking measurements for quantifying the local vacant lands are fundamental for the project's actuality, to demonstrate if they would be enough or if more land would be required to achieve the project's goals, which is not part of this thesis' scope. It is also paramount to calculate more accurately how many people would be affected or displaced by the riverside revitalization and with the growing housing crisis in the region, and cross this data with the number and sizes of available vacant lands. These procedures are suggested as the next steps for future research in the area.

Another direction for future research includes developing the specifications and detailing of one amphibious evolutionary housing in this region, calculating and sizing the buoyant foundation elements with local materials, to understand more its limitations in terms of budget and size. By understanding that the house will be heavier in the expansion scenario up to three or four storeys, it would be interesting that future research could study the limits to expansion in relation to buoyancy requirements to inform control parameters for expansions.

With this thesis, I hope to bring practical solutions that could heal or at least improve degraded urban rivers and their watersheds in low-income and vulnerable communities while enhancing public and community lives. The proposed solutions also aim at fostering local economies to fight the possible effect of gentrification as a consequence of implementing a network of parks along the river and within the urban fabric. To effectively regenerate a natural system, including river landscapes and their watersheds, nature indispensably needs to become the priority, and it needs to be balanced, integrated, and coincident with the community's needs and desires. To this end, it is fundamental to raise awareness of the importance of watershed preservation and to have people engaged as its stewards for long-term success. It is essential to focus on healing the whole, not just some parts of it, to create a sense of unity. The proposal affirms my position of applying decentralized, holistic, multi-scale, multifunctional, integrated, collaborative, and interdisciplinary solutions to achieve resilience and community empowerment in the urban space. By prioritizing design in time, designers must think not only in the present but also the prospect of a better future that, although uncertain, has the proper support to adapt to unknown circumstances.

As mentioned by Donna Haraway (2019), "There will be no going back to some fully repaired place. That is not the same thing as saying there can be no repair, restoration, restitution, cobbling together again, and

including new stuff, beings who are coming into the world, ways of living in the world that haven't been on this planet before". Water elements and community priorities are used to structure this proposal to weave a more sustainable and equitable way of living. It aims to dismantle the once considered dichotomy of nature vs people or polarized expressions in the urban fabric and generate a reconciliation between urban river ecosystems and communities, especially for the most vulnerable, by reconnecting them. What it generates, in the end, is the creation of possibilities and opportunities in an intentional relational state between nature and community. The chosen path for finding a more resilient solution lies in looking into nature, being open to learning from it, and prioritizing it in design applications. To seek a sustainable design proposition, it is also crucial to see the overall intervention as simultaneously addressing the needs of communities, individuals, and the environment since they are thought of as intertwined systems (Guatarri, 2000).

This thesis criticizes the top-down interventions in the surrounding neighbourhoods of Roncador River, responsible for decreasing the residents' quality of life. I propose implementing a series of bottom-up and nature-based strategies to prioritize the community and water in the design, driving residents to action and seeing water as an ally. By making space for water, returning the margins to the river to fulfill their function of accepting the river's transformations of dynamics and processes, it is possible to recover the riparian ecosystems and have a healthier watercourse. This is complemented by implementing green areas and park systems to increase soil permeability and, ultimately, mitigate floods. The same analogy is used for the housing design: by returning the "margins" (or spaces that accommodate changes), the residents can address their needs according to their stage of life, family size, budget limitations, and so on, becoming agents of change. People relocated from the precarious dwellings on the riverbanks will keep living within their communities, appropriating abandoned vacant lands to inhabit in amphibious houses adapted both to floods and to their needs.

In the Roncador River region, boundaries can be accepted in their dynamic, transitory, and transformative nature. In the threshold between water and land, the uncertainty and instability of inhabiting the place of in-betweenness would no longer threaten its residents: natural elements would be brought to increase permeability and, hence, reduce floods. Additionally, their houses can now adapt to floods and provide support for transformation to happen, expansions to be added, and customizations of space, accepting the natural flow of change that characterizes life. Transformations can be not only accepted as part of life but desirable, essential for building resilience.

As an analogy, I advocate that housing design should incorporate the essence of river systems: they should have space and opportunity to change their morphology according to the flow. Their margins are the flexible mechanism that embraces the needed or desired changes in time, ultimately generating improvements. The continuous processes of change make rivers unique, both spatially and temporally; this could also be true for homes if we welcome transformations to take place.

This thesis approached the theme of living "on the margins" in vulnerable regions as a critique of the current profit-centred logic that generates disparities, environmental degradation, spatial segregation, and social inequality. It is about the people marginalized from society who have been forced to live informally in the most precarious and undesirable places such as riverbanks. It is also about questioning the division resulting from the dichotomous relationship between humanity and nature, fueled by capital interests, and the desire to re-establish a more balanced and harmonic relationship. This threshold needs to be more relational and respectful of both sides. More fundamentally, I approach this theme because margins can also be opportunities for improvement, as they are spaces that encourage transformations toward adaptation, as per the analogy with river dynamics. Houses, especially for these vulnerable communities, should incorporate the concept of "margins" by accepting changes, seeking a more adaptable design that supports users' transformations over time, and adapting to varying and uncertain external circumstances. This would ultimately improve their lives, reduce their vulnerability, and enhance their resilience.

Bibliography

Aalbers, Manuel B, and Kenneth Gibb. 2014. “Housing and the Right to the City: Introduction to the Special Issue.” *International Journal of Housing Policy* 14 (3): 207–13. https://doi.org/10.1080/14616718.2014.936179.

Abreu, Maurício de Almeida. 1987. *Urban Evolution of Rio de Janeiro”, “Evolução urbana do Rio de Janeiro.* Rio de Janeiro: IplanRio/ Zahar.

Andrade, Liza Maria Souza de, and Raquel Naves Blumenschein. "Cidades sensíveis à água: cidades verdes ou cidades compactas, eis a questão?", "Water-related cities: green cities or compact cities, that's the question?", *Paranoá: Cadernos de Arquitetura e Urbanismo*, (10), 59–76, 2013. https://doi.org/10.18830/issn.1679-0944.n10.2013.12124

Ávila, Renata Oliveira. 2005. “Performance Evaluation Of Anaerobic Septic Tank-Filter Systems With Different Types Of Support Media”, “Avaliação Do Desempenho De Sistemas Tanque Séptico-Filtro Anaeróbio Com Diferentes Tipos De Meio Suporte”. Master’s thesis, Federal University of Rio de Janeiro – UFRJ. Available at: http://www.saneamento.poli.ufrj.br/images/Documento/teses/RenataOliveiradeAvila.pdf

Baca Architects. 2019. *Interview with Richard Coutts,* July 10, 2019.

Baca Architects. n.d. “Flood Resilient Architecture: Masterplanning” Accessed April 20, 2021. https://www.baca.uk.com/purpose.html.

Balbim, Renato. 2011. “Urban Policy and territorial integration”, “Política urbana e integração territorial." *Desafios do desenvolvimento – IPEA*, Brasília, ano 8, edição 64, fev. 2011. http://repositorio.ipea.gov.br/bitstream/11058/8599/1/Pol%c3%adtica%20urbana%20e%20integra%c3%a7%c3%a3o%20territorial_29.pdf

Barboza, Luciano da Silva. 2015. "A identidade do Movimento por Urbanização e Legalização do Pantanal da Zona Leste — SP: esperança e desalento na luta contra o deslocamento populacional", "The identity of the movement for urbanization and legalization of Pantanal in the Eastern Zone—SP: Hope and discouragement in the fight against displacement". Scortecci, São Paulo.

Barker, Robert, and Richard Coutts. 2016. *Aquatecture: Buildings and cities*

designed to live and work with water. RIBA publishing.

Brears, Robert C. 2018. "From Traditional Grey Infrastructure to Blue-Green Infrastructure". In *Blue and Green Cities: The Role of Blue-Green Infrastructure in Managing Urban Water Resources*, pp 1-41. Christchurch: Springer.

Benjamin, Amboko Muhiwa. 2013. “Evapotranspiration basin: domestic effluent treatment and food production”,
“Bacia de Evapotranspiração: tratamento de efluentes doméstico e produção de alimentos.” Master’s thesis, UFLA. Lavras, Minas Gerais. Available at:
http://repositorio.ufla.br/bitstream/1/1701/3/DISSERTACAO_Bacia%20de%20evapotranspira%C3%A7%C3%A3o....pdf

Brasil. Lei nº 11.977 de 2009. Diário Oficial da República Federativa do Brasil, Brasília, DF. 2009.

Britto, Ana Lucia, Suyá Quintslr, and Margareth da Silva Pereira. 2019. "Baixada Fluminense: Fluvial and social dynamics and in the territory formation", "Baixada Fluminense: dinâmicas fluviais e sociais na constituição de um território". *Dossiê Rios e Sociedades. Revista Brasileira de História* 39 (81), May-Aug 2019.

Britto, Ana Lucia, Jorge Fleury, Aline Pereira, Aline Sousa, Andria Roza;,Daniele Brito, Gizele Corner, João Dias, Lívia Jesus, Matheus Castro, Nathalia Gomes; Samantha Silva, Thais Costa, Vitória Carreiro, Yara Souza. 2019. “Revitalização De Rios Em Duque De Caxias: Uma Proposta para o Rio Roncador”. *Semana De Integração Acadêmica – Fau UFRJ*, 2019.

Browning, William. 2000. “Biomimicry, Biophilia, and Building Community”. In *Sustainable Architecture White Papers*, edited by Brown, David E., Mindy. Fox, and Mary Rickel. Pelletier. 1st ed. New York, NY: Earth Pledge Foundation.

Brunetti, Gian. 2017. “Bioclimatic Design for Informal Settlements.” In *Sustainable Urban Development and Globalization,* 157–171. Cham: Springer International Publishing.

Bosma, Koos, Dorine van Hoosgstraten, and Martijn Vos. 2000. *Housing for the Millions. John Habraken and the SAR (1960-2000).* Rotterdam: NAI Publishers.

Calabuig, Gomez. 2013. “The Strategies of Mat-Building: Dismantling

and Reframing Programme and Composition, Mat-Building Envisaged Architecture as a Dynamic, Flexible Armature." *The Architectural review* (London) 234, no. 1398 (August 1, 2013): 83–.

Cardoso, Alexandre. 2010. *Retratos da Baixada Fluminense*. Duque de Caxias: Wak.

Cardoso, Adauto Lucio (org). 2013. *O programa Minha Casa Minha Vida e seus efeitos territoriais*. Rio de Janeiro: Letra Capital, 2013.

Chan, Faith Ka Shun, James A Griffiths, David Higgitt, Shuyang Xu, Fangfang Zhu, Yu-Ting Tang, Yuyao Xu, and Colin R Thorne. 2018. "'Sponge City' in China—A Breakthrough of Planning and Flood Risk Management in the Urban Context." Land Use Policy 76: 772–78. https://doi.org/10.1016/j.landusepol.2018.03.005.

Conti, Eliane França, Teresa de Jesus Peixoto Faria, and Geraldo Márcio Timóteo. 2014. "The Urban voids versus the social function of property: the role of the master plan of the city of Campos dos Goytacazes", "Os vazios urbanos versus a função social da propriedade: o papel do plano diretor da cidade de Campos dos Goytacazes." *Boletim de Geografia* 32, no. 3 (2014): 151-169.

COPPETEC Foundation. 2014. "Preparation Of The State Water Resources Plan Of The State Of Rio De Janeiro". Available at: http://www.inea.rj.gov.br/cs/groups/public/documents/document/zwew/mdyy/~edisp/inea0062130.pdf

Costa, Pierre Alves. 2012. "The city of Petroleum: a geo-history of oil refining in Brazil", "A cidade do Petróleo: uma geo-história do refino do Petróleo no Brasil". Guarapuava: Unicentro, 2012.

Costa, Marianne. 2016. "Open Building as an international approach for multi-family housing production". Chiba: Chiba University, Graduate School of Engineering.

CRED EM-DAT. 2015. *The OFDA/CRED - International Disaster Database*, Université catholique de Louvain Brussels - Belgium.

Crombie, David. "Healing an Urban Watershed: The Story of the Don". In *Regeneration, Toronto's Waterfront and the Sustainable City : Final Report.* Toronto, Royal Commission on the Future of the Toronto Waterfront, 1992.

DCMCD – Civil Defense of Duque de Caxias City. 2013. “Relatório de Atividades da Defesa Civil de Duque de Caxias de 2013”. Duque de Caxias, RJ: Defesa Civil Municipal, 2013.

da Silva, Priscila Soares, Kelson Vieira Senra, and Daniel Taboada Placido. 2015. “Challenges and Perspectives for Restructuring Urban Space from Minha Casa Minha Vida, the Case of the Resettlement of the Gaspar Ventura Canal in the Municipality of Duque De Caxias, Rio De Janeiro”, “Desafios E Perspectivas De Reestruturação Do Espaço Urbano A Partir Do Minha Casa Minha Vida, O Caso Do Reassentamento Do Canal Gaspar Ventura No Município De Duque De Caxias, Rio De Janeiro.” Anais *Enanpur* 16, N. 1.

Delaqua, Victor. 2019. “What Can Nature Teach Architects about Resilience” ArchDaily, 22 Jul 2019. Accessed 7 Nov 2020. <https://www.archdaily.com/921428/what-can-nature-teach-architects-about-resilience> ISSN 0719-8884

Deleuze, Gilles and Felix Guattari. 1987. “Introduction: Rhizome”. In A *Thousand Plateaus: Capitalism and Schizophrenia*, trans. Brian Massumi, 1980 (1980, Les Editions de Minuit, in French), Minneapolis: University of Minnesota Press.

Döring, Jochum. 2017. “Revitalization of a Tamed River: The Isar in Munich.” In *Rivers Lost, Rivers Regained*, 288–. University of Pittsburgh Press.

Dupont, Patrick and Stuart White. 2000. “Green Building: Sustainable Water Consultancy”. *Australian Conservation Foundation/Surrowee Pty Ltd*, Institute for Sustainable Futures, Universiy of Technology, Sydney.

Ellis, J. Bryan. 1995. "Integrated approaches for achieving sustainable development of urban storm drainage". *Wat. Sci. Tech.*, 32(1), 1–6.

EN-Climate-Data. 2021. “Climate Duque de Caxias (Brazil)” Climate-Data.org. Available at: https://en.climate-data.org/south-america/brazil/rio-de-janeiro/duque-de-caxias-4040/

English, Elizabeth, Michelle Bullough, and Shabaan Khokhar. 2019. “Float When it Floods: Amphibious Architecture as an Alternative Floor Risk Reduction Strategy”. *HazNet* (Newsletter of the Canadian Risk and Hazards Network), vol. 12 no. 1.

English, Elizabeth, Meiyi Chen, Rebecca Zarins, and Iryna Humenyuk. 2018. “An innovative strategy to increase the resilience of flood-vulnerable communities while reducing risk of population displacement and psychological trauma”. *8th International Conference on Building Resilience* – ICBR Lisbon 2018

English, Elizabeth, Natasha Klink, and Scott Turner. 2016. “Thriving with water: Developments in amphibious architecture in North America.” *E3S Web of Conferences.* Vol. 7. EDP Sciences.

English, Elizabeth. 2009. “Amphibious foundations and the buoyant foundation project: Innovative strategies for flood resilient housing.” In *International Conference on Urban Flood Management* sponsored by UNESCO-IHP and COST Action C, vol. 22, pp. 25-27.

Federal Emergency Management Agency - FEMA. n.d. “Unit 10: Disaster Operations and Hazard Mitigation”. https://www.fema.gov/pdf/floodplain/nfip_sg_unit_10.pdf

Figueiredo, Isabel, Bárbara Santos, and Adriano Tonetti. 2018. “Sewage Treatment in the Rural Area: green septic tank and circle of banana trees”, “Tratamento de Esgoto na Zona Rural: fossa verde e círculo de bananeiras”. Campinas, SP; Biblioteca/Unicamp, 28p.

Figuerêdo, Maria Aparecida de. 2004. “Genesis and (Re) Production of the Baixada Fluminense Space”, “Gênese e (Re)Produção do espaço da Baixada Fluminense”. *Revista geo-paisagem* (on line) / Latindex, Ano 3, n 5, Janeiro/Junho 2004. Available at: http://www.feth.ggf.br/baixada.htm

Filho, Venceslau. 2013. “Flood invades the condominium of Minha Casa, Minha Vida, in Duque de Caxias”, “Enchente invade condomínio do Minha Casa, Minha Vida, em Duque de Caxias”. *Folha de S. Paulo.* Accessed March 13, 2021. https://www1.folha.uol.com.br/paywall/login.shtml?https://www1.folha.uol.com.br/cotidiano/2013/03/1248800-enchente-invade-condominio-do-minha-casa-minha-vida-em-duque-de-caxias-rj.shtml

FJP - Fundação João Pinheiro. 2000. “Housing Deficit in Brazil”, “Déficit Habitacional no Brasil”. Belo Horizonte/MG.

FJP - Fundação João Pinheiro. 2015. "Déficit habitacional no Brasil 2015", Diretoria de Estatística e Informações, accessed June 2021.

http://www.fjp.mg.gov.br/index.php/produtos-e-servicos1/2742-deficit-habitacional-no-brasil-3.

Freitas, João, João Branco Pedro, and Antônio Cabrita. Reis. 2002. "Residential quality concept: Bungee jumping into its complexity". In *Environmental quality and human well-being*, April 28 – 29, 2002, Ulrecht, Netherlands.

Fuller, Richard Buckminster, and E. J. Applewhite. 1976. S*ynergetics: Explorations in the Geometry of Thinking*. New York: Macmillan.

Gattoni, George. 2009. "A case for the incremental housing process in sites-and-services programs and comments on a new initiative in Guyana." *Inter-American Development Bank*: Washington, DC, USA.

Ghofrani, Zahra, Victor Sposito, and Robert Faggian. 2017. "A comprehensive review of blue-green infrastructure concepts." *International Journal of Environment and Sustainability* 6, no. 1.

Gibson-Graham, Hill. 2016. "Re-Embedding Economies in Ecologies: Resilience Building in More Than Human Communities." *Building research and information: the international journal of research, development and demonstration* 44, no. 7 (October 2: 703–716.

Gorzelak, Monika, Amanda Asay, Brian Pickles, Suzanne Simard. 2015. "Inter-plant communication through mycorrhizal networks mediates complex adaptive behaviour in plant communities". AoB Plants. 2015 May 15;7:plv050. doi: 10.1093/aobpla/plv050. PMID: 25979966; PMCID: PMC4497361.

Gould, Kenneth and Tammy Lewis. 2016. *Green Gentrification: urban sustainability and the struggle for environmental justice*. London, Routledge.

Grashoff, Udo. 2020. *Comparative Approaches to Informal Housing Around the Globe*. UCL Press.

Green Initiative – Iniciativa Verde. 2015. "How so planting waters?", "Como Assim Plantando Águas?" YouTube. YouTube, February 10, 2015. https://www.youtube.com/watch?v=xS2UQf7Z5h4.

GT Habitação e Cidade. 2020. "Casa Verde e Amarela: critical points of the new social housing program of the Federal Government",

"Casa Verde e Amarela: pontos críticos do novo programa habitacional do Governo Federal". *Observatório das metrópoles.* Published on September 3, 2020. https://www.observatoriodasmetropoles.net.br/casa-verde-e-amarela-pontos-criticos-do-novo-programa-habitacional-do-governo-federal/

Guattari, Félix. 2000. *The Three Ecologies*. New Formations, no. 8: 131–.

Habraken, Nicholas John. 2002. "The uses of levels." *Open house international* 27, no. 2: 9-20.

Habraken, Nicholas John. 2011. *Supports: an alternative to mass housing.* UK: The Urban International Press.

Harnish, Chris. 2018. "Eco-Incremental Housing: Researching Typologies and Systems in Pursuit of a Community-Based Approach to Housing Upgrades in Informal Contexts." In *Sustainable Urban Development and Globalization*, 449–461. Cham: Springer International Publishing, 2018. Bioclimatic Design for Informal Settlements.

Harvey, David. 2006. "Neo-liberalism and the restoration of class power." In *Spaces of Global Capitalism: Towards a Theory of Uneven Geographical Development*, Verso.

Harvey, David. 2008. "The right to the city." *The city reader* 6, no. 1: 23-40.

Hettiarachchi, Wasko. 2018. "Increase in Flood Risk Resulting from Climate Change in a Developed Urban Watershed – the Role of Storm Temporal Patterns." *Hydrology and earth system sciences* 22, no. 3 (March 29, 2018): 2041–2056.

Hough, Michael. 1995. *Cities and Natural Process*. 1. ed. New York: Routledge.

Hoyer, Jacqueline, Wolfgang Dickhaut, Lukas Kronawitter, and Bjorn Weber. 2011. *Water sensitive urban design: principles and inspiration for sustainable stormwater management in the city of the future*. Berlin: Jovis.

INEA – State Environmental Institute. 2011. "Vulnerability Map of the Population of the State of Rio de Janeiro to the Impacts of Climate Change in the Areas: Social, Health, and Environment", "Mapa de Vulnerabilidade da População do Estado

do Rio de Janeiro aos Impactos das Mudanças Climáticas nas Áreas: Social, Saúde e Ambiente". Rio de Janeiro: FIOCRUZ.

Intergovernmental Panel on Climate Change - IPCC. 2001. "Climate change 2001: Impacts, adaptation and vulnerability. Geneva: World Meteorological Organisation.

Jiang, Yong, Chris Zevenbergen, and Yongchi Ma. 2018. "Urban Pluvial Flooding and Stormwater Management: A Contemporary Review of China's Challenges and 'sponge Cities' Strategy." Environmental Science & Policy 80: 132–43. https://doi.org/10.1016/j.envsci.2017.11.016.

JvN/d. 2018. "Public Consultation Presentation: 468-476 James St N, Hamilton". Available at: https://www.slideshare.net/JohnvanNostrandDevelopments/public-consultation-presentation-468476-james-st-n-hamilton

Kendall, Sthepen, and Jonathan Teicher. 2000. "Residential Open Building, E & FN Spon." New York.

Kundzewicz, Zbigniew, Luis Mata, Nigel Arnell, Petra Döll, Pavel Kabat, Blanca Jiménez, Kathleen Miller, Taikan Oki, Zekai Şen, and Igor Shiklomanov. 2007. "Freshwater Resources and their Management". In *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 173-210.

Lamounier, Rosamonica da Fonseca. 2017. "Da autoconstrução à arquitetura aberta: o Open Building no Brasil." PhD diss., Universidade Federal de Minas Gerais.

Lawrence, A.I., J. Bryan Bills, Jiri Marsalek, B. Urbonas, and B. C. Phillips. 1999. "Total urban water cycle based management". Pages 1142–1149 In: *Proceedings of the 8th International Conference Urban Storm Drainage*, 30 August–3 September 1999. Sydney, Australia.

Lechner, Norbert. 2015. *Heating, Cooling, Lighting : Sustainable Design Methods for Architects*, Fourth Edition. Hoboken, New Jersey: John Wiley & Sons, Inc.

Lefebvre, Henri. 1996. "The right to the city." *Writings on cities*, translated

and edited by Eleonore Kofman and Elizabeth Lebas, Blackwell Publishers.

Lima, Amauri Alves Meira, and Andréa Paula de Souza. 2014. “Reflexões e Contribuições aos Estudos de Risco e Justiça Ambiental na Baixada Fluminense, Duque de Caxias-Rj.” *História, Natureza e Espaço-Revista Eletrônica do Grupo de Pesquisa NIESBF* 3, no. 2.

Liu, Huan, Yangwen Jia, and Cunwen Niu. 2017. “‘Sponge City’ Concept Helps Solve China’s Urban Water Problems.” Environmental Earth Sciences 76, no. 14: 1–5. https://doi.org/10.1007/s12665-017-6652-3.

Lotufo, José Otávio. 2020. “The Neighborhood as a buffer zone: Ecological precepts in the hydrographic basin of the black water stream”,“O Bairro como buffer zone: Preceitos ecológicos na bacia hidrográfica do córrego água preta”. In *VI Encontro da Associação Nacional de Pesquisa e Pós-graduação em Arquitetura e Urbanismo*.

Mann, Roy. 1973. *Rivers in the City*. United States of America: Praeger publishers.

McHarg, Ian. *Design with Nature*. New York: Natural History Press, 1969.

MC, Ministério das Cidades. 2010. “Plano Nacional de Habitação: Versão para debates”. Brasília: Ministério das Cidades/Secretaria Nacional de Habitação, Maio de 2010. Available at: <http://www.cidades.gov.br/images/stories/ArquivosSNH/ArquivosPDF/Publicacoes/Publiicacao_PlanHab_Capa.pdf>. Access: May 2021.

Meerow, Sara, Joshua Newell, and Melissa Stults. 2016. "Defining urban resilience: a review". In *Landscape and Urban Planning, 147, 38–49.* https://doi.org/10.1016/j.landurbplan.2015.11.011

Merringer, Ian. 2011. "History runs deep in Toronto’s Humber River". *Globe and Mail News Article*. *Globe and Mail*: Toronto. Retrieved from https://www.theglobeandmail.com/news/toronto/history-runs-deep-in-torontos-humber-river/article588348/

Meireles, Daniele. 2013. “Flooding in Parque Paulista!”, “Enchente no Parque Paulista!”. YouTube vídeo, 2:46, “Daniele Meireles”, March 18, 2013, https://www.youtube.com/watch?v=n77YgKG88Ls

Millington, Nate. 2018. “Linear Parks and the Political Ecologies of Permeability: Environmental Displacement in São Paulo, Brazil:

Linear Parks and the Political Ecologies of Permeability", *International Journal of Urban and Regional Research* 42, no. 5 (September 2018): 864–881.

Ministério do Meio Ambiente - MMA. 2012. "Convention on Biological Diversity (Convenção sobre Diversidade Biológica)". In *Panorama das Cidades e da Biodiversidade*. Rede BiodivERsA.

Ministry of Housing and Urban Rural Development (MHURD). 2014. "MHURD Announcement on Publishing Preliminary Technical Guidance for Sponge City Construction – Low Impact Development Rainwater System Construction". MHURD [2014]275. MHURD, Beijing(Available online: http://www.mohurd.gov.cn/zcfg/jsbwj_0/jsbwjcsjs/201411/t20141102_219465.html

Mitman, Gregg. 2019. “Reflections on the Plantationocene: A Conversation with Donna Haraway and Anna Tsing”, Edge Effects, 18 Jun 2019.

Molle, François, Peter Mollinga, and Philippus Wester. 2009. "Hydraulic Bureaucracies and the Hydraulic Mission: Flows of Water, Flows of Power." *Water Alternatives*, v. 2, n. 3, p. 328-349.

Moore, Rowan. 2016. “Alejandro Aravena: the shape of things to come.” *The Guardian*, April 10, 2016. Accessed December 8, 2020. https://www.theguardian.com/artanddesign/2016/apr/10/architect-alejandro-aravena-pritzker-prize-elemental-housing-iquique-constitucion-tsunami-defences.

Muehe, D. 2008. "Geomorfologia costeira". In *Geomorfologia: uma atualização de bases e conceitos*. 8. ed. Rio de Janeiro: Bertrand Brasil, p. 253-302

Nascimento, Denise Morado. 2012. “N. J. Habraken Explains The Potential Of The Open Building Approach In Architecture Practice.” *Open House International*. 37.4 (2012): 5-13. Print.

Nillesen, Anne Loes, and Jeroen Singelenberg. 2011. *Amphibious housing in the Netherlands: Architecture and urbanism on the water*. NAi.

Nogueira, Marcus Antonio Monteiro. 2008. “Baixada Fluminense: photographic memory ”, “Baixada Fluminense: memória fotográfica”. Rio de Janeiro: Inepac, 2008.

Neves, Luciana, Leandro de Deus, Antonio Oscar Junior, and Manoel Fernandes. 2019. “Land Use and Land Cover Changes and Flooding Areas – Case study of the County of Duque de Caxias / RJ”. *Revista do Departamento de Geografia* – Vol 37 (2019).

Nunes, L.H. 2015. “Urbanization and Natural Disasters: coverage of South America”, “Urbanização e Desastres Naturais: abrangência América do Sul”. São Paulo: Oficina de Textos. 112p.

Official Journal of the European Union. 2007. "Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks.", L 288, 6.11.2007 p. 27–34.

Oscar Junior, Antonio Carlos da Silva. 2012. “The landscape of the Baixada Fluminense: An analysis from a geological perspective”, “A paisagem da Baixada Fluminense: Uma análise na perspectiva geológica”. *Revista Brasileira de Geografia Física* V. 06, N. 02 (2013) 195-210

Oscar Junior, Antonio Carlos da Silva. 2015. “Extremos atmosféricos e desastres hidrometeorológicos em Duque de Caxias-RJ”. *Revista Brasileira de Climatologia*, v. 17, p. 192-208.

Oscar Junior, Antonio Carlos da Silva. 2018. “Suscetibilidade ao impacto pluviométrico na região metropolitana do Rio de Janeiro: estudo de caso no município de Duque de Caxias”. Geousp – Espaço e Tempo (Online), v. 22, n. 1, p. 210-226, mês. 2018. ISSN 2179-0892.

Osman, Amira. 2016. "Alejandro Aravena, Pritzker 2016 and some reflections from a Residencial Open Building perspective". Available at http://uj-unit2.co.za/wp-content/uploads/2016/01/Arevena-Prikzter-and-OB-some-reflections-012016.pdf.

Ottoni, Maria Luiza de Souza Oliveira. 2021. “Urban River Requalification: a proposal for the Roncador River watershed - Duque de Caxias, RJ”. Master's Thesis of Urbanism, Graduate Program in Urbanism - PROURB/ Universidade Federal do Rio de Janeiro.

Ottoni, Maria Luiza, and Ana Lucia Nogueira de Paiva Britto. 2020. “Requalificação Fluvial de Rios Urbanos: Uma Proposta para a Bacia do Rio Roncador–Duque De Caxias-RJ.” In *VI Encontro da Associação Nacional de Pesquisa e Pós-graduação em Arquitetura e*

Urbanismo. 2020.

Pachauri, Rajendra K., Myles R. Allen, Vicente R. Barros, John Broome, Wolfgang Cramer, Renate Christ, John A. Church et al. 2014. "Climate change 2014: synthesis report." *Contribution of Working Groups I, II and III to the fifth assessment report of the Intergovernmental Panel on Climate Change*. IPCC, 2014.

Pacheco, Susana Mara Miranda. 1984. "Production and reproduction of subdivisions on the peripheries of Rio de Janeiro", "Produção e reprodução de loteamentos na periferia do Rio de Janeiro". Master Thesis, Universidade Federal do Rio de Janeiro.

Pathak, Santosh. 2021. "Determinants of flood adaptation: Parametric and semiparametric assessment". *Journal of Flood Risk Management*, 14(2), p.e12699.

Pedro, João Branco. 2013. "Minha Casa Minha Vida Program: Risks, opportunities and recommendations for improving architectural and urban quality", "Programa Minha Casa Minha Vida: Riscos, oportunidades e recomendações para a melhoria da qualidade arquitetônica e urbanística." Conference: 2.º *CIHEL - Congresso Internacional da Habitação no Espaço Lusófono e 1.º CCRSEEL – Congresso Construção e Reabilitação Sustentável de Edifícios no Espaço Lusófono* At: LNEC, Lisboa, Portugal

Pires, Felipe Jacob. 2012. "Participatory construction of domestic sewage treatment systems in the Rural Settlement Olga Benário-MG", "Construção participativa de sistemas de tratamento de esgoto doméstico no Assentamento Rural Olga Benário-MG". UFV. Viçosa, MG. Available at: http://www.locus.ufv.br/handle/123456789/3786

Placido, Daniel Taboada, Leonardo Castro de Oliveira, and Marcos de Meneses Rocha. 2019. "Use of multicriteria analysis methodology to identify areas for social housing-Duque de Caxias / RJ.", "Uso de metodologia de análise multicritério para a identificação de áreas para a habitação de interesse social-Duque de Caxias/RJ." Revista Militar de Ciência e Tecnologia 36, no. 2.

Prominski, Martin, Antje Stokman, Susanne Zeller, Daniel Stimber, and Hinnerk Voermanek. 2017. *River. Space. Design: Planning Strategies, Methods and Projects for Urban Rivers*. Birkhäuser.

Raulino, Sebastiao Fernandes. 2009. "Neighborhood social constructions:

fear and consent in representations of the effects of proximity between large industrial enterprises and resident populations", "Construções sociais da vizinhança: temor e consentimento nas representações dos efeitos de proximidade entre grandes empreendimentos industriais e populações residentes". 338 f. PhD dissertation in Urban and Regional Planning – Instituto de Pesquisa e Planejamento Urbano e Regional, Universidade Federal do Rio de Janeiro, Rio de Janeiro. 2009. Available at: http://www.ippur.ufrj.br/download/pub/SebastiaoFernandesRaulino.pdf

Raulino, Sebastião Fernandes. 2016. "The Watersheds of Duque de Caxias and their Influences on the Daily Life of the Municipality's Population","As Bacias Hidrográficas de Duque de Caxias e suas Influências no Cotidiano da População do Município". In: *Duque de Caxias: O Território e sua gente*, p. 100-149. http://lurdinha.org/site/wp-content/uploads/Duque_de_Caxias_-_o_territorio_e_sua_gente.pdf

Rhodes, Christopher. 2015. "Permaculture: Regenerative – Not Merely Sustainable." *Science progress* (1916) 98, no. 4 (January): 403–412.

Richemond, Nancy Meschinet and Yvette Veyret. 2013. "The Types of Risks", "Os Tipos de Riscos". In: *O homem como vítima e agressor do meio ambiente*. 2.ed. São Paulo: Contexto.p.63-76

Riley, Ann L. Restoring Streams in Cities: a guide for planners, policymakers and citizens. United States of America: Island Press, 1998.

Roberto, Geraldo. 2013. "Flooding on March 18, 2013 at Parque Paulist, Duque de Caxias city, RJ", "Enchente 18-03-2013 Parque Paulista Duque de Caxias RJ". YouTube vídeo, 4:46, "Geraldo Roberto Fotografo", March 18, 2013, https://www.youtube.com/watch?v=Pqrepr1CivQ

Rocha, André Santos da. 2015. "Os efeitos da reestruturação econômica metropolitana na Baixada Fluminense: Apontamentos sobre o "novo" mercado imobiliário da região", *Espaço e Economia* [Online], 6 | 2015. URL: http://journals.openedition.org/espacoeconomia/1677; DOI: https://doi.org/10.4000/espacoeconomia.1677

Rodrigues, Arlete Moysés. 2004. "City Statute: social function of the city and property. Some aspects of urban population and space."

C*adernos Metrópole*. 12.

Rolnik, Raquel. 2014. "Afterword - place, inhabitance and citizenship: Right to housing and the right to the city in contemporary urban world". *International Journal of Housing Policy*, 14(3), 293_300.

Rolnik, Raquel, and Anderson Nakano. 2009. “Direito à moradia ou salvação do setor?”. *Folha de São Paulo*, São Paulo, p. A3 - A3, 14 mar. 2009.

Royse, Flávia. 2009. “Environmental recovery of urban rivers: guidelines for the Rio Botas in the Baixada Fluminense”,“Recuperação ambiental de rios urbanos: diretrizes para o Rio Botas na Baixada Fluminense”. Master's Thesis - Faculdade de Arquitetura e Urbanismo (FAU), Universidade Federal do Rio de Janeiro (UFRJ). Rio de Janeiro.

Samara, Tony, Anita Sinha, and Marnie Brady. 2013. “Putting the ‘public’ back in affordable housing: Place and politics in the era of poverty deconcentration.” *Cities*, 35, 319_326.

Sánchez-Calderón, Vladimir. “A ‘Slum River’: The Unequal Urbanization of Bogotá (Colombia) and the Transformation of the Tunjuelo River in the Twentieth Century.” In *Rivers Lost, Rivers Regained*, 123–. University of Pittsburgh Press, 2017.

Santos, Milton. 1993. *A Urbanização Brasileira. The Brazilian Urbanization*. São Paulo: Editora HUCITEC Ltda.

Schmidt III, Robert, and Simon Austin. 2016. *Adaptable architecture: Theory and Practice*. Routledge.

Silva, João Paulo Rodrigues Pacheco. 2009. "Flood mapping in Brazil: a proposal for environmental management through a geographic information system". In: *IX Postgraduate Seminar in Gepgraphy of UNESP Rio Claro*, Rio Claro. Expanded Summaries. São Paulo: Paulista State University.

Silva, José Afonso. 2010. *Brazilian Urban Law, Direito Urbanístico Brasileiro*. São Paulo, Malheiros.

Simões, Manoel Ricardo. 2007. “The shattered city: economic restructuring and municipal emancipations in the Baixada Fluminense”, “A cidade estilhaçada: reestruturação econômica e emancipações municipais na baixada fluminense”.

PhD Dissertation, Universidade Federal Fluminense, Instituto de Geociências.

Simonsen, Sturle Hauge, Reinette Biggs, Maja Schlüter, Michael Schoon, Erin Bohensky, Georgina Cundill, Vasilis Dakos, Tim Daw, Karen Kotschy, Anne Leitch, Allyson Quinlan, Garry Peterson, and Fredrik Moberg. 2013.
"Applying resilience thinking: seven principles for building resilience in social-ecological systems." *Stockholm Resilience Centre*, Stockholm, pp 1–20.
Available at: https://www.stockholmresilience.org/download/18.10119fc11455d3c557d6928/1459560241272/SRC+Applying+Resilience+final.pdf

Thorne, C., Lawson, E., Ozawa, C., Hamlin, S., and Smith, L. 2015. "Overcoming uncertainty and barriers to adoption of blue-green infrastructure for urban flood risk management", *Journal of Flood Risk Management* v. 11, issue S2.

Torres, Pedro Henrique, Mariana Vivian, and Taísa Sanches. 2019. "Capitalist production of space and environment: urban-environmental activism and green gentrification in Brazil". *Cad. Metrop.*, São Paulo, v. 21, n. 46, pp. 689-713, set/dez 2019.
Available at: http://dx.doi.org/10.1590/2236-9996.2019-4601

UN E/1992/23, Annex III at 114. 1991. *The Committee's General Comment no. 4 on the right to adequate housing*.

UN, United Nations. 2002. "Human rights: The Human Right to Decent Housing", "Direitos humanos: O Direito Humano a uma Habitação Condigna". *Lisboa: Procuradoria-Geral da República.* (Ficha Informativa Sobre Direitos Humanos n.º 21). Tradução de: Gabinete de Documentação e Direito Comparado.
Available at: https://gddc.ministeriopublico.pt/sites/default/files/documentos/pdf/ficha_informativa_21_direito_habitacao_condigna.pdf. Accessed: May 2021.

UK Department of Energy & Climate Change. 2014. "2012 UK Greenhouse Gas Emissions, Final Figures". London: *Office for National Statistics*, p.8 [Online].
Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/295961/20140204_2012_UK_Greenhouse_Gas_Emissions_Final_Figures_-_revised_27_March_2014.pdf (acessed October 2020).

Van Nostrand, John. 2000. *Pro-Home: A Progressive, Planned Approach to Affordable Home Ownership – Research Report External Research Program*. Canada Mortgage and Housing Corporation (CMHC) & Planning Alliance.

Verdélio, Andreia. 2020. “Government launches Casa Verde e Amarela Program”, “Governo lança Programa Casa Verde e Amarela”. *Agência Brasil*. Accessed March 27 2021.

“Villa Verde Housing / ELEMENTAL” 13 Nov 2013. *ArchDaily*. Accessed Dec 8, 2020. <https://www.archdaily.com/447381/villa-verde-housing-elemental> ISSN 0719-8884

Water Infrastructure Improvement Act. 2019. "Water Infrastructure Improvement Act", US Congress, PUBLIC LAW 115–436—JAN. 14, 2019.

Watson, Donald, and Michele Adams. 2010. *Design for flooding: Architecture, landscape, and urban design for resilience to climate change*. John Wiley & sons.

McDonough, William, and Michael Braungart. 2000. “Eco-effectiveness: a New Design Strategy” in D.E. Brown, M. Fox, and M.R. Pelletier, eds., *Sustainable Architecture: White Papers* (New York: Earth Pledge Foundation, 2000), p. 3.

Williams, Erica. 2009. "Aquatecture: Architectural adaptation to rising sea level [Online]". Scholar Commons Graduate Theses and Dissertations. Available at: http://scholarcommons.usf.edu/cgi/viewcontent.cgi?article=1084&context=etd. [Accessed 13 March 2021].

Woods Ballard B.W., Wilson S., Udale-Clarke H., Illman S., Scott T., Ashley R. and Kellagher R. 2015. "The SuDS Manual", Version 5 including errata 2016, CIRIA, C753, London, UK (ISBN: 978-0-86017-760-9), 968 pages. Go to: www.ciria.org