ECOSYSTEM-BASED BIOMIMICRY AS A POTENTIAL INFORMER OF REGENERATIVE ARCHITECTURE:

a Proposed Regenerative Research Centre on the Docks of the Durban Bay

Jared Mac Millan

A Dissertation Submitted in partial fulfilment of the
Requirements for the degree of Master of Architecture to
the School of Built Environment and Development Studies
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DECLARATION

Submitted in fulfilment of the requirements for the degree of Master's in Architecture, for the Postgraduate program of Architecture at the University of Kwa-Zulu Natal, Durban, South Africa.

I declare that this dissertation is my own unaided work. All citations and references have been duly acknowledged. It is being submitted for the degree of Master in Architecture in the faculty of Humanities, Built Environment and Development Studies, Kwa-Zulu Natal, Durban, South Africa.

None of the presented work has been submitted previously for any degree or examination at any other University or institution for higher learning.

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ABSTRACT

The context of the 21st century is the epoch of the 'Anthropocene' which characterizes the contemporary geological age we have entered – one defined by causative human activity and its decisive influence on planetary systems. This stems from the conceptualisation of human systems to be separate from natural systems leading to a problematic relationship between man and nature. This is manifested through our built environments where processes of urbanization and industrialization continue to pollute and degrade ecosystems both in & beyond their hinterlands.

The built environment has been identified as a potential medium for mitigating the causes for ecosystem degradation and the loss of biodiversity – because of its role as a driver of ecosystem degradation, because it is the primary habitat for humans, and because the built environment presents potential opportunities for change.

The purpose of this research was to explore regenerative design as a means for the built environment to restore the capacity of ecosystems. The research focussed on ecosystem-based biomimicry as a potential informer for regenerative architecture, so that it may motivate architecture as a vital component in the regeneration of local biodiversity and the wider ecological habitat. The research was primarily focused on the city of Durban and in particular the Durban Bay.

The study is of an interdisciplinary nature and gathers insight from experts in their respective fields. The disciplines explored were Architecture, Urban Design and Town planning, Ecology, and Biomimicry.

The research findings indicate that there is a need for socio-ecological change in the way we conceive of our built environments, to re-think the problematic relationship between man, the built environment, and the ecologies that they are an intrinsic part of. Regenerative Design begins to alter this relationship, and promotes the positive integration with ecological systems, regenerating ecosystems particularly in human dominated urban contexts. Mimicking ecosystems goes beyond a basic understanding of local ecological systems, but rather critically changes how buildings should function in relation to nature, shifting from a consumer of ecosystems towards a producer of natural resources.

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CHAPTER ONE: INTRODUCTION TO RESEARCH

1.0 Introduction

This chapter describes the background, objectives, aims and scope of the research to be undertaken. The chapter begins by establishing the state of the planetary systems, which is under severe stress from causative human activity, posing urgent challenges such as climate change and the degradation of ecosystems leading to biodiversity loss, while understanding the consequences of these issues in the context of the built environment. Our cities and inherently our built environments have a primarily negative relationship with the natural environment causing ecosystem degradation leading towards biodiversity loss. Therefore, the study focusses on the built environment as a means of positive environmental change for the regeneration of degraded habitats. Lastly, the study explores the locale of the Durban bay, in South Africa, whereby it is established that the development of the city has largely been at the expense of local ecosystems. The Durban Bay estuarine ecosystem continues to provide ecosystem services to the city and its inhabitants; however, it is in a critical condition. Thus, it is drawn from the literature that architecture may have a pivotal part to engage in the regeneration of the Durban Bay estuarine ecosystem.

1.1 Research Background

1.1.1The Planet, Climate and Ecosystems

The context of the 21st century is the epoch of the 'Anthropocene' (Crutzen & Stoermer, 2000, pp. 17-18) which characterizes the contemporary geological age we have entered – one defined by causative human activity and its decisive influence on planetary systems. It is increasingly evident that the climatic conditions that support life on earth are changing (IPCC, 2007d). These Climatic conditions support not only humans, but all forms of life which inhabit our planet including the complex interrelationship between them (Parmesan, 2006). Ecosystems are understood as the networks of interrelationships. Human activity has become a primary driver for climate change and the damage of ecosystems, meaning most of earths' life-supporting ecosystems are in decline or in a critical condition. (Walther, et al., 2002). A study compiled by the Millennium Ecosystem Assessment (2005b) indicates that 60% ecosystems services provided by the planet are currently being managed in an unsustainable manner and are severely degraded.

Negative impacts of human activity towards ecosystem damage and climate change include: the pollution of the atmosphere, oceans, waterways, and soil from commercial, industrial, agricultural and transportation activities which all create and dispose of wastes (IPCC, 2007c); the clearance of natural habitats for urban and agricultural development (Rands, et al., 2010); as well as the unsustainable and exponential consumption of natural resources (Macgranahan, et al., 2005). These issues are exacerbated by planetary urbanization and increasing global population that demand an increased use of natural resources for energy (Rands, et al., 2010). Each of these drivers of change are important to address. However, it is the convergent effects of these factors, that present an ecosystemic crisis in need of response on a large scale (Brook, et al., 2008). Within the context of our cities, architecture may be well positioned as a catalyst for changing the way our built environments are conceived in response to these global issues from the bottom up.

Contemporary human civilization within its' current trajectory is in danger, largely due to the interrelated issues of climate change and ecosystem degradation leading to the loss of biodiversity (MEA, 2005a; Rands, et al., 2010). These problems which are human induced, and indicate that current mode of living, understanding, and relating to the world is not conducive for the long-term existence and survival of humanity (Turner, 2008). As Zari (2018) illustrates [see figure 1], humans are nested within ecosystems, and are not separate from them. Furthermore, ecosystems are a part of, and influence the planets climatic system. Therefore, humanity must now address the dualistic challenge of climate change as well as the degradation of natural ecological systems resulting in biodiversity loss.

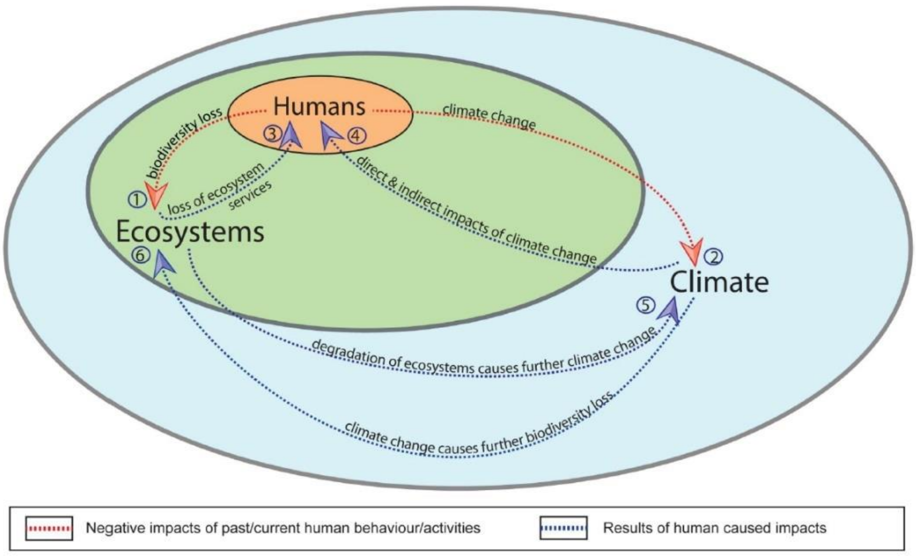

Figure 1.1 Drivers and Results Of Change (Pedersen Zari, 2018, p. 6)

The red arrows indicate the negative influence of human activity towards the climatic systems as well as ecosystems. It is widely accepted that climate change is of an anthropogenic nature (Walther, et al., 2005; IPCC, 2007d). The blue arrows represent the direct and indirect impacts of humans towards climate and ecosystems. The damage inflicted on ecosystems are cause by several human activities (Wood, et al., 2000), which result in the loss of ecosystem services and biodiversity loss (Diaz, et al., 2006). It is clear that there is a self-reinforcing relationship between climate and ecosystems, and that humanity should address both issues as one in the same.

1.1.2 Consequences of Global Biodiversity Loss

A broad definition of biodiversity is:

> *"Biodiversity is the variability among living organisms from all sources, including terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species, and of ecosystems. Biodiversity forms the foundation of the vast array of ecosystem services that critically contribute to human well-being" (MEA, 2005a).*

It is widely accepted that global biodiversity loss is anthropogenic in nature (Diaz, et al., 2006) and are exacerbated and accelerated by on-going climate change (Gitay, et al., 2002; Brook, et al., 2008). Despite current conservation efforts as well as the recognition of the benefits received by humans from ecosystems and biodiversity, the current depletion in global biodiversity are of a large and increasing trajectory (Rands, et al., 2010). Much of the global decline of biodiversity is in the developing world (Turner & Daily, 2008). The Living Planet Index indicates a 30% loss of health in the planet's species since 1970 (World Wide Fund For Nature (WWF), 2010) and 12% of this decline has occurred since 1992 (UNEP, 2011).

The current trajectory of global biodiversity loss and the damaging of ecosystems will certainly impact on human society across aspects of psychological, physical and economic well-being (Chapin, et al., 2000; MEA, 2005a). Human activity as a driver of ecosystem degradation and biodiversity loss often resulting in a loss of ecosystem services. Ecosystem services are understood as the befits that humans receive from natural ecosystems. Cities, built environments, and their inhabitants are dependent on local ecosystem services, which will continue to be exacerbated as the climate continues to change (Gitay, et al., 2002).

The survival of humanity is largely dependent on a on the health of global biodiversity because are nested within ecosystems and intrinsically affect their process and therefore the ecosystem services they provide (Diaz, et al., 2006). The loss of biodiversity leads to disruptions in the ecological processes, which in turn is likely to result in chain of cascading extinctions (Brook, et al., 2008). Thus, the need to address global biodiversity loss is as essential as addressing climate change.

Due to the symbiotic nature of climate and ecosystems (Gitay, et al., 2002; Chapin, et al., 2000) it may be possible to address the causes and impacts of climate change by restoring the health of damaged ecosystems and its biodiversity. Concurrently, this would add resilience to ecosystems and regenerate and restore ecosystem services (Chapin, et al., 2000; Rands, et al., 2010).

1.1.3 The Built Environment as a Mechanism for Environmental Change

The drivers of environmental change are vast and interconnected and almost entirely emanate from the processes of how humans live in, understand, and relate to the world around them (Pedersen Zari, 2018; Pederson Zari, 2012). The advent of the Anthropocene hypothesis has widely changed our perception of our place in the world and our role within it. There is a critical shift required in our cities and our built environments. As Paul Crutzen (2011) mentions:

> *"To master this huge shift, we must change the way we perceive ourselves and our role in the world.[…] Rather than representing yet another sign of human hubris,[the Anthropocene] would stress the enormity of humanity's responsibility as stewards of the earth.[…] Living up to the Anthropocene means building a culture that grows with Earths biological wealth instead of depleting it." (Crutzen & Schwagerl, 2011)*

Cities all over the world increasingly face ecological and societal pressures attributable to global patterns of unstainable production and consumption. The built environment has become a heavy consumer of natural resources and polluter of natural ecosystems (Newman, 2006). The context of the global climate and environmental changes further exacerbated by an ever-growing human population – projected to be 9 billion inhabitants by 2050, much of this growth will be absorbed by cities (UN DESA, 2015). The contemporary process of complete urbanization of humanity worldwide which Henri Lefebvre (2003) predicted over half a century ago – with the consequent rise in "demand for inputs water, food, energy, and material resources, shelter infrastructure, transport and so on" (Cunha & de Faria, 2014, p. 2), directly contributes toward rising environmental pressures and the destruction of natural ecosystems.

Cities - largely because they are the dense built environments primarily for humans - play a critical in the consumption of finite natural resources and the disposal of wastes. 30% of the global greenhouse gases (GHC) emissions emanate from processes related to the built environment. (UNEP, 2007). The emission of such gases have a detrimental effect on the atmosphere and are the dominant cause for climate change (Walther, et al., 2002, p. 389). UNEP (2011) states that:

> *"The global use of natural resource materials increased by over 40% between 1992 and 2005, from about 42 to nearly 60 thousand million tonnes. On a per capita basis, the increase was 27%[...] There has been a major increase in extraction of construction minerals of almost 80%"*

It is clear that our contemporary cities are treated as a linear system, which consumes critical inputs such as water, energy, food as well as number of environmental resources. Most of these resources which we consume are non-renewable and are disposed of as wastes. This perpetuates a one-way flow of materials is completely unsustainable and requires us to reconsider how cities and built environments should function in relation to the environment.

The built environment is largely responsible for a number of causes for both negative climate and ecosystem change, it is also primarily a habitat for humans, and a focus towards the built environment presents the potential for systemic change. Thus, this dissertation will focus on the built environment as a mechanism for reducing the causes for ecosystem degradation and the loss of biodiversity.

The issues presented above occur globally. Built environments continue to develop and spread due to the needs of humans, almost entirely at the expense of natural resources and ecosystems. The negative relationship between built environments, thus the following section examines the development of the city of Durban, South Africa, and how it has negatively affected the health and functioning of the local estuarine bay ecosystem.

1.1.4 The Context of The Durban Bay

The city of Durban is situated on the east coast of South Africa, characterised by a unique natural bay which has formed the focal point for the development of the city.

Historical Topography and Ecology of Durban

During the early 1800s much of the natural environment was untouched, and the dense topography and natural habitat restricted growth of the inhabitants that settled along the Durban Bay. On the coastline towards the eastern edge laid the city's primary sand dune, which stretched from the Umgeni river estuary down towards the natural bay. To the north of the bay development was restricted by a dense marshland and two streams, namely the Eastern and Western vlei, which flowed from the Umgeni river into the Durban Bay. These waterways proved to be challenging for early settlers often flooding streets in the city centre. The Durban bay was a natural haven for wide and diverse range of species, including birds, marine species, and even large mammals (Ellis, 2002; eThekweniMunicipality, 2016).

Since the early 1800s, much of existing topography and ecology have been drastically changed and reduced in order to aid in the growth of the urban centre. This resulted in a huge clearance of the mangrove forests along the water's edge, as well as draining the two vleis which flowed into the bay. Much of these changes were due to the transformation of the bay to facilitate port development. As a result, there is very little remnants of the predevelopment local ecology (Ellis, 2002; eThekweniMunicipality, 2016)

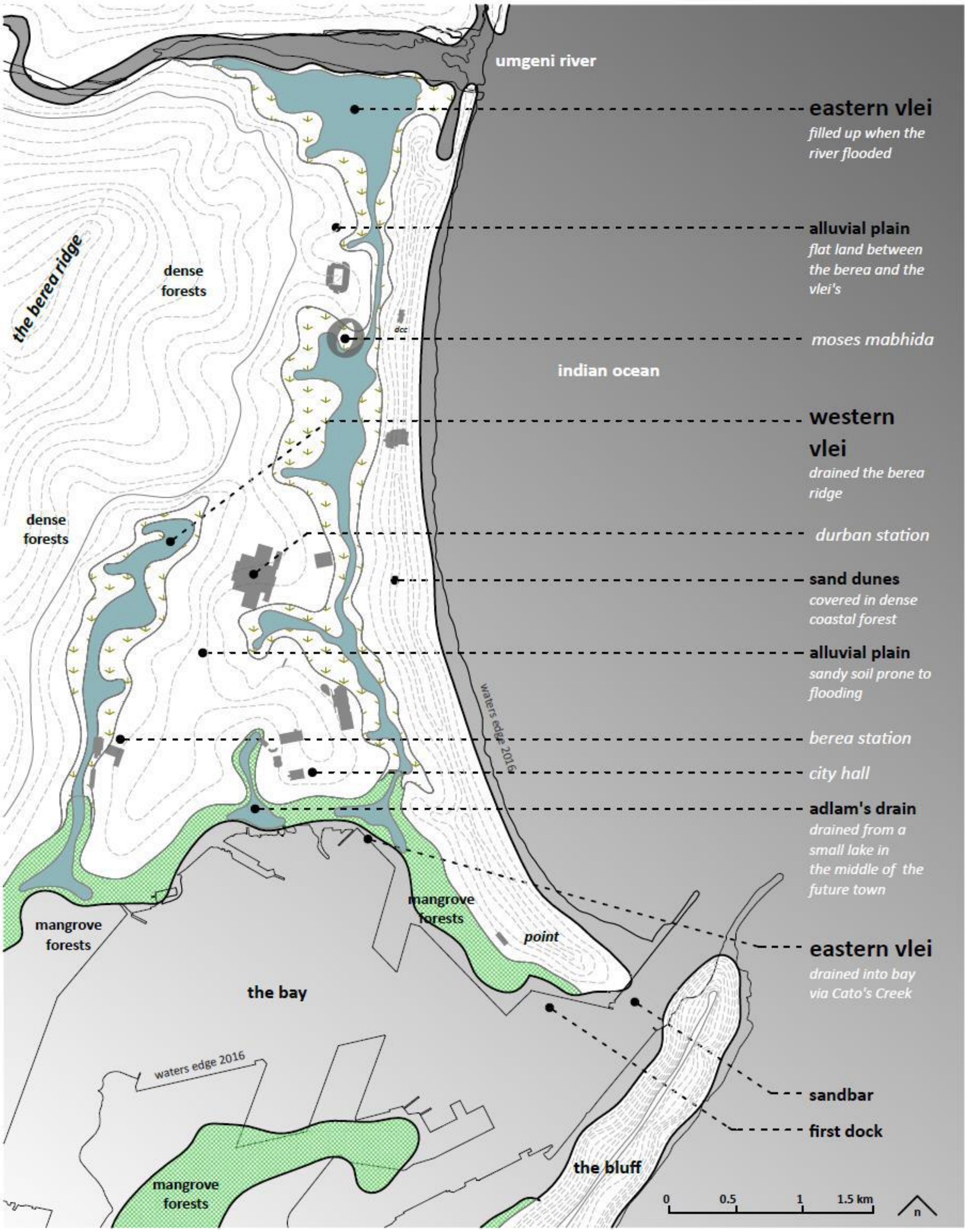

Figure 1.2: Durban Natural Environment 1823 (eThekweniMunicipality, 2016, p. 26)

Much of built environment during this time was of little negative impact towards the natural environment.

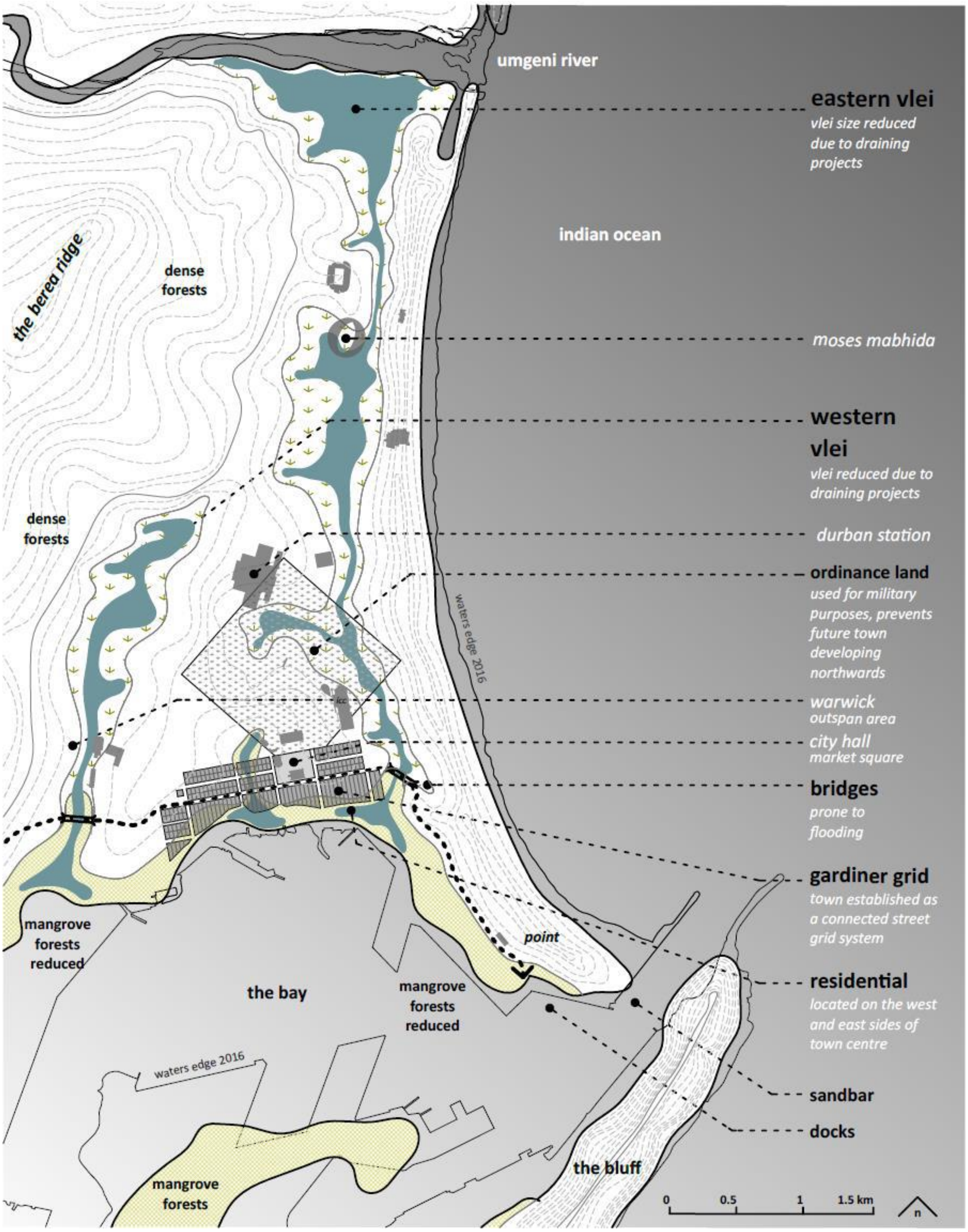

Figure 1.3: Durban Inner City 1845 (eThekweniMunicipality, 2016, p. 27)

The northern edge of the bay was primarily a dense low-lying marshland with mangrove forests. The development of the city began by filling out the marsh land and gradually reducing the mangrove forest ecosystem along the edge of the bay. The Western Vlei was reduced, and thus cutting off significant ecological processes to the bay. The built environment slowing began to impose itself on the natural environment.

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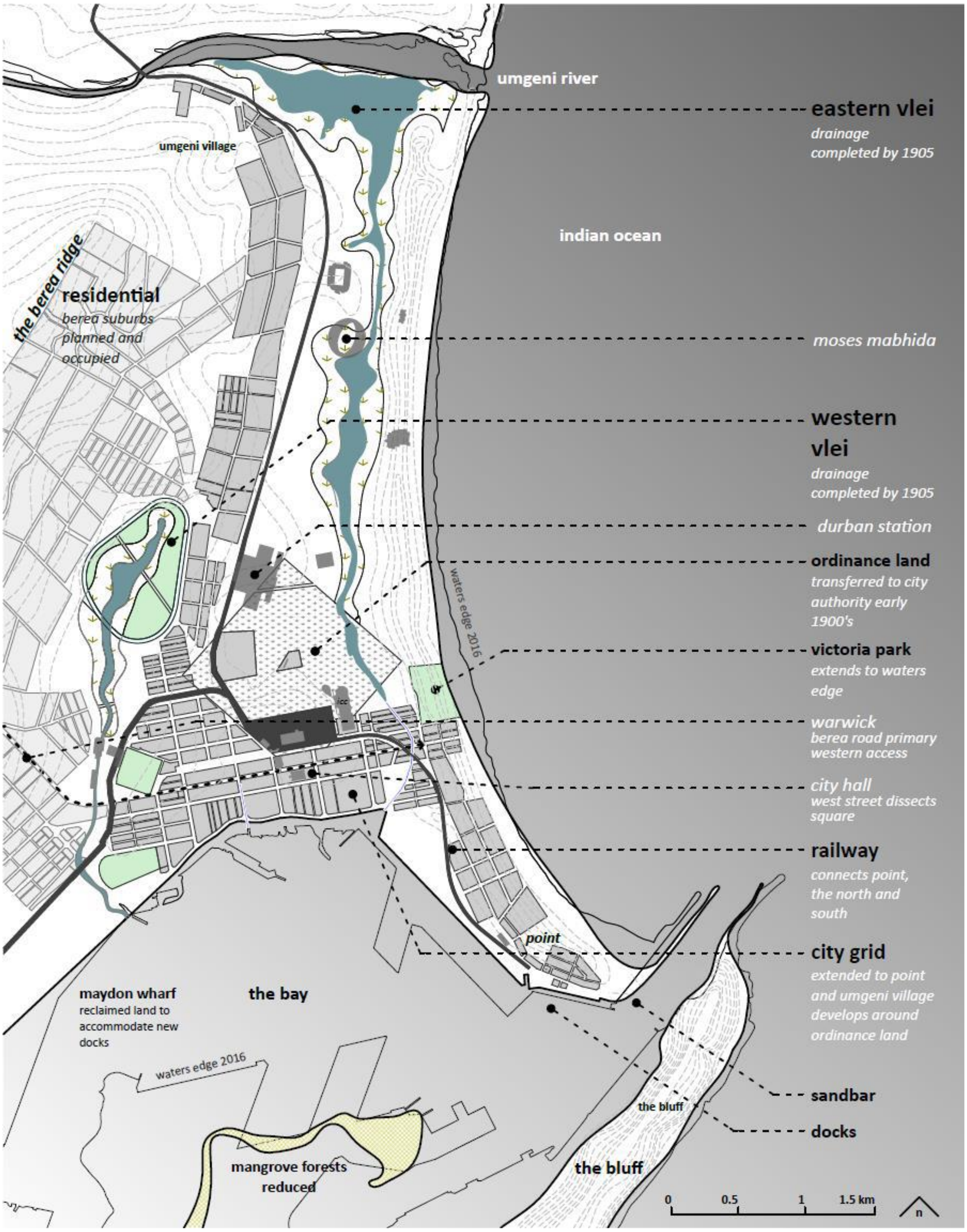


Figure1.4: Durban Inner City 1898 (eThekweniMunicipality, 2016, p. 28)

Withing half a century the city of Durban had expanded so drastically that there was little remnant of the once dense and thriving Durban bay ecosystem. Much of the mangrove forests along the edge have been reclaimed to accommodate new docks for trade.

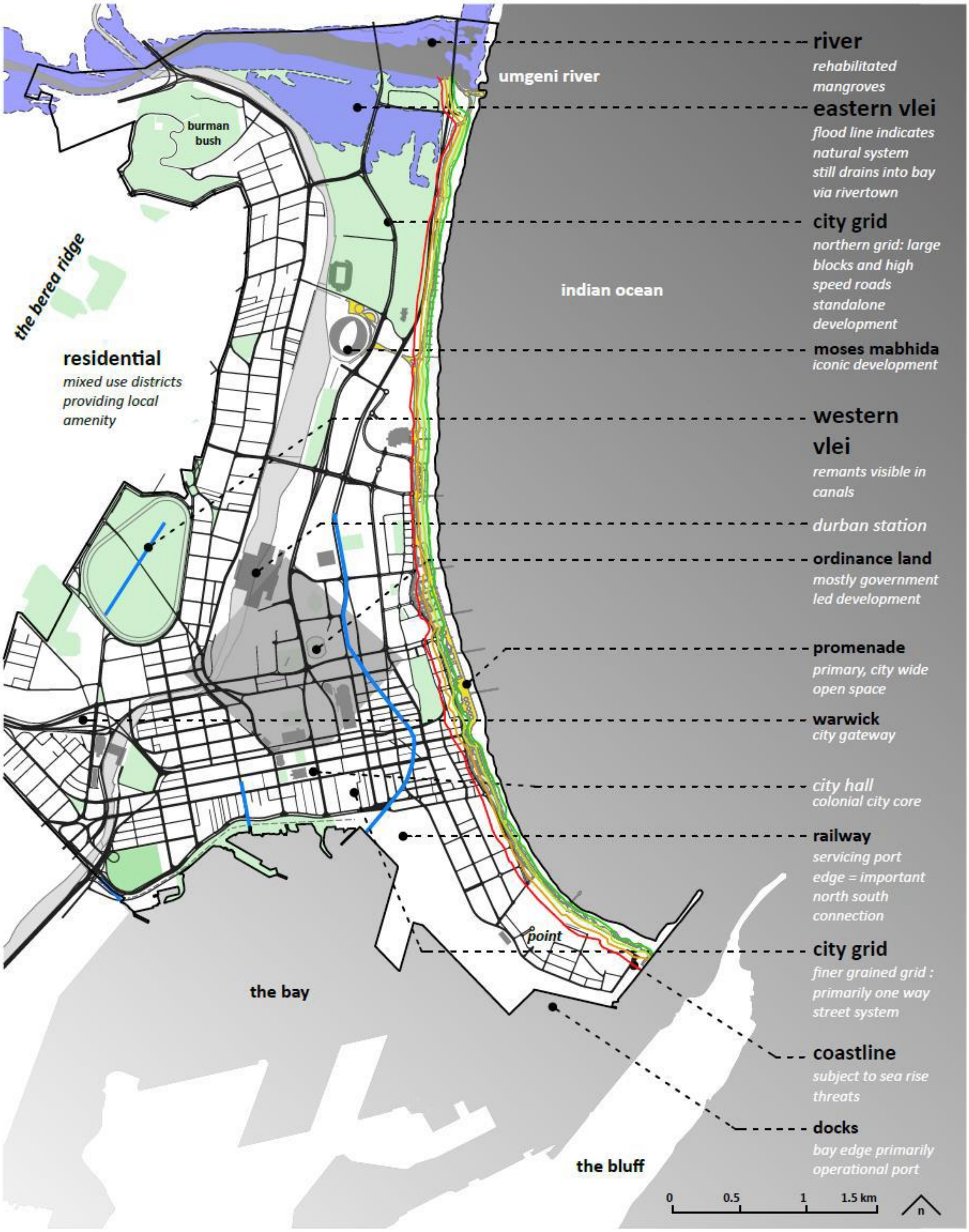


Figure 1.5: Durban Inner City 2016 (eThekweniMunicipality, 2016, p. 29)

The development of the Harbour and the city resulted in the total domination of the Durban bay ecosystem. The Durban bay has been exploited for economic purposes resulting in the almost irreversible damage of the ecosystem leading to biodiversity loss.

The role of the Durban Bay

Durban is situated on the eastern coast of South Africa, the natural qualities of the local topography and ecology served as a basis for the development of the city. There are three rivers which bring fresh water into estuarine bay. Currently, all three streams are canalised as they run through the peri-urban and urban context. There are several stormwater outlets which drain into various points along the bays edge namely, the Point, Victoria Embankment, Bayhead and Maydon Wharf (Environmental Affairs, 2015)

The Durban Bay is classified as a estuarine bay which is a large tidal system where there is both a strong freshwater as well as marine influence. Estuarine Bays are the rarest type in South Africa whereby, the Durban bay is one of three in the entire country. The Bay also known as the Port of Durban, which the largest container port in the southern hemisphere. The bay is a key asset to the country for its role in international trade (Forbes & Demetriades, 2008). Moreover, it is important resource for the city's inhabitants providing many recreational and social benefits (Environmental Affairs, 2015).

Much of the Bays natural ecosystem has been endangered while losing much of its resilience due to many contributing factors related to both "Port uses and the socio-economic activities undertaken within the catchments which drain into the bay" (Forbes & Demetriades, 2008). The Bay currently has lost much of its estuarine support habitats i.e., wetlands &mangroves. Only a total of 15 ha of the entire 440 ha of the mangrove habitat remains and is currently protected (Forbes & Demetriades, 2008). Although there are very little remnants of the predevelopment ecology which has become severely degraded, it continues to be estuary of significant importance.

Estuaries often fulfil many important social and economic functions. Natural mangrove habitats and salt marshes provide a protective layer for human settlements along the waters edge, reducing the potential damage caused by coastal storm surges. They also intercept contaminants in runoff and serve as natural filters buffering the effects of urbanisation. These social and environmental functions provided by the natural ecology are know as ecosystem services (Environmental Affairs, 2015).

As mentioned previously, the degradation of ecosystems has a direct impact on its ability to provide ecosystem services to its inhabitants. The Durban Bay Estuarine Management Plan (2015, p. 6) summarises the Situation Assessment of the Bay as follows:

Summary of Situation Assessment of the Bay
• Durban Bay is **highly modified** as a result of urban and Port development in and around the Bay. • Virtually the entire **catchment of the Bay** is either urbanised or industrialised. • The estuary has **three rivers** and **several storm water drains** which discharge into it. • Although the ecosystem is compromised to a point where it has lost much of its resilience, the Bay remains a **unique & highly productive ecosystem of local, regional and national significance; it is important to note that some of the impacts are reversible and in achieving this, the resilience of the estuary will be strengthened**. • The Bay is an important resource for citizens of Durban and continues to provide **a range of goods and services** shared by many. • However, the **Bay is highly sensitive and vulnerable**. • The Bay is home to the **leading container port** in the southern hemisphere, • **Lack of coordination of mandates** poses a challenge for the effective management of the Bay. • Opportunities exist for improving the functioning of the Bay through **more effective management of negative impacts within the estuary and its catchments**, the main effect of which would be **improved water quality**. • Explore **opportunities** for enhancing the benefits to be arrived from the Bay. For example, through the **protection and restoration of key habitats in the Bay**. • Sustainable **future port expansion could provide opportunity for enhancing estuarine functioning** (e.g. enhance circulation and create opportunities for habitat re-creation and restoration). • For the integrity of the system to be enhanced and for estuarine functioning to be improved, there is a **need to avoid, minimize or mitigate significant negative impacts**. • The EMP offers a basis **for collaboration between key stakeholders**, including private sector/entities and civil society in estuarine management.

Table 1.1Summary Assessment of the Durban Ba. Source: (Environmental Affairs, 2015, p. 6)

The city of Durban due to processes of urbanization and population growth, with increasing social and economic demands continues to exacerbate the health of the Durban bay ecosystem. Increasing pressures towards the local ecosystem, not only affects the health of the ecosystem, but also results in a decline in the ecosystem services it is able to provide. In the context of anticipated increasing social and economic demands on the estuary that is Durban Bay, it is therefore critical to ensure that the estuary is able to continue providing its valuable ‘ecosystem services’ to the city of Durban and its people, by carefully managing the impact of human activities on the functioning of the estuary while preserving and regenerating the estuarine ecosystem. Architecture may have a vital role to play in the regeneration of the Durban Bay estuarine ecosystem.

1.1.5 Motivation/Justification for The Study

The advent of the 'Anthropocene' has characterized as characterizes the contemporary geological age we have entered – one defined by causative human activity and its decisive influence on planetary systems. (Cunha & de Faria, 2014). Climatic Conditions support life as well as the complex relationships between them. These networks of relationships make up ecosystems. Most ecosystems are in a crisis or decline with 60% of global ecosystem services degraded or managed unsustainably. It is clear that there is a synergistic relationship between climate and ecosystems and that strategies to address the causes of climate change and ecosystem damage may be found in reducing biodiversity loss and restoring the health of ecosystems. This would firstly strengthen the resilience as well as restoring/creating ecosystem services (Rands, et al., 2010).

The critical condition of the Durban Bay Estuarine Ecosystem is threatening the existence of local biodiversity as well as a loss of ecosystem services provided to the city as well as its inhabitants. This is largely due to the extent of the built environment which has largely compromised the ecosystem to a point where it has lost much of its resilience and is highly sensible and vulnerable. It is important to acknowledge that although the Durban bay ecosystem is vulnerable, it remains a highly productive ecosystem, and that some damaging impacts are reversible, in an attempt to achieve this the health and resilience of the estuary will be enhanced. Thus, the built environment and architecture have a potential opportunity to reverse some of its negative impacts within the estuary and the wider ecosystem by transforming cities into life-giving environments and forming a symbiosis between man and nature.

It has been identified that the built environment plays a major role in the cause of negative climate and ecosystem changes. The built environment is the primary habitat for humans, and a focus towards the built environment thus brings about potential for change. Therefore, this thesis focusses on the built environment as a mechanism for reducing the causes of the degradation of ecosystems with specific focus on the Durban Bay Estuarine Ecosystem and its Biodiversity.

> *"Due to the non-ecological structure of the building industry and the historical lack of environmental awareness of many building professionals, the way buildings, built environments and the process of building have been created, has played a major role in the decline in Earth's ecological health. Ecosystems are life-supporting systems and building that can be sustained by ecosystems rather than damage them is urgently required." (Graham, 2003, p. 1).*

1.2 DEFINITION OF THE PROBLEM, AIMS & OBJECTIVES

Processes of urbanization and industrialization have made humanity the major consumer of nature's ecosystems. Cities are a type of socio-ecological system with a range of articulations with natures ecologies nested within planetary systems. Most of these articulations degrade and damage the environment, going well beyond the urban space. Thus, global environmental issues become apparent urgent in contemporary cities (Sassen, 2009).

1.2.1 Definition of The Problem

The 'Anthropocene' is the new geological epoch we have entered, one defined by causative human activity and its decisive influence on planetary systems. Human activity has been linked to global climate changes, furthermore inducing a cascading effect altering planetary processes and ecosystems, effectively degrading Earth's life support systems within critical condition (Cunha & de Faria, 2014).

Contemporary issues of global climate and environmental change, exacerbated by a new urban reality of an ever-growing population and the complete urbanization of the humanity around the planet (Lefebvre, 2003). Cities have become distinct socio-ecological systems with planetary reach (Sassen, 2009). Saskia Sassen indicates the critical positioning of cities given within our current ecosystemic crisis:

> *"It is now urgent to make cities and urbanization part of the solution: we need to use and build upon those features of cities that can re-orient the material and organizational ecologies of cities towards positive interactions with natures ecologies. These interactions, and the diversity of domains they cover, are themselves an emergent socio-ecological system that bridges the cities and natures ecologies [...] It is now time to develop and implement complex systems that address our environmental challenges" (Sassen, 2009, pp. 45-52)*

From this understanding, cities and architecture are uniquely at the centre of the problem, but simultaneously strategically positioned in defining our ecological future.

The gradual development and dominance of the built environment over the Durban Bay has significantly damaged the ecosystem, and in turn the ecosystem has lost its resilience and has become highly sensitive and fragile. The city of Durban depends on the Bay for a wide range of ecosystem services, which if not managed correctly are under threat. The perception of humans, and the built environment as separate from nature is problematic. Architecture should not let one value system dominate another, therefore there should be a symbiotic relationship between man and nature. Thus, there is a potential for architecture to re-orient itself towards a built environment that supports conditions conducive for life, instead of continuing to infuse synthetic chemicals and persistent waste into our valuable ecosystems.

1.2.2 Problem Statement

The fundamental challenge is the problematic relationship between man and nature. Humans and their built environments are primary drivers for climate change and ecosystem degradation. The Durban Bay plays an important role in the supply of ecosystem services to the city and its inhabitants. Processes of urbanization and industrialization continue to damage the Bay's ecosystem. The relationship between the built environment and the Durban Bay continues to be of a parasitic nature consuming a range of environmental resources. The ecological status of the Durban Bay is in a critical condition and has been severely degraded. However, much of these impacts are reversible, and in doing so resilience of the local ecosystem may be restored. The Anthropocene brings about the need to alter the way we perceive ourselves and the role in the world, building a culture that grows with earths biological wealth instead of depleting it. This thesis focusses on understanding how architecture can be a medium of positive environmental change. Architecture may be a means towards the regeneration of the Durban Bay ecosystem and its Biodiversity.

1.2.3 Aim of Research

This thesis focuses on understanding how architecture can be a medium for mitigating ecosystem degradation. This study aims to explore the phenomena of biomimicry, specifically ecosystem-based biomimicry, and its potential to contribute to regenerative architecture.

1.2.3 Objectives

Key Objective

- To explore ecosystem-based biomimicry as a potential informer for regenerative architecture. (so that architecture may become a life supporting environment that contributes towards the regeneration of local ecosystems for the mutual benefit of both human and non-human life).

Sub- Objectives

- To understand the nature of ecosystems [the interrelationships between ecosystem functions (what they do) and their potential for a regenerative architecture]
- To understand the relationship and influences on ecosystem degradation and biodiversity loss in the Durban bay
- To generate principles to be applied to an architecture that regenerates the local ecosystem and biodiversity health of the Durban Bay

1.3 Setting the Scope

1.3.1 Table of Terms

Anthropocene: The current geological age we have entered, one defined by human activity and its dominant influence on planetary systems – climate and the environment (Crutzen & Stoermer, 2000).

Biodiversity: "Biodiversity is the variability among living organisms from all sources, including terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species, and of ecosystems. Biodiversity forms the foundation of the vast array of ecosystem services that critically contribute to human well-being" (MEA, 2005a).

Biomimicry: an emerging design discipline that looks to nature genius for sustainable and regenerative design solutions (Benyus, 1997).

Built Environment: refers to man-made physical structures of buildings, including architecture that is designed for the sole purpose of human benefit, such as the city and the harbour.

Cradle-to-cradle: framework for designing manufacturing processes "powered by renewable energy, in which materials flow in safe, regenerative, closed-loop cycles", and which "identifies three key design principles in the intelligence of natural systems, which can inform human design: Waste Equals Food; Use Current Solar Income; Celebrate Diversity" (McDonough & Braungart, 2003; McDonough & Braungart, 2002)

City: Cities are manifestations of cultural, social and economic interchanges and thus cannot be singularly described. For the purpose of this dissertation however, the city will be described conceptually as a complex socio-ecological system with an expanding range of articulations with natures ecologies. A significant contributor towards climate change, ecosystem degradation leading to biodiversity loss and a major consumer of natural resources enormously destructive of the natural environment (Sassen, 2009).

Ecology: The study of living systems and their relations to one another (Dinur, 2005).

Ecological Design: Ecological Design refers to sustainability from a whole systems design perspective. Ecological design is a multifaceted field embracing green architecture, sustainable agriculture, ecological engineering, ecological restoration and regenerative development which can sustain the pattern of ecological interdependencies and nurture the conditions for all living systems to thrive.

Ecosystem-Services: Ecosystem services are the many and varied benefits to humans gifted by the natural environment and from healthy ecosystems. This research focusses on the Durban Bay and its role in sustaining the city and its inhabitants.

Ecosystem: A biological community of interacting organisms and their physical environment. A complex network or interconnected system between living and non-living organisms.

Estuarine Bay: Estuarine bays are large tidal systems where there is freshwater input but also a strong marine influence. They represent the rarest estuarine type in South Africa, where the Durban Bay is one of three in South Africa (Environmental Affairs, 2015).

Estuarine Ecosystems: Estuaries are where rivers discharge into the sea. They are semi-enclosed bodies of water, connected to the open sea, but where the sea water is diluted by fresh water from the land. Both land and sea affect estuaries, and their influence varies throughout the day and from season to season. These factors pose serious challenges for living organisms, and estuaries have developed unique ecosystems in response.

Homeostasis: The tendency towards a relatively stable equilibrium between interdependent elements, especially as maintained by physiological processes.

Living systems thinking: a thinking technology, using systemic frameworks and developmental processes, for consciously improving the capacity to apply systems thinking to the evolution of human or social living systems.

Locational Patterns: The patterns that depict the distinctive character and potential of a place and provide a dynamic mapping for designing human structures and systems that align with the living systems of a place (Mang & Reed, 2013).

Natural Environments: Natural environments encompasses all living and non-living things occurring naturally or in a state not influenced by humans on Earth (Hogan, 2013).

Natural Resources: Natural resources are substances that occur naturally. They can be sorted into two categories: biotic and abiotic. Biotic resources are gathered from the biosphere or may be grown. Abiotic resources are non-living, like minerals and metals. Natural resources are often exploited for economic gain.

Natural Resource Asset Base: Natural assets are assets of the natural environment. These consist of biological assets, land and water areas with their ecosystems, subsoil assets and air.

Resilience: The ability of a system to move through periods of episodic change and absorb or recover from disturbances without losing its functional identity.

Permaculture: a contraction of permanent agriculture or permanent culture, permaculture was developed as a system for designing ecological human habitats and food production systems based on the relationships and processes found in natural ecological communities, and the relationships and adaptations of indigenous peoples to their ecosystems.

Place: the unique, multi-layered network of ecosystems within a geographic region that results from the complex interactions through time of the natural ecology (climate, mineral and other deposits, soil, vegetation, water and wildlife, etc.) and culture (distinctive customs, expressions of values, economic activities, forms of association, ideas for education, traditions, etc.). (Mang & Reed, 2013)

Regenerative Design: Regenerative design seeks to address the continued degradation of ecosystem services by designing and developing the built environment to restore the capacity of ecosystems to function at optimal health for the mutual benefit of both human and non-human life (Pedersen Zari, 2018).

Sustainable (Sustainability): Conserving (or ability to conserve) an ecological balance by avoiding depletion of natural resources. However, this thesis suggests sustainability is no longer enough and suggests the built environment encompasses a regenerative capacity.

Symbiosis: Interaction between two different organisms living in close physical association, typically to the advantage of both.

Systems thinking: a framework for seeing interrelationships rather than things, and for seeing patterns of change rather than static "snapshots." It addresses phenomena in terms of wholeness rather than in terms of parts (Capra, 1996).

1.3.2 Delimitation of The Research Problem

The study investigates the problematic relationship between man and the natural environment, and how this is manifested in a built environment that is divorced from and continues to damage the natural environment. The study recognises that urban built environments play a major role in the negative environmental impact caused by humans, and that a critical shift is required in how we conceive of and realise our built environments. The researcher acknowledges that the urban built environments cannot alone be tasked with solving all the ecological issues identified, however it is strategically positioned as a medium of positive change for the restoration and regeneration of degraded ecosystems.

The research will focus on regenerative architecture as a means for the built environment to restore the capacity of ecosystems, particularly in the Durban Bay where processes of urbanization and industrialization have severely damaged the Durban Bay Ecosystem leading to the loss of biodiversity. The research looks towards ecosystem-based biomimicry as a potential informer for regenerative architecture. The research approach is of transdisciplinary nature which explores ecosystem processes and functions and their potential application towards architecture. The data will be informed by a diverse set of experts which will allow the researcher generate principles to be applied to an architecture that regenerates and improves natural ecosystems and biodiversity in the Durban Bay. This will inform the design of a Proposed Regenerative Centre on the Docks of the Durban Bay. The design may be influenced by other factors that are not the key focus of the research but are mentioned in the study.

1.3.3 Stating the Assumptions

This dissertation assumes that the built environment can reverse some of the negative and undeniable effects it has imposed on the natural environment. It is assumed that architecture may be conceived so that it may be a life supporting environment for all forms of life. Developing an understanding of how the living world works and what ecosystems do into architecture may be a step towards the creation and evolution of cities that are radically more sustainable and potentially regenerative.

It is understood that complex nested systems of cities, and the built environment are intrinsically similar to those of ecosystems and that there is a great deal that may be applied towards architecture. Thus, it is assumed that architecture can be a catalyst for the regeneration of the Durban Bay ecosystem and also for wider socio-cultural and environmental transformations. Thus, Architecture may cultivate and promote awareness of ecosystem services and biodiversity of the Durban Bay while fostering multiple interactions, relationships, and values.

1.3.4 Key Questions

Key Question

How may ecosystem-based biomimicry inform a Regenerative Architecture. [so that the built environment may become a life supporting environment conducive for both human and non-human life]?

Sub Questions

- How may an understanding of ecosystems and the interrelationships of their functions (what they do) be understood so that they may be applied to a regenerative architecture?
- What is the relationship between ecosystem degradation and biodiversity loss in the Durban Bay?
- What principles may be applied to architecture so that it may regenerate the local ecosystem and biodiversity health of the Durban Bay?

1.4 Concepts & Theories

Through this dissertation, the researcher sets out a theoretical & conceptual framework by exploring concepts and theories that may be applicable to the research question. The researcher will explore two theories, and two concepts which will critically guide the design process. The theories explored are Whole & Living systems thinking as well as Ecology of Mind. The theories chosen, serve to reorient our mental model of the world and our we may conceive of a built environment with the whole system in mind. The concepts investigated are those of Regenerative Design and Ecosystem-based Biomimicry which shift the role of the built environment towards contributing towards positive environmental change, growing with nature as apposed to degrading it. By setting out this theoretical and conceptual framework the researcher will develop principles which may be applied to a regenerative architecture.

1.4.1 Regenerative Design

Regenerative design is described by Reed (2007, p. 677) as offering, instead, a process:

> *"that engages all the key stakeholders and processes of the place – humans, other biotic systems, earth systems, and the consciousness that connects them – [to build] the capability of people and the 'more than human' participants to engage in continuous and healthy relationship through co-evolution".*

There are three fundamental aspects when creating regenerative conditions. These aspects are not conceived as steps but rather a cyclical spiral whereby the process continuously evolves as the context continually changes over time (Reed, 2007, p. 678).

These aspects are:

- understanding the master pattern of place (defining the necessary health-generating network of relationships for a project in a specific place it seeks to inhabit)
- translating these patterns into design principles guiding the conceptual design
- a conscious process of ongoing learning, evaluation and feedback

It is on the basis of this that the theoretical framework is set to critically inform a regenerative built environment, which will be explored in Chapter Three.

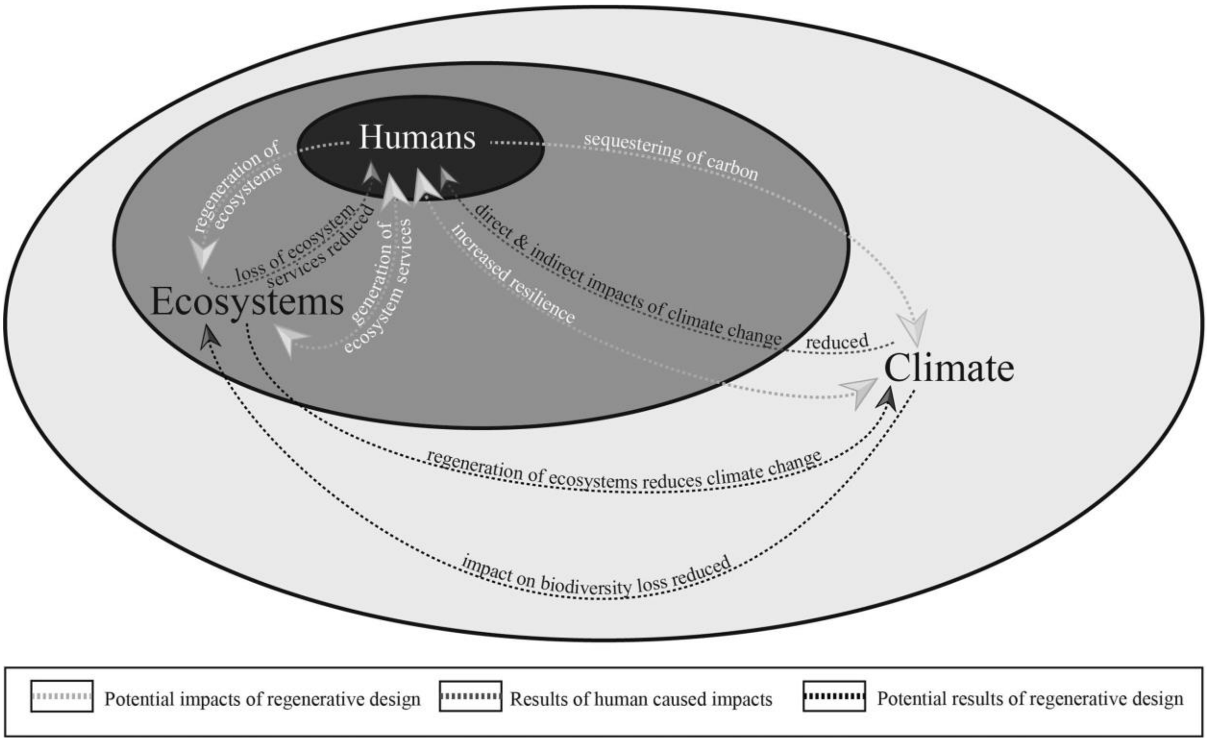


Figure 1.6 Impacts of Regenerative Design. Source: (Pedersen Zari, 2018, p. 6)

1.4.2 Living/Whole Systems Thinking

The critical issue is the need for significant change in our mechanistic mental model of the world, towards one that encapsulates new understandings of how the world works, enabling humans to design, build and heal with the whole system in mind (Reed, 2007). Whole/Living Systems Thinking represents a method of understanding how elements and systems are related, and their influence on one another in the context of the whole. This is particularly useful given our dualistic separation between man-made systems and natural systems. Systems thinking focusses on cyclical rather than linear a cause and effect.

1.4.3 Ecology of Mind

Within the context of this study, Ecology is used as philosophical methodological tool in the process of interpretation and intervention within the complex reality of our current ecosystemic crisis. This may inform an architecture that is not only reduced to environmental challenges but also addresses wider conditions of the whole environment, of social relations, and of human subjectivity (Cunha & de Faria, 2014). Furthermore, Ecology of mind will be explored further mind. Ecology of as it focusses on the unity of the human mind and nature. It is further explored whether a shift in the human mindset towards the environment may begin to shift our perception and role within the natural world.

1.4.4 Ecosystem-based Biomimicry

Lastly, the concept of ecosystem-based biomimicry derived by Pedersen Zari (Pederson Zari, 2012) whereby mimicking ecosystem functions and services may be useful for regenerative urban built environments. She sees a number of advantages which will be explored. Critical to her work is an ecosystem services analysis for a particular place, analysing what is the best an ecosystem can do on the same site and climate, as opposed to a generalized approaches or standards defined by humans. Importantly Pedersen has developed principles for the application of ecosystem biomimicry at a functional level to the built environment, it is foreseen that this framework will enable designers and architects to begin to understand how to apply place specific ecological knowledge a beyond simplistic level of application in our built environments and providing a scientific basis for environmental goals and design imperatives (Pederson Zari, 2012).

1.4.5 Theoretical & Conceptual Framework

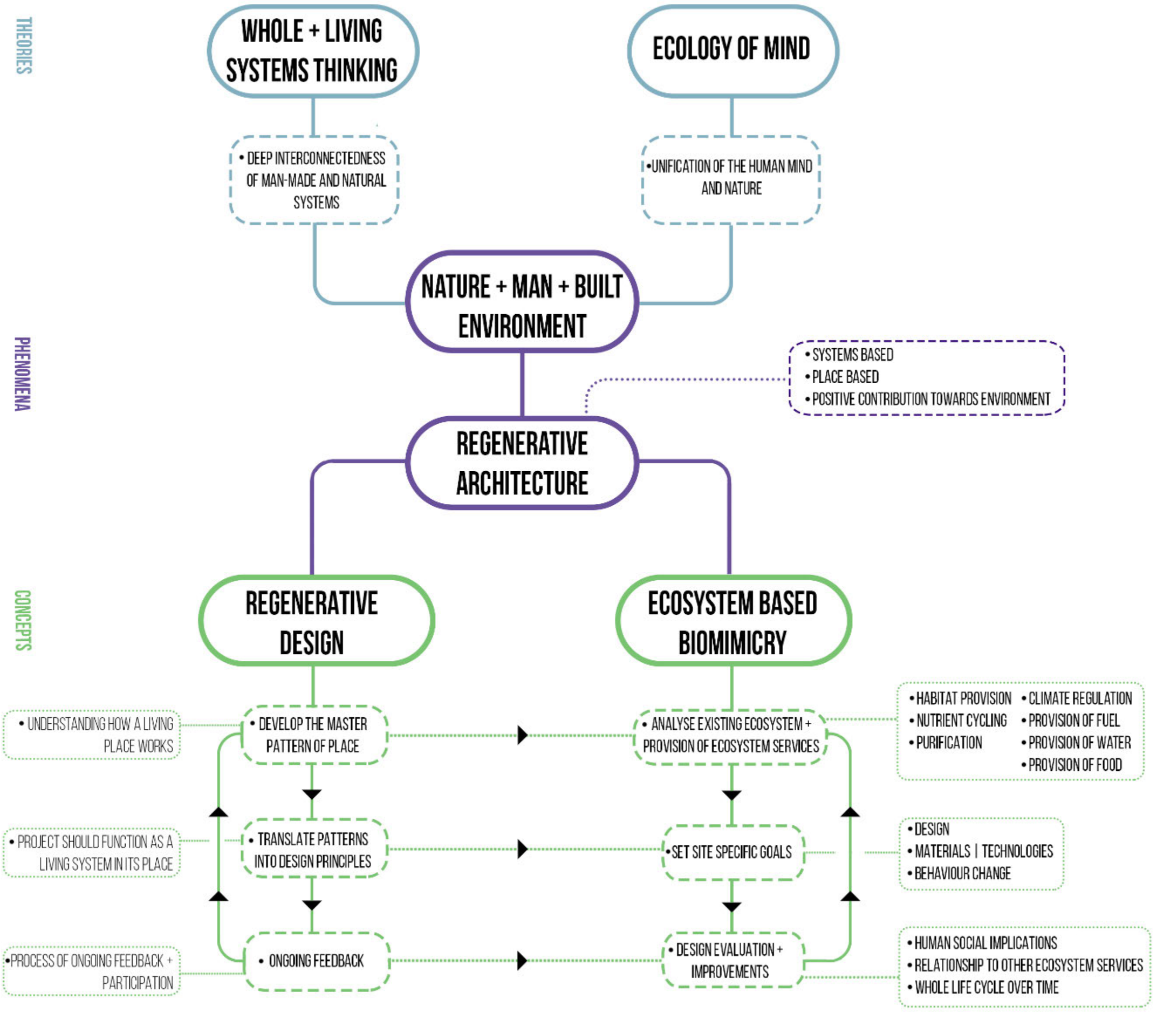


Figure 1.7 Theoretical & Conceptual Framework (Image developed by author 2020)

1.5 Research Methodology and Materials

This section defines the research methodology and approach which is applied to this dissertation. It outlines methods for data collection and identifies the techniques used to gather the information for the study.

Approach:

The research study implemented a qualitative approach within the interpretative paradigm which promotes the researcher to interpret elements of the study. The interpretivist paradigm requires an understanding of knowledge and science. Furthermore, the research used a qualitative approach which takes the interpretation of subject views as a starting point for the study.

The purpose of this research was to explore regenerative design as a means for the built environment to restore the capacity of ecosystems. The research focussed on ecosystem-based biomimicry as a potential informer for regenerative architecture, so that it may motivate architecture as a vital component in the regeneration of local biodiversity and the wider ecological habitat. The research was primarily focused on the city of Durban and in particular the Durban Bay.

Primary Data Collection:

The research focussed on understanding ecosystem-based biomimicry as a potential informer for regenerative architecture, and therefore required a transdisciplinary approach seeking valuable insight from experts in their respective fields.

The researcher acknowledged the implications of gathering data during the current covid19 pandemic. The researcher acknowledged the restrictions of face-to-face contact or the inability to perform case studies and observations. The researcher used a desktop approach in gathering data via email and zoom with the selected experts.

Expert Interviews: The study is of an interdisciplinary nature and required insight from experts in their fields. The disciplines explored were Architecture, Urban Design and Town planning, Ecology, and Biomimicry. This allowed the researcher to purposefully select individuals who meet the respective criteria assuring that the research identified the 'right' cases for the study. The researcher interviewed an expert in their respective fields. Some participants have knowledge from more than one field, aiding in the interdisciplinary nature of the study. The researcher conducted four expert interviews varying and overlapping fields of expertise. The fields were ecologists, biomimicry experts, architects, engineers, urban designers. The researcher set up virtual meetings on Zoom, which varied from 45-70 minutes each. Each of the meetings were transcribed and thematically coded. The researcher conducted interviews until saturation was reached due to respective data gathered.

Semi-structured Interviews: These experts may be, but are not limited to ecologists, biomimicry experts, conservationists, architects, urban designers, and engineers. The data gathered is crucial to gain information from a transdisciplinary approach from samples that have first-hand experience in their fields which may inform the research.

Sampling - Purposive: The study is of a transdisciplinary nature and required insight from experts in their fields. The research is considered primarily with experts with backgrounds in biomimicry, ecology, biodiversity, engineering, and the built environment. This allows for the researcher to purposefully search for individuals who meet these criteria and will assure that the research has identified the 'right' cases for the study.

Data Analysis: The data collected from interviews was familiarized and inductive general codes and themes were generated from this. All the data collected was broken down according to the themes identified for the development of a conceptual framework, where it was interpreted to inform architecture as a vital component in the regeneration of natural ecosystems and the wider ecological habitat.

Secondary Research:

Secondary research is comprised of various published media such as books by various authors; journal articles by various authors; reports, documents and academic papers; and the world wide web.

Through-out this dissertation, the research explores and builds on concepts and theories that are relevant to the study's focus. Furthermore, a literature review is conducted by the researcher where various bodies of published literature are explored in relation to the research question posed, so that the researcher may develop an argument that will be presented for ecosystem-based biomimicry and regenerative architecture. Empirical studies gained through the sources mentioned above will assist in developing a critical argument presented by the research question that will be further tested by the primary sources and data analysis.

1.6 Conclusion

The chapter highlighted the new geological epoch we have entered – 'the Anthropocene' - one defined by causative human activity and its decisive influence on planetary systems. This stems from the conceptualisation of human systems to be separate from natural systems leading to a problematic relationship between man and nature. This is manifested through our built environments where processes of urbanization and industrialization continue to pollute and degrade ecosystems both in & beyond their hinterlands.

The built environment has been identified as a potential medium for mitigating the causes for ecosystem degradation and the loss of biodiversity – because of its role as a driver of ecosystem degradation, because it is the primary habitat for humans, and because the built environment presents potential opportunities for change.

The natural topography and ecology of the Durban Bay have been altered drastically since the early 1880s in order to facilitate development of the inner city of Durban. It was further established that the Durban Bay's natural ecosystem plays an important role in the supply of ecosystem services to the city and its inhabitants. However, the ecological status of the Durban bay is in a critical condition.

Thus, the built environment and architecture have a potential opportunity to reverse some of its negative impacts within the estuary and the wider ecosystem by transforming cities into life-giving environments and forming a symbiosis between man and nature.

The research has been critically guided by the conceptual, theoretical framework and research methodology which was put in place. Chapter Two undertakes secondary research by means of a literature review. The specific theoretical and conceptual framework has been established in chapter one and is explored further in chapter Three. Chapter four explores relevant precedent studies focussed around key areas defined by the theoretical framework. Lastly, data gathered from research is thematically coded and analysed whereby the findings of the research is presented along with the key principles that will inform a regenerative research centre on the docks of the Durban bay.

CHAPTER TWO | LITERATURE REVIEW: TOWARDS A REGENERATIVE BUILT ENVIRONMENT

> *"The power of abstract thinking has led us to treat the natural environment – the web of life – as if it consisted of separate parts, to be exploited by different interest groups [. . .] To regain our full humanity, we have to regain our experience of connectedness with the entire web of life. This reconnecting, 'religio' in Latin, is the very essence of the spiritual grounding of deep ecology" (Capra, 1996, p. 296)*

2.1 Introduction

It has been established that the built environment plays a major role in the degradation and damage of environmental systems. This chapter will be reviewing literature within the field of architecture, more specifically sustainability of the built environment as a response to our current ecosystemic crisis. Two dominant paradigms within the sustainability discourse- *'Negotiated Sustainability'* and *'Ecological Modernization'*- will be juxtaposed with an emerging paradigm – *'Radical Ecologism'* (Du Plessis, 2012; Kidd, 1992). It is argued that these dominant sustainability paradigms- *Negotiated Sustainability'* and *'Ecological Modernization'*- fall short and have reached their limitations in the context of our complex-ecological crisis, representing a too narrow and mechanistic response failing to engage with a highly complex, dynamic, and living world (Capra, 1996). It is further argued that the emerging *'Radical Ecologism'* paradigm – which underlies regenerative design and development – provides an alternative that shifts from a fragmented towards a whole systems model – designed to engage with the living world (Reed, 2007). It represents an emerging sustainability paradigm that is relevant to an ecological worldview as opposed to the two dominant sustainability paradigms that are conceptually based on an inappropriate mechanistic worldview. The regenerative sustainability paradigm displays a move toward holistic living systems as a critical point of enquiry towards issues with sustainability. Fundamental to this paradigm is the need to address the problematic human-nature relationship by forming a mutually exclusive partnership with nature based on strategies of adaption, resilience, and regeneration (Du Plessis, 2012). Regenerative design and development require an in-depth ecological understanding of particular place. It is therefore posited that ecosystem-based biomimicry may be a potential informer of regenerative architecture. Therefore, it is anticipated that by understanding and mimicking ecosystemic processes and functions architects may be able to determine the most beneficial health-generating pattern of relationships for a particular project in its place – i.e. understanding the master pattern of place (Reed, 2007).

2.2 The Premise of Sustainable Development

It is necessary to situate the concept of regenerative design within the general background of sustainability. The following section serves to recognise the early influences and origins of the sustainability discourse from various social, cultural and worldview perspectives. This will lay the foundations for the chapter establishing the dominant paradigms within the sustainability discourse. Thus, the aim of this chapter is to juxtapose the emergent *'Radical Ecologism'* paradigm with the two dominant sustainability paradigms - *'Negotiated Sustainability'* and *'Ecological Modernization'*- through a historical and chronological understanding of their evolution.

Kidd (1992, p. 2) describes how the concept of sustainability emerged out of several differing yet often interlinked theoretical underpinnings, which were themselves the result of larger societal concerns which indeed shaped the vision of the state, private sector and civil society subsequent to world war two. Each of these sustainability paradigms which will be discussed, emerging as a response to rising challenges in the context of natural and socio-cultural environments. This is particularly critical in the 20^{th} century where the extent of human needs, and the need to continue meeting those needs has a decisive impact on the functioning of ecological systems (Du Plessis, 2012). The contention between development and protecting natural environment is not new. The use of resources in a sustainable manner has been traced as far back as medieval German forestry methods (Held, 2000).

The origins of sustainable development emanated from the nascent environmental movement in the United States, which highlighted the need to balance the protection of the natural environment with the increasing demands of industrial and economic development. This movement then resulted in several global conferences coordinated by the United Nations (UN), with the overarching need to develop a strategy for the protection and conservation of the natural environment as a counter towards the exponentially damaging practices of industrialization (Du Plessis, 2012).

The second concern within the context of sustainable development is what was called the Brown Agenda (McGranahan & Satterthwaite, 2000), which focussed on the issues of providing an equitable, safe, and healthy habitat for an exponentially rising human populace. During the age of industrialization and following the second world war, western aspirations for a civilization based on material prosperity gained traction. The UN determined much of the global south to be underdeveloped and embraced the ideology of modernization, which is described by Hobart (1993, p. 5) as: "the transformation of traditional societies into modern ones characterized by advanced technology, material prosperity and political stability".

This modernization manifested in the context of the built environment by adopting the views of the Modern Movement and urban planning schemes based on the automobile, which was replicated throughout the world to accommodate the needs of rapid urbanisation. This resulted in much of the modernist cities exhibiting an urban fabric that was dysfunctional at a human scale, and exceedingly resource intensive (Jacobs, 1961).

Concurrently to this modernization movement, a considerable proportion of the increasing world population lived in harsh conditions without the basic access to clean water, energy, and sanitation. International conferences coordinated by the UN raised the issue of the marginalised in developing countries and highlighted the need for developmental measures. These early UN Conferences served as a catalyst towards the development a paradigm of 'Negotiated Sustainability' declared in reports such as the Habitat Agenda and Agenda 21 (Du Plessis, 2012).

Subsequently, issues were challenged about the Brown Agenda as well as the basis of the development model holistically and how planetary systems are critically at risk given the current trajectory. This brought light to the interdependent nature of planetary systems and the urgency to reconfigure the human-nature relationship (Du Plessis, 2012). From this understanding emerged a self-sufficiency movement geared towards limiting development and consumption and based on local, renewable, and available resources (Vale & Vale, 2010). As a result, practices and technologies developed by this movement - natural building materials; renewable energy generation; organic farming; permaculture and urban agriculture; and development models of eco villages – formed the basis of which the regenerative paradigm evolved from (Du Plessis, 2012).

The early approaches towards sustainable development indeed sought to tackle the critical issue of the human-nature relationship. However, these initial responses were not useful for large urban scale and failed to comprehend the urban growth and urbanization and were more pertinent for smaller villages or peri-urban contexts. The foundations laid by this movement were not in vain and continue to guide sustainable design and development policy (Du Plessis, 2012).

2.3 Internationally Negotiated Sustainability

The initial responses to the environmental crisis formed the basis for contrasting sustainability paradigms which will be discussed in this chapter. The first of these dominant sustainability paradigms to be explored is *'Negotiated Sustainability'*. Negotiated sustainability evolved in public policy and was coordinated by the United Nations geared towards developing a framework of methodologies and strategies through international agreement. As mentioned previously consensus was achieved through many international conferences and meetings organized by the UN, which resulted in the development of frameworks which became sustainable development primarily defined by the western governments of the world (Kidd, 1992).

The first international consensus report known as the Brown Agenda was the product of the 1992 Earth Summit in Rio, Brazil which served as the standard for sustainable development. (United Nations Commission on Environment and Development (UNCAD), 1992).The birth of this negotiated sustainability was the product of many publications and documents which envisioned an idealized society where the basic needs of humanity such as clean water, shelter, electricity, a safe and healthy physical and social environment, education etc. , while concurrently maintaining a healthy relationship with the environment. Based on the balance between human development and protecting the natural environment, several principles and aspects of sustainable city design were advanced, which are generally based on concepts such compact, high density cities and mixed-use neighbourhoods to name a few (Du Plessis, 2012).

Many publications in the UN documents reflected a utopic vision of sustainable cities based on concepts of ideal, liveable, and environmentally sustainable cities. A distinguished and highly criticised concept is the New Urbanism movement which referenced small-town America and European cities (Calthorpe, 2004). Principles of New urbanism city models are a compact city, medium density neighbourhoods and walkable streets, all of which connected by a system of transport nodes. Replicating these urban models outside of Europe has proved to be problematic. Ellin (1999, p. 13) points out that new urbanist ideologies succumbed to the ploy of "building new cities which resemble old ones". Frei (1999) suggests that one urban form cannot be prioritised over another, where research suggests that compact and dense cities embody economic efficient, and not fundamental providing socio-ecological benefits

There has been much criticism of the sustainability agenda driven through international consensus, questioning their definition of sustainability and whether it critically rethinks the way we think about development. The United Nations Development Programme asks: "How do we sustain development?" The semantics of the discussion around sustainable development has been skewed and reinterpreted to mean 'sustained development'. Critics have argued that the core ideals of international sustainability agenda (to address the dysfunctional relationship between man and nature) were lost, and more importantly the framework for development from which it is based is flawed (Du Plessis, 2012).

Thus, as du Plessis (2012, p. 6) argues, the sustainability agenda is in fact a product of an "ideologically inspired and politically negotiated process largely dominated by the values, traditions and economic systems of the developed world".

2.4 Ecological Modernization

While the ideologies of a negotiated sustainability were being pursued by governments, an alternate sustainability agenda was being pursued by the private sector. This resulted in the idea of 'Ecological Modernization' whereby the primary goals serves to integrate the needs of business and the needs of protecting the environment (Du Plessis, 2012). The following paradigm to be explored is the *'Ecological Modernization'* paradigm which emerged out of the 1980s and 1990s, an era where privatization combined with globalization meant that the private sector acquired influence and power that overshadows those of international governments (Mathews, 1997). This highlighted the need for sustainability advocates to engage with business, and therefore adjusting to the ideologies of business.

During an era of defined by development and consumerism, the concept of limits proved an effective argument for this paradigm. Within this context limits refers to ecological limits and the extent of finite resources which could be extracted from the natural environment before systematic collapse. The projections of "The Limits to Growth" (Meadows, et al., 1972) were heavily scrutinized, although the underlying issue finite environmental resources was accepted- largely due to the discovery of the hole in the ozone layer, as well as research indicating the rapidity and scale of environmental degradation leading to the loss of biodiversity. Therefore, the sustainability debate shifted towards determining limits and in turn, living within these limits (e.g. ecological footprint) – simply put, to determine how much damage can be inflicted within reason (Du Plessis, 2012). As a result, the objective of the debate gravitated towards economists and excluded views of environmentalists and activists. Whereby, previously the debate was structured around the human-environment relationship, the role of the economy was repositioned in a new found triad of sustainable development being; people, the planet, and profit/prosperity.

Emerging out of this paradigm are two aspects related to sustainable business practices. The first, namely *'sustainable capitalism'* (Pearce, et al., 1989) which is centred around ensuring the inheritance passed on to future generations is not diminished. The premise of sustainable capitalism is the objective of a sustainability whereby the earths capital was not in decline (Dresner, 2002). The second approach, namely 'eco efficiency' first coined by the World Business Council for Sustainable Development in 1991 (Schmidheiny, 1992). Eco-efficiency acknowledges the notion of limits to planetary resources and focuses primarily on the efficient use of resources. The premise of eco-efficiency is the role of business in searching for environmental improvements with equal economic benefits - in essence both economic and ecological efficiency, sustaining development with less impact. The concept of doing more with less is an easy premise for business to understand, and this translated directly into the built environment with a measure of improved efficiency in performance standards. As (Du Plessis, 2012, p. 8) states, this resulted in a shift (in the context of the built environment) “from design innovation to performance measurement, monitoring and evaluation”. Concurrently birthing the concept of green buildings as an influential benefit towards business. This is known as green washing whereby built environments appear to be green, but in actuality are largely unstainable and resource dependent.

Faults in the Business Model

Du Plessis (Du Plessis, 2012) points out that there are three fundamental flaws in this variance of sustainability centred on the ideals of business. Firstly, the semantics and ideals of the private sector led to the calculations of measurable limits of the natural resources as well as the monetary value attached to those resources. This approach inherently diminishes the potential to foster a better relationship between humans and the natural environment and rudimentarily transforms it into a shallow economic exchange, which reframes the sustainable development issue to one which is primarily an accountancy problem solved through sustainable capitalism (Elkington, 1998).

The second issue is the premise that sustainability may be achieved through a fragmented approach whereby the sum of these individual solutions in some way add up to form a sustainable built environment or city. Thus, it may be argued sustainability is largely problem related to systems (Capra, 1996) and therefore, what should be considered are not simply individual problems and their solutions, but rather a wholistic understanding of the interrelationships and interactions between problems in a complex constantly evolving system (Du Plessis, 2012).

Thirdly, the eco-efficiency perspective fails to recognise the complexity of systems to be managed and that “the behaviour of natural systems is fundamentally unknowable” (Rees, 1999, p. 24). This is in special regard to the prediction of limits – nature is fundamentally too complex to allow any accurate predictions. Therefore, the last issue with this approach is that it applies static thinking such as targets and criteria to complex processes, with an ideal of an optimal end state (Moffat & Kohler, 2008, p. 263).

Thus, Ecological Modernization has failed to address the destructive nature of the relationship between humans and the natural world (Du Plessis, 2012). Contrary to this is, it has been helpful in paving the way for what Hawken et al. (1999) and McDonough and Braungart (2002) describe as the next industrial revolution and the next paradigm to be discussed.

2.5 Radical Ecologism

While conflicting variants of a sustainability were being advocated by politicians and businessmen alike, another channel was being probed by the mavericks of 'radical ecologism' based on alternate worldview (Du Plessis, 2012). As du Plessis states:

> *"This worldview represented a shift from seeing the planet as a deterministic clockwork system in which humans are separate from nature to seeing it as a fundamentally interconnected, complex, living and adaptive social–ecological system that is constantly in flux. In this system, humans are seen as an integral part of nature and partners in the processes of co-creation and co-evolution instead of being merely users or clients of various ecosystem services" (Du Plessis, 2012, p. 11).*

Du Plessis (2012), indicates that this shift in worldview changes the premise by which sustainability is characterized in three critical aspects. Firstly, it initiates the idea that to be sustainable, it is crucial to step towards a "development model that aligns human developments with the creative efforts of nature" (Du Plessis, 2012, p. 10). This indicates that humans must shift their approach towards development based on inner workings of nature and not how humans would prefer nature to function. Secondly, an understanding of the world as an constantly evolving, and unpredictable system of processes that continue to shift the definition of sustainability. Thirdly, the idea that mankind and nature are not two separate entities, but rather a holistic system where humans are intrinsically involved in the "production, transformation and evolution of the ecosystem in which they are a part of" (Du Plessis, 2012, p. 10). This reconfigures the role of humans to not only be accountable for their actions but also the health of the entire system that they are a part of. It is these three insights that provide a framework for a regenerative paradigm.

2.6 Aligning Human Development with Nature

> *"The idea that we live in something called 'the environment' […] is utterly preposterous […] 'Environment' means that which surrounds or encircles us; it means a world separate from ourselves, outside us […] The real state of things, of course, is far more complex and intimate and interesting than that. The world that environs us, that is around us, is also within us. We are made of it; we eat, drink, and breathe it […] No settled family has ever called its home place an 'environment' […] The real names of the environment are the names of rivers and river valleys; creeks, ridges, and mountains; towns and cities; lakes, woodlands, lanes, roads, creatures, and people" (Berry, 1992, p. 34).*

McGrath (2003, p. 183) argues that "our attitude towards the world must be grounded in the deep structures of nature – structures that we did not place there and did not invent, but that were there before us, and must shape our responses to nature". If humans are inherently part of 'nature' or the ‘environment’, then they should follow the ‘rules of nature’. Barry commoner succinctly defines these rules as: “Everything is connected to everything else; everything has to go somewhere; there is no such thing as free lunch; and Nature knows best” (Commoner, 1971, p. 41).

The potential for constructing and designing both mutually beneficial and life-supporting relationships between natural and built environments, where the built environment follows the “non-negotiable laws of nature” (Graham, 2003, p. 8) and emulates life’s genius (Benyus, 2002) relies on the co-evolution of a number of differing sustainability strategies such as building ecology (Graham, 2003), ecological design (Van der Ryn & Cowan, 1996) and ecosystem biomimicry (Pedersen Zari, 2018). In considering urban ecosystems or the design processes of buildings and cities, these approaches are all rooted in the overarching strategy that looks towards nature not just as a partner, but also as a ‘mentor, model and measure’ (Benyus, 2002, p. iii). The concept is not to simply impersonate nature, or to even replace living systems with high-tech artificial replicas of natural systems or functions, but to design for and with nature to create cities, and built environments that function as an ecosystem, using ‘Natures designs and processes’ as the basis for human designs and processes (Kilbert, 2008, p. 367). Newman and Jennings (2008) take this approach, by suggesting to better understand the city form and dynamics of urban social-ecological systems(SESs), and develop appropriate design and development strategies for urban SESs.

The first strategy, relies on ‘designing and reconstructing ecosystems that serve human needs’ allowing biological species and ecosystems top do the work(e.g. clearing pollution) that in an environmental/infrastructure approach would have been done by mechanical means, such as scrubbers, filters and chemical precipitators (Mitsch, 1993). This approach has been used with some success in landscape restoration and the design and regenerative ecosystems for urban greening (as described by McHarg, 1969); wastewater treatment (Todd & Todd, 1993); and permaculture (Mollison, 1990).

The second strategy, ecological design is defined by van der Ryn and Cowan (1996, p. 33) as “any form of design that minimizes environmentally destructive impacts by integrating itself with living processes” and as “the effective adaption to an integration with nature’s processes”. Kibert (2008, pp. 370-372) defines it as “design which transforms matter and energy, using processes that are compatible and synergistic with nature and that are modelled on natural systems”. Resnick (Resnick, 2003) suggests that ecological design and planning processes have four main characteristics: they are responsive to local conditions, adapt to changing conditions, employ decentralized approaches, and are developed through the contribution and collaboration of many simple entities through processes of bottom-up self-organization that follow certain generative rules.

Thus, ecological design introduces goals that are focussed not only on material output, but also on hard-to quantify aspects such as connection to place, equity, and aesthetics. Designing and developing new ecological technologies, buildings, municipal infrastructure systems and urban forms would thus also necessitate the development of different processes for planning, design, decision-making and delivery systems that can respond to uncertainty and the non-rational and qualitative aspects of the planet (Du Plessis, 2012).

2.7 Creating a Regenerative Built Environment

Du Plessis, (2012, p. 15) states that Regenerative Design and Development as described by Reed (2007) and Girardet (2010) emerge out of the following philosophical departure points:

- Humans, their artifacts, and cultural constructs are an integral part of ecosystems
- Human activity should contribute positively to the functioning and evolution of ecosystems
- Human endeavours should be rooted in aspirations of the context (place)
- Development and design are an ongoing participatory and reflective process.

The over-arching focus is for the built environment and the development processes related to it, to then support and enable the 'continual evolution of culture in relationship to the evolution of life' (Mang & Reed, 2012). A regenerative design approach would prompt an increased natural and social capital that leaves 'the ecology better than before development' (Birkeland, 2008), due to the fact that it 'not only preserves and protects: it restores a lost plenitude' (Van der Ryn & Cowan, 1996, p. 37). McDonough and Baumgart (2002) refer to this approach as 'eco-effectiveness' and further suggest 'instead of using nature as a mere tool for human purposes, we can strive to become tools of nature who serve its agenda too' and by doing so amplify a world full of abundance. their mutual evolution (Du Plessis, 2012). The primary objective of regenerative design and development in the trajectory of sustainability is to construct a future where humanity may exist through a mutually supportive symbiosis with their social and biophysical environment (their whole ecological system) – supporting

This mutual evolution of the social and biophysical environment is critical in differentiating from other models of 'urban regeneration' which focuses on bringing new life to derelict, and lost spaces within cities through infrastructural upgrades and an eventual gentrification of the area. The Regenerative Design process engages and focus on the evolution of the whole system of which we are a part. Regenerative Design is described by Reed (2007) as a process that "engages all the key stakeholders and processes of the place – humans, other biotic systems, earth systems, and the consciousness that connects them – [to build] the capability of people and the 'more than human' participants to engage in continuous and healthy relationship through co-evolution".

John Tillman Lyle proposed that it is possible to develop buildings and cities with the capabilities of regenerating lost ecosystems (Lyle, 1994). The method of regenerative design has roots in bioregionalism and permaculture but has evolved since Lyle by expanding these whole system models of engaging with place to include cultural systems. This approach therefore engages with the entire social-ecological system to build to system's capacity and evolve its potential. Mang and Reed (2012)highlight how regenerative approaches are not exclusive, but rather represent a progression, building on and integrating other sustainability approaches – such as efficient use of resources, ecological design, and resilience – that operate at different levels of work, which add to the regenerative potential in a system. Du Plessis (2012) states that "the regenerative potential in a socio-ecological system is revealed through a set of processes that engage with and integrate various narratives at different levels and scales of the system" within a wholistic narrative to extract a vision, purpose, and principals to guide the development and design process.

The regenerative process develops from the macro-scale (the watershed or bioregion) to the local. The starting point for the design process can only begin by reconnecting to the essence of place, which as Mang (Mang, 2009) states this involves a "reconnection to the historical cultural, ecological, and economic patterns of place". He sees it as both a process of building scientific understanding and a "psycho-spiritual embedding" in the identity and aspirations of the particular context that asks: What does nature want to be in the place? This requires the architect to consider the context of the intervention by identifying the essence of place- the functional identity of the system and its potential. This may be understood as determining the most appropriate health generating patterns of a particular place (Reed, 2007).

The challenge is how to map this construct of place as simultaneously a spatial and a process locale described through an open system in a useful way. Attempting to get an accurate picture of all the elements in a system and the dynamics and flows between them is an impossible task. Mang and Reed (2012) propose looking for 'pattern clues' to understand the environment and the relationships comprising the system of place. This poses the question, how can architects better understand place and the most appropriate health-generating patterns of a particular place in order to maximise the regeneration and evolution of the whole system? It is posited in the theoretical framework that ecosystem-based biomimicry enables designers and architects to begin to understand how to apply ecological knowledge a beyond simplistic level of application and further integrating with ecological processes and flows. This is the premise of the theoretical framework to be discussed in the following chapter.

2.8 Summation and Conclusion

Within the context of sustainability over the last half century, three paradigms evolved and were considered. The boundaries between these paradigms although presented linearly, are blurred and in reality, occurred alongside one another with many variations and cross-pollination (Du Plessis, 2012). A common goal shared by all three sustainability paradigms is the basis of improving the human-nature relationship so that human activity and development may be sustained. The critical difference is that the regenerative paradigm recognises that this may only be achieved where conditions are created for all life to flourish and to co-evolve (Du Plessis, 2012)

Du Plessis (2012) succinctly indicates that: *"The focus of the first two paradigms is on aligning the modernization project with the realities of a limited resource base and declining ecosystem services in the context of a growing global population with expectations of ever-improving standards of living."* It was argued that these two paradigms have reached their limitations. However, these two paradigms have contributed greatly towards the discussion around sustainability and should not be negated completely.

The regenerative sustainability paradigm represents a shift towards the holistic living systems worldview held by many (Capra, 1996; Bossel, 1998; Kumar, 2002) as an important point of departure for addressing issues related to sustainability. This paradigm attempts to address the dysfunctional human-nature relationship by entering into a co-creative partnership with nature. It aims to restore and regenerate the global socio-ecological system through a reconnection to and understanding of place and the specific patterns and flows rooted to that system of place.

The regenerative paradigm brings about alternative ways to engage with nature, in two significant ways. It will build the adaptive capacity to survive the implications of global climate change and increase the regenerative capacity of the planetary system to foster conditions under which humans and other life can thrive (Du Plessis, 2012).

Reed (2007)states, a reconnection to place and to the rituals of place (system of place) would foster the shift from sustainable design to restorative and regenerative design. Fundamental to the regenerative design process is attempting to understand how the systems of life work in each place.

This is described in the literature as understanding the master pattern of place, followed by this is translating these patterns into design guidelines. The regenerative paradigm acknowledges required from architects in this regard but fails to guide the architect in developing an ecological understanding of a particular place and furthermore translating this into design principles which inform a regenerative architecture. This is the gap that this research will attempt to fil. This forms the basis for the theoretical and conceptual framework whereby the researcher posits that an ecosystem-based biomimicry may potentially inform a regenerative architecture. Thus, it is posited that ecosystem biomimicry at the functional level will enable designers and architects to begin to understand how to apply place specific ecological knowledge a beyond simplistic/generalized level of application in our built environments and providing a scientific basis for environmental goals and design imperatives (Pederson Zari, 2012).

CHAPTER THREE | THEORETICAL & CONCEPTUAL FRAMEWORK

"Imitating nature is more than flattery on the part of human kind, it is also copying systems that function in an extraordinarily successful fashion" (Kilbert, et al., 2002).

3.1 Introduction

The literature review explored the emergent regenerative paradigm and how it serves to address the dysfunctional human-nature relationship by entering into a co-creative partnership with nature. This paradigm aims to restore and regenerate the global socio-ecological system through a reconnection to and understanding of place and the specific patterns and flows rooted to that system of place (Du Plessis, 2012). The researcher has identified a gap in which this study seeks to fill. The literature on regenerative design and development acknowledges the fundamental shift required in constructing regenerative built environments. However, it is unclear in guiding built environment practitioners in developing an ecological understanding of a particular place and furthermore translating this into design principles which inform a regenerative architecture. This is the gap that this framework attempts to fill.

The chapter is divided into two parts: Theoretical framework and Conceptual Framework. The first part will explore relevant theories as necessary philosophical departure points which will inform a regenerative built environment (architecture). The theories to be explored are *'Whole & Living Systems Thinking'* and *'Ecology of Mind'.* The theoretical framework serves to reconceptualise the human-nature relationship by understanding how to co-evolve with the whole system in mind (Whole & Living Systems Thinking), as well as the realisation of how the human mind and nature can be integrated to create to create environments both built and natural, so that they may work together to sustain all forms of life (*Ecology of Mind*).

The second part & the main focus of this chapter explores the concept of regenerative design, and where it falls short in prescribing architects and designers with a method of engaging with ecological systems of a particular place. It is thus argued that the concept of ecosystem biomimicry at the functional level may move us beyond generalized/simplistic methodologies on how to work with nature by providing a scientific basis for environmental goals and design imperatives (Pedersen Zari, 2018). Mimicking ecosystems can offer insights into how the built environment could function more like a system than a set of unrelated buildings, and thus become better able to adjust to change (Pedersen Zari, 2018). Therefore, it is posited that ecosystem-based biomimicry (mimicking ecosystem functions and services) may enable designers to better understand and utilise the ecology of a particular place, and furthermore shift the mindsets and objectives of how architecture can function at a regenerative level.

3.2 Theoretical Framework

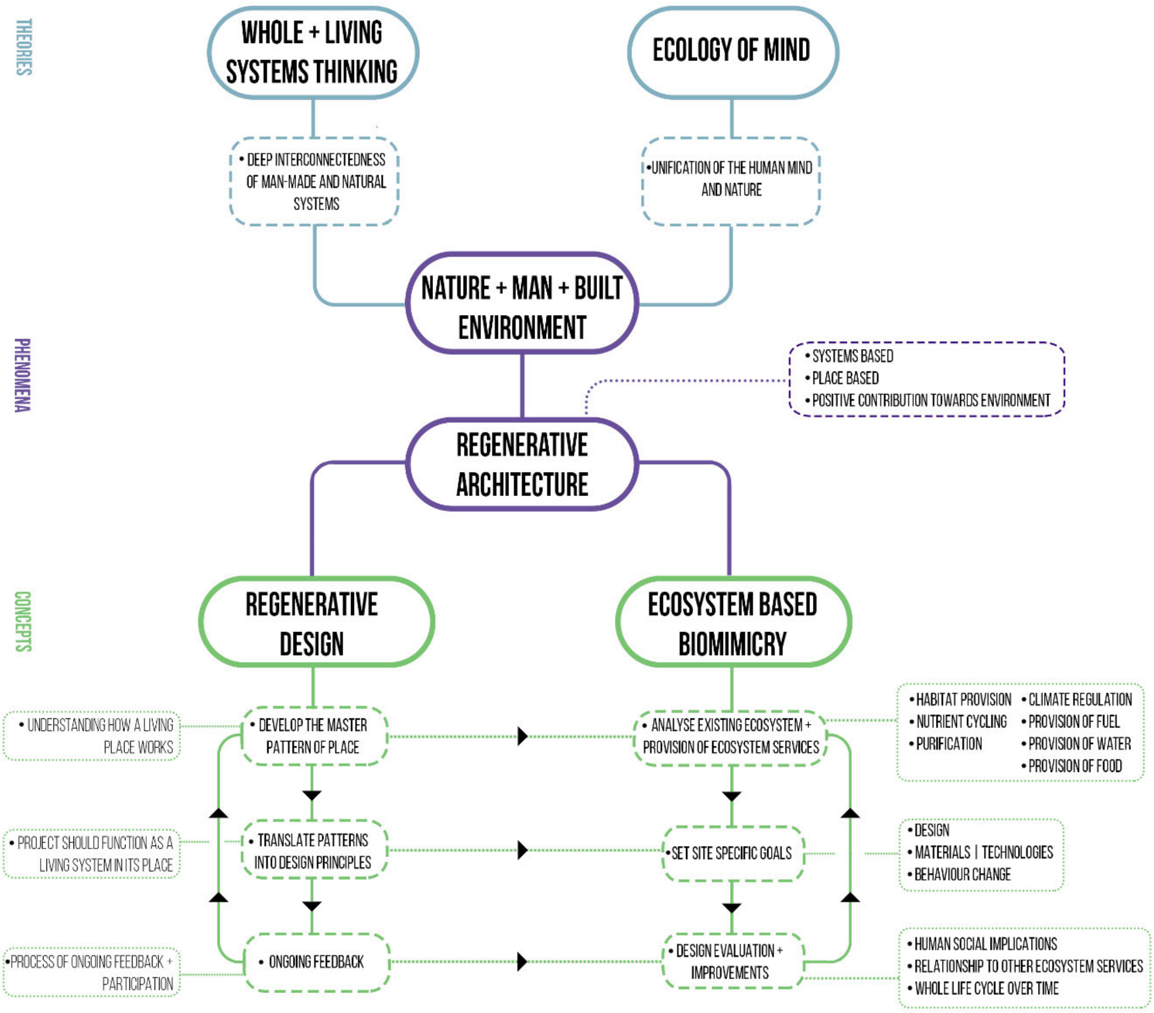


Figure 3.1 Theoretical & Conceptual Framework (Image developed by author 2020)

3.2.1 Whole and Living Systems Thinking

The advent of the Anthropocene hypothesis indeed poses a wide range of implications, but importantly brings about a collective awareness of a whole new ecological reality. Humanity is forced to reconsider our relationship with the planet, and the perception of our place and role within it. A critical and necessary shift is required in our built environments, our cities and even our lifestyles. As Peter Graham (2003) mentions:

> *"Due to the non-ecological structure of the building industry and the historical lack of environmental awareness of many building professionals, the way buildings, built environments and the process of building have been created, has played a major role in the decline in Earth's ecological health. Ecosystems are life-supporting systems and building that can be sustained by ecosystems rather than damage them is urgently required"*

This forces us to ask new kinds of questions and demands deeper reflections in the ways of thinking and doing Architecture, requiring a critical reassessment of values and practices, and a greater accountability for our actions as architects and citizens (Cunha & de Faria, 2014). A significant shift is required in our mental model towards one that better reflects the new understandings of how the world works, and also enables us to design, build and heal with the whole system in mind – a deeply integrated worldview (Reed, 2007).

A system is defined by Schoderbek, et. al. as : *"A system is set of objects together with relationships between the objects and their attributes connected or related to each other and to their environment in such a way as to form an entity or a whole"* (1975, p. 30)

Regenerative architecture is primarily systems-based which considers the interconnections within and between ecological, social, and economic systems at various scales. Whole and Living Systems Thinking represents a method of understanding how elements and systems are related, and their influence on one another in the context of the whole. This is particularly useful given our dualistic separation between man-made systems and natural systems. Systems thinking focusses on cyclical rather than linear a cause and effect. Reed (Reed, 2007) defines indicates that: "*Whole systems thinking recognizes that the entirety is interconnected, and moves us beyond mechanics into a world activated by complex interrelationships – natural systems, human social systems, and the conscious forces behind their actions."*

Whole systems thinking brings about an awareness of the deep the interconnectedness of man-made systems and natural systems. Sassen (2009), states that cities are kind of socio-ecological system that with a distinctive and expansive range of articulations with natures ecologies with planetary reach, flowing far beyond urban fabric. Thus, our current global ecological crisis, becomes apparent and urgent from the city scale, which highlights the need to develop complex systems that address environmental issues. From this perspective, cities and inherently architecture are concurrently at the centre of the problem and the solution, as they both continue to exacerbate environmental degradation while also possessing the potential in shifting the way in which built environments should function. This brings about a conscious understanding of how built environments are inextricably engaged in direct and indirect reciprocal influences from the locale of place, nested within and expanding towards planetary systems (Reed, 2007). Figure 3.1 illustrates the various nested scales of urban impacts on the biosphere showing the interconnectivity from the largest scale of the biosphere right through to the scale of the individual. Whole & Living Systems thinking forces us to think critically across scales, boundaries, and disciplines. This is particularly in reconceptualising the way cities & built environments can function from a whole systems perspective. This leads onto our next theoretical idea, Ecology of Mind where it is anticipated that the human mind and nature can be integrated to create environments both built and natural, so that they may work together to sustain all forms of life.

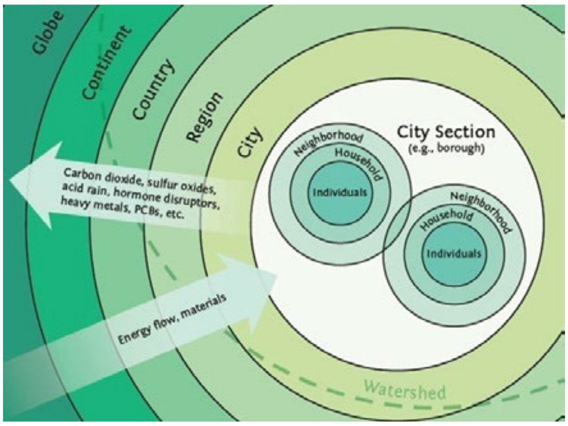


Figure 3.2 The Nested Scales of Urban Impacts on the Biosphere.

Figure shows the interconnectivity of the world from the largest scale to the scale of the individual, with watersheds showing across regions. Energy and materials – which release carbon dioxide, sulphur oxides, acid rain, hormone disruptors, heavy metals, PCBs, and other poisons that are often shipped from developed countries to developing countries – flow into the city. Each urban combination of elements is unique, as is the way it fits within local and regional ecosystems. (Ray C. Anderson, 2012, p. 37)

3.2.3 Ecology of Mind

Ecology as defined by Dinur (2005) is the: *"The study of living systems and their relations to one another."* The perception of these deep interconnections underlies the necessity of seeking new ways of cultivating our capacity to address complex-ecological systems – what key ecological theorist Gregory Bateson describes as *"the patterns that connect"* (Bateson, 1979). This emphasises the need to think ecologically and transversally across different meanings, ideas, and fields, which is prevalent given the context of our ecosystemic crisis. The use of ecology has been gradually integrated in the discourse and practice of architecture and has been regarded as a relevant methodological tool and source of knowledge, scientifically and philosophically capable of dealing with organic-complex-ecological processes and systems (Cunha & de Faria, 2014).

Our ecosystemic crisis is one that stems from the problematic relationship between man and nature. As Gregory Bateson (1973) wrote: *"The major problems in the world are the result of the difference between how nature works and the way people think*". In this sense, the critical issue is the way people think -our mindset, which may be understood as the way we perceive ourselves and our role in the world (Crutzen & Schwagerl, 2011). Jaworski states that:

Our mental model of the way the world works must shift from images of a clockwork, machinelike universe that is fixed and determined, to the model of a universe that is open, dynamic, interconnected, and full of living qualities (Jaworski, 1996, p. 183).

Humanities role in our complex and interconnected living planet is a negative one, which stems from the perception of our dualistic separation from nature and is manifested in our man-made systems and our built environments.

Graham (Graham, 2003) states that original premise of constructing buildings was in fact a response to our human physiology, surroundings, protection from weather or an attack, and to store and prepare food. All of which informed by the cultural, geographical location, climatic and economic circumstances, and all intrinsically tied to time and history. These could be understood as basic securities or needs, once these were achieved buildings were constructed for the mind; religious buildings, learning institutions, government houses etc. Thus, all buildings are constructed in relation to the perceptions of the human mind, and in turn, separated from the natural world and its living systems (Graham, 2003).

Our current ecosystemic crisis is one that stems from the dualistic separation between the human mind and that of the natural world. An endemic separation and disconnection between the built environment (architecture) and the natural environment. From this perspective McDonough appropriately asks: "Could we be any further from an architecture that sustains us and connects us with the natural world? Perhaps not." (Gisssen, 2002)

This forces us to reconceptualise the way we design and build architecture, where buildings may be able to support the functioning and regenerative capacity of ecosystems. A critical shift is required not only from the way we design, but how we perceive architecture, a shift in the human mindset (Jaworski, 1996). Primitive architecture once served to protect humans from the natural world, architecture must not serve to protect nature from humans by means of conservation, instead built environments (architecture) must enter into a co-creative partnership with nature for the benefit of the entire system, a mutually beneficial co-existence between man and nature- between living and non-living. This mutual understanding is what Bateson (Bateson, 1973) characterises as an "Ecology of Mind"

An 'Ecology of Mind' is defined by Bateson (Bateson, 1973) as the realisation of how the human mind and nature can be integrated to create to create environments both built and natural, so that they may work together to sustain all forms of life. According to Graham (2003), for much the previous millennium humans have protected the body and conceived of a world for the mind, where the perceptions of the mind have been separated from that of the natural world, and in turn resulted in the construction of human environments that were influenced by similar ideologies. An ecology of mind is beginning to advance a unification between mind and nature.

Thus, the ecosystems of the Durban bay should be identified, and the fundamental relationship between the human inhabitants and the ecosystems of the Durban bay should be understood. It is through the recognition that our existence is inseparable from nature and intrinsically connected within nature that we may begin to shift the human mindset towards reconceptualising our own built environments as one within nature.

3.3 Conceptual framework

3.3.1 Regenerative Design

The concept of Regenerative Design has its roots in an ecological worldview, a worldview where an *"almost infinite inter-relationships of "ecological systems" are the way of living entities, including humans, relate to, interact with and depend on each other in a particular landscape in order to pursue and sustain healthy lives"* (Mang & Reed, 2015, p. 135). Thus, regenerative design is an approach towards supporting the co-evolution of human and natural systems in a partnered relationship (Robinson & Cole, 2015). Furthermore, (Robinson & Cole, 2015) it is not the building itself that is being regenerated comparative to the self-healing properties of a living system; rather it is about how the process of building can be the impetus for positive change and add value to the place it is situated. Adding value to an ecological system is to *"increase its systematic capability to regenerate, sustain and evolve increasingly higher orders of vitality and viability for the life of a particular place"* (Mang & Reed, 2015).

Advocates for regenerative design make use of various theoretical and philosophical sources, however the most noteworthy are those with ecological underpinnings. Lyle (1994), considered to be an early pioneer of regenerative design elaborates that regenerative design states that the ecosystem concept should guide the relationship between humanity and nature, and that understanding of local ecosystems should inform the design of human environments.

Svec et al. (2012) identified the following basis for regenerative approaches; Regenerative practices emerge out of a perspective that is systems-based, place based and directed around creating positive outcomes towards the place/environment the project inhabits.

- A systems-based considers the interconnections within and between ecological, social, and economic systems at various scales.
- A place-based approach indicates the need to incorporate into decision making a deep understanding of the unique story of place.
- Regenerative approaches seek to contribute positive, mutually beneficial, enduring benefits to humans and ecological systems.

Reed (2007) indicates that there are three fundamental perspectives required in order to catalyse a regenerative condition. These three aspects represent an evolutionary spiral as the process creating of regenerative condition is continually evolving as the context and its ecosystems continually evolve.

This means that the process of regeneration continues long after the design team and consultants have completed the project.

the three aspects are indicated below:

- Understanding the master pattern of place
- Translating the patterns into design guidelines and conceptual design
- Ongoing feedback – a conscious process of learning and participation

As defined by Mang and Reed (2013), place is:

> *"the unique, multi-layered network of ecosystems within a geographic region that results from the complex interactions through time of the natural ecology (climate, mineral and other deposits, soil, vegetation, water and wildlife, etc.) and culture (distinctive customs, expressions of values, economic activities, forms of association, ideas for education, traditions, etc.)".*

The regenerative paradigm posits that any development should positively contribute towards all the natural, cultural, and economic systems that it affects in a place. The basis of this claim lies in notion of realising a co-creative partnership between humans and the places they inhabit. Furthermore, within the regenerative paradigm, place forms the basis for the development and design process. By understanding how a living place works, it is possible for the architect to develop and organize how the project must function as a living system nested in its place, in order to achieve a mutually beneficial relationship with the natural ecology (Mang & Reed, 2012).

This is described as understanding the master pattern of place (Reed, 2007), which requires an understanding of the patterns of relationships between parts, in order to understand how the system is sustained, how they self-organize and how the emergent outcomes are produced (Mang & Reed, 2012). The issue is that Architects generally are not equipped to deal with complex ecological knowledge and may struggle with understanding the complex relationships between the parts of the living systems of place- *the master pattern of place*.

Thus, it was posited in the literature review that the challenge within the regenerative framework lies in mapping the construct of place, by understanding the unique and multi-layered network socio-ecological systems of a particular place. To get an accurate picture of all these elements and the dynamics and flows between them is a mammoth task. It is thus posited that an ecosystem-based biomimicry may be useful in better understanding these dynamics and flows in developing the master pattern of place and in turn *translating these patterns into design guidelines or principles*. This is the basis of the following section which looks towards the key concept of Ecosystem-based biomimicry which will be explored in the following section.

3.3.2 Ecosystem-based Biomimicry

Understanding Biomimicry

The term 'Biomimicry' can be easily broken down, 'bio' translates from the Greek 'bios' meaning life, and 'mimicry' is from 'mimesis' meaning imitation (Benyus, 1997). The term 'biomimicry' originates from a multidisciplinary scientist Otto Schmitt, who first used the term in a published paper in 1969 (Bensaude-Vincent, et al., 2002). 'Biomimicry' gained popularity due to a biologist named Janine Benyus, in her book *Biomimicry – Innovation Inspired by Nature.* She described biomimicry in three parts: using 'natures models' as inspiration for designs that seek to solve human problems; using ecological standards to judge the effectiveness of innovations; and using biomimicry as a way to redefine how humans relate to nature (Benyus, 1997). Van Der Ryn & Pena (2002) state that:

> *"Designers looking to natural systems to discover analogues useful in the design of the built environment have an extremely large field of potential information to absorb. We are only at the beginning of the learning curve, shifting the guiding metaphor in architecture from thinking of buildings as static machines or works of sculpture to conceptualising them as dynamical living systems that are the very nature of Nature"*

It is clear that there is still much to learn from nature and enormous potential for our built environments to engage and integrate within the very systems and workings of nature.

Biomimicry framework

The study is concerned with developing an understanding of the living systems of a particular place and translating these into design principles/guidelines. Ecosystems are defined by complex nested hierarchies and so to there are various levels of biomimicry to be understood.

Zari (2018) has developed a framework for understanding biomimetic design which identifies the various levels and dimensions and its application within an architectural context. It also looks at how biomimicry may potentially increase the regenerative capacity of the built environment. The framework serves as a tool to determine which aspect of 'bio' is being mimicked, which is referred to as a 'level'. There are three levels of mimicry: organism, behaviour, and ecosystem which will be explored briefly.

Organism level: It is widely recognised that life on earth has been evolving from as far back as 3.8 billion years (Birkeland, 2009). There is much to learn from organisms that have developed survival mechanisms that have withstood drastic change (Spiegelhalter & Arch, 2010), thus there is a multitude of examples to be drawn from organisms that may be adapted towards societal problems. Biomimicry at the Organism level refers to a specific organism (plant or animal) and includes mimicking part of or the whole organism. An architectural example of biomimicry at the organism level would be the mimicking of the Namib desert beetle in the design of a fog catcher for the hydrological centre for the university of Namibia (Pedersen Zari, 2018). The beetle is able to capture moisture from the fog that moves over the dessert, water condense on the surface of the beetles back which run down towards his mouth. The building references the beetle by using a nylon mesh to intercept fog, hold the moisture and drain towards storage tanks.

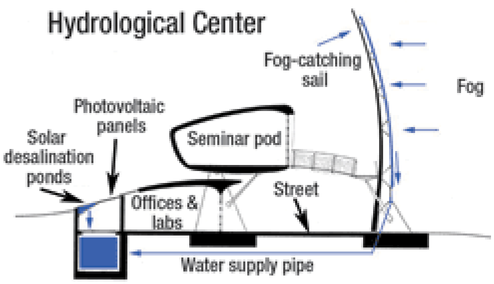


Figure 2 Matthew Parkes Hydrological Center Source: https://architecturever.com/2019/09/07/levels-of-biomimecry-and-its-importantance-part3/

It is important to acknowledge that the mimicking of an organism is generally a specific feature instead of a whole system, this biomimicry often leads to high-tech solutions that are attached to buildings rather than being an integral part of them. This results in an architecture that remain conventional and have very little to do with the whole system in mind. This is critical for a regenerative architecture.

Behaviour level: Behaviour level mimicry looks to towards the behaviour of an organism that is mimicked and not the organism itself. Organisms exist and operate within a specific context with limits of energy and material availability. These constraints result in organisms that have evolved and developed organism behaviours and relationship patterns between organisms and species. Thus it may be possible to mimic the relationship between organisms in a similar way (Pedersen Zari, 2018).

Behaviour level biomimicry is largely focussed on translating an aspect of organism behaviour, or relationship to a larger context into human design. An architectural example of biomimicry at the behaviour level may be the Eastgate building in Harare, Zimbabwe. The building mimics the mound-building behaviour of the termite to achieve temperature regulation through careful orientation, spatial organization, and techniques of passive ventilation. This level of biomimicry requires decisions about what is being mimicked and translated for the human context. This is selective, and disregards the whole system as mimicking the behaviour of termites may be beneficial from a passive cooling point of view but may offer very little in regenerative potential of place. For this reason, mimicking whole systems rather than single organisms offers the greatest potential for creating regenerative built environments.

Ecosystem level: Integral to biomimicry is the mimicking of ecosystems, which is also described as 'eco-mimicry' (Lourenci, et al., 2004). Eco-mimicry according to Marshall (2009) is a sustainable form of biomimicry that looks towards the wellbeing of ecosystems and people, instead of economic gain. He further advocates that biomimicry at the ecosystem level studies the fauna and flora of a particular place in order to find technologies or methods that are ideal for integrating with the unique conditions of the site. This correlates with the core ideal of regenerative architecture and design. Mimicking ecosystems may potentially transform built environments that work more like a system instead of unrelated buildings. Ecosystem level biomimicry refers to the mimicking of whole ecosystems and the common principles that permit them to work successfully, or their actual functions (Pedersen Zari, 2018).The challenge lies in shallow or generic interpretations of how ecosystems work and hindering the success and potential of a regenerative architecture. An Ecosystem-based biomimicry framework developed by Pedersen Zari (2018) will be explored further on.

Precedent of architecture that mimics entire ecosystems is still uncommon. An example is the Urban Greenprint project in Seattle. The pre-existing forest existed on the site before development, the forests functions were studied, to determine how urban space, and buildings may potentially restore those functions of the pre-development ecosystem (Taylor Buck, 2017). An approach like this is useful in the context of the Durban bay, where architecture may regenerate the local ecosystem functions.

The table below indicates differences between each kind of biomimicry with an example of how different aspects of a termite, or a termite ecosystem could be mimicked. Nested within each of these 'levels' are a further five possible 'dimensions' of scale of mimicry exist. The design may be biomimetic in terms of:

1. **Form:** what it looks like
2. **Material:** what it is made out of
3. **Construction:** how it is made
4. **Process:** how it works
5. **Function:** what it is able to do

Level and dimension	Example – A building that mimics termites	
Organism level (mimicry of a specific organism)	*Form*	The building looks like a termite.
	Material	The building is made from the same material as a termite; a material that mimics termite exoskeleton/skin.
	Construction	The building is made in the same way as a termite; e.g. it goes through various growth cycles.
	Process	The building works in the same way as an individual termite: e.g. it produces hydrogen efficiently through meta-genomics.
	Function	The building functions like a termite in a larger context; e.g. it recycles cellulose waste and creates soil.
Behaviour level (Mimicry of how an organism behaves or relates to its larger context)	*Form*	The building looks like it was made by a termite; e g. a replica of a termite mound.
	Material	The building is made from materials that a termite builds with; e.g. using digested fine soil as the primary material.
	Construction	The building is made in the same way that a termite would build; e.g. piling earth in certain places at certain times.
	Process	The building works in the same way as a termite mound would; e.g. by careful orientation, and natural ventilation, or it mimics how termites work together.
	Function	The building functions in the same way that it would if made by termites; internal conditions are regulated to be optimal and thermally stable. It may also function in the same way that a termite mound does in a larger context.
Ecosystem level (Mimicry of an ecosystem)	*Form*	Building looks like an ecosystem (a termite would live in).
	Material	The building is made from materials that (a termite) ecosystem is made of; e.g. it uses common compounds, and water as the primary chemical medium.
	Construction	The building is assembled in the same way as a (termite) ecosystem; e.g. principles of succession and increasing complexity over time are used.
	Process	Building works in the same way as a (termite) ecosystem; e.g. it captures energy from the sun, stores water, etc.
	Function	The building is able to function in the same way that a (termite) ecosystem would and forms part of a complex system by utilising the relationships between processes; e.g. it is able to participate in the hydrological, carbon, nitrogen cycles, etc. in a similar way as an ecosystem.

Table 3.1 Levels and dimensions of biomimicry: a framework for understanding biomimetic design (Pedersen Zari, 2018, p. 29)

It is important to note that overlaps between different kinds of biomimicry may exist, and that each kind is not mutually exclusive. For example, several interacting elements working like an ecosystem would be functioning at the ecosystem level. However, ecosystems are made up of nested, complex relationships between a myriad of single organisms, and so individual details of a system functioning at an ecosystem level, may be based organism or behaviour biomimicry (Pedersen Zari, 2018).

This framework serves to highlight distinctions between different kinds of biomimicry and their regenerative potential. The regenerative potential would be most effective at the ecosystem level. Although architectural examples are uncommon, the researcher will aim to assemble precedents that reflect aspects of ecosystem level biomimicry. As Pedersen Zari (2018) suggests, in order to increase the potential of a building to be a part of a regenerative built environment, it must be able to mimic natural processes and function like an ecosystem in its creation, use and eventual end of life.

Ecosystems & Architectural Design

The fundamental difference of architecture that embodies an ecological understanding, is not that a building is designed in a way that it looks as though it has emerged from a living process, but rather the 'creation of spaces that become living processes and systems over various temporal and spatial scales' (Pedersen Zari, 2018). If we look towards ecosystems, designers are presented with examples of how life can function effectively in the context of a given site and climate, which may offer insights into how urban built environments could function more like a system or set of relationships, rather than as a set of individual unconnected 'object-like' buildings (Pedersen Zari, 2018). A vital step in achieving this is for urban practitioners to have a basic understanding of how ecosystems work, while avoiding shallow interpretations of natural processes. Where an understanding of ecosystems drives the design process, (Pedersen Zari, 2018) focus is shifted away from the act of designing isolated objects that rudimentarily provide shelter, towards 'visualising architectural, spatial and urban design as a process of forming, leveraging, and creating flexible sets of relationships of social conditions, flows (materials, energy, carbon, water etc.) and reactions over time in very real and tangible physical ecological spaces'.

Developments/projects in the built environment tend to be led by architects, engineers, or planners with little to no ecological background, often under significant time and financial pressure to complete projects quickly and cheaply. This may lead to shallow experiments in biomimicry, which can result in simplistic form-based biomimicry that may fall short of improving sustainability performance (Armstrong, 2009). An understanding of ecosystems operating formatively in setting the initial goals and in establishing the performance standards of the development/project, may have the potential to create a significantly more ecologically sustainable built environment (Gamage & Hyde, 2012).

Ecosystem Services & Urban Environments

The concept of ecosystem services can be simply understood as the benefits acquired by humans from ecosystems that support human physical, psychological and economic well-being; either directly or indirectly. Even though ecosystem services are based on people's ability to use them, within this context they are used to understand what it is that ecosystems do that is so important for human life, so that these services may be mimicked in the built environment. The functions of ecosystems (what they do) are much less controversial in ecology literature than their processes (how they do it)

(Pedersen Zari, 2018). The ecosystem services received by humans is divided ‘provisioning services’ such as food and medicines; regulation services such as pollination and climate regulation; supporting services such as soil formation and fixation of solar energy; and cultural services such as recreation and artistic inspiration (Daily, 1997).

Most contemporary cities have been described as ‘intensive nodes of consumption’, while being increasingly dependent on the services of faraway ecosystems rather than local ecosystems for their resources (Rees, 1999). Due to the built environment’s high consumption of the services of ecosystems, important ecological processes for humans as well as all life on earth such as climate regulation, salinity control, soil formation, nutrient cycling, the hydrological cycle, photosynthesis, pollination and waste assimilation are negatively affected (Shepherd, et al., 2002; Vitousek, et al., 1997). Ecosystem services in urban environments are less well understood, use of these services in cities occur at low rates, with exception to cultural services (Gomez-Baggethun & Barton, 2013). On the contrary, several valuable urban ecosystem services in cities have been identified, which include air purification, water flow regulation, microclimate regulation and carbon sequestration (Gomez-Baggethun & Barton, 2013). The urban ecosystem services urban green areas such as forests or parks or blue areas such as lakes and wetlands. These valuable areas in cities present important opportunities for novel design interventions, particularly related to increased resilience to climate change (Elmqvist, et al., 2016). It is clear that ecosystem services are closely related to socio-ecological systems, however contemporary cities are largely sites focussed towards cultural expression and the facilitation of trade, rather than for the production of physical resources or the generation of services that produce tangible physical health of ecosystems or humans (Doughty & Hammond, 2004). More often than not, human-made systems and activities taking place in urban environments have a clear negative effect on non-cultural ecosystem services (Newman, 2006).

Urban environments are typically representative of highly disturbed ecosystems; however they do present some unique benefits for restoring ecosystems (Given & Meurk, 2000).Urban environments must be considered in terms of their impact on ecosystems and their potential role in facilitating the regeneration of them (Pedersen Zari, 2018). This is critical given our current ecological crisis and that more than half of humanity inhabit cities.

Mimicking ecosystemic functions and services for regenerative urban built environments.

In her thesis, Pedersen Zari creates a framework for the use of ecosystem biomimicry at the process level (how they do things), positing that it could a means of giving order in a plethora of methods for creating sustainable built environments. However, she acknowledges that the application of ecosystem biomimicry at the process level *"may be complicated both to understand and use in a design context…because of the large amount of complex ecological information that has to be understood to do this meaningfully"* (Pederson Zari, 2012).

Thus, Pedersen Zari states that mimicking ecosystemic functions and services may be more useful in achieving regenerative urban environments.

Ecosystem services are not only determined by the functions of ecosystems, but also by human ingenuity in deriving benefit from them (Heal, et al., 2005). Ecosystem services biomimicry which includes the 'ecosystem services analysis' process, should be used with other aspects of regenerative design that focusses on the development of relationships between humans, the built environment and wider ecological systems (Pedersen Zari, 2018; Mang & Reed, 2012; Du Plessis, 2012).

Pedersen Zari (2018) identified seven ecosystem services that were most suitable in a built environment context enabling it to integrate with and contribute towards local ecosystems. The following ecosystem services suggest that in a similar way to the functioning of an ecosystem, an urban environment (and individual buildings as a part of it) could be designed with deliberate focus on generating a system that:

1. Contribute to regulating climate through mitigating greenhouse gas (GHG) emissions and the heat island effect, and by sequestering carbon
2. Purifies air, water and soil;
3. Provides habitat for species suitable for co-inhabitation with humans in the urban built environment, prevents erosion and reduces wind, wave and flood disturbances;
4. Uses waste as a resource and contribute to soil formation and fertility through careful cycling of biodegradable wastes and recycling of non-biodegradable wastes;
5. Collects, stores and distributes fresh water;
6. Produces renewable energy; and
7. Produces food.

When considering the outputs of local ecosystems, there is a potential for an architecture to integrate and co-evolve with the systems of that place that sustain life. The ecosystem services mentioned above are most suitable in a built environment context, there is potential for the architect to embed these services in the fabric of the architecture, using them as design drivers in the conceptualisation of a regenerative project. These ecosystem services are further characterised in the table below in terms of ranking their potential applicability within the built environment, and where a focus to some may be more effective, especially in the early stages of the project.

Table 3.2 Ecosystem processes list

Ranking of ecosystem services for consideration in a built environment context				
Ecosystem services in a built environment context		*Applicability to the built environment*	*Ecological significance*	*Negative impact of built environment*
Regulating Services	1. Climate regulation	High	High at both global and biome scales	High at global scale
	2. Purification of air, water, and soil	High	High at biome & ecosystem scales	High at biome & ecosystem scales
Supporting Services	3. Habitat Provision (including: genetic resources; pollination; fixation of solar energy; prevention of disturbance; and species maintenance)	Medium	High at biome & ecosystem scales	High at biome & ecosystem scales
	4. Nutrient cycling (including: decomposition, soil building; and raw materials)	Medium	High at the biome scale	High at biome & global scales
Provisioning Services	5. Provision of fresh water	High	High at the biome scale	High at the biome scale
	6. Provision of fuel/energy for human consumption	High	Medium at the global scale	High at a global scale
	7. Provision of foo (including: provision of biochemicals)	Medium	Medium at ecosystem scale	High at a global scale

Source: (Pedersen Zari, 2018, p. 131)

The table above suggests that the three ecosystem services of regulation of climate, purification and provision of water should be the initial focus as they might be easiest to focus on in a built environment context, which also have a high number of benefits for ecosystems and the species within them. The remaining four are still important and are dependent on local conditions as well as the vision of design, for example where the integration with the built environment (focus may be towards provision of fuel/energy and fresh water), or benefit of ecosystems in general (focus towards habitat provision, climate regulation and nutrient cycling would be preferential) (Pedersen Zari, 2018). This table will inform the selection of precedent studies which embody the mimicry of ecosystem services and function.

Furthermore, it should be acknowledged that this is not a ranking exercise in terms of importance of each ecosystem service, but rather e applicability of mimicking such processes in a built environment context. The following figure shows how the seven ecosystem services are related by means of potential synergies and trade-offs. The potential trade-off relationships are important from a design perspective, increases in a particular ecosystem service, potential trade-offs with that service reinforce others, creating enhanced feedback loops between the mimicking of each service (Pedersen Zari, 2018).

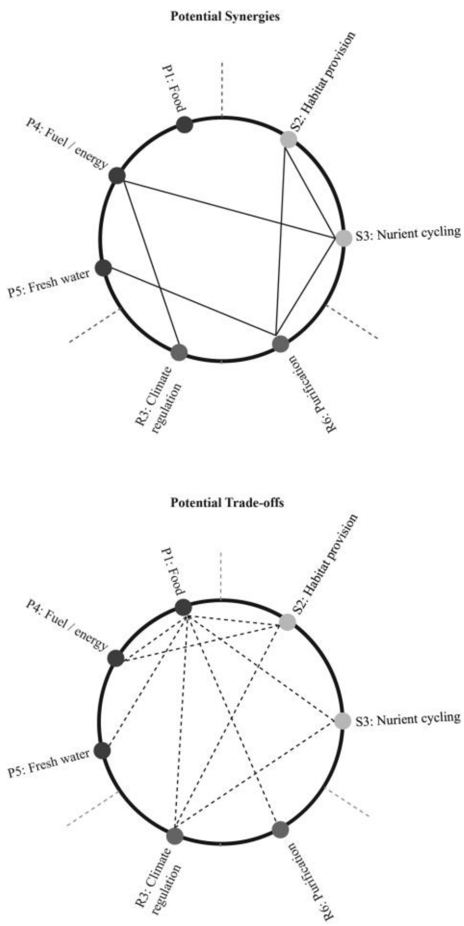


Figure 3 Potential synergies and trade-offs between ecosystem services for a built environment context

Source: (Pedersen Zari, 2018, p. 133)

Understanding how the various ecosystem services are interrelated and have potential trade-offs will be useful in the conceptualisation of a regenerative architecture that incorporates various interrelated functions of an ecosystem. For example, the figure above shows the synergies between ecosystem services which may inform how the architect can develop systems that maximises from these ecosystem function synergies, integrating the systems of place within the fabric of the architecture.

Ecosystem Services Analysis

As Pedersen Zari (2018) has considered which ecosystem services are most applicable to architectural and urban design, important in moving forward is understanding how to practically use this set in a built environment context. Pedersen Zari (2018), has developed an 'ecosystem services analysis' (ESA) methodology which may be used by teams of designers and ecologists as well as urban planners, policy makers among others. It is an incremental process which focusses on improving existing ecosystem services in a particular place to optimal or pre-existing levels, as well as initiating measures to reintroduce ecosystem services that may be absent to urban areas due to past degradation and removal of ecosystems. This suggests a process of regenerating ecosystem services in an urban built environment, and thus a regenerative built environment will need to incrementally evolve over timeinstead of being expected to be fully functional when the design comes to realisation (Pedersen Zari, 2018).The follow figure summarises the ESA methodology:

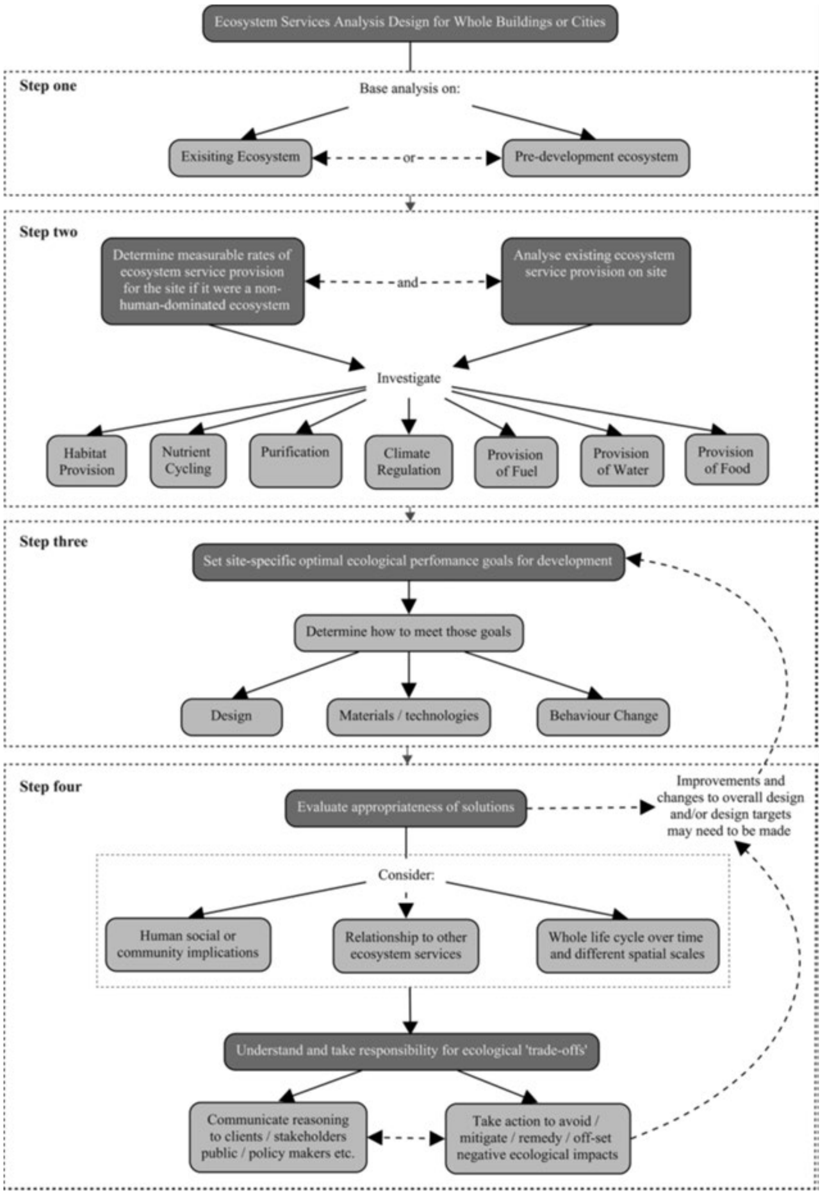


Figure 4 Ecosystem Services analysis process

Source: (Pedersen Zari, 2018, p. 142)

The Ecosystem Services Analysis methodology may serve as a useful tool specifically for architects in realising regenerative built environments. Using ecosystem services in a design context requires design teams to consider the hierarchy of importance of ecosystems services for a particular site, prior to any design process of buildings or urban areas. Critical to furthering the hierarchy of importance of ecosystem services for a specific site are discussions with ecologists who have knowledge of local ecosystems which will identify an appropriate ecological focus (Pedersen Zari, 2018).

Fundamental to the regenerative design process is understanding the unique and multi-layered network socio-ecological systems of a particular place. Pedersen Zari's framework for ecosystemic biomimicry at the functional level provides a clear directive for designers to and architects to begin to understand how to utilise ecology of a particular place beyond the level of metaphor. Thus, it is posited by the researcher that the mimicking of ecosystem services provides a necessary basis for architects and urban practitioners to begin to understand the functioning of local ecosystems, with an appropriate and suitable ecological focus - specifically in terms of ecosystem services they provide for people - when undertaking a regenerative project.

The Ecosystem Services Analysis methodology will be used both as part of the analytical framework in order to analyse precedents, as well as informing the conceptual design process in developing an ecological understanding of place and translating this into design principles for a regenerative centre on the docks of the Durban bay.

3.4 Summation

The basis of this chapter was to define a theoretical and conceptual framework which will inform a regenerative architecture. The first part explores relevant theories which serve as necessary philosophical departure points in the creation of regenerative built environments. Key to the theoretical framework is reconceptualising the human-nature relationship.

Whole & Living Systems Thinking shifts our perspective towards understanding our ecosystemic crisis, and the critical positioning of architecture to position itself within the whole system.

Ecology is used as a relevant methodological tool and source of knowledge, scientifically and philosophically capable of dealing with organic-complex-ecological processes and systems (Cunha & de Faria, 2014). This develops into the Ecology of Mind which highlights the potential for the human mind and nature to be integrated in order to construct environments both built and natural, so that they may sustain all forms of life.

The second part juxtaposes Regenerative Design and Ecosystem-based biomimicry. Aspects of regenerative design are explored. Key to regenerative design is understanding the master pattern of place and translating those patterns into design guidelines. It was posited that the challenge within the regenerative approaches lies in mapping the construct of place and translating this into design guidelines. Regenerative design falls short in prescribing architects and designers with a method of engaging with ecological systems of a particular place beyond the generic metaphor. Ecosystemic biomimicry at the functional level provides a clear directive for designers and architects to begin to understand how to utilise ecology of a particular place beyond the level of metaphor, providing clear ecological focus when undertaking a regenerative project. Furthermore, it is posited that the

Ecosystem Services Analysis methodology will form part of the analytical framework used to analyse precedents in the following chapter.

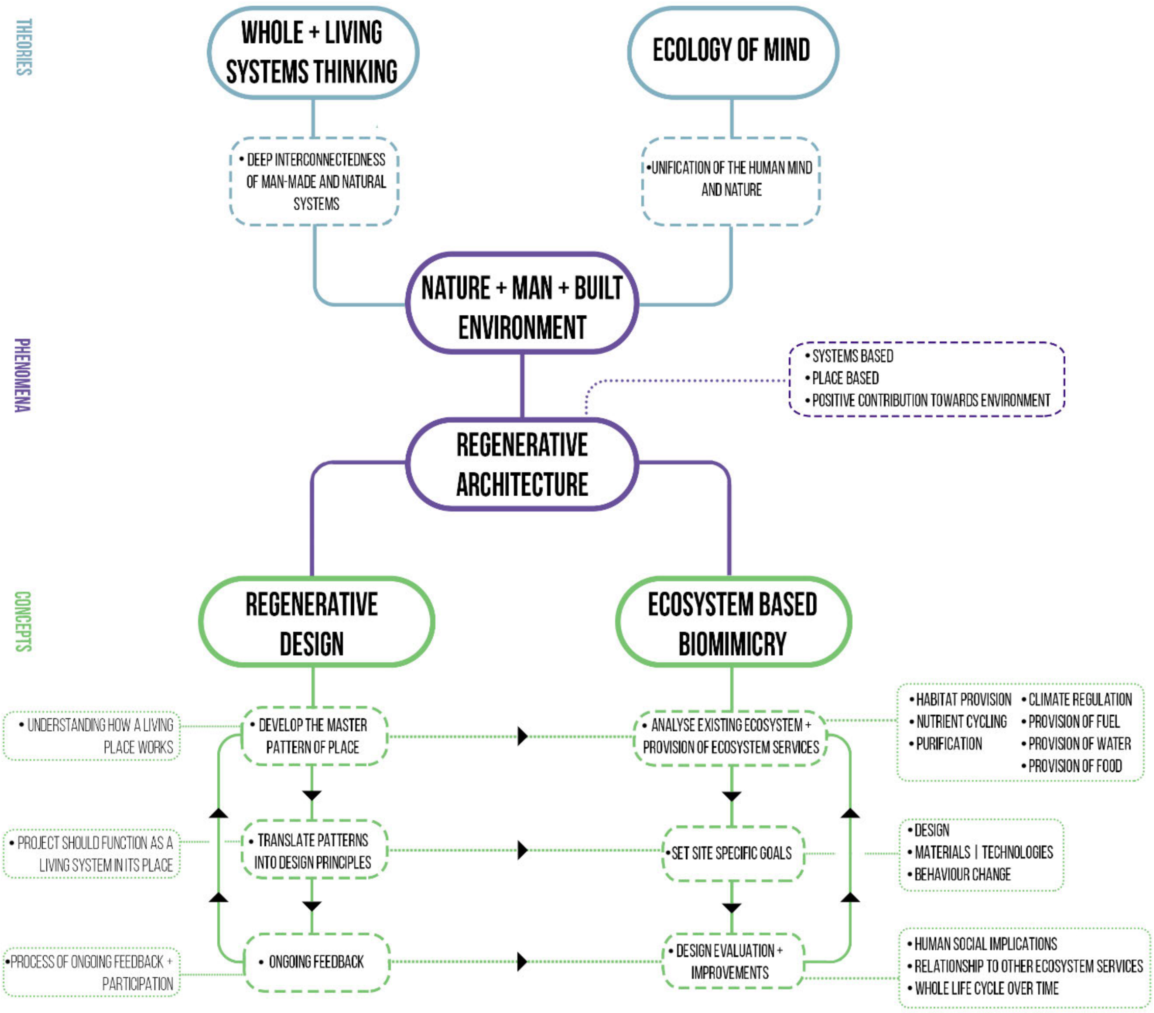


Figure 3.6 Theoretical & Conceptual Framework (image developed by author 2020)

CHAPTER FOUR | PRECEDENT STUDY

4.1 Introduction

The researcher set out to explore contrasting architectural precedents across different scales and typologies which may be analysed using an analytical framework derived from the theoretical framework. The precedents selected seek to reconceptualise the architecture and nature dichotomy. It is acknowledged that the precedent study focusses on engaging on an environmental level and not on the social or economic level as it is not the focus of this study. Below the analytical framework will be described:

The researcher set out to conduct a literature review and develop a theoretical framework in order to critically inform a regenerative architecture. An analytical framework was developed by the author which juxtaposes and synergises key aspects of the two concepts explored: ***'Regenerative Design'*** and ***'Ecosystem-based Biomimicry'.***

Below is a summary of the theoretical framework followed by the analytical framework developed.

Nature-Man-Built Environment

The two core theories explored were '*Whole &Living Systems Thinking'* and '*Ecology of Mind'*. The combination of these two serve to realise firstly the interconnectedness of man-made and natural systems, and secondly the unification between mind and nature. This continues the discussion of how Nature, Man and the Built Environment (spaces man creates) are interconnected and the relationships between them. The relationship between nature, man and the built environment will be used as an over-arching assessment of the selected architectural precedents.

Regenerative Architecture

The focus of this dissertation was to explore ecosystem-based biomimicry as a potential informer of regenerative architecture. The researcher explored two key concepts in this regard, namely *'Regenerative Design'* and *'Ecosystem-Based Biomimicry'.* Key aspects of these concepts are summarised below:

Regenerative Design: The key aspects of regenerative design are:

- *Understanding the master pattern of place*
- *Translating the patterns into design guidelines and conceptual design*
- *Ongoing feedback – a conscious process of learning and participation*

Ecosystem-based Biomimicry - Ecosystem Services Analysis (ESA) methodology

Step one– Analyse pre-development ecosystem functioning

Step two - Analyse existing ecosystem services provision on site

Step three: Site specific goals for development.

- *Design intent*
- *Materials/ technologies*
- *Behaviour change*

Step four – Evaluation and improvements.

Analytical Framework:

The analytical framework was developed by synergising the two key concepts and their respected approaches towards the design process. The researcher draws parallels between each stage and how the ESA may inform the regenerative design process. Regenerative design has three key aspects that are cyclical in process, the ESA methodology has 4 key steps that are also cyclical. The processes will be correlated as follows. Furthermore, each step unfolds criteria which will be used to analyse the selected architectural precedents.

Understanding the master pattern of place – *Step one & two of ESA methodology (ecosystem analysis & provision).*

- *What was the functioning of the ecosystem pre-development?*
- *How were existing ecosystem services understood and incorporated into the design?*

Translating patterns into design guidelines – *Step three ESA methodology (site specific goals)*

- *How did the design aim to positively contribute towards the environment?*
- *What material/systems/ technologies were used in the project?*
- *Did the architecture bring about a change in human behaviour?*

Ongoing feedback – a conscious process of learning and participation – Step 4 ESA methodology (Evaluation and improvements)

- Does the project allow for improvement and changes to the overall design?

Furthermore, to accommodate a more critical view the researcher further interrogates the selected precedents based on the following criteria and its relevance to the study:

- Scale
- Focus
- Liveability
- Universality

4.2 Lavasa, Hillside Town

Architect: HOK

Client: HCC Group

Location: Lavasa, India

Typology and Scale: Town – Urban Design

Context: Spread across 12,000 acres in a Western Ghats valley located outside Pune. The site's original ecosystem was a moist deciduous forest, which was converted into an arid landscape in recent times.

Justification: Regenerative potential from urban down to the architectural scale.

Figure 4.2.1 World Map locating India (image developed by author)

Figure 4.2.2 Map of India locating town of Lavasa (image developed by author)

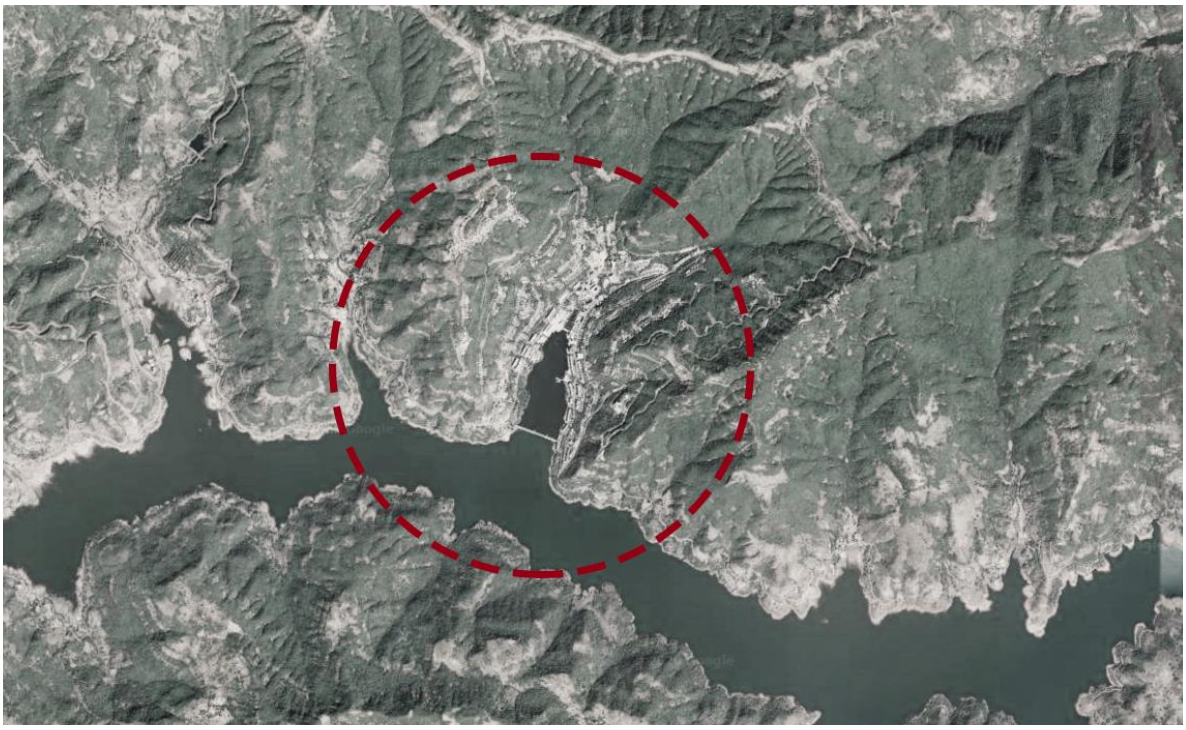


Figure 4.2.3 Location of the hillside town of Lavasa. Notice it is situated in a rural setting in the Western Ghats valley located outside Pune.

Understanding the master pattern of place

Lavasa, India is a township situated on steep hills within the Western Ghats Valley, which is susceptible to Natural threats such as monsoons, droughts, and soil erosion. The predevelopment local ecosystem was once a dense deciduous forest which was converted into an arid landscape, thus much of the local ecosystem has lost much of its resilience, which in turn made the landscape vulnerable natural phenomena such as monsoons, droughts, and soil erosion.

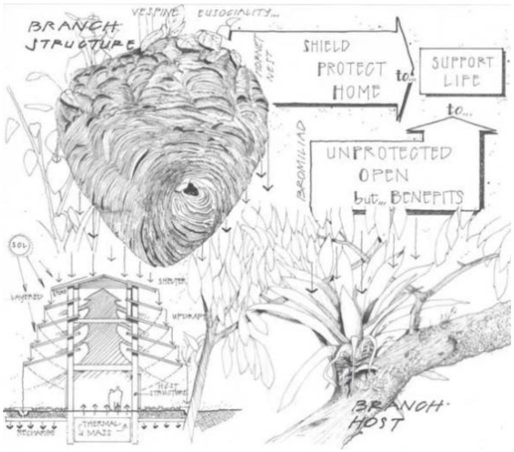


Figure 4.2.4 Concept sketches. Source: hok.com

To combat these issues, the design team used a biomimetic approach to understand how the local ecosystem could deal with such severe natural phenomena, and in turn how they could design a city that worked with the genius of place. Lavasa, India is one of the few current urban-scale examples of biomimicry. The design process was heavily influenced by biomimicry and involved a transdisciplinary team who engaged in a 3-day workshop to truly understand the master pattern of Lavasa. The team identified six ecosystem services supported by the local forest ecosystem, namely: water collection, solar gain, carbon sequestration, water filtration, evapotranspiration, and the nitrogen phosphorus cycle. Emulating these ecosystem functions formed the basis for the urban design (Buck, 2015).

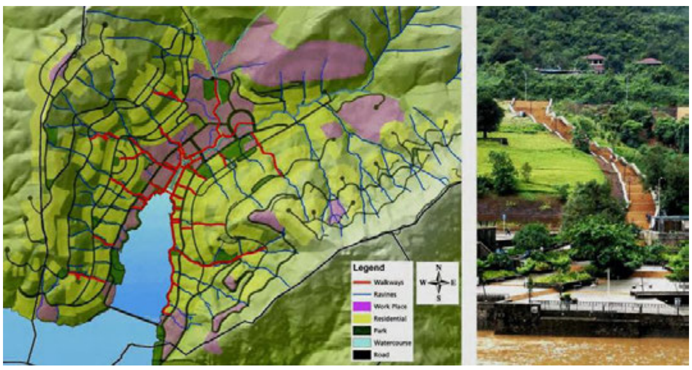


Figure 4.2.5 Concept Urban Design Soucre: HOK.com

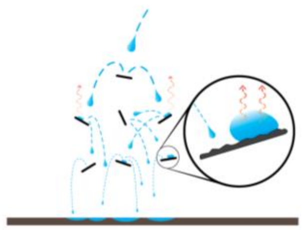
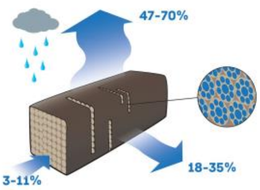
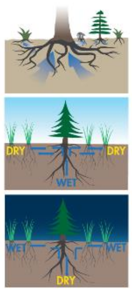
Translating the patterns into design guidelines and conceptual design

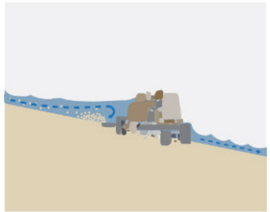
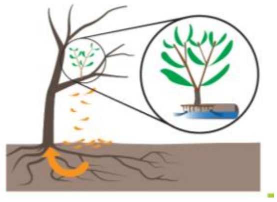
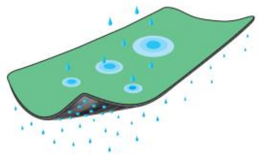
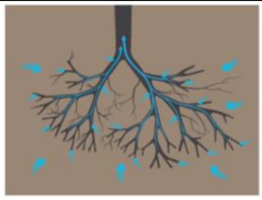
The key challenge of developing the city of Lavasa, was understanding how the local ecosystem functions (what ecosystems do) responded to heavy monsoons and stayed intact. The design team studied the genius of place which looks to the living organisms of a particular place to provide ecological performance standards to ensure the built environment performs at the same level as the natural environment. An understanding of how the local ecosystem worked with water was fundamental in developing design principles for the town:

- Collects water
- Stores water
- Absorbs water
- Attenuate water (slow down the movement of water)
- Transport or moves water

This resulted in a number of strategies or principles which the urban design could integrate with the functions of the local ecosystem. The following table was developed by a team in prescribing the design principles for the project:

Table 1 Design Principles adapted Source: (Oregon, 2013)

Organism / Ecosystem Attribute	**Design Principle**	**Design Graphic**
Canopy Structure	Overlapping, redundant surfaces at multiple layers above the ground intercept and store water, reducing erosive force and increasing the potential for evaporation.	
Downed Wood	Bundles of hollow cylinders transport water. Holes in the walls between hollow cylinders allow water storage, absorption, and evaporation.	
Hydraulic Redistribution	A subterranean network transports water along a water potential gradient.	

Beaver	Interlocking matrix of mixed material spanning an arch perpendicular to water's flow creates a high cavity surface area that slows water for storage and increased absorption.	
Mistletoe	1) Optimize water uptake and resource sharing using multiple inline channels. 2) Enhance a relationship by exchanging complementary resources at appropriate locations and times.	
Moss	Overlapping concave units with water repellent lower surface and hydrophilic concave upper surface absorbs water and capture energy.	
Mycorrhizal Fungal Network	Optimize water uptake using network architecture that increases surface area over which osmosis occurs.	

The urban design resulted in a number of strategies implemented where roof canopies slowed down the kinetic force of monsoon water by intercepting and storing water, reducing erosive force and increasing the potential for evaporation. Pavements that allow water to permeate back into the ground. Foundations that grip the hillside like roots of trees. Roads that mimicked local anthills that are able to remain structurally sound during heavy rain seasons, which channels and slows the flow of water down. The urban example serves as a repository of how future cities can integrate with local ecosystems with the aim of functioning just like a natural habitat would.

Figure 4.2.6 Arial photo & Rendering. Source: http://www.hok.com/about/sustainability/lavasa-hill-station-master-plan/

Ongoing feedback – a conscious process of learning and participation

The project is currently is nearing the end of its completion and has encountered many successes and failures. Lavasa city has become a renowned source of biomimicry from the urban scale, providing useful insight for many designers in successfully introducing biomimicry as a methodology into the development of a project. The overall design of the town works with the functions and processes of the local ecosystem which has made the city adaptable to local conditions. The completion of the project should highlight the various successes and failures which may inform the design of future cities.

Further Analysis

Scale:

The Hillside town of Lavasa explores the regenerative potential at the town planning and urban design scale. The town of Lavasa is a conceptualisation of how a city can be designed around the local ecosystem functioning in order to sustain pressures from natural threats as well as being adaptable to local conditions. Of course, the regenerative potential at the city scale is more likely to be successful when considered from conception as opposed to retrofitting certain flows or processes of an existing city.

Focus:

Lavasa brings about an interesting perspective of how its biomimetic approach filters across various scales. This aspect is critical in achieving the regenerative potential of a city whereby the flows of nature are embedded from the urban scale right down to the architectural scale. This has potential to transform individual unresponsive buildings into a network of living buildings that are fundamental to the regenerative potential of the whole city.

Liveability:

The example of Lavasa is in a rural context and offers very little in terms of liveability, especially since it is yet to be completed. However, the city is planned around new urbanism principles which although have been criticised, are based on a human-scaled design approach with focus on walkability and accessibility to public spaces and nodes of activity. This would suggest that the project is liveable and suitable from the human scale.

Universality:

As mentioned above, the location of the project is rural and offers very little in terms of universality. Cities that are completely urbanised with very little remanences of the predevelopment ecosystem may not be able to draw on certain aspects of local ecosystem functioning, but rather a more generalised approach.

6.3 Netherlands Institute of Ecology

Architect: Claus and Kaan Architects

Client: Royal Netherlands Academy of Arts and Sciences (KNAW)

Location: Wageningen, Netherlands

Typology and Scale: Research Centre/Laboratory – Architectural scale

Context: The Netherlands institute for Ecology is located on a University Campus in Wageningen. It is situated in a peri-urban context with a strong environmental influence.

Justification: Synthesis of architectural systems and maximising the regenerative potential at the architectural scale

Figure 4.3.1 World Map locating Netherlands (image developed by author)

Figure 4.3.2 Map of Netherlands locating town of Wageningen (image developed by author)

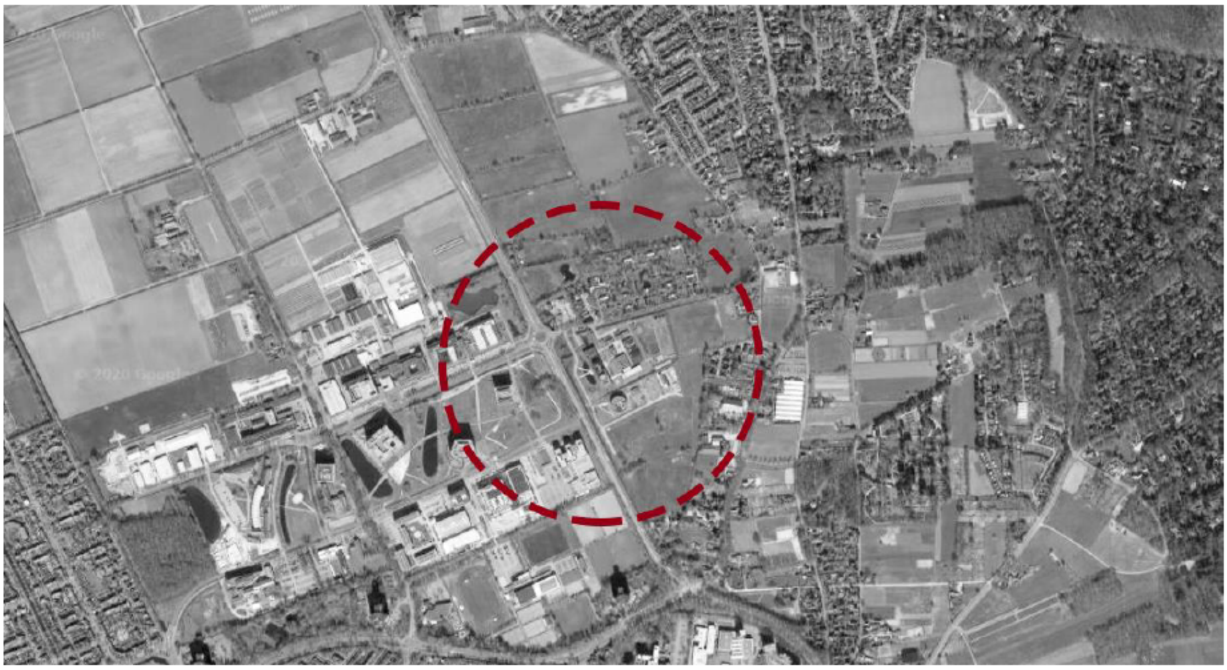


Figure 4.3.3 Location of the immediate context. It is a peri-urban context situated on the Wageningen University Campus (imaged developed by author)

Understanding the master pattern of place

The Netherlands Institute of Ecology is a research institute that studies the effect of nature in all its many forms. This understanding of ecological processes and the dynamics of nature played a critical role in the design and construction process. The project was inspired by the Cradle-to-Cradle (C2C) concept. The C2C principles are the closing of cycles, the use of solar energy and the celebration of biodiversity. Thus, the principles which informed the design were not particular to the local ecosystem, but generalised principles of ecosystem functioning. The principles were translated into five key areas which will be explored below. Some of these principles correlate with the ecosystem functions in the ESA methodology, such as Purification, Provision of energy, Provision of water, Provision of Food, Habitat Provision, and Nutrient Cycling. However, they do not specifically mimic the local ecosystem services.

Figure 4.3.4 aerial photo showing the connection to local water bodies. Source: https://www.e-architect.com/holland/netherlands-institute-of-ecology

Translating the patterns into design guidelines and conceptual design

Energy: The approach towards energy efficiency covered two areas: reducing consumption and sustainable production. Various systems are used within the building to reduce CO2 emissions. Thus the building becomes a sustainable production of various forms of energy.

- Hybrid ventilation system, which encourages natural ventilation and thermal migration through walls. Mechanical ventilation is only enabled based on CO2 detection.
- Solar collector stores and provides heat that is able to be used for the following winter.
- These various energy systems produce energy saving of up to 80%

Figure 4.3.5 Integrated solar, heat storage systems. Source: https://www.e-architect.com/holland/netherlands-institute-of-ecology

Efficient energy systems, and how they relate towards other heating, cooling and water systems should be considered in order fulfil the cradle-to-cradle concept.

Material: The brief imposed stringent material specifications, which meant the building had to be environmentally friendly, and made from renewable raw materials and economically produced without harmful emissions. The structure of the building is made of durable concrete free from artificial additives, sealants, or solvents. The use materials such as wood, glass, steel, ground limestone and granular debris exude sustainable methods and allowed for an open and natural appearance.

Figure 4.3.6 Elevational photograph subtle use of form and materials integrates the building with its surrounds. Source: https://www.archdaily.com/316294/netherlands-institute-for-ecology-nioo-knaw-claus-en-kaan-architekten

Thus, locally sourced materials with little to no environmental impact should be chosen.

Water: The cradle-to-cradle approach is most notable in the buildings water systems which aim to purify wastewater so that it can be discharged locally and indeed of the same quality of drinking water. The buildings water system consists of three different water circuits:

- Rainwater
- Domestic water
- Wastewater (toilets)

The purification process uses a helophyte filter. Helophytes are aquatic plants which remove contaminants from wastewater, thus reducing the buildings ecological impact. The purified water flows into a pond where it is then passed through the local ecosystem. Understanding local plants, and their potential use in purifying water may be a useful ecosystem function to mimic.

Waste = Food: The building implements a zero-waste strategy, by creating an ecological system that mirrors those found in nature. A unique system is used which turns wastewater into both energy as well as an algae cultivation system, which both purifies water and harvest algae used as an agricultural fertilizer. The building has zero waste and regenerates what ever resources it produces.

Biodiversity: The building uses a green roof, where the roof vegetation filters water, air and helps with temperature control. This green roof also being constructed with the local biodiversity in mind, providing a habitat where local biodiversity is encouraged.

Figure 4.3.7 Roof vegetation indicatinf habitat provision for local biodiversity Source: https://www.archdaily.com/316294/netherlands-institute-for-ecology-nioo-knaw-claus-en-kaan-architekten

The building integrates the various systems such as materials, water, energy, waste and vegetation, which allows the building to not only make efficient use of separate systems, but also creating effective links between systems and flows, creating a truly regenerative architecture.

Ongoing feedback – a conscious process of learning and participation

The building resembles and ongoing experiment that is never really finished, allowing for experimentation and improvement in the future. The building mimics the dynamics found in nature. Although much of it is not place specific, it remains an important precedent that exudes the cradle-to-cradle concept and positively impacts the local ecology through regenerative close-loop systems.

Further Analysis

Scale:

The Netherlands institute of Ecology is particularly relevant to the study due to the scale and the typology. It is a research laboratory which is grounded within its context and contributes positively towards the local ecological systems

Focus:

The research laboratory represents what is achievable in terms of regenerative potential at the architectural scale, furthermore the role of the architect/design team in coordinating various systems (influenced by the genius of nature) and integrating them within the flows and functioning of the architecture.

Liveability:

The institute for Ecology may be described as a living piece of architecture, it exudes liveability not only from the human perspective but also the natural systems in which it regenerates. In the context of this study liveability should extend beyond the human scale, and this project does that. It is a building that is both comfortable and functional from a human perspective but also integrates with and regenerates its surrounding environment.

Universality:

One of the downfalls of this project is that it does not mimic place-specific ecosystem functioning. On the contrary, it indicates how the mimicking of generalized ecosystem flows, still have a rather significant regenerative potential, which aids in the universality of the project and how it may be replicated within a different context. It is important to acknowledge that a combination of place specific ecosystem outputs along with general principles of ecosystems is acceptable.

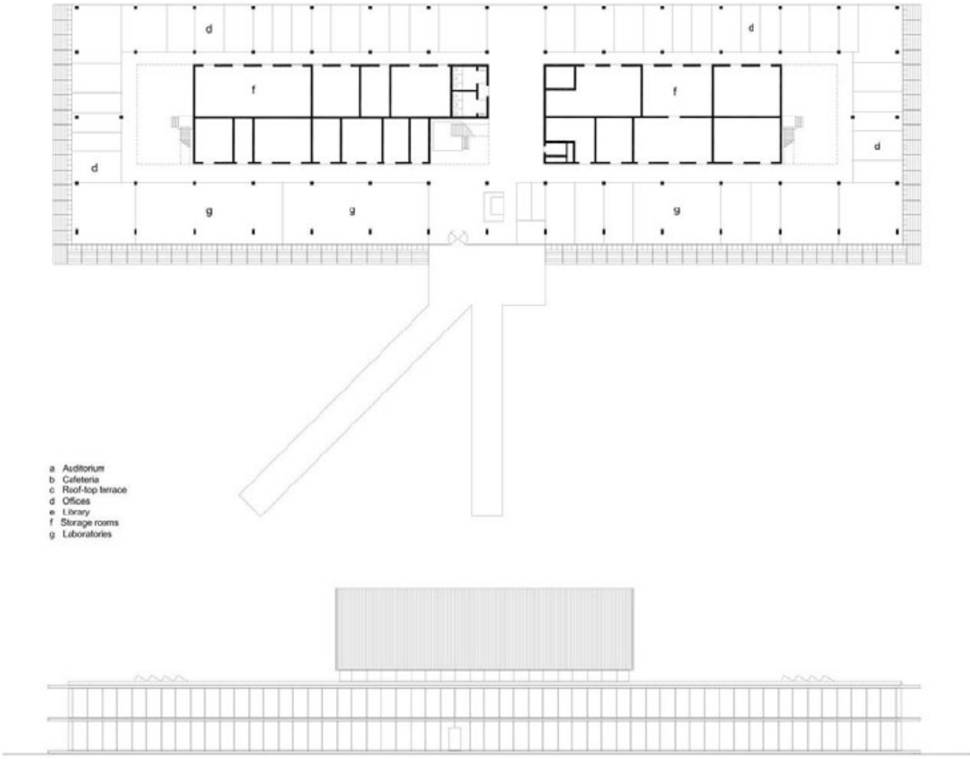


Figure 4.3.8 Open Floor plan and elevation maximising efficiency of the floor plate Source: https://www.archdaily.com/316294/netherlands-institute-for-ecology-nioo-knaw-claus-en-kaan-architekten

4.4 Plane-Tree-Cube Nagold

Architect: Ludwig + Schoenle Architects

Client: Regional Horticultural Show

Location: Nagold, Germany

Typology: Experimental Architecture - Pavilion

Context: The Plane-Tree-Cube was designed as a contribution for the Regional Horticultural Show in Nagold in 2012. It was conceptualized as a long-term Baubotanik experiment within an urban context. The project serves as an experiment in combining man-made construction methods with natural & living trees in the construction process.

Figure 4.4.1 World Map locating Germany (image developed by author)

Figure 4.4.2 Map of Germany locating Nagold (image developed by author)

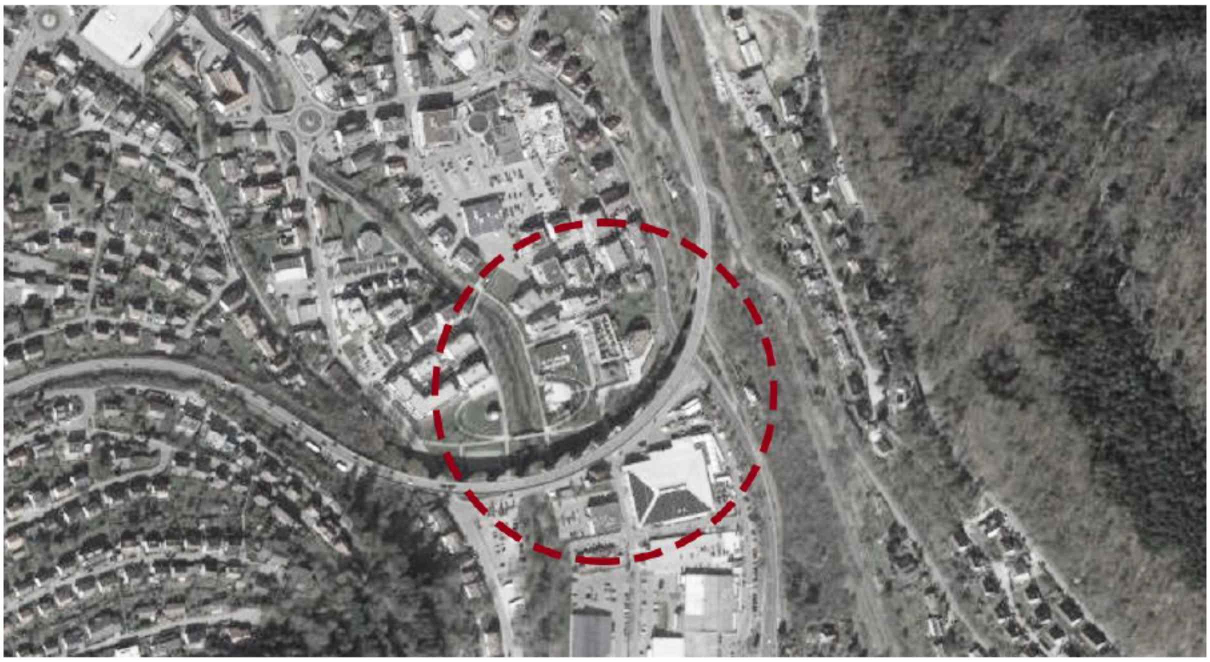


Figure 4.4.3 Location of the immediate context. It is a peri-urban context situated town of Nagold (imaged developed by author)

Understanding the master pattern of place

Baubotanik2, a research group was founded in 2007 at the Institute for Architectural Theory to develop a scientific basis of a living architecture, by exploring the constructive and ecological potentials in architectural, landscape, and urban design. The lead of Baubotanik2, and architect Ferdinand Ludwig conceptualised Baubotanik, which is now described as a system of building with living trees, which follow the rules and growth patterns of the plants used. As discussed in the theoretical framework, mankind must not only co-exist with nature but also contribute positively towards the natural world. The Plane-Tree-Cube was designed as a contribution for the Regional Horticultural Show in Nagold in 2012. It was conceptualized as a long-term Baubotanik experiment within an urban context.

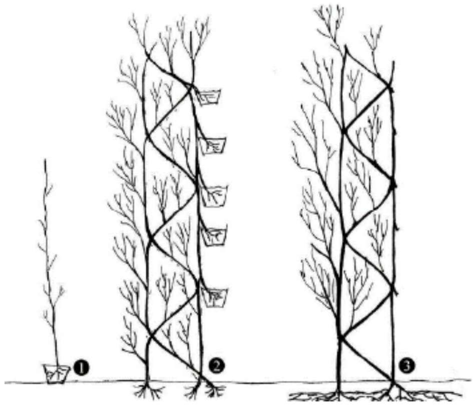


Figure 4.4.4 Concept sketch of Plant Addition (Ludwig, 2014)

The Plane-Tree-Cube importantly experiments with merging man-made materials, with living, breathing trees and thereby creating an architecture that is essentially alive. This experiment moves architecture beyond the dichotomy of living and non-living into an interconnected system growing with nature. The project depending on the context, and the use of living trees as a construction element forms an integral part of the local ecosystem, providing habitat and converting carbon dioxide, and thereby mitigating climate change.

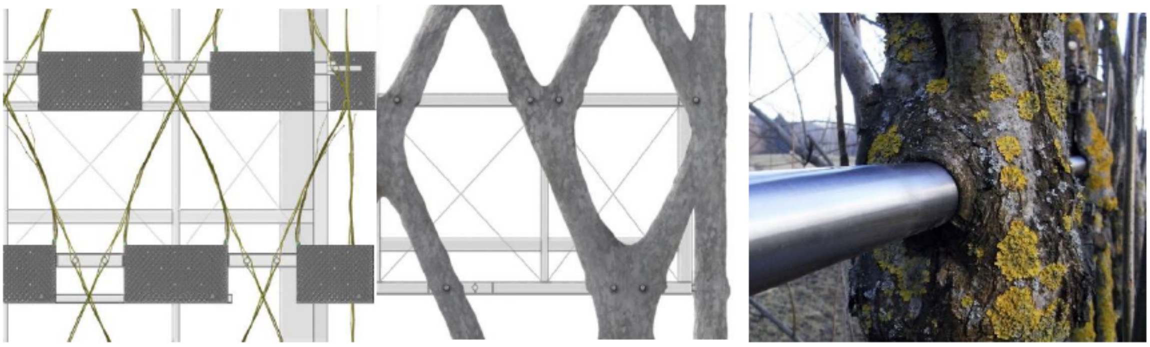


Figure 4.4.5 Elevational view showing the progression from young branches to strong trunks. Image shows the merging of the steel and tree trunk

Source: https://arqa.com/en/_arqanews-archivo-en/plane-tree-cube-nagold.html

Translating the patterns into design guidelines and conceptual design

The building forms part of the local ecosystem, essentially knitting itself within the living systems of a particular place. The experimental three-storey building is made of around 400 plants of salix alba that were planted in the ground and on 6 levels in special plant containers. The whole structure is supported by tubular scaffolds until the plants will be strong enough to take over the main load-bearing function. To achieve this, the plants have to be arranged in a way that a firm structure emerges with the least possible need for (living) material. At the same time the arrangement has to respect the growth patterns described above to ensure that the plants grow vitally and develop in accordance with the intention of the designer. Another target of the project was to find a structure that is easy and cheap to realize and that is not too complex in terms of prediction of growth. The result of these considerations is a rhombic plant structure where the plants are tilted only slightly and all in the same angle so that they all should show only little and more or less equal geomorphic reactions. The rhombs are divided horizontally by the ingrowing platforms and handrails to create triangles and thereby a stiff structure.

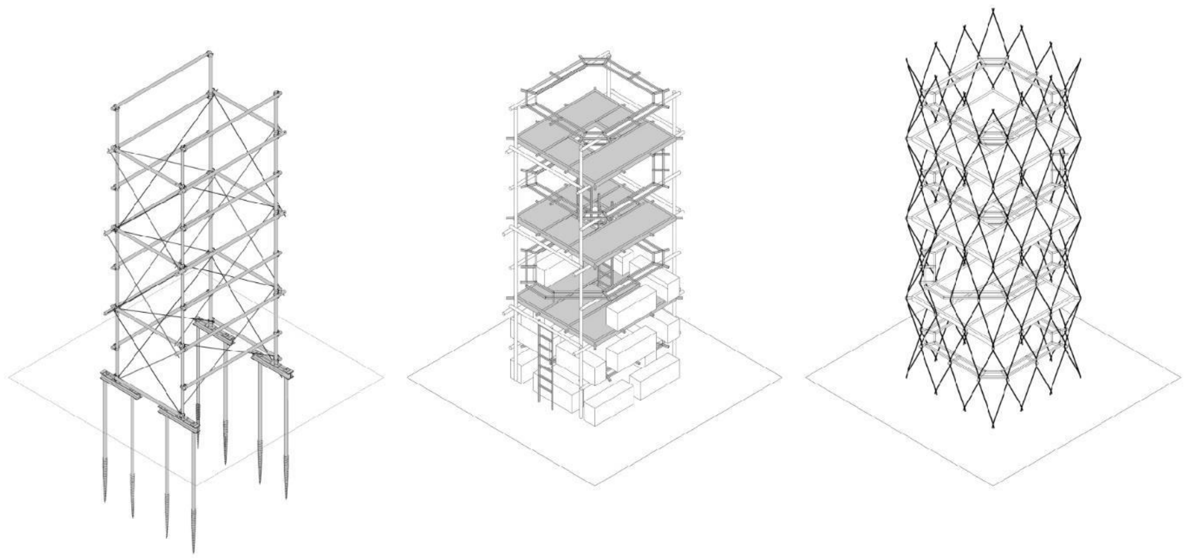


Figure 4.4.6 Construction process. Temporary scaffolding(left), plant containers and ingrowing elements(middle) and plant structure (right) (Ludwig, 2014)

Ongoing feedback – a conscious process of learning and participation

During the horticultural show, the building was an event: Visitors were allowed to enter the three platforms and facilities indicated for maintenance. Thereby they got in contact with the structure where technical facilities fuse with growing plants. The atmosphere is shaped on the one hand by pipes, regulators, sensors, and valves and on the other hand by the fresh green of the young leaves and shoots which sprout everywhere all over the green walls. In the course of further development, the plant structure will become stronger and more well developed whilst town houses will be built on the surrounding plots. Then the building is supposed to act as a vertical pocket park for the inhabitants.

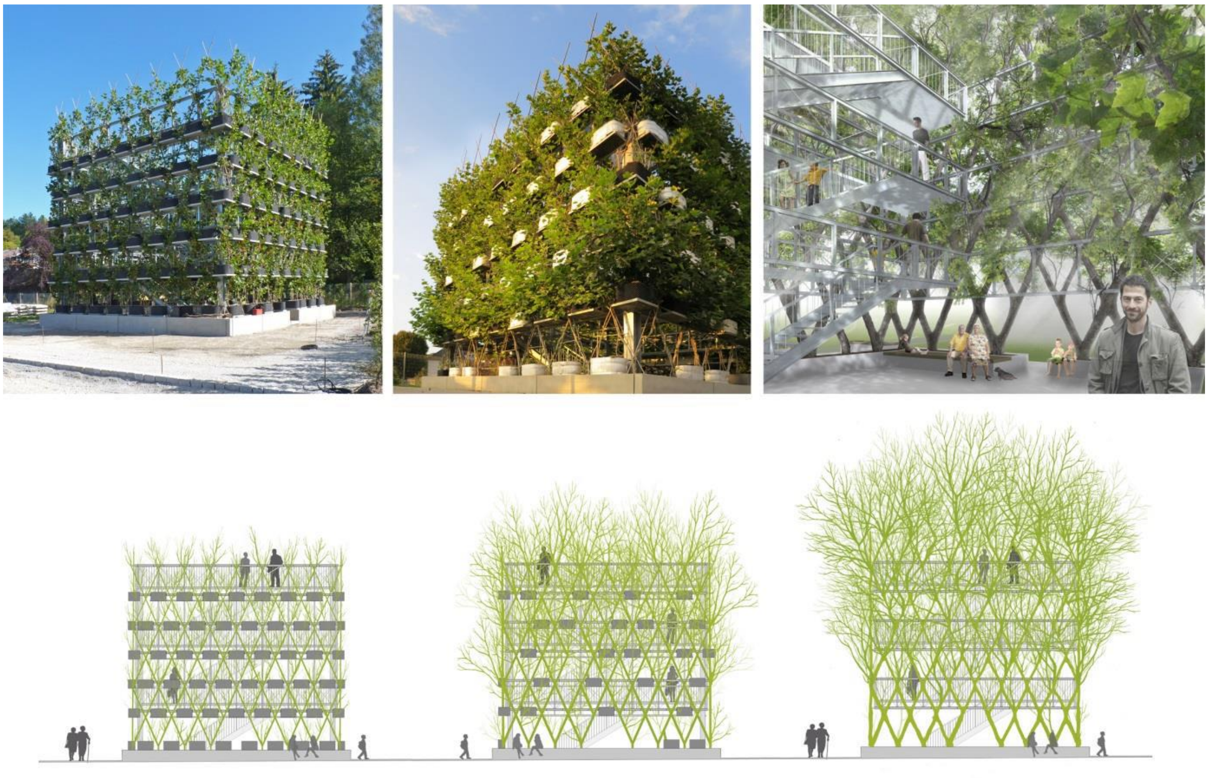


Figure 4.4.7 Top: Plane Tree Cube directly after completion (left), third growth period (middle) and visualization of future situation (right)

Bottom: Expected development of the plants structure within 15 years. (Ludwig, 2014)

Using the Baubotanik technique the architect may plan for future adaptions. Architecture may initially provide the framework for the structure, and many years on the steel work can be removed whereby the structure of the trees will be sufficient in keeping the building structurally sound. This is an interesting concept which brings an awareness to the potential 'living' qualities architecture may acquire.

Further Analysis

Scale:

The Baubotanik building methodology is one that is fundamentally restricted to the growth of nature, which ultimately limits the scale of which this methodology is viable. This results in an architecture takes a long time to reach fruition. Perhaps architecture shouldn't solely use the baubotanik methodology, but rather incorporate elements of it within the architecture.

Focus:

The key focus of this project is the way in which it incorporates the use of living materials in its construction. It represents a shift away from carbon intensive materials used in the construction process which ultimately aid in the degradation of ecosystems. There is so much potential for architecture to incorporate aspects of living materials, and in doing so the perception and role of architecture is able to embrace bio-design, and harness the benefits of nature.

Liveability:

This architecture represents something like a folly, a vertical public space, which serves no real function and thus is clearly not liveable. This precedent should be used as a shift in building methodologies, and not as entirely new way of doing architecture.

Universality:

From a universality perspective, the building methodology is limited to a number of tree species, which in turn restricts where it may be replicated. The construction methodology is not only labour intensive, but also requires ongoing maintenance, but nevertheless represents a shift towards architecture that embraces living materials.

4.5 Conclusion

This chapter set out to analyse precedents using the analytical framework developed from the theoretical & conceptual framework. Key the analytical framework were the three main aspects of 'regenerative design': **Developing the Master Pattern of place**, **Translating Patterns into Design Principles**, and lastly how the project allows for **Ongoing Feedback and Participation over time**.

Although, contrasting, scales and architectural typologies were presented, all projects in some way or another adhered to the key aspects of the analytical framework. The researcher acknowledges that the precedent study focusses on architectural examples with an emphasis on the regenerative capacity from an ecological perspective and not particularly from a social or economic perspective as it is not the focus of this dissertation.

The township of Lavasa proved to be an important precedent in understanding how the design team can develop a master pattern of place, by rigorously understanding the local ecosystem and how it deals with challenges posed by monsoons, and soil erosion. The design process revealed an important connection between understanding the master pattern of place and translating those patterns into design principles which formed the basis for the urban design. The urban context of this precedent gives insight into how future cities can be design or retrofitted by implementing strategies that mimic the local ecosystem services.

The Institute for Ecology embraced the cradle-to-cradle concept, which although not based on understanding the master pattern of place, it crucially brought light to how architecture should use sustainable consumption and production methods using cyclical closed loop systems, with zero waste.

The project importantly recognises the potential of architecture to have efficient systems, but realises the synergy between systems, and maximises this. This may be important in synergising the various ecosystem services mimicked from local ecosystems. Ecosystems are cyclical by nature and so when ecosystem functions are mimicked, they should be synergistic and interconnected.

Lastly, the Plane Tree Cube offers insight into how man can develop a built environment that is intrinsically informed by the rules of nature. This experimental architecture converges man-made constructions materials as an initial structure, and over the growth of the tree structure, the scaffolding may be removed resulting in an architecture that is both natural and man-made. Aspects of this construction methodology may be used to capture an architecture that is essentially a living, breathing part of the ecosystem. Although still very early in its development it offers insight into how architects can merge the built and natural environment.

All three precedents offer key elements that will be used in the design and development of a regenerative centre on the docks of the Durban bay, which will seek to understand the master pattern of place, translate those patterns into design principles, and create an architecture that is never truly finished but in a constant process of feedback and participation.

CHAPTER FIVE | FINDINGS & ANALYSIS

6.1 Introduction

The key research question has been formulated as: *How may ecosystem-based biomimicry inform a Regenerative Architecture [so that the built environment may become a life supporting environment conducive for both human and non-human life]?*

The Secondary questions are:

- *How may the nature ecosystems and the interrelationships of their functions (what they do) be understood so that they may be applied to a regenerative architecture?*
- *How may ecosystem degradation and biodiversity loss in the Durban Bay inform a regenerative architectural response?*
- *What principles may be applied to architecture so that it may regenerate natural ecosystems and biodiversity in the Durban Bay.*

The research questions presented lead to the investigation of how built environments may be conceived as life-supporting environments for both human and non-human life, particular in the urban context of the Durban bay. The researcher has established a theoretical framework, through an investigation of various literatures, that enhance the notion that a built environment should integrate with and contribute positively towards local socio-ecological systems. Fundamental to achieving a regenerative architecture is addressing the problematic relationship between man, nature, and the built environment, which formed the basis of the theoretical framework.

The structure of this chapter will be divided into three sections. The first section described as 'level one' will give a brief description of each interview's contribution towards the research questions.

Second is 'level two' which is an analysis of these contributions by cross comparing viewpoints allowing the researcher to draw key ideas which may contribute toward or contradict towards the research questions. This section provides a description of the data collected and analysed using the methods discussed earlier in the dissertation. This section aims to analyse the data thematically by continuing the discussion from the literature review, theoretical framework, and precedent. Semi-structured interviews were conducted four experts in their respective fields.

Lastly, 'level three' will explore how learning from these interviewees has extended or merely supported the literature.

6.2 Contribution to Research

6.2.1 Interview – Claire Janisch – Biomimicry Expert

Claire Janische is founding Director of BiomimicrySA. As a Certified Biomimicry Professional, Claire spends her time exploring nature's genius in diverse ecosystems and shares this new way of viewing and valuing nature through biomimicry expeditions and coaching– teaching & training professionals, students, and scholars. Claire has a MSc Chem-Engineering in Industrial Ecology and is both a graduate of and has been a lead trainer for the Biomimicry Professional Certificate Program offered by Biomimicry3.8.

Claire's expertise in biomimicry are particularly relevant to this study. With many years of experience and having worked all over the planet, Claire knows how to understand ecosystems and critically use them within a design context. She strongly believes that our biomimicry is primary to design, and allows the design team to critically engage with the local patterns of place. She is quite optimistic about the future and how humans may learn to work with nature instead of depleting it.

Claire believes that cities should *"be equally as healthy and function themselves like ecosystems…every building, every process within a building, every component of the city can continue to figure out how it fits within its context and contribute to its context, not just try and minimize its impact on the environment"*

6.2.2 Interview – Dr David le Maître – Ecologist

Dr David Le Maitre is a principal researcher at the Council for Scientific and Industrial research (CSIR) with specific expertise in biodiversity and ecosystem services. David investigates the impacts of ecosystem change on socioeconomic benefits, focusing especially on invasive alien plant species ecology and impacts, landscape hydrology and wildfire risks in the context of climate change. David Le Maitre holds a PhD in Plant Ecology from the University of Cape Town. David being an ecologist gives us a deeper understanding of the ecological systems we may be trying to regenerate.

David brings a crucial ecologist's point of view, someone with little expertise in the design field but an extensive understanding of ecosystems, biodiversity, and climate. Much of David's contribution top this study is where is the most beneficial place to intervene within degraded ecosystems, particularly in the Durban bay which is a large catchment for the city's stormwater.

The Durban bay is home to a degraded mangrove forest ecosystem, David brings some key understandings of how to intervene. *"you need to think about the catchment and you need to think about the local influences of the city where is storm-water coming in? What can be done to reduce the stormwater? What can be done to put the stormwater to better use in terms of restoring the ecosystems? Now, mangroves are really established themselves at that interface between the sea and* *the land, so you also need to make sure that they're getting proper sea water circulation to maintain that system with that curious mixture of fresh and salt water that sustains that ecosystem."*

Quite an interesting point made by David was how architecture may be used as a communicative device to educate people: *"So I think an important part of that architecture should be the experience that people have of that. And how much your architecture or things that go with the architecture explain to people what's being done here and increase that experience".*

6.2.3 Interview – Paul Wygers – Urban Designer & Architect

Paul Wygers is an experienced architect and urban designer with 25 years of practice in South Africa, Europe, the Middle East and Indian Ocean Islands. Principal designer on a variety of large-scale projects both for government and private sector clients ranging from city wide planning and design, government precincts, university campus planning, large scale residential neighbourhood design, large scale commercial projects and a variety of building typologies.
Paul contribution to the study is that of the urban scale as well as the architectural. His vast understanding of cities as complex networked systems has many synergies with realising a regenerative architecture.

"if you don't have a strong enough, kind of what I essentially call, from urban design point of view. A regulating plan, that is a big picture not only of the entire city, but the inner city and then down to individual sites and what they can contribute to each development"

Paul is able to take a step back and see the city as a whole seeing potential links between ecological and urban systems. As he highlights in the context of Durban "*I think there are opportunities to link those links into those systems that still exist (bay, wetlands, the dunes etc.) , even though they are enormously degraded"* and his vast understanding of Durban provides insight into how architecture may *intervene "So things like the draining of the wetland that is essentially the entire city is something that one, I think is a clue to what could be done".*

"if you're doing a piece of architecture in the particular place that you're doing it and they are, there are places along that edge that are connected directly into the into the natural environment, of course, that you don't see anymore because it's been kind of concreted over buildings and roads and all the other kind of stuff"

6.2.4 Interview – Richard Stretton - Architect

Richard Stretton is an experienced architect, who founded Koop Design in 1993, focussing on furniture as well as architectural design. The ethos of the practice is to produce buildings and products that are environmentally sensitive and energy efficient. Richards approach to architecture is primarily systems based, which is particularly useful given he systemic nature of the study.

Richard defines biomimicry as follows*: "the term biomimicry in the real plain physical reality of what it is, is just that it's biomimicry. It is a learning system, it's a form deriving system. It's a process deriving system. It's a system by which we understand things and more and more in life as sort of a reaction to the, you know, the industrial complex, which is the concept that man can overcome anything through his ingenuity"*

"if you're designing a system-based thing, you first got to understand the list of principles and needs of that system"

Understanding the needs of a particular place and needs of that system to support life are crucial in the regenerative potential of architecture.

6.3 Thematic Analysis

Due to the overlap in the narratives from each expert, a thematic analysis is applied. The themes convey similar ideas from different perspectives. Following on from the secondary research conducted from the literature review, theoretical framework, and precedent the researcher drew on various aspects of the study which were organised and grouped into basic themes which became the sub-headings of this chapter. The data can contribute towards answering the key question of this dissertation. Moreover, it can contribute towards defining a set of design guidelines to inform the design of a regenerative centre on the docks of the Durban bay.

6.3.1 Addressing the problematic relationship of Man, Nature, and the Built Environment

The problematic relationship between man, nature and built environment was explored in the literature review and the theoretical framework.

"It's quite wisely named the Anthropocene because we have an enormous influence on the globe and the Earth will carry on. If all humans die out, the earth will probably breathe a sigh of relief and carry on. So, it's actually about our survival and what kind of a world we want to bequeath our children. So what we're seeing is a convergence of a whole lot of things. It's not just too many people it's also far too much consumption[…]It's all on an unsustainable trajectory[…]As human activity is now the equivalent of huge natural disasters affecting our planetary metabolism….we've got to change something radically" – Dr David le Maitre, 2020

It has largely got to do with mechanistic man-made systems that have been created without considering their impacts on the earths life-supporting systems. Man has become a consumer of all major ecosystems; it is paramount that man and the man-made systems (the built environment in this context) need to shift from degrading ecosystems to supporting them.

“The Anthropocene has got to do with designing of systems in a context where you think the world is abundant and it’s got unlimited space and resources and that anything you do won’t have an impact and you know you have a mindset of no linkage to any other being” -Claire Janische, 2020

It is widely acknowledged that the Anthropocene is human induced. But what is it about humans? Is it the exponentially increasing population? Is it a crisis of design, where man has imposed mechanistic systems on the planet?

“the cause seems to be the humans but is it just the humans or is it something about the humans… It’s not just about being human, it’s about the mindset and the capacity to understand and work within complexity and understand life and that’s critical” - Claire Janische, 2020

The current context of our ecosystemic crisis is not one of design, but rather one of mindset. Claire states that the human mindset is primary to design, and that if we shift our mindset, we shift our goals. Critical to changing our relationship between man, nature and the environment is reconsidering our place and role within the natural world. It is posited that architecture may have a role in shifting realising this shift.

6.3.2 Understanding the Master Patterns of Place

If humanity, and our built environments are to become integral parts of tour bio-physical world it is critical that we understand our living systems work across all scales.

“so, what I'm trying to say to you is if you're talking about the systemic construct of our existence, you've got to see it from the microbial scale through to the macro scale of interconnected spaces of urbanity, the major interconnection of spaces” – Richard Stretton, 2020

As explored in the theoretical framework, understanding the master pattern of place is described as understanding the unique and multi-layered-socioecological systems of a particular place of which the project seeks to inhabit.

“if you're designing a system, or responding to an ecosystem like this thing that you are choosing to introduce into the system, is it actually a need or is it something that you want because it's going to make you feel better? So, if you're designing a system-based thing, you first got to understand the list of principles and needs of that system” – Richard Stretton, 2020

The biomimicry approach is important in this regard as is a primary to design, not an add on at the end, requiring as much time as possible understanding the local ecology, how it functions and why it functions and how you may work with it.

*“What do you do as a designer to integrate within the ecology rather than try and put a green line around it? Right up front is your fundamental thing, how does life work and how do I fit my built environment in with life and contribute to life? ....*Everything has a role, everything cycles and working with those cycles is really important, and understanding those cycles is important especially if you

build environment to contribute to those cycles rather than diminishing them or interrupting them" – Claire Janische, 2020

Fundamental to understanding the master pattern of a particular place is considering how that ecosystem sustains itself, only when that is understood may we begin to think about how architecture should fit within that system. A transdisciplinary understanding is vital in this regard. Much of the issue stems from the separation between disciplines and the lack of collaboration in the development of many projects.

6.3.3 Separation of Disciplines & The need for a transdisciplinary approach

If we are to readdress the relationship between man, nature, and the built environment, we need to shift the way we work as built environment practitioners.

"part of the problem with kind of authorities in South Africa is, they're incredibly silo based. So, one department never talks to another department, never talks to another department. Provincial, doesn't talk to local, et cetera, et cetera. So, and we're quite good at making legacy projects, but we're not very good at kind of making sure that all of these systems work with each other" – Paul Wygers, 2020

So, the problem arises not only the separation between man and nature, but also the separation between disciplines. As mentioned previously, a critical shift in our mindset as built environment practitioners is required, and the need to collaborate and share ideas is how the mindset may begin to shift.

"I do think it has a lot to do with the separation of disciplines and the separation of ourselves from nature That's been one of the problems. I studied master's in chemical engineering, and I was given no training in what life is or how life works. I was given no training in toxicology or health and the impacts of the chemistry that I used on anything to do with life. Same as economist, same as most engineers, same as every architect who I don't think ever has to learn how life works" - Claire Janische, 2020

Although it is posited that a transdisciplinary approach and collaboration is paramount in shifting the way our built environments function, it is also acknowledged that it might take more time and cost more, as well as requiring a client that supports this vision, but the potential is enormous as it puts contrasting perspectives in developing solutions, which are critically needed in our current global context.

"So it's about understanding the entire context when you're designing for something, not just a part of it. It does require a major shift in those disciplines. But it's a cool thing because when we do it, it leads to such amazing innovation" – Claire Janische, 2020

6.3.4 Biomimicry's potential contribution towards regenerative architecture

Fundamental to realising a regenerative built environment is understanding the master pattern of place, and furthermore translating those patterns into design guidelines. This requires an architecture that works within the living systems of place. As explored in this dissertation, biomimicry has a key role to play in this regard.

"Biomimicry is a learning system, it's a form deriving system. It's a process deriving system. It's a system by which we understand things and more and more in life as sort of a reaction to the, you know, the industrial complex, which is the concept that man can overcome anything through his ingenuity" – Richard Stretton, 2020

It has been argued in the theoretical framework that mimicking the functions and services of ecosystems will increase architectures regenerative potential by integrating with the systems of place.

"So it's about designing built environment to understand what the local ecosystem services are, not just trying to reduce the impact on those ecosystem services… So you're going to have to make the built environment function the same or provide the same ecosystem services and be totally integrated within its context" – Claire Janische, 2020

There is potential for cities to realise their regenerative potential across all scales, from buildings, to every process within the building, where every component of the city can continue to figure out how it fits in its context and positively contribute towards its context. Paul Wygers talks about the potential in Durban to link natural systems within the urban fabric, particularly on the urban edge interface with the Durban bay:

I think there are opportunities to link those links into those systems that still exist, even though they are enormously degraded…So things like the draining of the wetland that is essentially the entire city (Durban)is something that one, I think is a clue to what could be done…And if you're doing a piece of architecture in the particular place that you're doing it and they are, there are places along that edge that are connected directly into the into the natural environment" – Paul Wygers, 2020

This highlights the potential of a regenerative architecture on the docks of the Durban bay, that integrates with the natural processes and flows of the local ecological systems.

6.3.5 Shift in Mindset and Behaviour Change

"How do you get people to think differently and how do you get architects and urban planners and then even city and town planners to even agree and then building standards to agree on something. It requires us to shift the mindset first, then shift the goals of the system"- Claire Janische, 2020

When asked if the current ecological crisis is a crisis of design, many of the experts replied that it goes beyond design, but rather a change in mindset. A critical rethinking of our role as humanity on the planet. If we change our mindset, we change the goals and outcomes of the systems we create. This is particularly relevant to regenerative architecture, as we change our mindset of how buildings should function, we shift the aims and goals of architecture. As Claire states:

"I think it's a crisis of mindset, actually, this design as a subsidiary to mindset…, it's the mindset behind the designing… Because the moment we asked designers to design a solution that's regenerative and they've got the time and the money and the space to do it, they always do" – Claire Janische, 2020

I believe that architecture is critically positioned to affect change in the behaviour of its users, especially within regenerative architecture that integrates with and positively contributes towards local ecosystems.

"So I think an important part of that architecture should be the experience that people have of that. And how much your architecture or things that go with the architecture explain to people what's being done here and increase that experience"- Dr David Le Maitre, 2020

Regenerative architecture thus goes beyond positively contributing towards the natural environment, but it reintegrates the individual into the local ecosystem processes of a particular place. If people are to realise that they are an integral part of the living world perhaps a shift in mindset and societal values will occur. Perhaps architects have an important role to play.

"It's something about a designer that can actually design an environment where the feedback loops are so much more visual and so much more visceral that will enable the behavioural shift in making a connection to each other (man and the environment)" – Claire Janische, 2020

6.4 Contribution to Research

This chapter discusses the primary data gathered through semi-structure interviews with key experts in their respective fields who helped facilitate and contextualise the research problem. The thematic analysis referred to regenerative built environments may be achieved.

Firstly, an acknowledgement of the separation between man, nature and the built environment, and the need to reconceptualise their interrelationships. Secondly, key to any regenerative project is a fundamental understanding of the patterns of place, which highlights that biomimicry has a critical role to play as it is primary to design and may uncover the most beneficial health generating patterns of place. Thirdly, architects cannot be alone tasked with understanding the ecological systems in the bio-physical context, and a transdisciplinary approach is required in integrating various systems across scales. Fourth, realising the potential of biomimicry as a learning, and process deriving system in setting the guidelines of how *built environment should function (mimic ecosystem services) the same or provide the same ecosystem services and be totally integrated within its context*. Lastly the realisation that our current ecological crisis not a crisis of design, but rather a crisis of mindset, and that if we change our mindset, we may begin to form a co-creative partnership with nature.

The findings of this data have indeed extended the views of the literature explored. It is clear that there is a need for socio-ecological change in the way we conceive of our built environments, in an attempt to re-think the problematic relationship between man, the built environment, and the ecologies that they are an intrinsic part of. Regenerative Design begins to alter this relationship, and promotes the positive integration with ecological systems, regenerating ecosystems particularly in human dominated urban contexts and furthermore allowing architecture to play a role in the production and maintenance of biodiversity and ecosystem services. Mimicking ecosystem functions/services goes beyond a basic understanding of local ecological systems, but rather critically changes how buildings should function in the context of ecosystems, shifting from a consumer of ecosystems services towards a producer of ecosystem services.

It is now apparent that architecture and the cities they are a part of, across all nested scales should in some way become a positive and active contributor towards socio-ecological systems, instead of remaining isolated and passive contributors towards ecological damage and degradation.

CHAPTER SEVEN | RECOMMENDATIONS & CONCLUSION

7.1 Introduction

The exploration of the relevant literature, the development of a theoretical and conceptual framework, and the analysis carried out in the precedent studies makes an effort to address the problem statement of this dissertation that:

The fundamental challenge is the problematic relationship between man and nature. Humans and there built environments are primary drivers for climate change and ecosystem degradation leading to biodiversity loss.

This has been done with the aim of indicating conclusions and recommendations that are relevant to the research problem. The following conclusions and recommendations seek to address the findings of this study, with the objective of generating design principles and strategies for the Proposed Regenerative Centre on the Docks of the Durban Bay, South Africa.

7.2 Conclusions

Contemporary society faces a unique and critical moment in our history defined by profound environmental, economic, and socio-political crisis as parts of a whole ecosystemic crisis. This is particularly relevant to what French philosopher Bruno Latour describes as the "entanglements" of everything that was once perceived as to be separate – science, morality, religion, law, technology, finance and politics (Cunha & de Faria, 2014). All of the human and non-human associations are beginning to come together at the centre of our consciousness, and it is clear that humanity cannot be separated from the non-human world, and importantly that we, our culture, our technologies, and nature can no longer be "disentangled" (Latour, 2011).

Regenerative architecture grounded within an ecological worldview begins to guide the "disentangled" relationship between humanity and nature. Regenerative architecture is grounded in a perspective that is systems-based (socio-ecological systems), placed based (deep understanding of place) and directed around contributing positively and foster mutually beneficial relationships between humans, their built environments, and ecological systems.

Ecosystem-based biomimicry provides the necessary quantifiable biological knowledge needed to for the positive integration of architecture and urban design reconceptualising how buildings should function in relation to the ecosystems they are a part of. The literature explored brings about an interesting concept "entanglement" which is particularly relevant given the context of this study.

> *"To be entangled is not simply to be intertwined with another, as in the joining of separate entities, but to lack an independent, self-contained existence. Existence is not an individual affair. Individuals do not precede their interactions; rather, individuals emerge through and as part of their entangled intra-relating" (Barad, 2007, p. xi)*

Karen Barad puts forward a new philosophical framework called 'agential realism' in her book called *Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning* (2007).

> *"I propose 'agential realism' as an epistemological-ontological-ethical framework that provides an understanding of the role of human and non-human, material and discursive, and natural and cultural factors in scientific and other social-material practices, thereby moving such considerations beyond the well-worn debates that pit constructivism against realism, agency against structure, and idealism against materialism. Indeed, the new philosophical framework that I propose entails a rethinking of fundamental concepts that support such binary thinking including notions of matter, discourse, causality, agency, power, identity, embodiment, objectivity, space, and time" (Barad, 2007, p. 26)*

Barads work is largely dedicated to de-centering the human from understandings about meaning, bodies and boundaries formed. Barad earned her doctorate in theoretical physics where she started out in quantum physics, which is known to challenge and disrupt long-standing ideologies (Niesche & Gowlett, 2019). As stated in (Barad, 2014), classical Newtonian physics, 'everything is one or the other; particle or wave, this or that, here or there. Quantum physics queers the binary type of difference at every layer of the onion…'. Therefore, Barad uses quantum physics to reject the binary of being this or that, but rather embodying the idea of simultaneity and seemingly opposites coming together (Niesche & Gowlett, 2019).

This is particularly relevant to the discussion on addressing the problematic human-nature as well as built-natural environment dichotomies. Therefore, it is not that humanity must treat the bio-physical world in a more positive way, or that built environments should sustain damage towards the natural environment. Rather an emphasis of *the connectedness* of animate and inanimate things, shifting attention towards *the process* of how these things entangle and thus give each other meaning. Through their entanglement meaning is formed (Niesche & Gowlett, 2019). Importantly, Barads disputes the Cartesian binary thinking, and instead puts forward the idea that the human and the non-human are inseparable in the mean-making process (Niesche & Gowlett, 2019).

The notion of entanglement is a realisation that there is an underlying connectedness between animate and inanimate things, and that these things can never be separate, but rather a continuous process of entanglement, and by this give each other meaning. This is useful in the context of a regenerative architecture, which seeks to realise that humans are an inherent part of natural systems, and that man and the environment are inseparable, and that they are in a constant state of entanglement. In the same sense, the built environment (inanimate) and man (animate) are also in a state of entanglement, which would suggest that through the entanglement of man and the built environment, new meaning is formed. This may be particularly useful where architecture has the potential to shift the mindsets of people, and how they too are entangled with the natural world.

Barads Framework on Entanglement suggests that the human and non-human/living and non-living are inextricably linked no matter their separation from one another. This notion of entanglements of realises that there is an underlying connectedness between animate and inanimate things, and that these things can never be separate, but rather a continuous process of entanglement. This particularly useful where architecture has the potential to shift the mindsets of people, and how they too are entangled with the natural world.

7.3 Recommended Design Guidelines

The following design guidelines serve to provide valuable and insightful premise for the design of a proposed *Regenerative Centre on the Docks of the Durban Bay, South Africa.* Therefore, drawing from the preceding theoretical frameworks explored, the following design guidelines will form the contextual basis for designing facility of this nature.

- The location of a regenerative centre is critically important. The regenerative potential is limited to the ecological context it is situated in. Therefore, the site selection must be accompanied by understanding the master pattern of place, to identify key areas fro a regenerative project to intervene.
- Prior to any design, it is critical to develop the master pattern of place. This may be understood as understanding how a living place functions. This requires an analysis of the existing ecosystem and the provision of its ecosystem services. Key focus to ecosystem services that are applicable to a regenerative built environment context are namely: habitat provision, Nutrient cycling, purification (air, water, soil), climate regulation, provision of fuel(energy), water and food. An understanding of the provision of existing ecosystem services will provide a means to where architecture may harness these flows beneficial for both human and non-human life.
- Once a master pattern of place is developed it is necessary to translate the patterns into design principles. This will prescribe how the project should function as a living systemin the place that it inhabits. These design principles may enable site-specific goals to which the

project should attain. How will the project realise the synergies between ecosystem serices and become a contributor towards ecosystem services for the benefit of both human and non-human life.

- Careful selection of materials and technologies should be considered that first have little to no negative impact towards the environment, as well as attempting to use as many locally sourced materials as possible.
- The design should be fully regenerative with zero waste, maximising from closed loop cycles that feed back into the local context. In nature, form follows flow, and natures flows are the path of least resistance and cyclical by nature.
- Architecture should be used as a communicative tool to educate people that they are not separate from nature, but rather are an intrinsic element in many ecosystem flows that sustain life. Architecture may serve as a medium to shift the behaviour of humans and how they interact with the environment.
- Architecture should understand its whole life cycle over time and be flexible enough to adapt and change to the needs of the context. The architecture should be in a constant cycle of participation and ongoing feedback, revaluating itself and making improvements where possible.
- Fundamental to any regenerative project, it should be systems-based, place-based and become a positive contributor towards the local socio-ecological context.

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CHAPTER ONE

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CHAPTER FOUR

APPENDICES

The study is of an interdisciplinary nature and required insight from experts in their fields. The disciplines explored were Architecture, Urban Design and Town planning, Ecology, and Biomimicry. This allowed the researcher to purposefully select individuals who meet the respective criteria assuring that the research identified the 'right' cases for the study. The researcher interviewed an expert in their respective fields. Some participants have knowledge from more than one field, aiding in the interdisciplinary nature of the study. The researcher conducted four expert interviews varying and overlapping fields of expertise. The fields were ecologists, biomimicry experts, architects, engineers, urban designers

Interview Schedule A – Urban Designers and Architects

Establishing Rapport

It would be nice if you could tell me a little bit about yourself. What is your background and what influenced your choice of profession?

Architecture

1. Cities face ecological and societal pressures attributable to global patterns of unstainable production and consumption. The built environment has become a heavy consumer of natural resources and polluter of natural ecosystems. In your opinion, what role should architecture play given its primarily negative environmental influence?

2. Within the context of the 'Anthropocene' , where urbanization and industrialization have made humankind the major consumer of all significant ecosystems, how may the Built Environment be conceived so that it is may become a life supporting environment conducive for all forms of life?

3. What are your thoughts on sustainable architecture? Do you think that sustaining our current negative impact really enough?

4. From your experience, do architects consider regenerative design when engaging with different projects across varying contexts?

Prompt: What role should architecture play in the regeneration of local ecosystems?

5. From your experience, do you engage with ecologists when undertaking a new project?

Prompt: Do you think there may be benefits when collaborating with ecologists?

Prompt: if so, how early on should the architect engage with them?

6. What is your understanding of biomimicry in the context of architecture?

Prompt: Is it a term that is confusing or misused?

Prompt: Do you think a better understanding of Biomimicry should be taught at a schools (architecture)

7. Resource scarcity in cities is a real issue in the foreseeable future. Do you think cities can produce their own food, energy and water?

Prompt: Can they be designed to regulate climate, provide habitat, cycle nutrients and purify water, air and soil?

Collaboration

1. What relationships exist, if any, between built environment practitioners and ecologists in the development of the built environment?

2. Do you think an understanding of ecosystems in collaboration with ecologists, formatively in the initial stages of the design and development may provide a significantly more ecologically regenerative built environment?

3. Do you think that the current ecological crisis is also a crisis of design?

Prompt: What role do architects, engineers, and ecologists have in bringing about systemic change in the built environment?

Conclusion

Is there anything else that you would like to comment on that I haven't already asked you about?

Thank you very much for your time and the information you shared today.

Interview Schedule B – Ecologist and Biomimicry Experts

Establishing Rapport

It would be nice if you could tell me a little bit about yourself. What is your background and what influenced your choice of profession?

Context: Anthropocene – Climate – Ecosystems- Biodiversity- Cities – Built Environment.

1. We are currently living in the epoch of the 'Anthropocene'. What are your thoughts on the ecological impact of human activity on planetary systems?

Prompt: What makes human activity a major consumer of nature's ecologies?

2. In your opinion, what is the relationship between climate, ecosystems and biodiversity?

Prompt: Would you say that this is a synergistic relationship?

3. In your opinion, what is the role of biodiversity nested within ecosystems and climatic systems?

Prompt: Is it fair to say that biodiversity resembles the basic building blocks essential for life?

4. In your opinion, how does the damage and loss of biodiversity affect ecosystems and the services they provide?

Prompt: Is the loss of ecosystem service and biodiversity reversible?

Prompt: If so, to what extent? Is there a tipping point?

5. In your opinion, what are the potential impacts of the decline of biodiversity health and ecosystem services on urban built environments?

Prompt: How does the built environment contribute to these issues?

6. In your opinion, do you think it is necessary for cities to better manage ecosystem services and biodiversity?

Prompt: how may, cities better manage and restore ecosystem services and biodiversity?

7. The built environment is often conceptualised as separate from the natural. Ecosystems are open systems nested within other systems. In your opinion, is the built environment nested within ecological systems?

Prompt: How can the built environment form a symbiotic relationship with varying nested ecosystems?

8. In your opinion, what are the similarities and differences between ecosystems, and the man-made systems of urban built environments?

Prompt: Is it fair to say man-made systems are largely wasteful and unsustainable?

9. The built environments' intensive development model treats the city as a linear system. The consumption of energy, water, food and a range of environmental resources are largely disposed of wastes. How do ecosystems deal with consumption and production of energy, materials and resources?

Ecosystem Biomimicry - Architecture

1. In your opinion, do you think regenerative architecture may be a means towards restoring local biodiversity and ecosystem services?

Prompt: If so, how may architecture achieve this?

Prompt: Do ecosystem processes and functions offer insight into how architecture may regenerate local biodiversity and ecosystem services?

2. Is mimicking the ecosystem processes and functions a potentially useful strategy to employ in increasing the regenerative potential of architecture as a response to ecosystem damage and loss of biodiversity?

Prompt: If so, in what way?

3. What are the Features of ecosystems that make them resilient and adaptable?

Prompt: Do you think that these could be useful in the context of adapting towards a built environment that sustains life and is regenerative?

4. How can generalised ecosystem processes (how they work) and functions (what they do) be understood and presented so they are relevant for a built environment context?

Prompt: if so, which are better applicable? How they work, or, What they do?

5. What relationships exist between ecosystem processes and how does understanding these, aid in the employment of relating ecosystem processes to the architecture?

Prompt: Should architecture function as a living organism within an ecosystem(the city)?

6. Where are the key places to intervene in the built environment in terms of ecosystem services for maximum benefit when working with development goals that seek to regenerate ecosystems and address the causes and impacts of climate change and biodiversity loss?

7. Resource scarcity in cities is a real issue in the foreseeable future. Do you think cities can produce their own food, energy and water? Can they be designed to regulate climate, provide habitat, cycle nutrients and purify water, air and soil?

Collaboration

1. What relationships exist, if any, between built environment practitioners and ecologists in the development of the built environment?

2. Do you think an understanding of ecosystems in collaboration with ecologists, formatively in the initial stages of the design and development may provide a significantly more ecologically regenerative built environment?

3. Do you think that the current ecological crisis is also a crisis of design?

Prompt: What role do architects, engineers, and ecologists have in bringing about systemic change in the built environment?

Conclusion

Is there anything else that you would like to comment on that I haven't already asked you about?

Thank you very much for your time and the information you shared today.

ECOSYSTEM-BASED BIOMIMICRY AS A POTENTIAL INFORMER FOR REGENERATIVE ARCHITECTURE

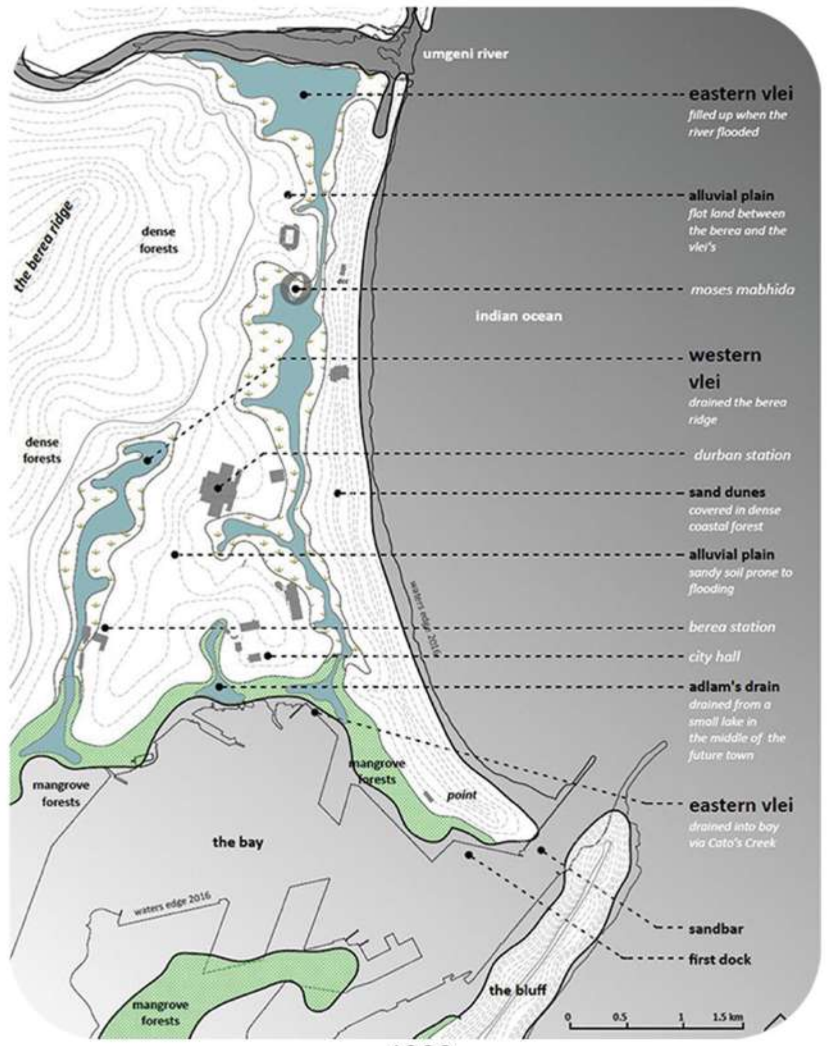
TOWARDS A REGENERATIVE RESEARCH CENTRE ON THE DOCKS OF THE DURBAN BAY

PROBLEM STATEMENT

THE **FUNDAMENTAL** CHALLENGE IS THE **PROBLEMATIC** AND **DESTRUCTIVE RELATIONSHIP** BETWEEN **MAN, AND NATURE.**

HUMANS AND **THEIR BUILT ENVIRONMENTS** ARE PRIMARY **DRIVERS** FOR **CLIMATE CHANGE** AND **ECOSYSTEM DEGRADATION** LEADING TO **BIODIVERSITY LOSS**

STATE OF THE DURBAN BAY



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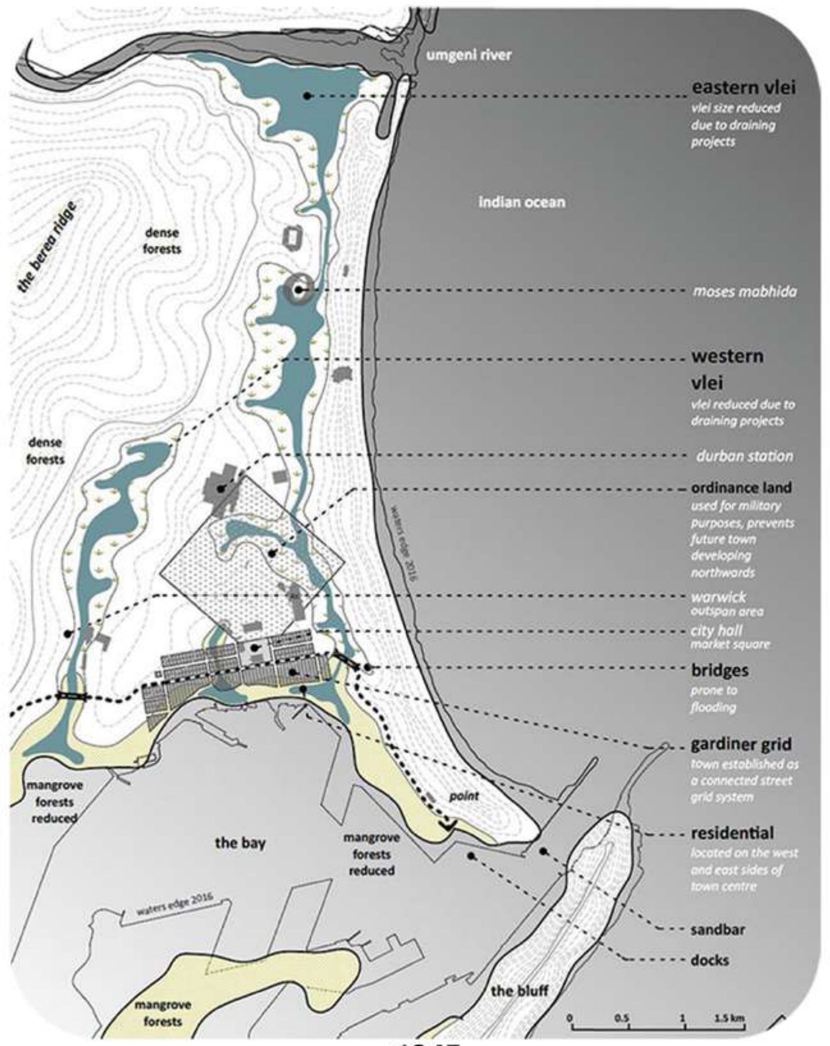

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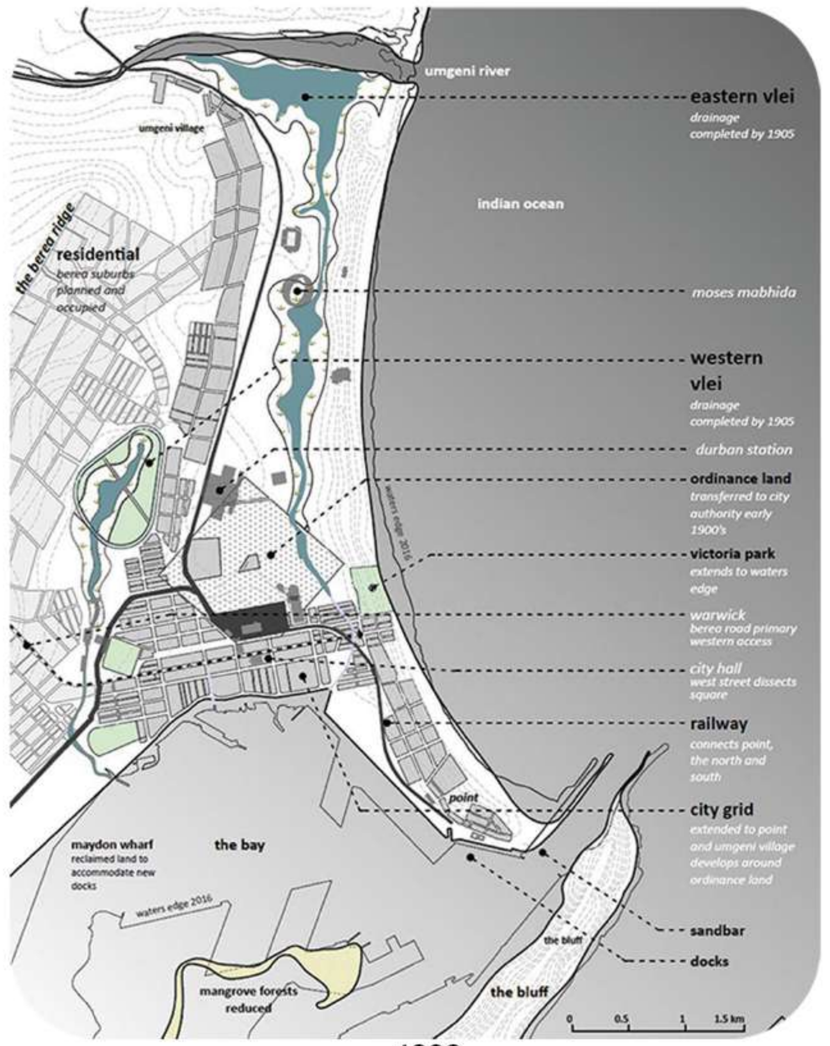

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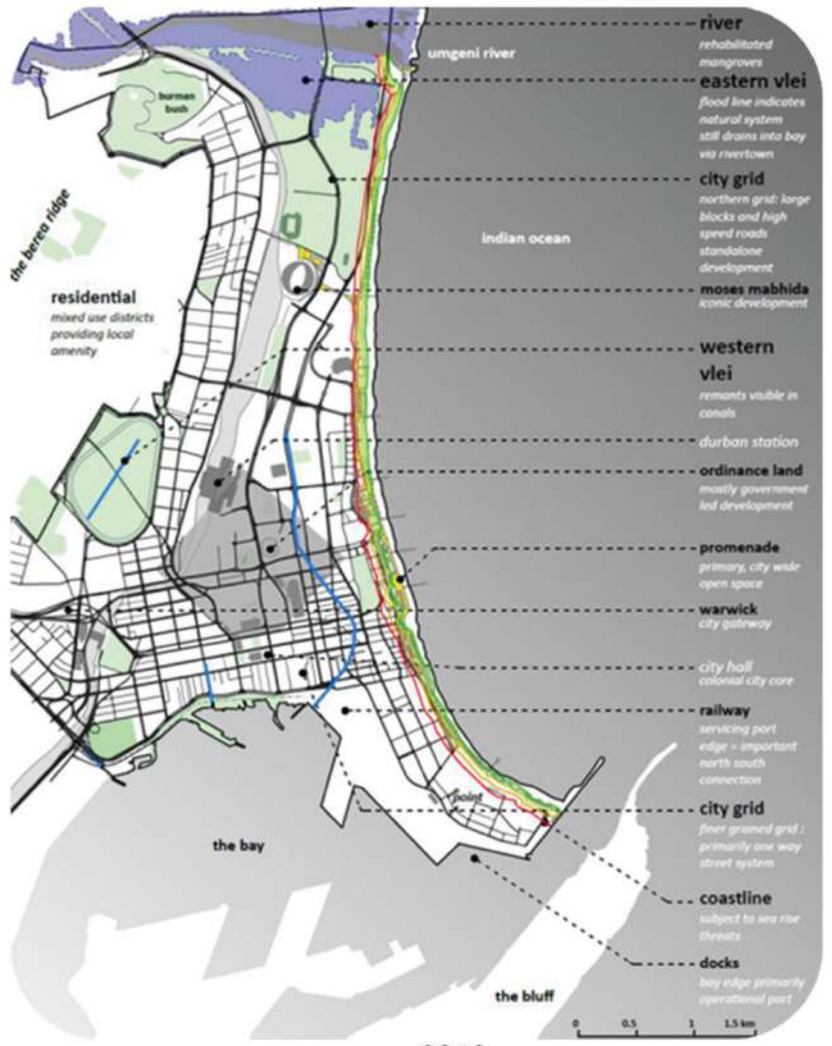


2016

THE **NATURAL TOPOGRAPHY** AND **ECOLOGY** OF THE **DURBAN BAY** HAVE BEEN **ALTERED DRASTICALLY** SINCE THE EARLY 1800S TO **FACILITATE DEVELOPMENT** OF THE INNER CITY..

THE **DURBAN BAY ECOSYSTEM** PLAYS AN **IMPORTANT ROLE** IN THE SUPPLY OF **ECOSYSTEM SERVICES** TO THE **CITY** AND ITS **INHABITANTS**.

THE **ECOLOGICAL STATUS** OF THE DURBAN BAY IS IN A **CRITICAL CONDITION**.

AIM OF RESEARCH

TO MOTIVATE AND INFORM **ARCHITECTURE** AS A **MEDIUM** FOR MITIGATING **ECOSYSTEM DEGRADATION** IN ORDER TO **RECONFIGURE** THE **RELATIONSHIP** BETWEEN **MAN**, THE **BUILT ENVIRONMENT** AND **NATURES ECOLOGIES**.

KEY QUESTION

HOW MAY **ECOSYSTEM-BASED BIOMIMICRY** INFORM A **REGENERATIVE ARCHITECTURE** [SO THAT THE **BUILT ENVIRONMENT** MAY BECOME A **LIFE-SUPPORTING ENVIRONMENT** CONDUCIVE FOR BOTH **HUMAN** AND **NON-HUMAN LIFE**]?

OBJECTIVES

- **TO UNDERSTAND THE NATURE OF ECOSYSTEMS** [THE INTERRELATIONSHIPS BETWEEN ECOSYSTEM FUNCTIONS (WHAT THEY DO) AND THEIR POTENTIAL FOR A REGENERATIVE ARCHITECTURE]
- TO UNDERSTAND THE **RELATIONSHIP** AND INFLUENCES ON **ECOSYSTEM DEGRADATION** AND **BIODIVERSITY LOSS** IN THE DURBAN BAY
- TO **GENERATE PRINCIPLES** TO BE APPLIED TO AN **ARCHITECTURE** THAT **REGENERATES** AND IMPROVES **NATURAL ECOSYSTEMS** AND **BIODIVERSITY** IN THE **DURBAN BAY.**

JUSTIFICATION OF RESEARCH

THE **BUILT ENVIRONMENT** PLAYS A MAJOR ROLE IN THE **CAUSE** OF **NEGATIVE CLIMATE** AND **ECOSYSTEM CHANGES.**

THE BUILT ENVIRONMENT IS THE **PRIMARY HABITAT FOR HUMANS**, AND A **FOCUS** TOWARDS THE **BUILT ENVIRONMENT** THUS BRINGS ABOUT **POTENTIAL FOR CHANGE**.

THEREFORE THIS THESIS FOCUSSES ON THE BUILT ENVIRONMENT AS A **MEDIUM FOR REDUCING** THE CAUSES OF THE **DEGRADATION OF ECOSYSTEMS** WITH SPECIFIC FOCUS ON THE **DURBAN BAY ECOSYSTEM AND ITS BIODIVERSITY.**

RESEARCH SCOPE

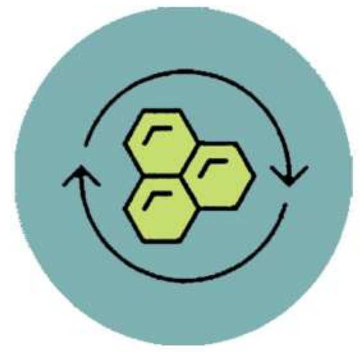
WHO?

HUMANITYS' ECOLOGICAL IMPACT ON PLANETARY SYSTEMS

WHAT?

THE BUILT ENVIRONMENT AS A CAUSATIVE AGENT DAMAGING ECOSYSTEMS

WHY?



REGENERATIVE ARCHITECTURE TO RESTORE DAMAGED ECOSYSTEMS

HOW?

MIMICKING THE FUNCTIONS & PROCESSES OF ECOSYSTEMS

THEORETICAL & CONCEPTUAL FRAMEWORK

THEORIES

WHOLE + LIVING SYSTEMS THINKING
- DEEP INTERCONNECTEDNESS OF MAN-MADE AND NATURAL SYSTEMS

ECOLOGY OF MIND
- UNIFICATION OF THE HUMAN MIND AND NATURE

PHENOMENA

NATURE + MAN + BUILT ENVIRONMENT

REGENERATIVE ARCHITECTURE
- SYSTEMS BASED
- PLACE BASED
- POSITIVE CONTRIBUTION TOWARDS ENVIRONMENT

CONCEPTS

REGENERATIVE DESIGN
- UNDERSTANDING HOW A LIVING PLACE WORKS → DEVELOP THE MASTER PATTERN OF PLACE
- PROJECT SHOULD FUNCTION AS A LIVING SYSTEM IN ITS PLACE → TRANSLATE PATTERNS INTO DESIGN PRINCIPLES
- PROCESS OF ONGOING FEEDBACK + PARTICIPATION → ONGOING FEEDBACK

ECOSYSTEM BASED BIOMIMICRY
- ANALYSE EXISTING ECOSYSTEM + PROVISION OF ECOSYSTEM SERVICES
  - HABITAT PROVISION
  - NUTRIENT CYCLING
  - PURIFICATION
  - CLIMATE REGULATION
  - PROVISION OF FUEL
  - PROVISION OF WATER
  - PROVISION OF FOOD
- SET SITE SPECIFIC GOALS
  - DESIGN
  - MATERIALS | TECHNOLOGIES
  - BEHAVIOUR CHANGE
- DESIGN EVALUATION + IMPROVEMENTS
  - HUMAN SOCIAL IMPLICATIONS
  - RELATIONSHIP TO OTHER ECOSYSTEM SERVICES
  - WHOLE LIFE CYCLE OVER TIME

THEORETICAL DESIGN PROCESS DRIVERS

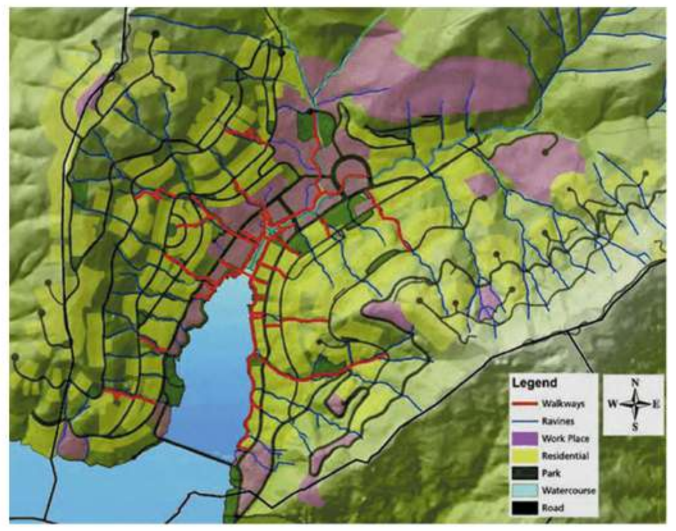
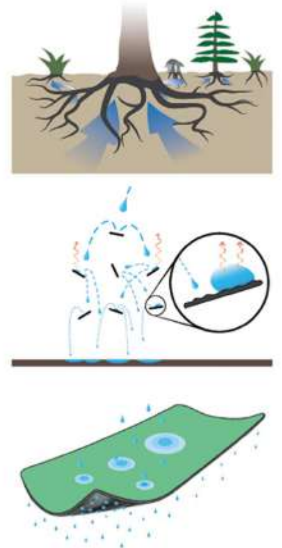
HOW DOES A LIVING PLACE FUNCTION? → UNDERSTAND THE PATTERN OF PLACE → ANALYSE MANGROVE ECOSYSTEM & PROVISION ECOSYSTEM SERVICES → HABITAT PROVISION, NUTRIENT CYCLING, PURIFICATION, CLIMATE REGULATION, PROVISION OF FUEL/FOOD, PROVISION OF ENERGY, PROVISION OF WATER

HOW CAN ARCHITECTURE FUNCTION FUNCTION AS A LIVING SYSTEM? → TRANSLATE PATTERNS INTO DESIGN PRINCIPLES → DETERMINE PROJECT GOALS AND OUTPUTS → DESIGN STRATEGIES, MATERIALS/TECHNOLOGIES, BEHAVIOUR CHANGE

HOW CAN ARCHITECTURE FACILITATE ONGOING CHANGE? → ON-GOING PROCESS OF DESIGN AND FEEDBACK → DESIGN EVALUATION + IMPROVEMENTS → HUMAN SOCIAL IMPLICATIONS, RELATIONSHIP BETWEEN ECOSYSTEM FUNCTIONS, WHOLE LIFE CYCLE OVER TIME, INCORPORATE FLEXIBLE DESIGN

KEY PRECEDENT STUDIES

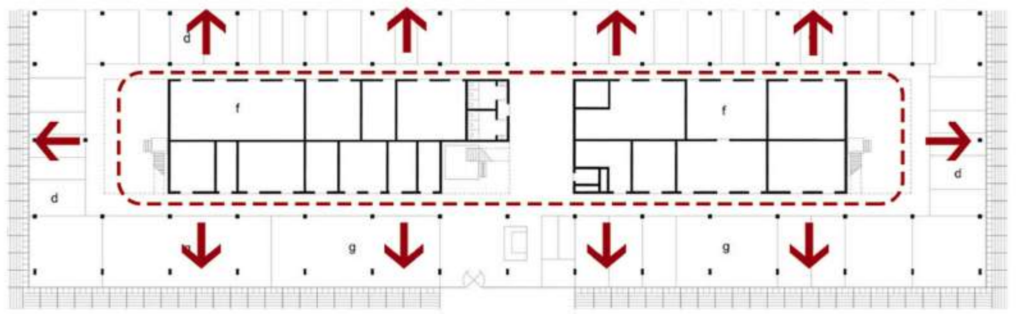
LAVASA HILLSIDE TOWN

KEY ATTRIBUTES
- UNDERSTANDING THE GENIUS OF PLACE
- PROCESS OF ANALYSIS AND DESIGN DEVELOPMENT
- DESIGN PRINCIPLES BASED ON LOCAL ECOLOGY

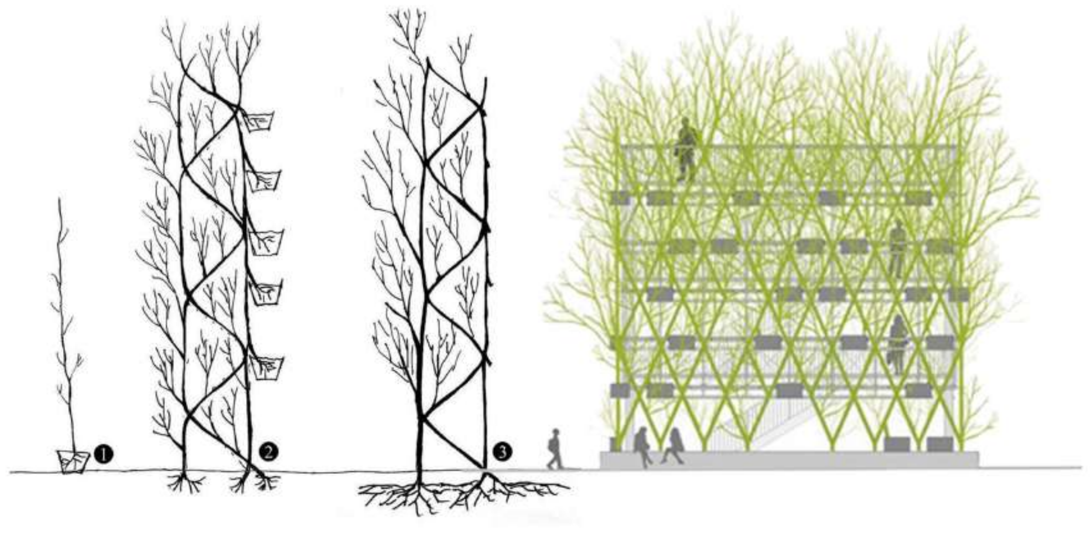
NETHERLANDS INSITUTE OF ECOLOGY





KEY ATTRIBUTES
- CRADLE TO CRADLE APPROACH - ZERO WASTE
- SYNTHESIS OF SYSTEMS. MATERIALS-WATER-WASTE-FOOD-BIODIVERSITY
- ARCHITECTURE AS AN ONGOING EXPERIMENT

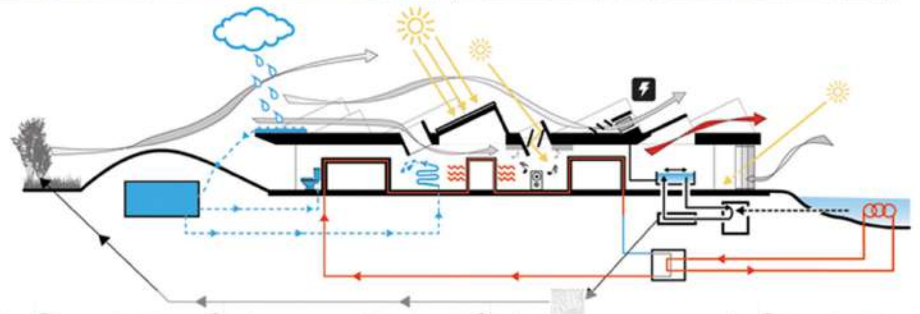
PLANE TREE CUBE



KEY ATTRIBUTES
- EXPERIMENTS WITH MAN-MADE AND LIVING MATERIALS + CONSTRUCTION METHODOLGIES
- DESIGN THAT FOLLOWS THE RULES + CONSTRAINTS OF NATURE
- A BUILDING THAT IS ESSENTIALLY ALIVE. LIMITTED APPLICABILITY

MARINE EDUCATION CENTRE

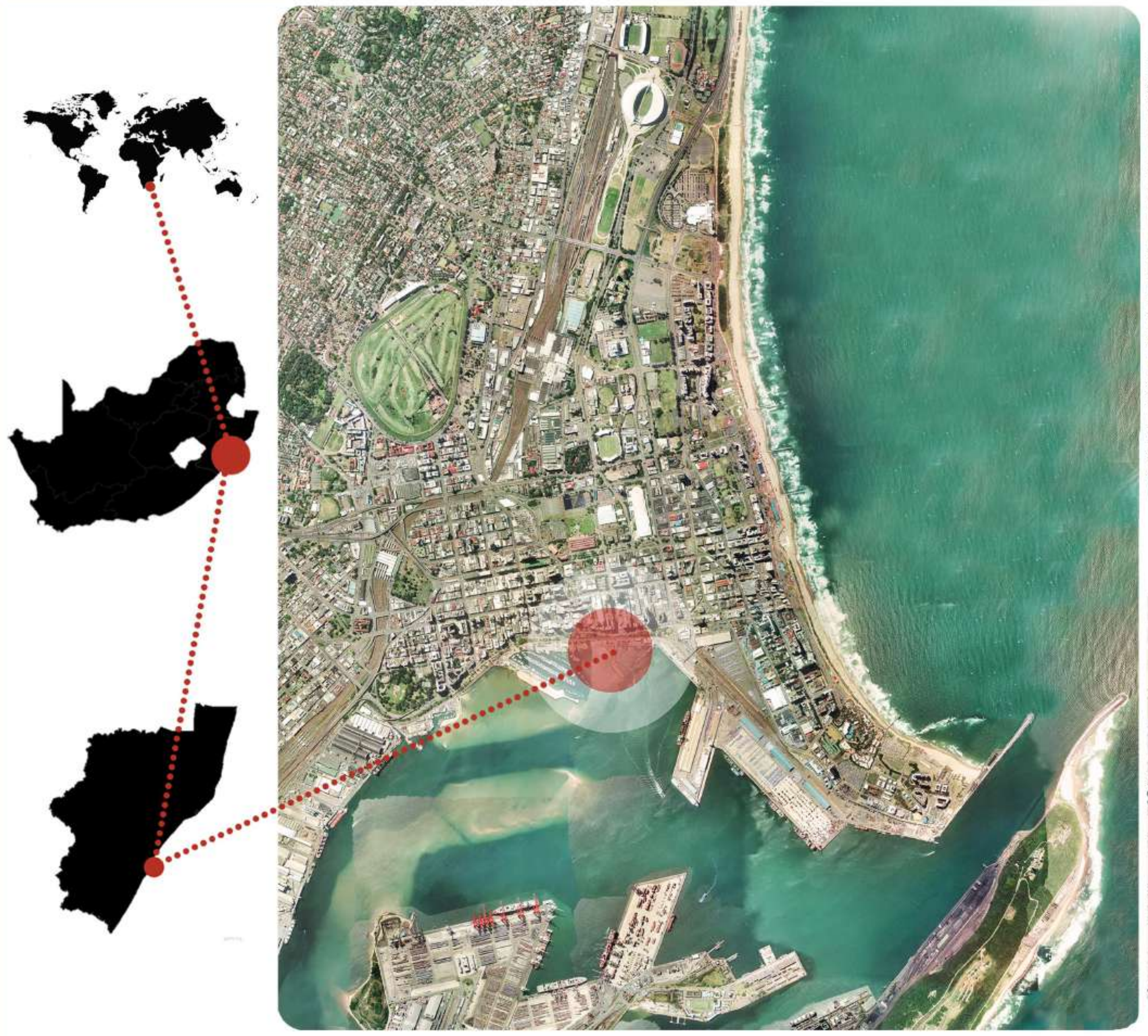




KEY ATTRIBUTES
- CONTRASTING PROGRAMS CENTRED AROUND EXPERIENCE AND LEARNING
- ARCHITECTURAL SYSTEMS ON DISPLAY - EDUCATING USER ABOUT RESOURCES AND SUSTAINABILITY
- INVITES USERS TO EXPLORE USING THEIR SENSES AND THEREAFTER ANALYSE AND UNDERSTAND THEIR

SITE SELECTITON CRITERIA

SITE LOCALITY



MACRO ANALYSIS

CONTEXTUAL ANALYSIS

URBAN ISSUES

- URBAN FABRIC DISCONNECTED FROM THE WATER'S EDGE.
- PHYSICAL BARRIERS PREVENTING ACCESS TO DURBAN BAY
- CRITICAL MANGROVE FOREST ECOSYSTEM
- LACK OF PUBLIC SPACE TO BENEFIT FROM BAY ECOSYSTEM SERVICES.

URBAN RESPONSE

- RE-EMBED NATURE AS AN INTEGRAL PART OF THE CITY AS AN ESSENTIAL RESOURCE.
- RECONFIGURE THE RAILWAY LINE TO ALLOW A LINEAR PARK ALONG THE ESPLANADE
- PRIORITIZE ECOLOGICAL SYSTEMS WITHIN THE CITY, & REGENERATE MANGROVE FORESTS ALONG THE WATERS EDGE
- EXTEND BEACH PROMENADE TOWARDS WILSONS WHARF MAXIMISING PUBLIC SPACE AND ECOLOGICAL SYSTEMS. THIS WILL IMPROVE PEDESTRIAN ACCESS.
- REWORK BAY EDGE INTERFACE WITH THE GREEN BELT.
- RELOCATE INDUSTRIAL ACTIVITIES ALONG THE POINT. REMOVAL OF RAIL
- RECONNECT THE CITY CENTRE TO THE DURBAN BAY - IMPROVE LINKAGES & INTERACTIONS BETWEEN INNER CITY AND THE HARBOUR, REINFORCING PEDESTRIAN CONNECTIONS.

URBAN FRAMEWORK

DESIGN BRIEF

CLIENT

agriculture, forestry & fisheries
Department:
Agriculture, Forestry and Fisheries
REPUBLIC OF SOUTH AFRICA

ETHEKWINI MUNICIPALITY

ENVIRONMENTAL PLANNING & CLIMATE PROTECTION DEPARTMENT
BIODIVERSITY | CLIMATE | PEOPLE

USER

- GENERAL PUBLIC
- YOUTH
- ACADEMICS
- STUDENTS
- RESEARCHERS
- ECOLOGISTS

PROJECT AIMS + OBJECTIVES

- RECONNECT THE CITY TO THE DURBAN BAY
- RESEARCH HEALTH OF LOCAL ECOSYSTEM
- ENVIRONMENTAL EDUCTAION & AWARENESS
- PRODUCTIVE + SELF SUFFICIENT ARCHITECTURE

BUILDING REQUIREMENTS

SOCIO- ECOLOGICAL

PRODUCER OF ECOSYSTEM SERVICES

ENVIRONMENTAL

REGENERATE, RESTORE & MANAGE MANGROVE ECOSYSTEM

URBAN

INTEGRATE URBAN & NATURAL ENVIRONMENT

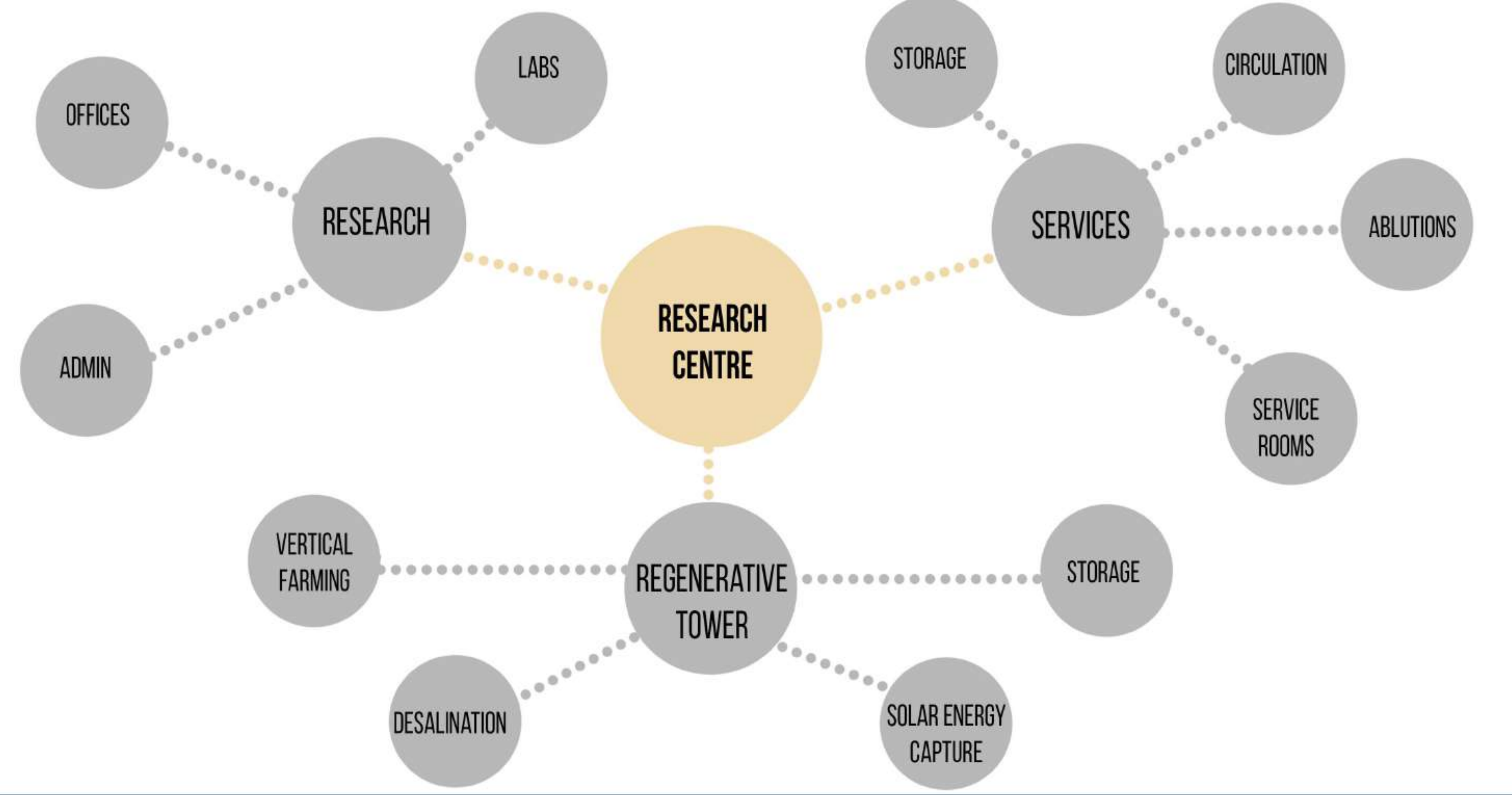
ARCHITECTURAL

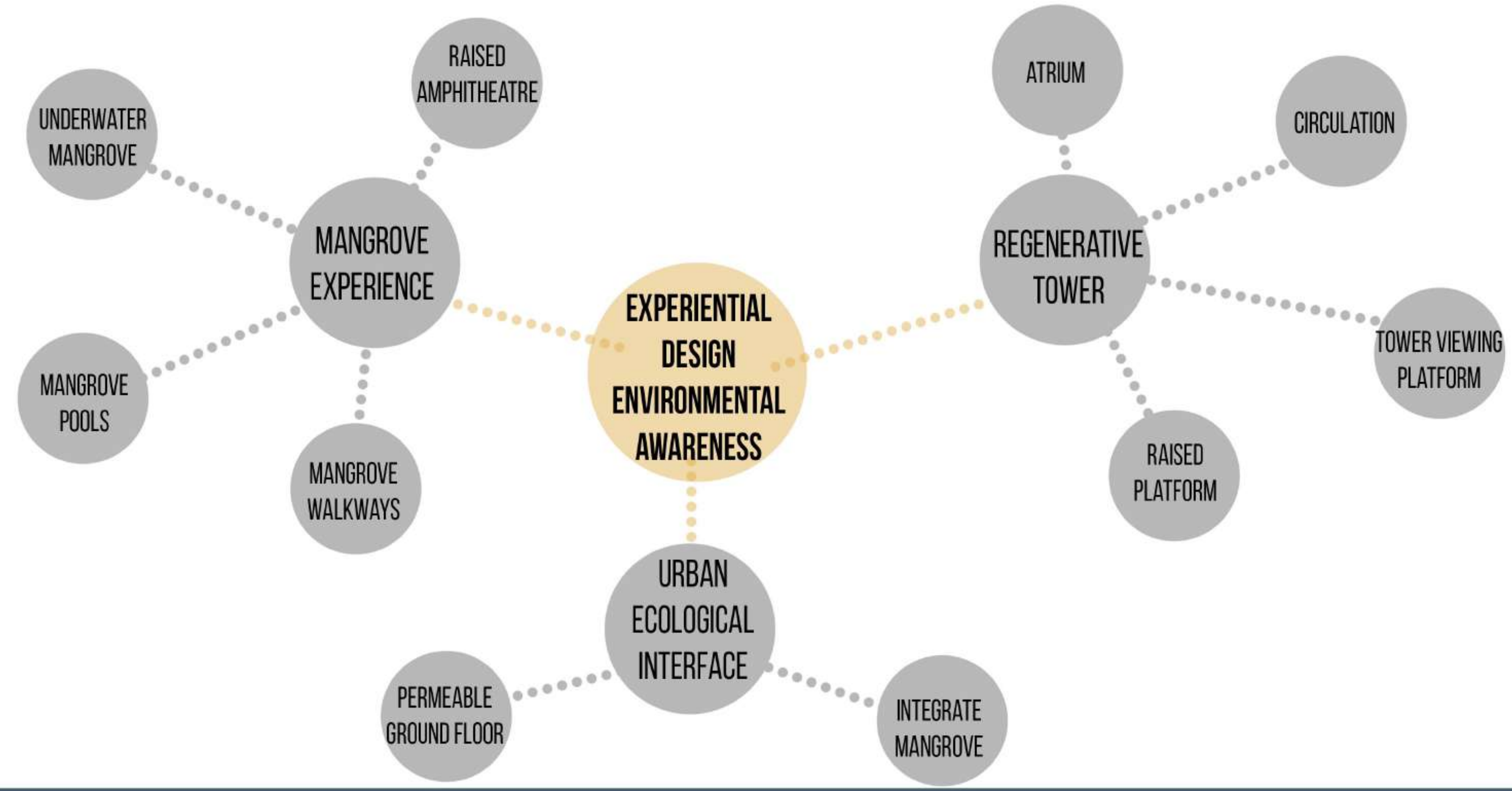
EXPERIENTIAL DESIGN - SHIFT BEHAVIOUR

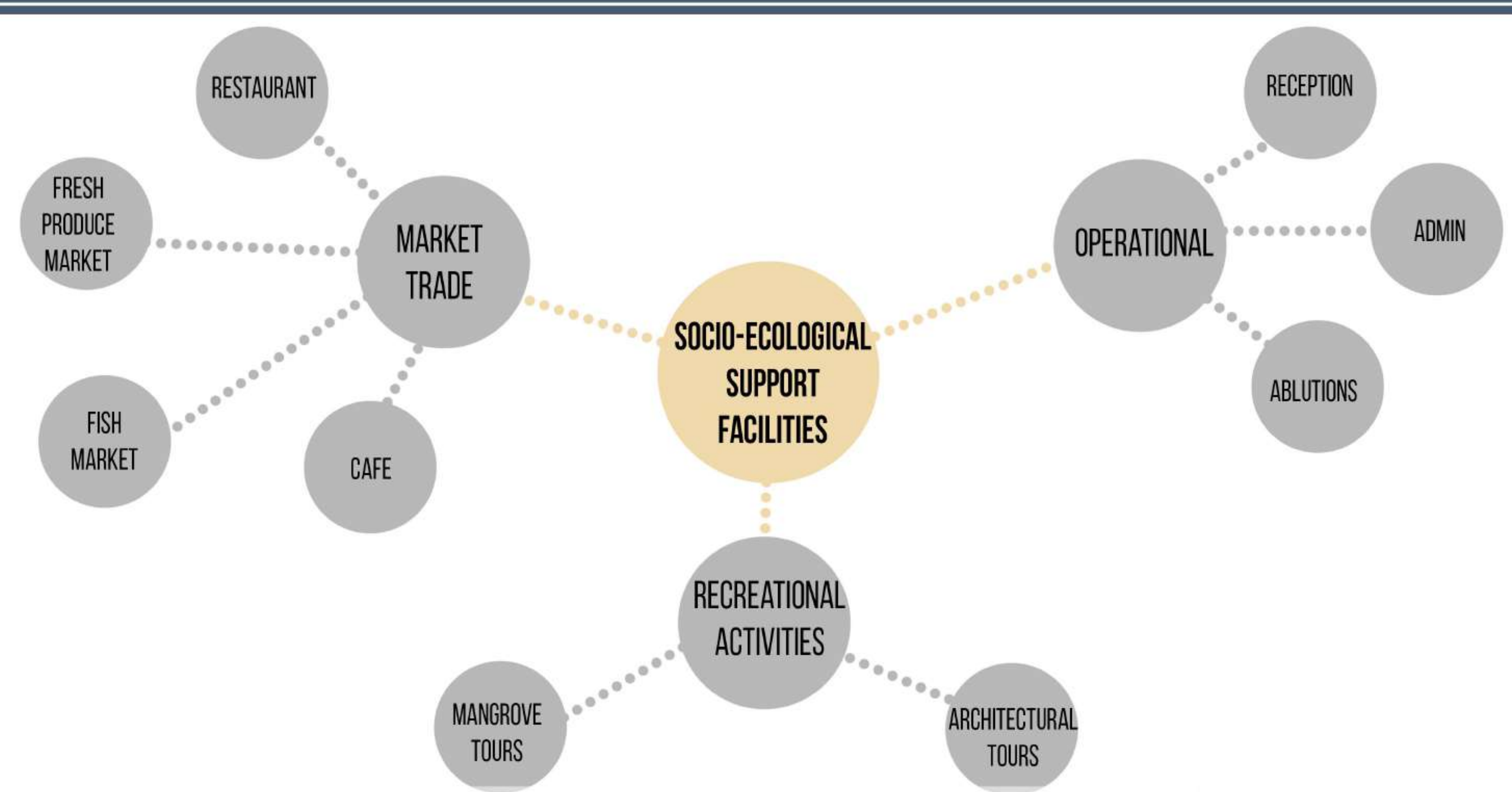
SOCIO-ECONOMIC

MARKET + COMMERCIAL SUPPORT ACTIVITY

PROGRAMMATIC FUNCTIONS







CONCEPTUAL FRAMEWORK

DESIGN PRINCIPLES

NATURE AS PRIMARY TO DESIGN

- ECOSYSTEM ANALYSIS - MASTER PATTERN OF PLACE
- ARCHITECTURE AS A LIVING SYSTEM
- MANGROVE ECOSYSTEM AS A BASIS FOR DESIGN

PRODUCER OF ECOSYSTEM FLOWS

- MIMICK ECOSYSTEM FUNCTIONS/OUTPUTS
- PRODUCER OF HABITAT, ENERGY, NUTRIENTS & MATERIALS
- POSITIVE CONTRIBUTOR TOWARDS ECOSYSTEM

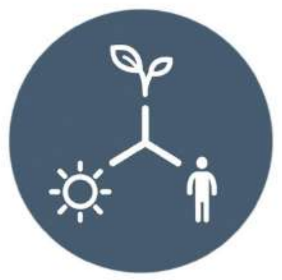
FORM FOLLOWS FLOW+FUNCTION

- FORM IS SUBSIDERY TO NATURES FLOWS
- ARCHITECTURE AS AN INTEGRAL PART OF THE ECOSYSTEM
- FLUID SPATIAL DESIGN INFORMED BY ECOSYSTEM FLOWSFUNCTIONING

INTEGRATIVE+REGENERATIVE SYSTEMS

- MINIMISE/REDUCE WASTES
- POSITIVE INTEGRATED FEEDBACK LOOPS – CIRCULAR METABOLISMS
- FEED BACK INTO ECOSYSTEM FUNCTIONING

EXPERIENTIAL DESIGN



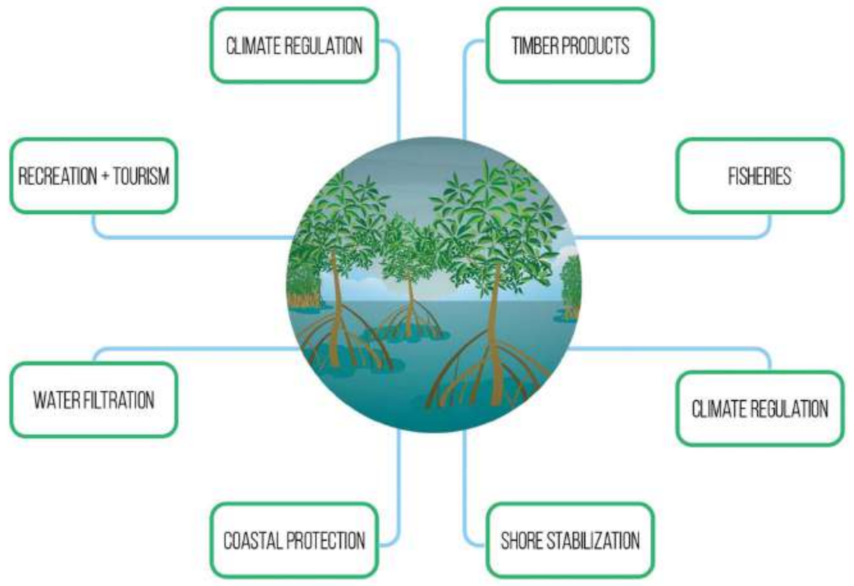
- RECONNECT THE USERS TO NATURES ECOLOGIES
- POTENTIAL TO SHIFT HUMAN BEHAVIOUR
- ECOLOGY OF MIND

ADAPTABLITY + PLUG & PLAY

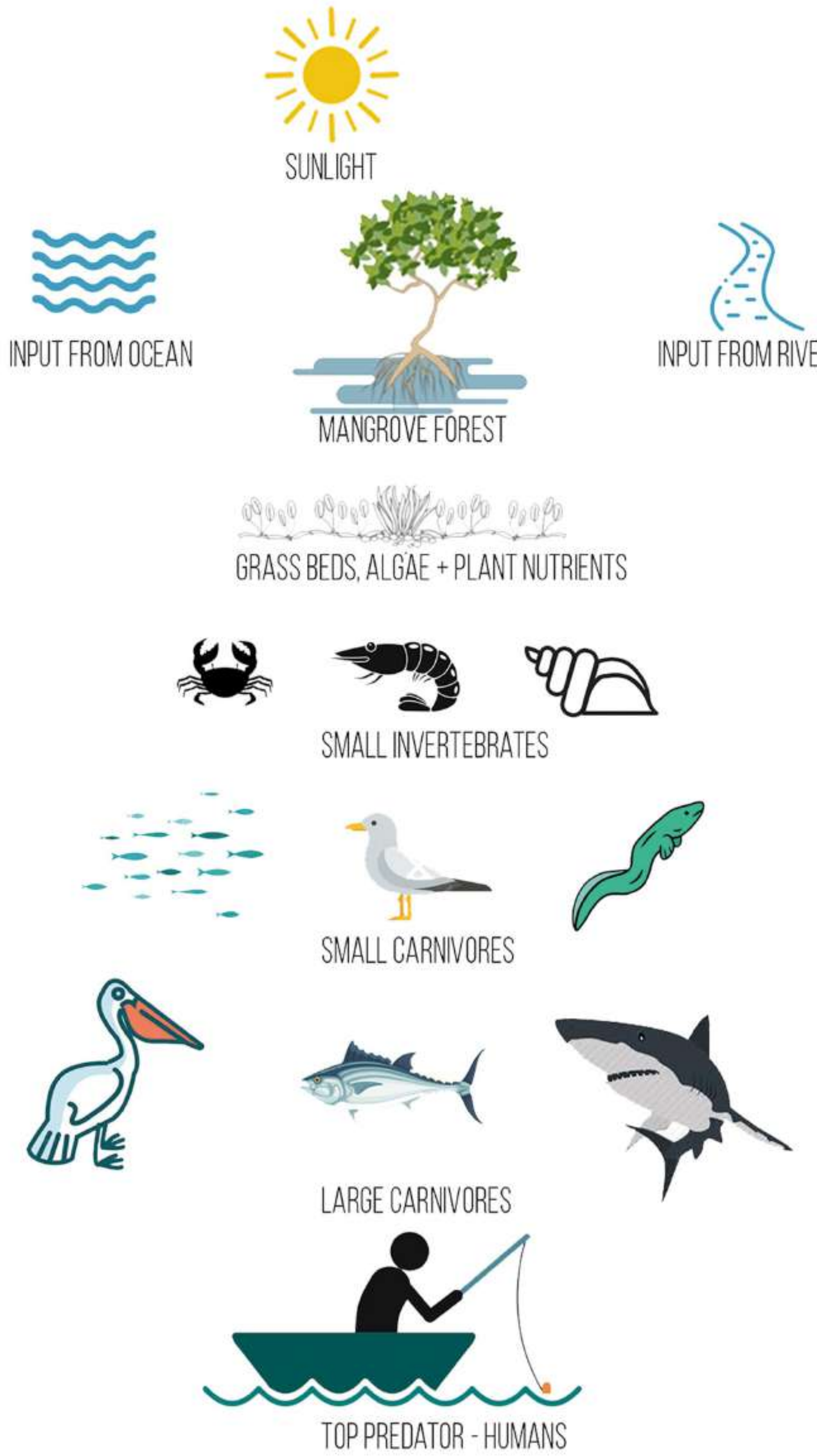
- FLEXIBLE MODULAR DESIGN
- PLUG & PLAY
- CONSTANT EVOLUTION OF DESIGN

ECOSYSTEM ANALYSIS

IMPORTANCE OF MANGROVE ECOSYSTEMS



LIFE CYCLES OF MANGROVE ECOSYSTEMS



DESIGN CONCEPT

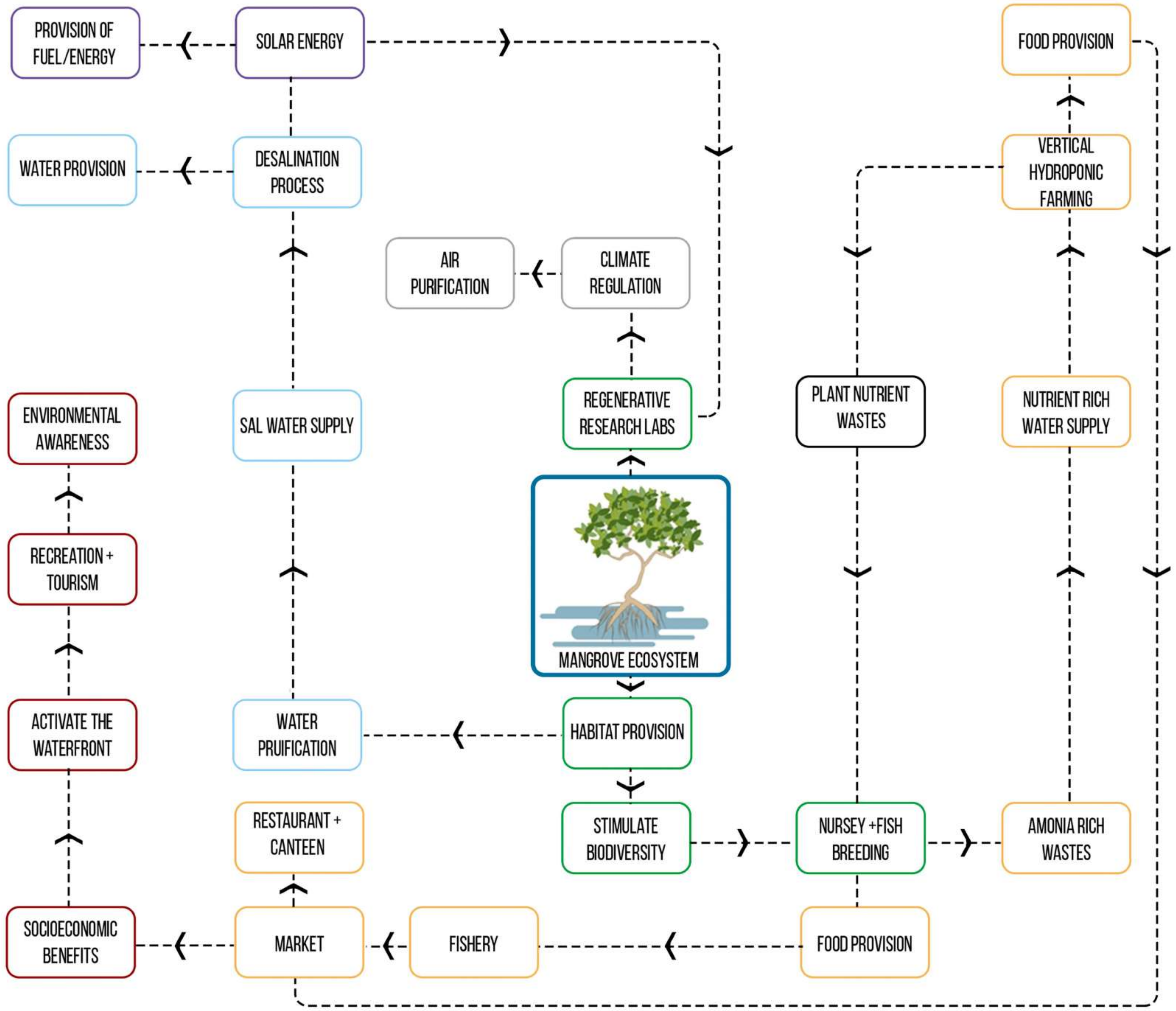
| LIVING-SYSTEMS-ARCHITECTURE |

ECOSYSTEMIC ARCHITECTURE THAT **FACILITATES** HEALTHY **RELATIONSHIPS** BETWEEN **MAN**, THE **BUILT ENVIRONMENT** AND **NATURE** THROUGH **EXPERIENTIAL DESIGN** AND CREATES **LIFE-SUPPORTING CONDITIONS** FOR BOTH **HUMAN** AND **NON-HUMAN LIFE.**

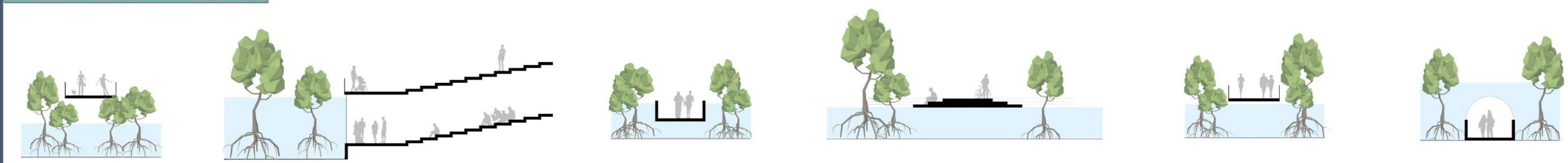
REFRAMING ARCHITECTURAL, SPATIAL AND URBAN DESIGN AS A PROCESS OF FORMING, LEVERAGING AND CREATING FLEXIBLE SETS OF RELATIONSHIPS OF SOCIAL CONDITIONS, FLOWS (MATERIALS, ENERGY, CARBON, WATER, ETC.), AND REACTIONS OVER TIME IN VERY REAL TANGIBLE PHYSICAL ECOLOGICAL SPACES

ARCHITECTURAL SYSTEMS DESIGN

SYNTHESIS OF MAN + NATURAL + ARCHITECTURAL SYSTEMS

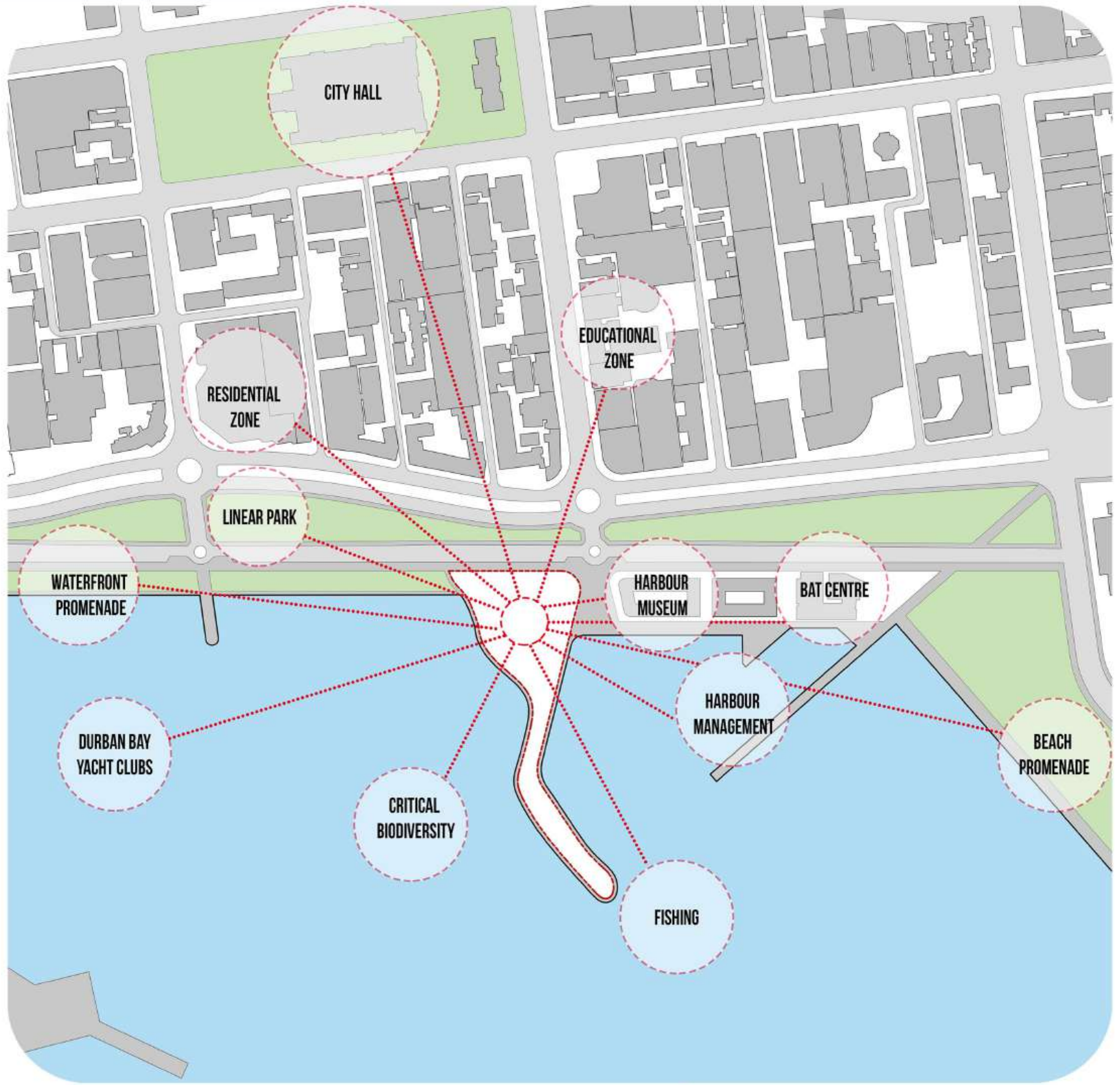


EXPERIENTIAL DESIGN PRINCIPLES

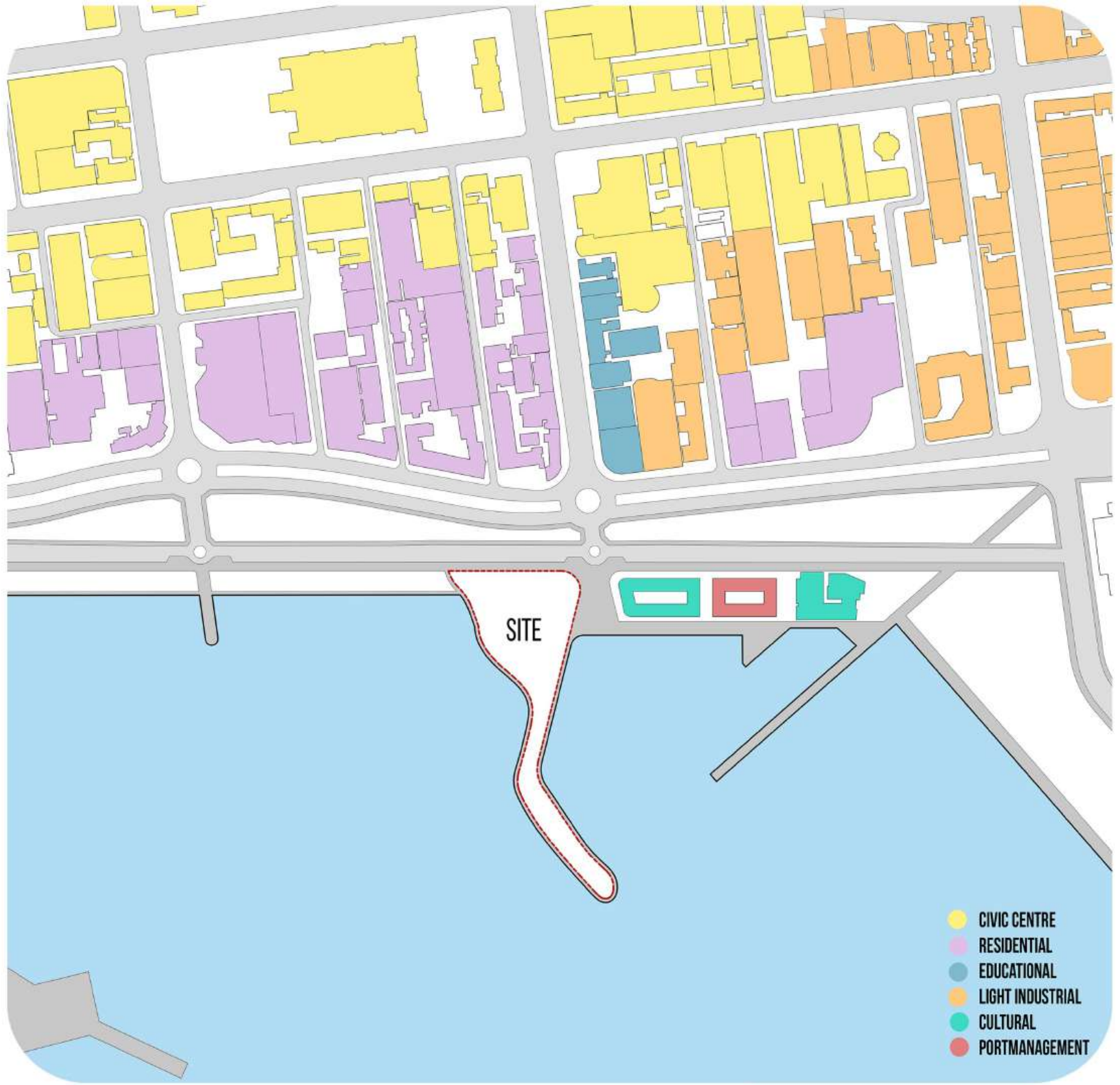


CONTEXTUAL ANALYSIS

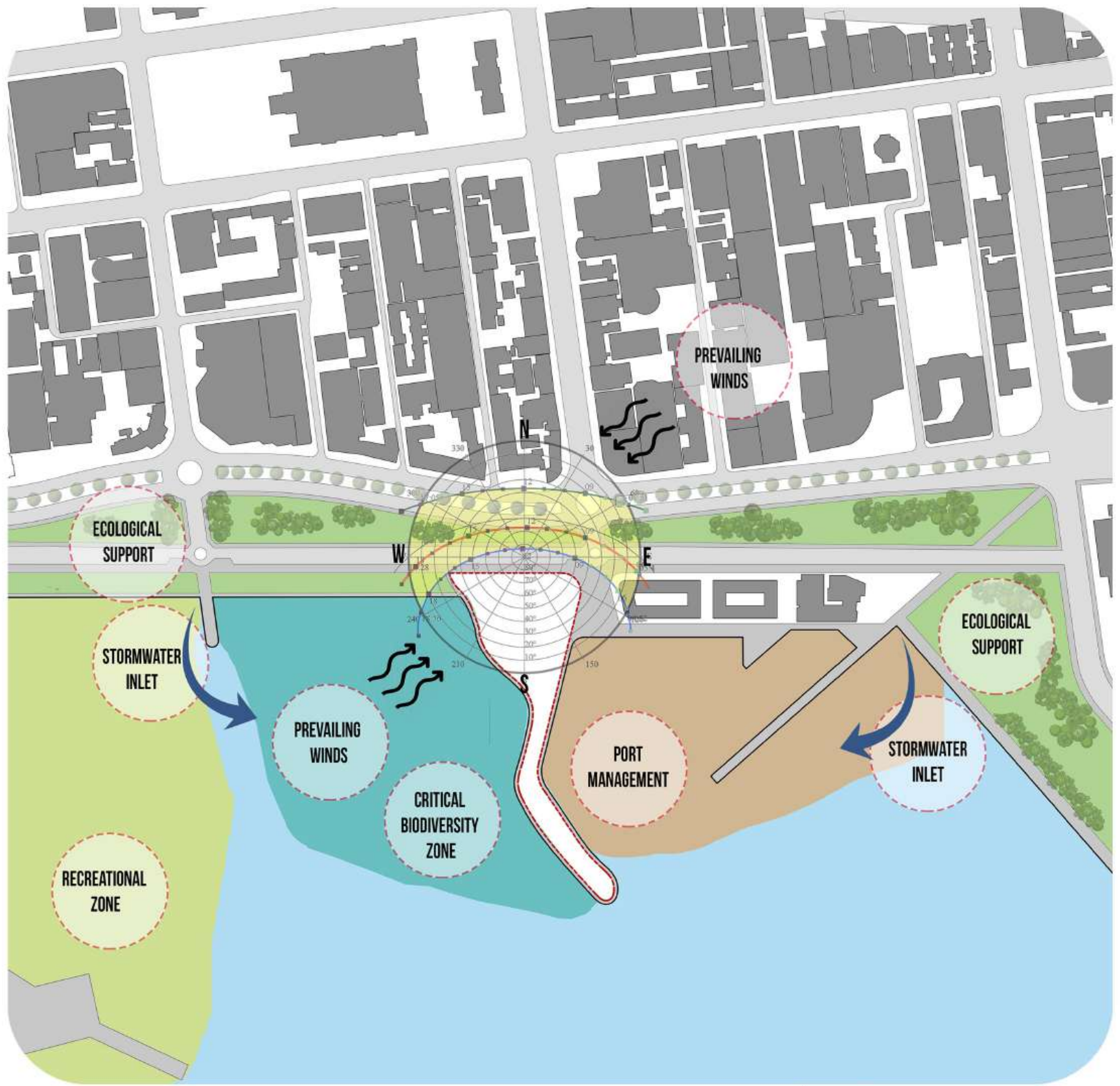
LINKAGES TO SURROUNDS



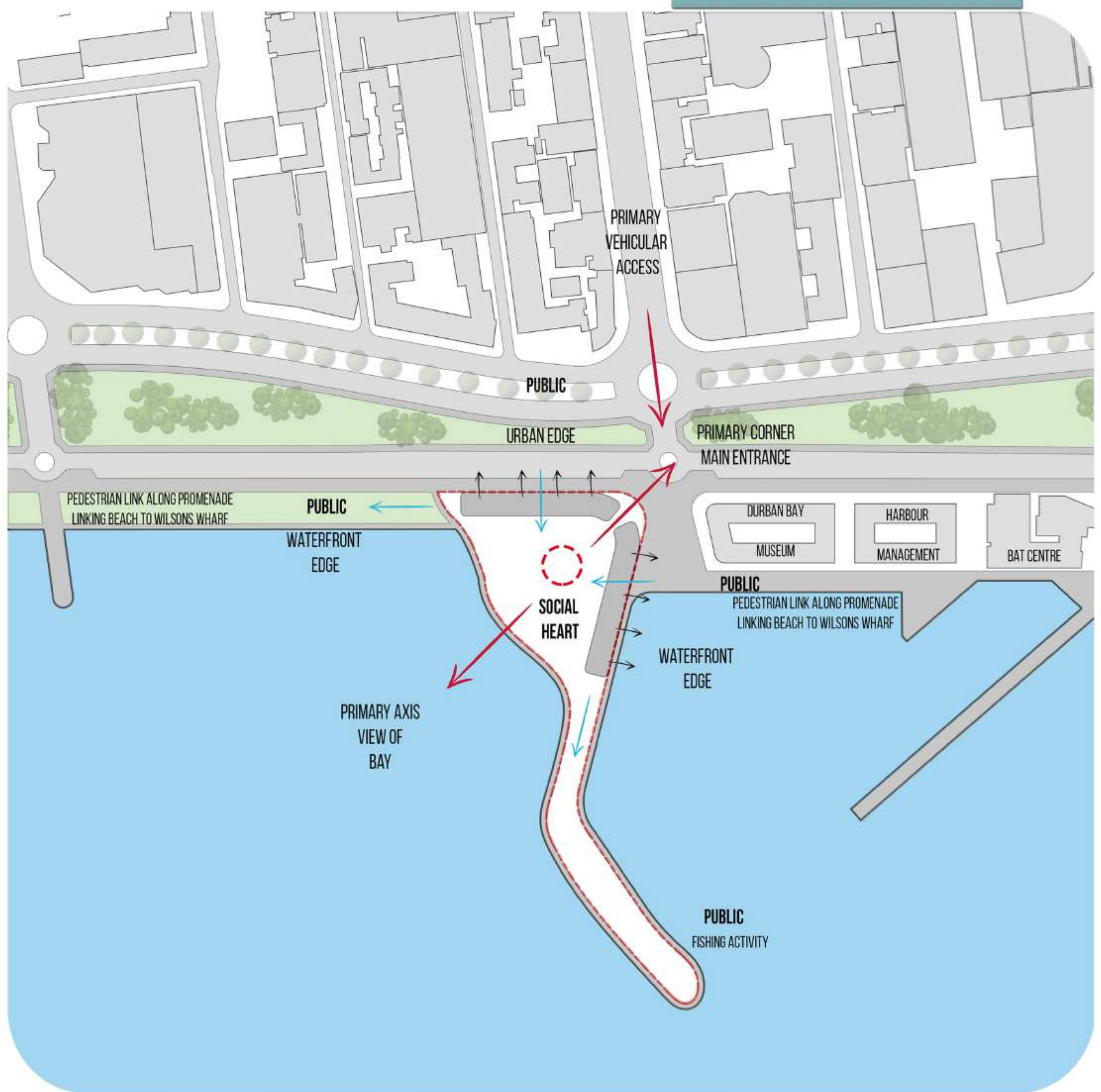
ZONING



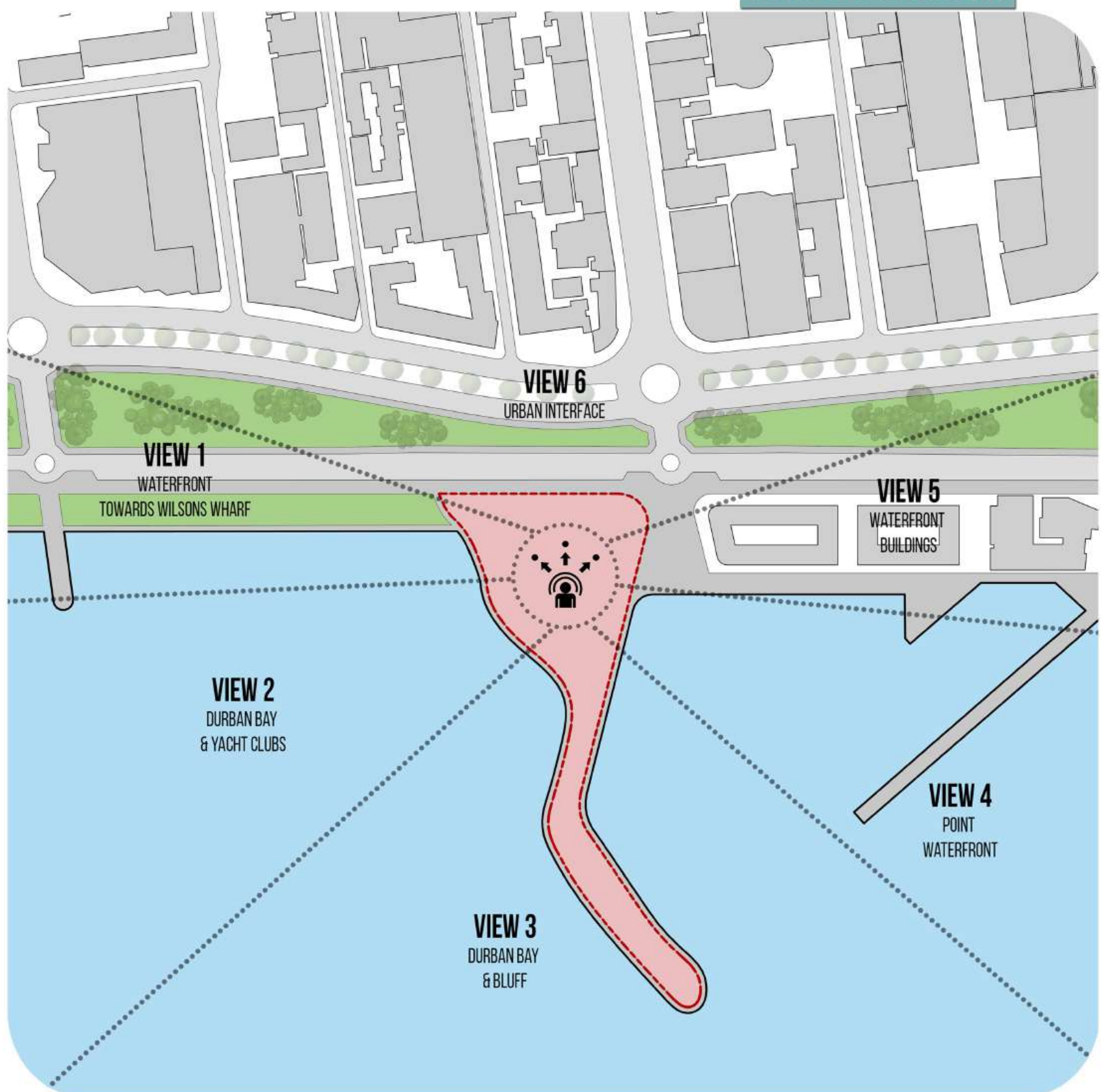
ENVIRONMENTAL ANALYSIS



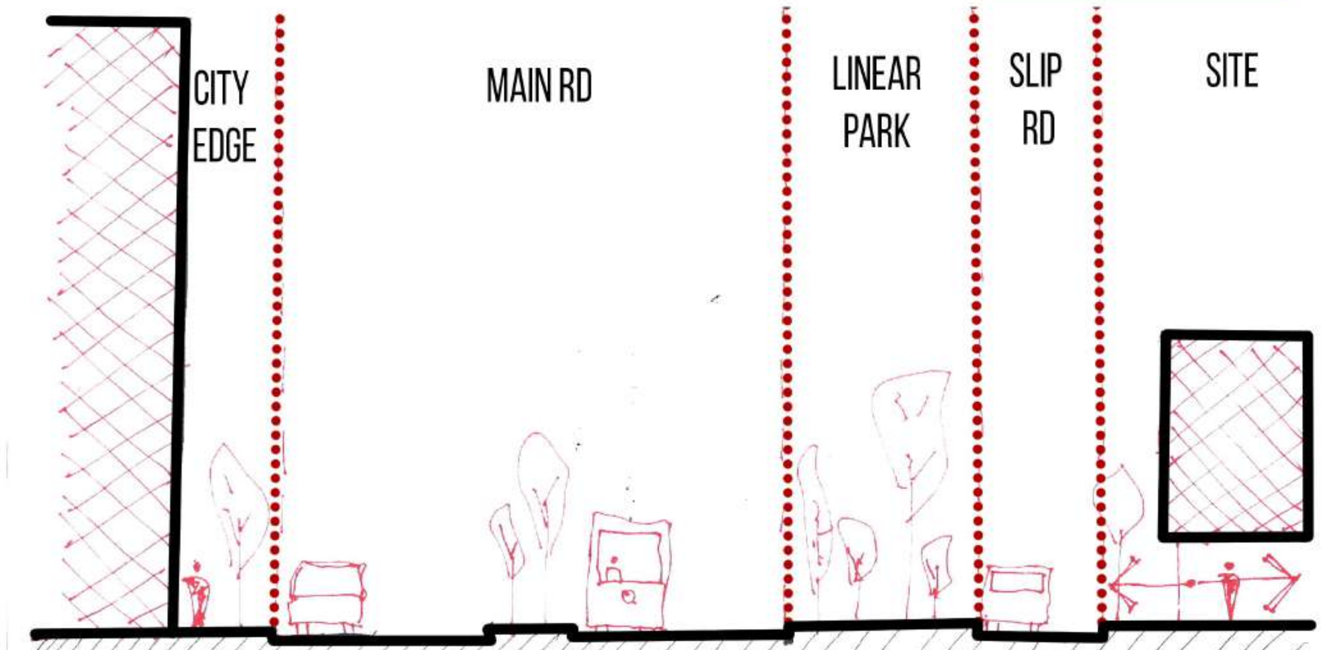
COMPOSITIONAL ANALYSIS



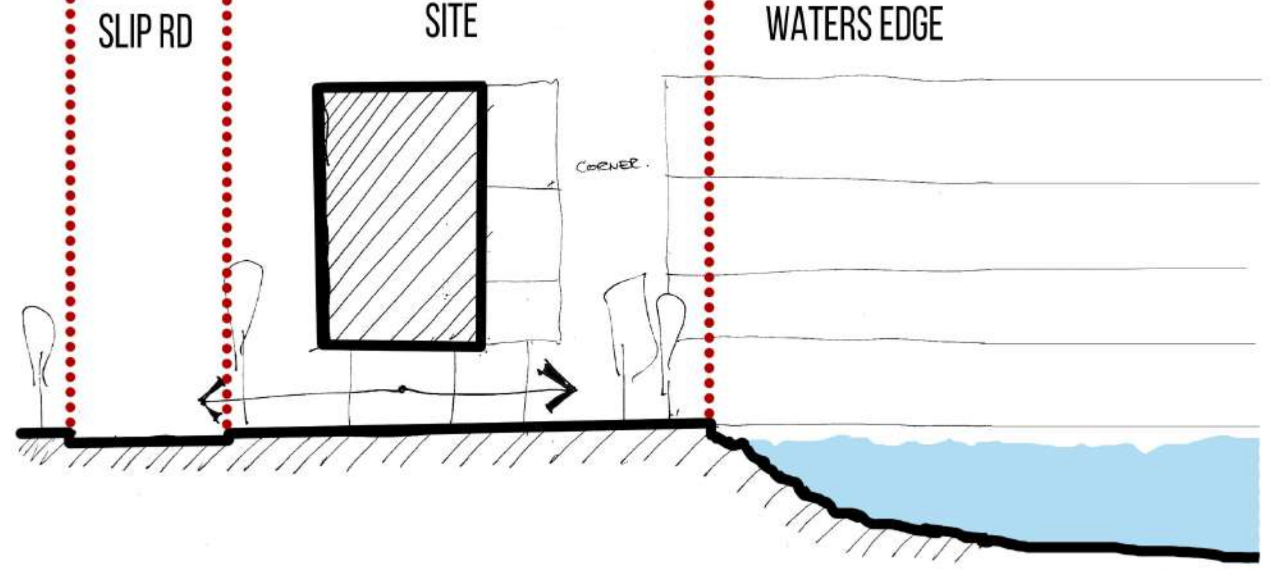
SENSORY ANALYSIS



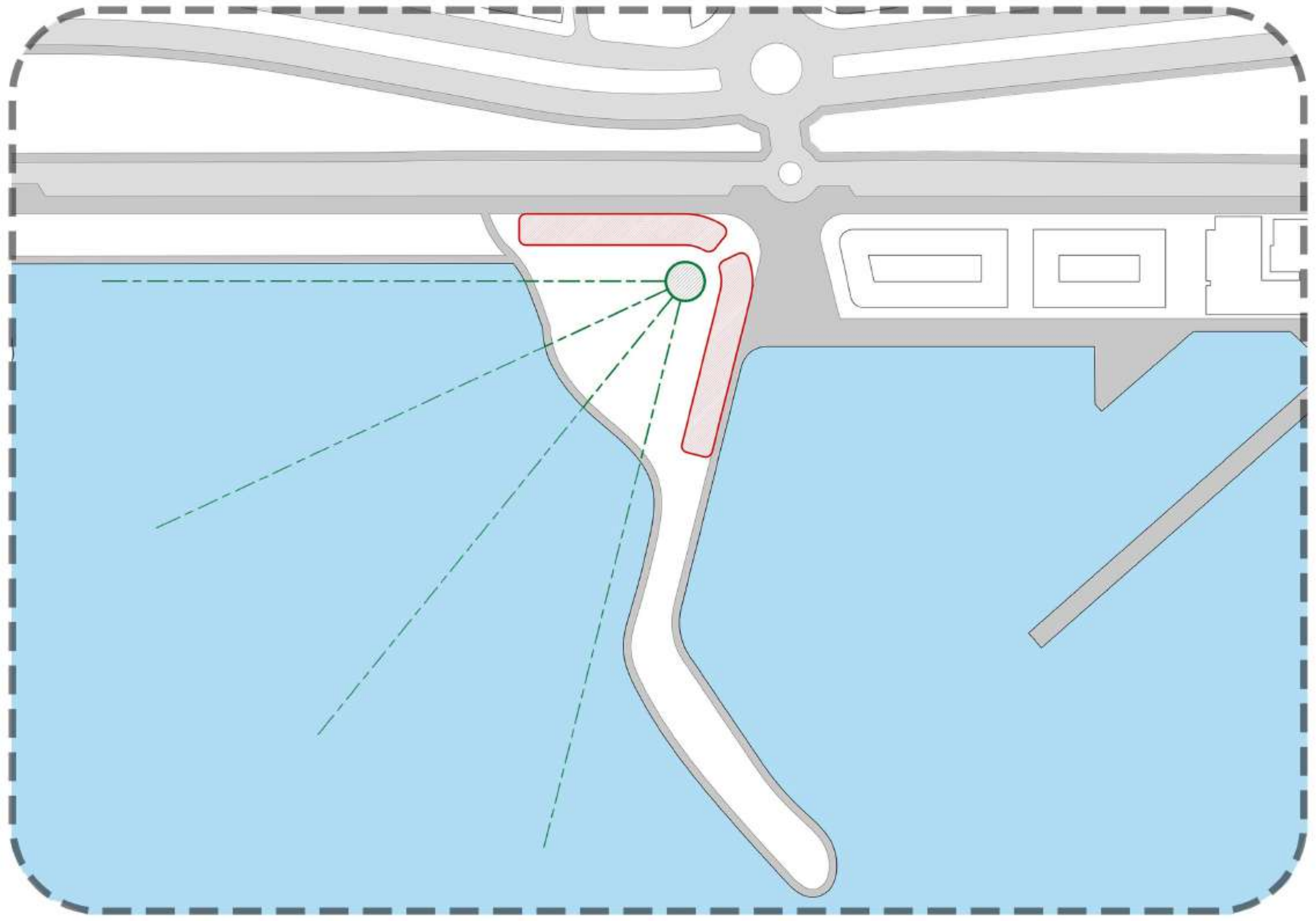
EDGE RESPONSE



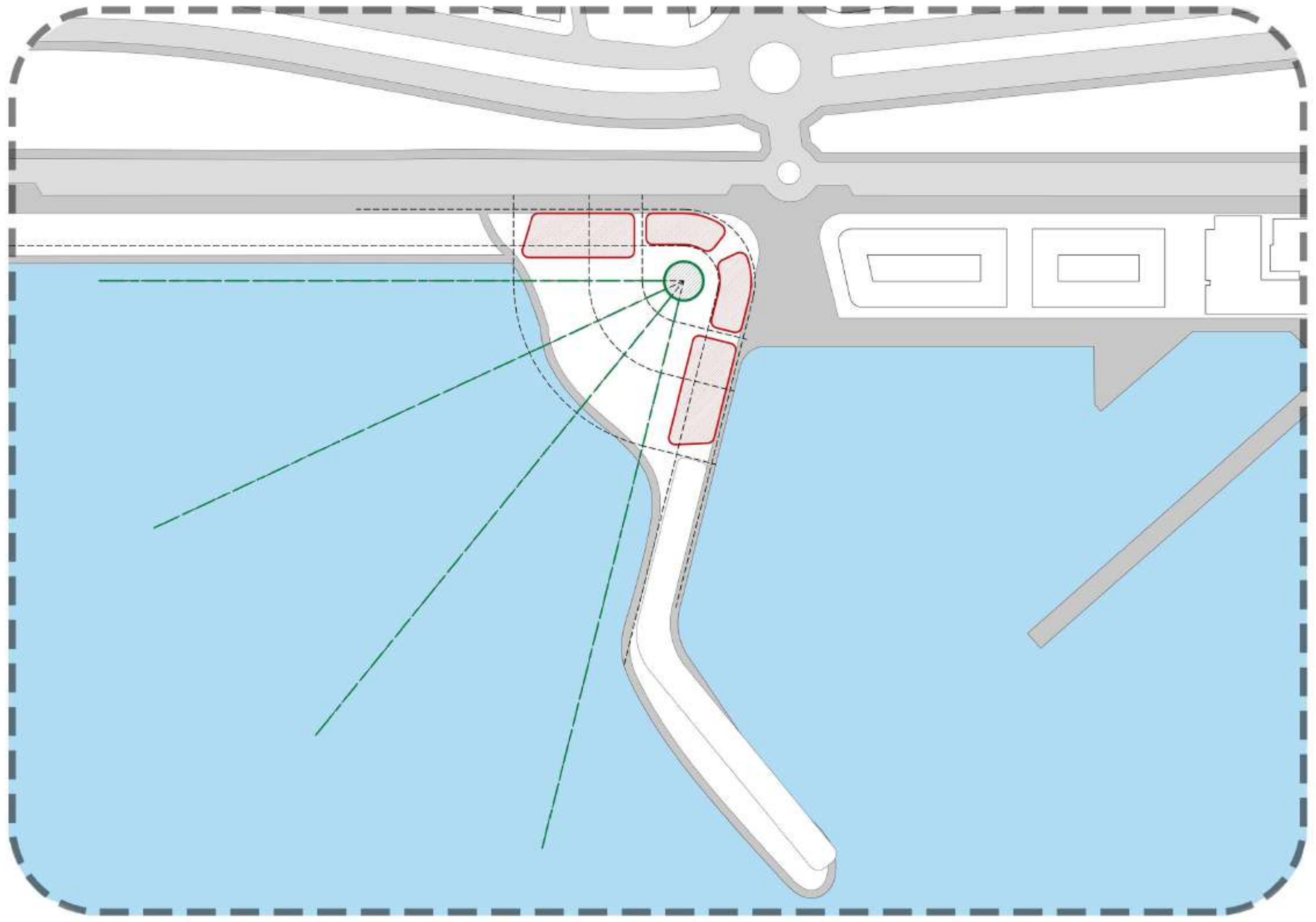
SITE SECTION



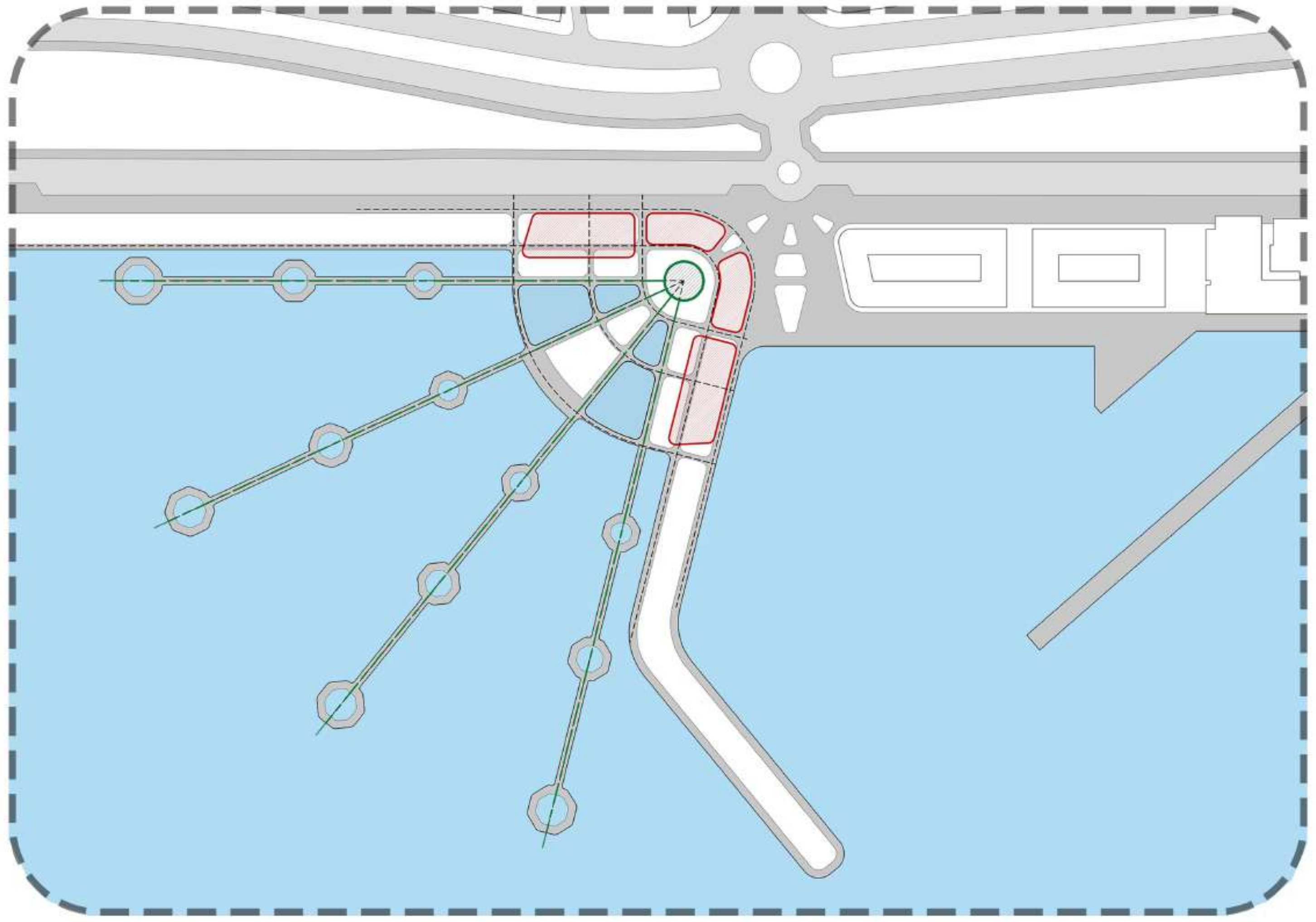
DESIGN DEVELOPMENT



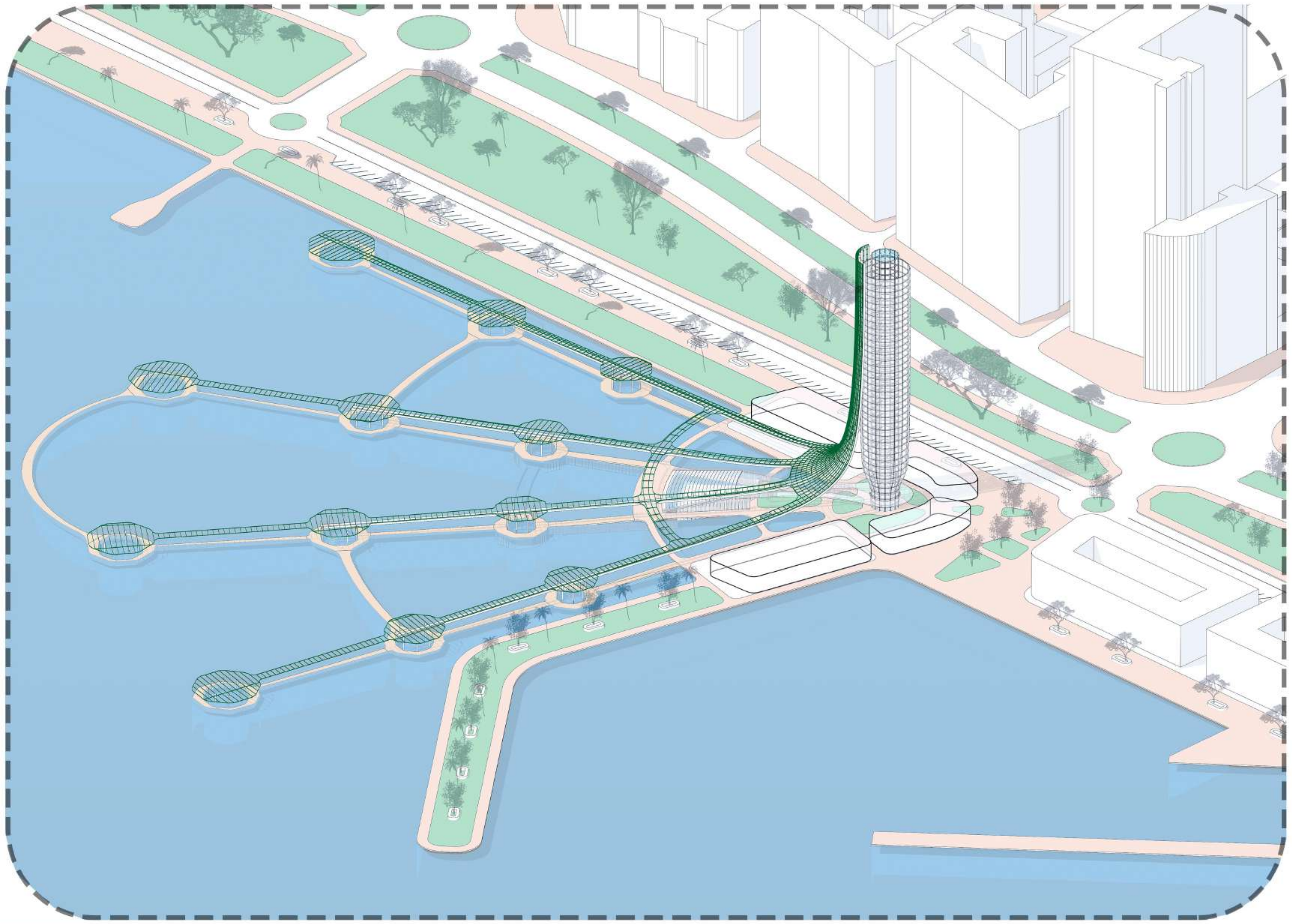
URBAN EDGE & REGENERATIVE TOWER



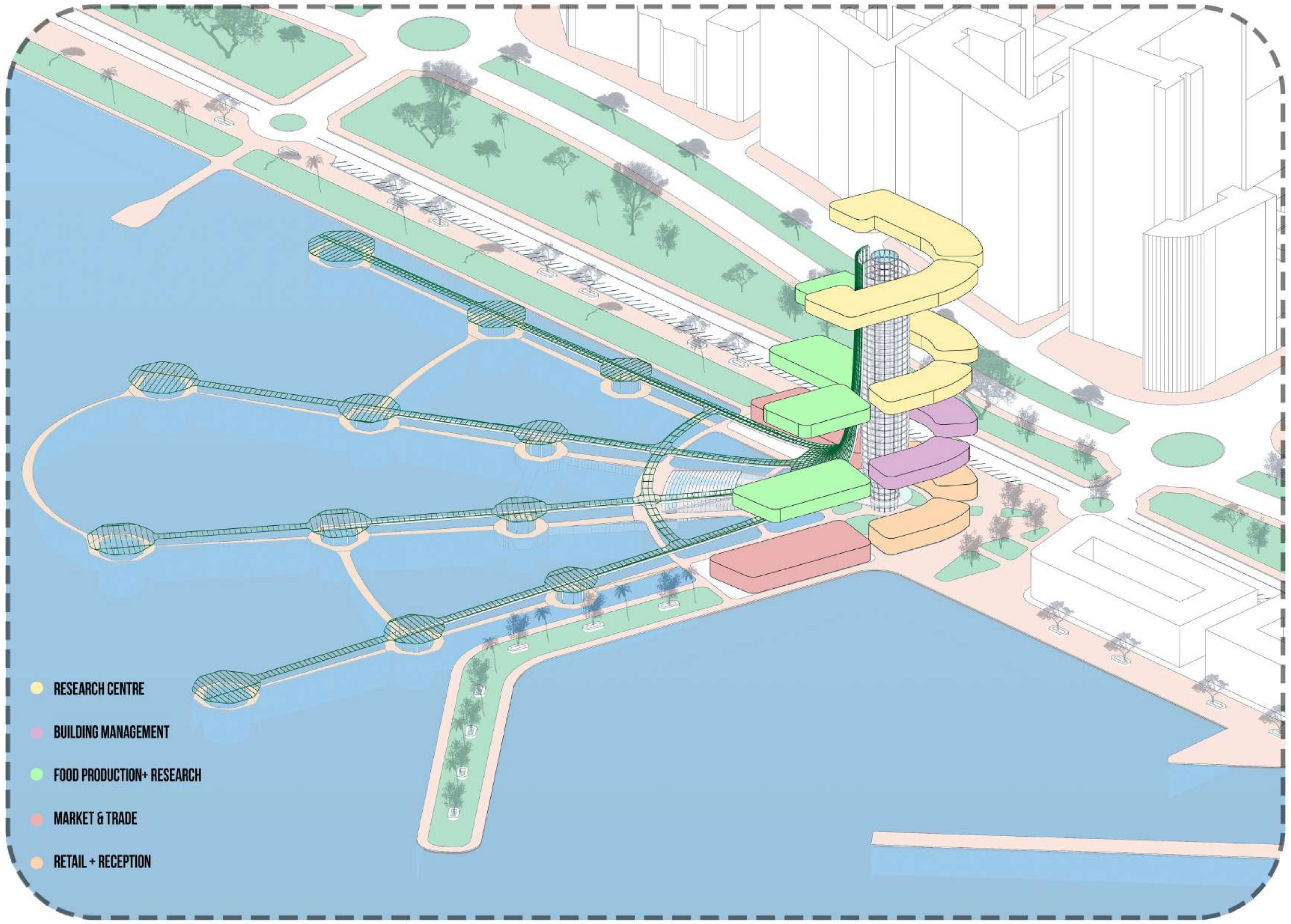
PERMEABILITY + FLUIDITY



INTEGRATING BUILT & NATURAL ENVIRONMENT

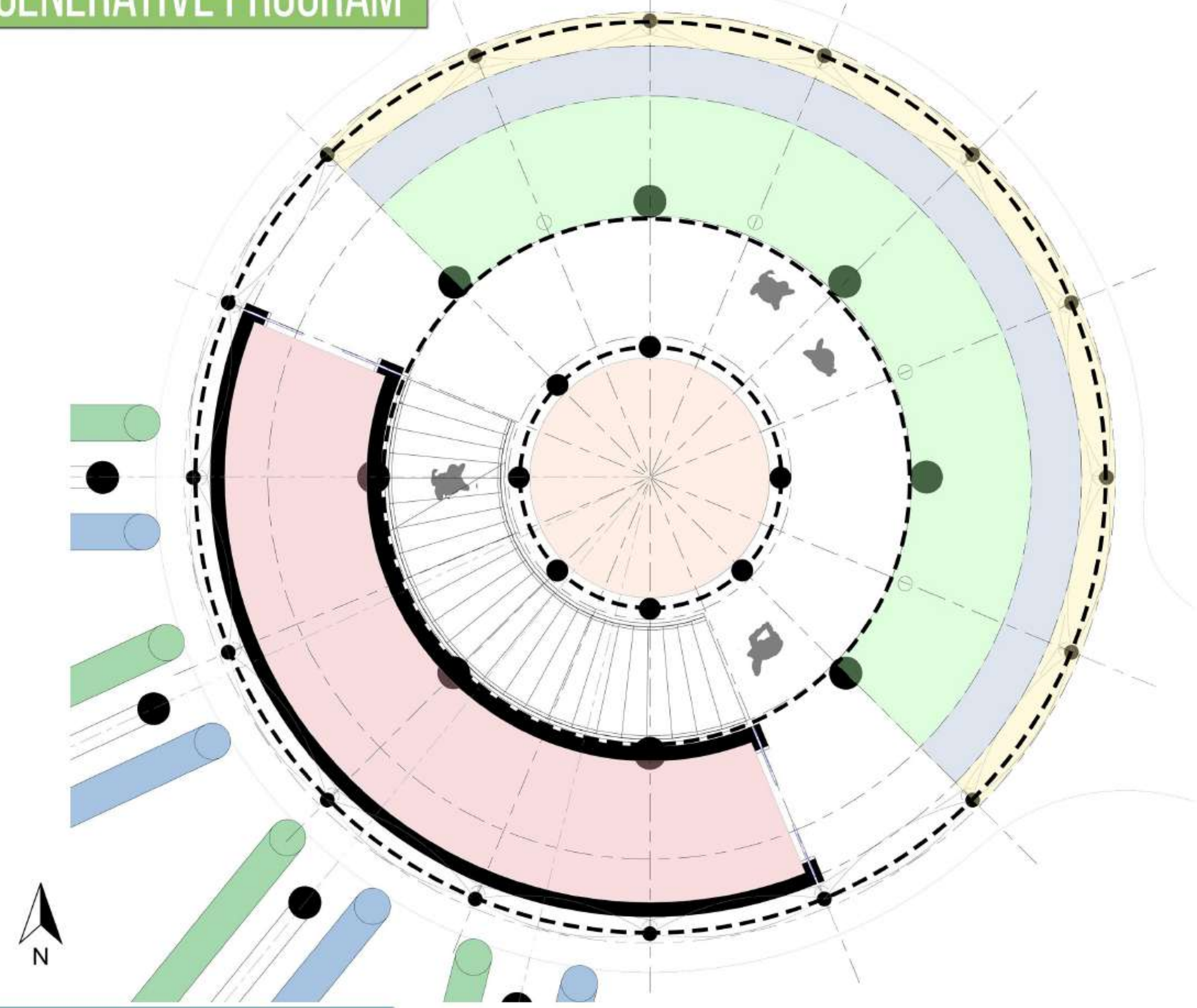


URBAN-ECOLOGICAL EXPERIENCE



PROGRAM DEVELOPMENT

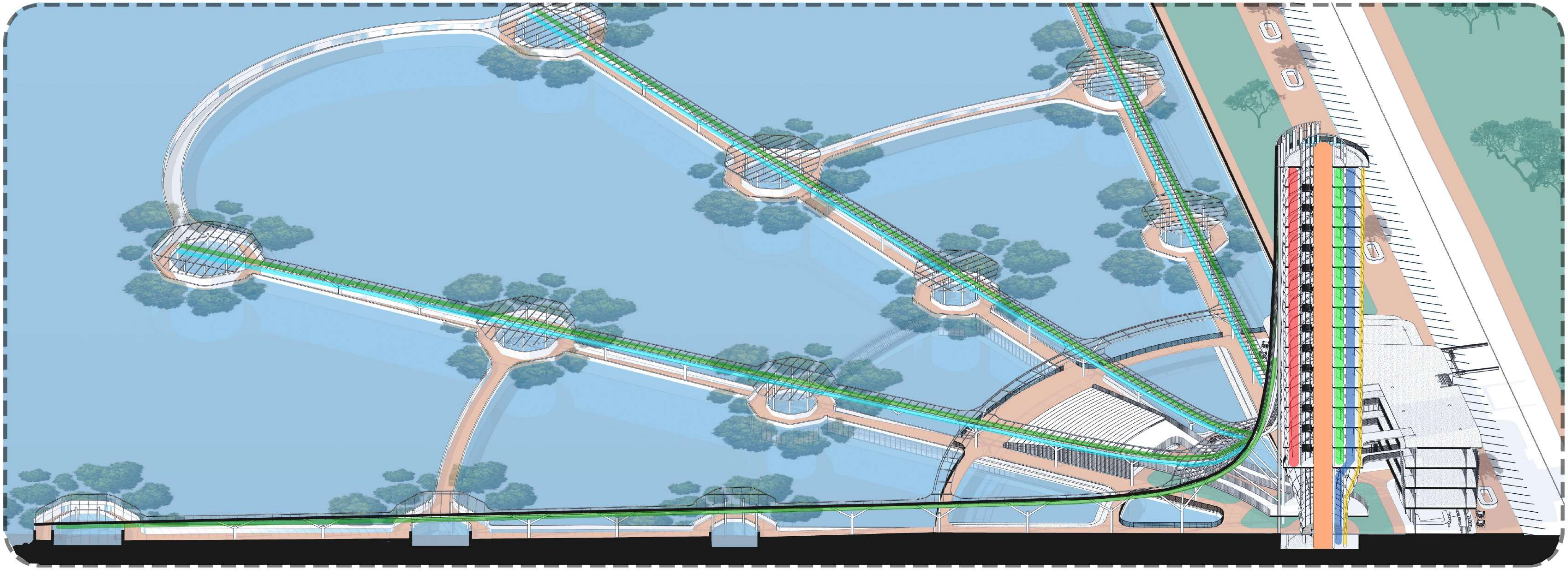
REGENERATIVE PROGRAM



TYPICAL TOWER PLAN 1:25

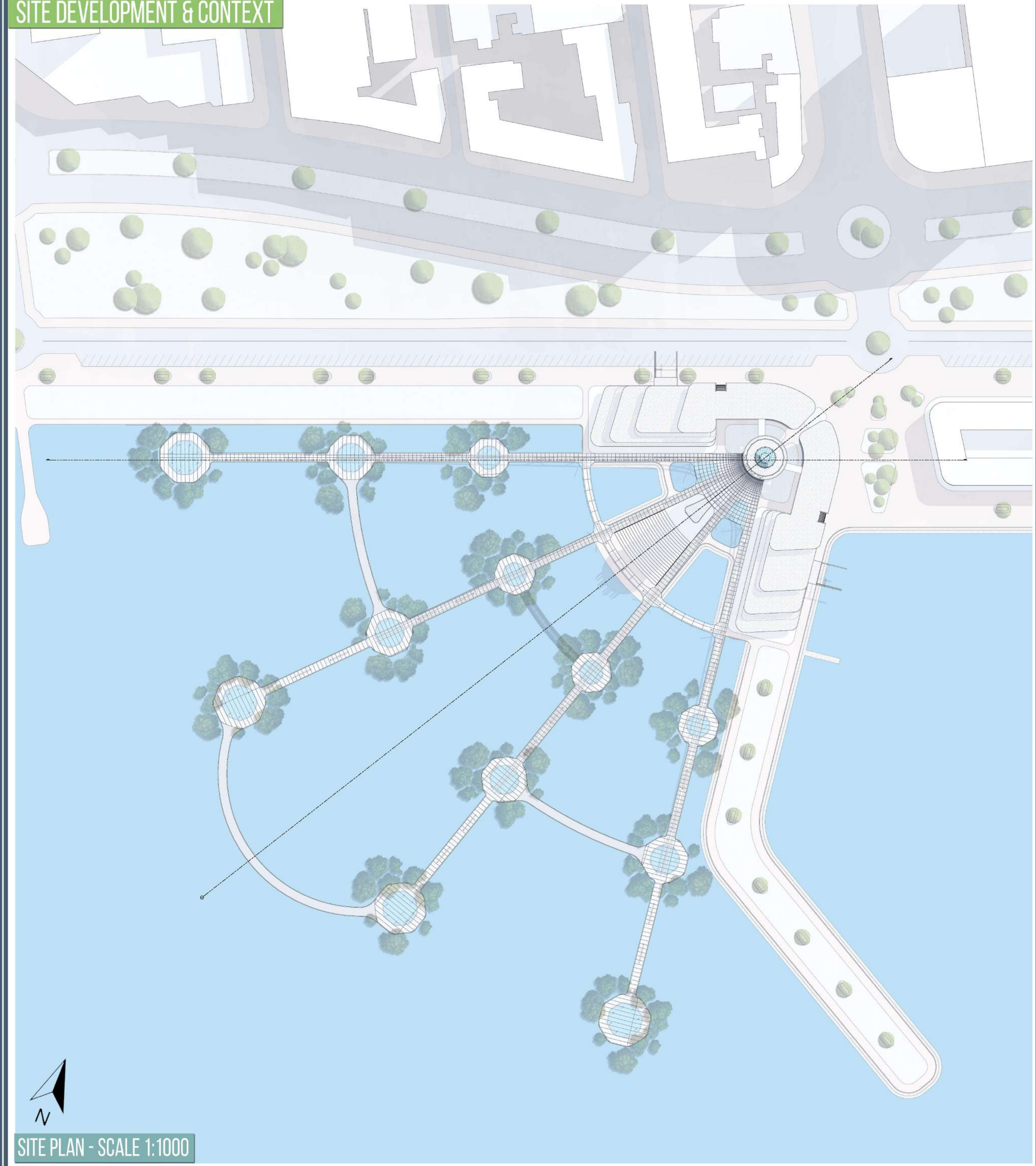
TYPICAL TOWER SECTION 1:20

- SOLAR ENERGY
- DESALINATION
- VERTICAL HYDROPONIC FARMING
- LIFT CORE
- STORAGE/SERVICE
- MANGROVE NUTRIENTS
- SALT WATER

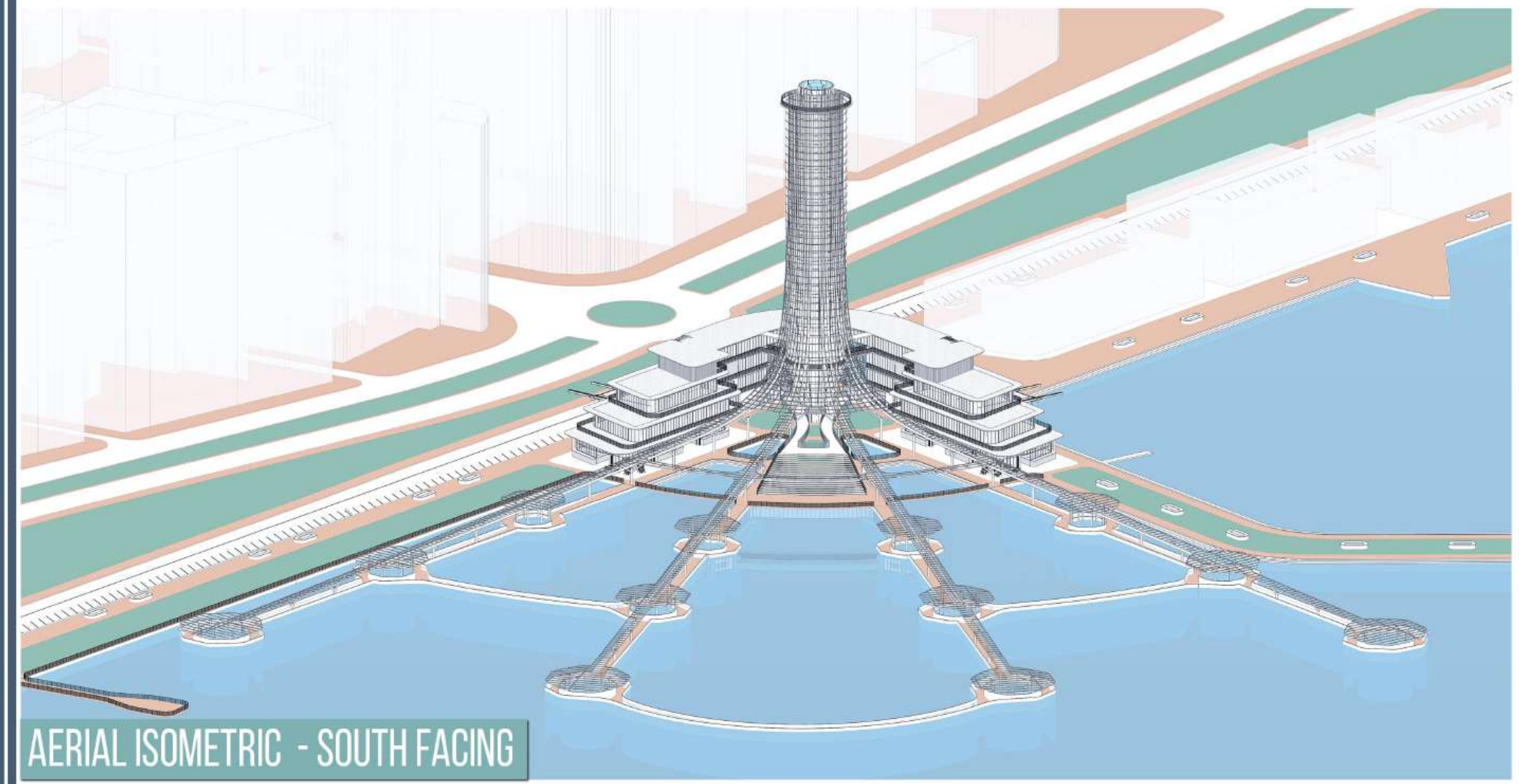


REGENERATIVE TOWER ISOMETRIC

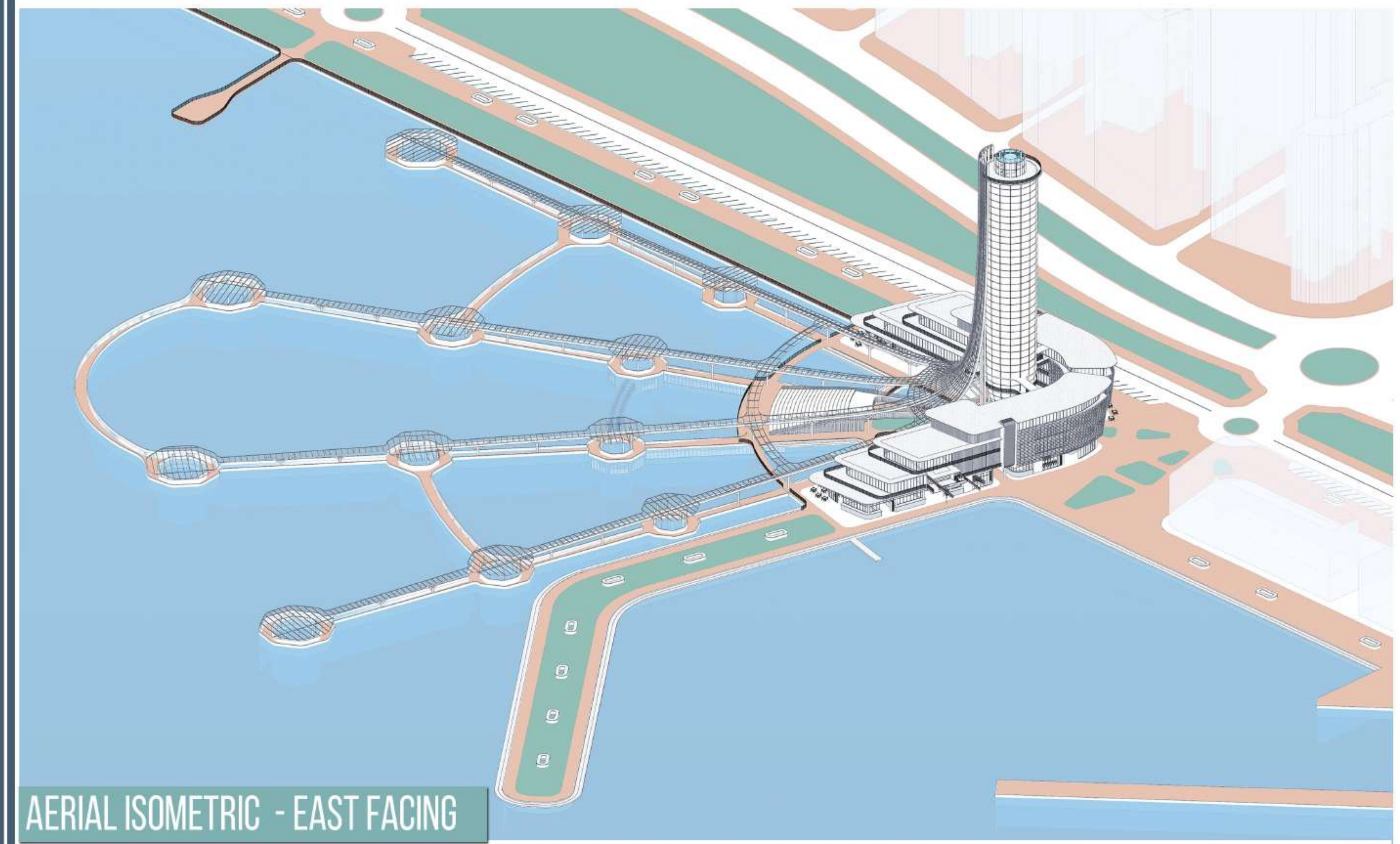
SITE DEVELOPMENT & CONTEXT



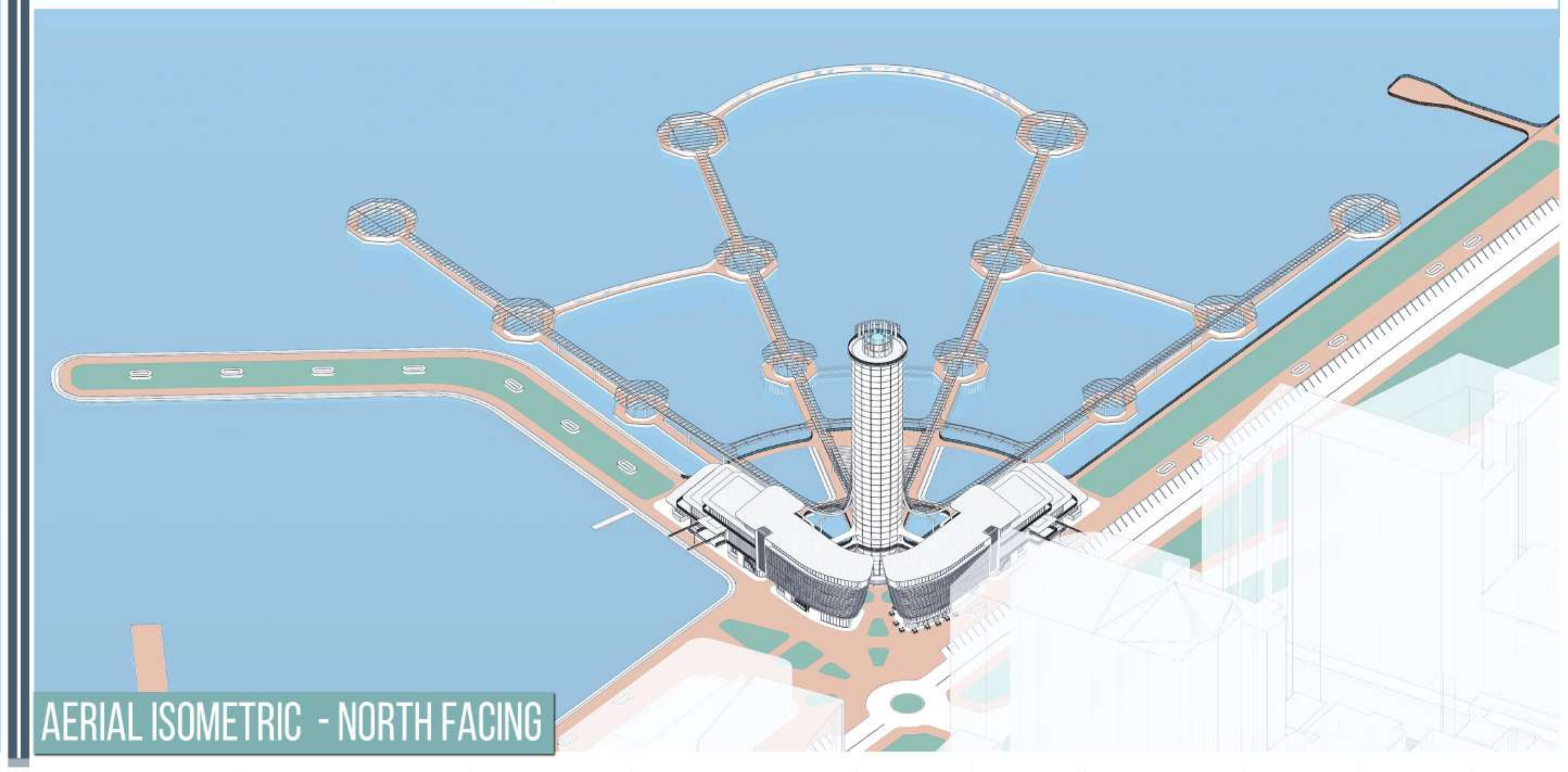
SITE PLAN - SCALE 1:1000



AERIAL ISOMETRIC - SOUTH FACING

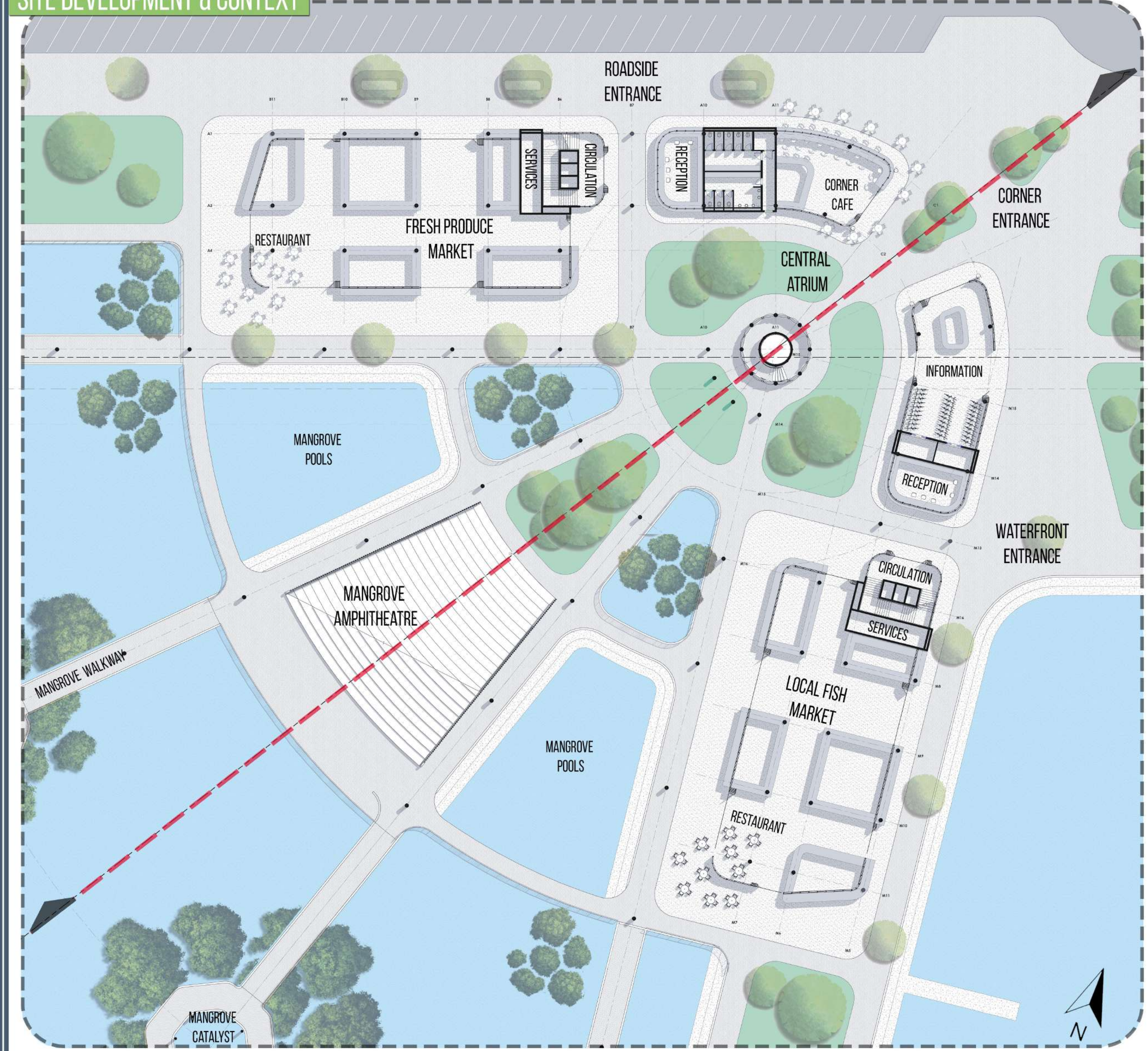


AERIAL ISOMETRIC - EAST FACING

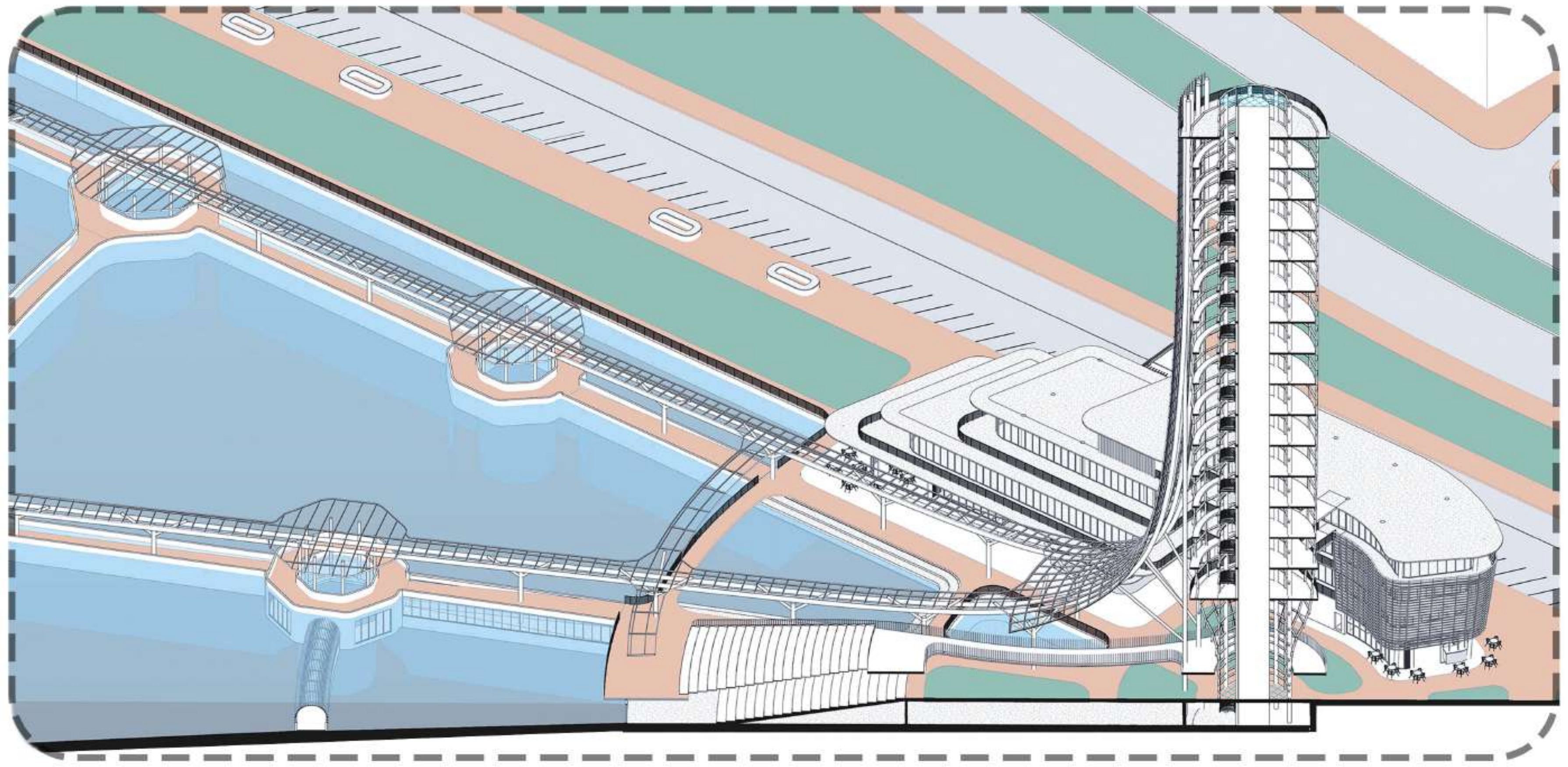


AERIAL ISOMETRIC - NORTH FACING

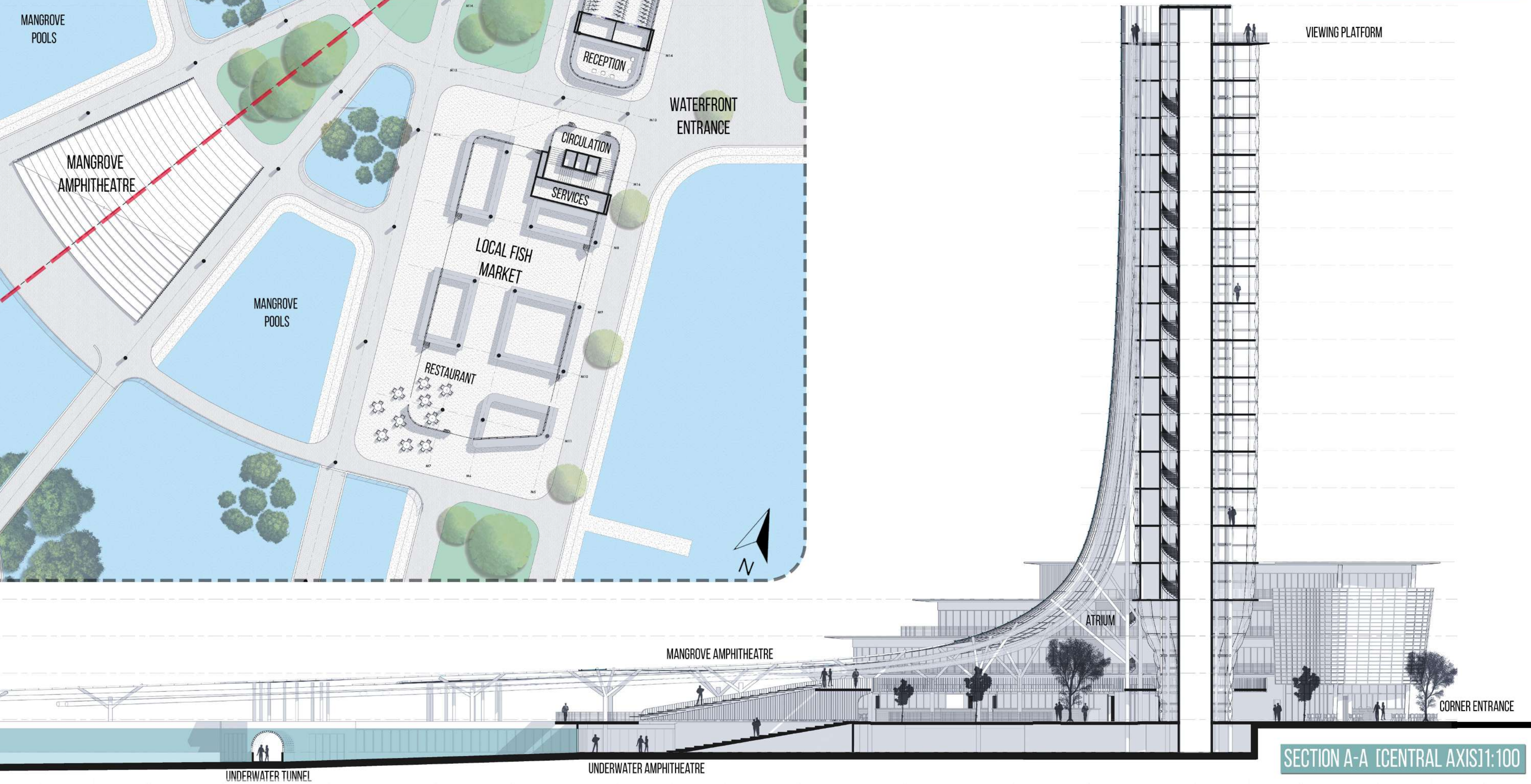
SITE DEVELOPMENT & CONTEXT



GROUND FLOOR PLAN -1:200



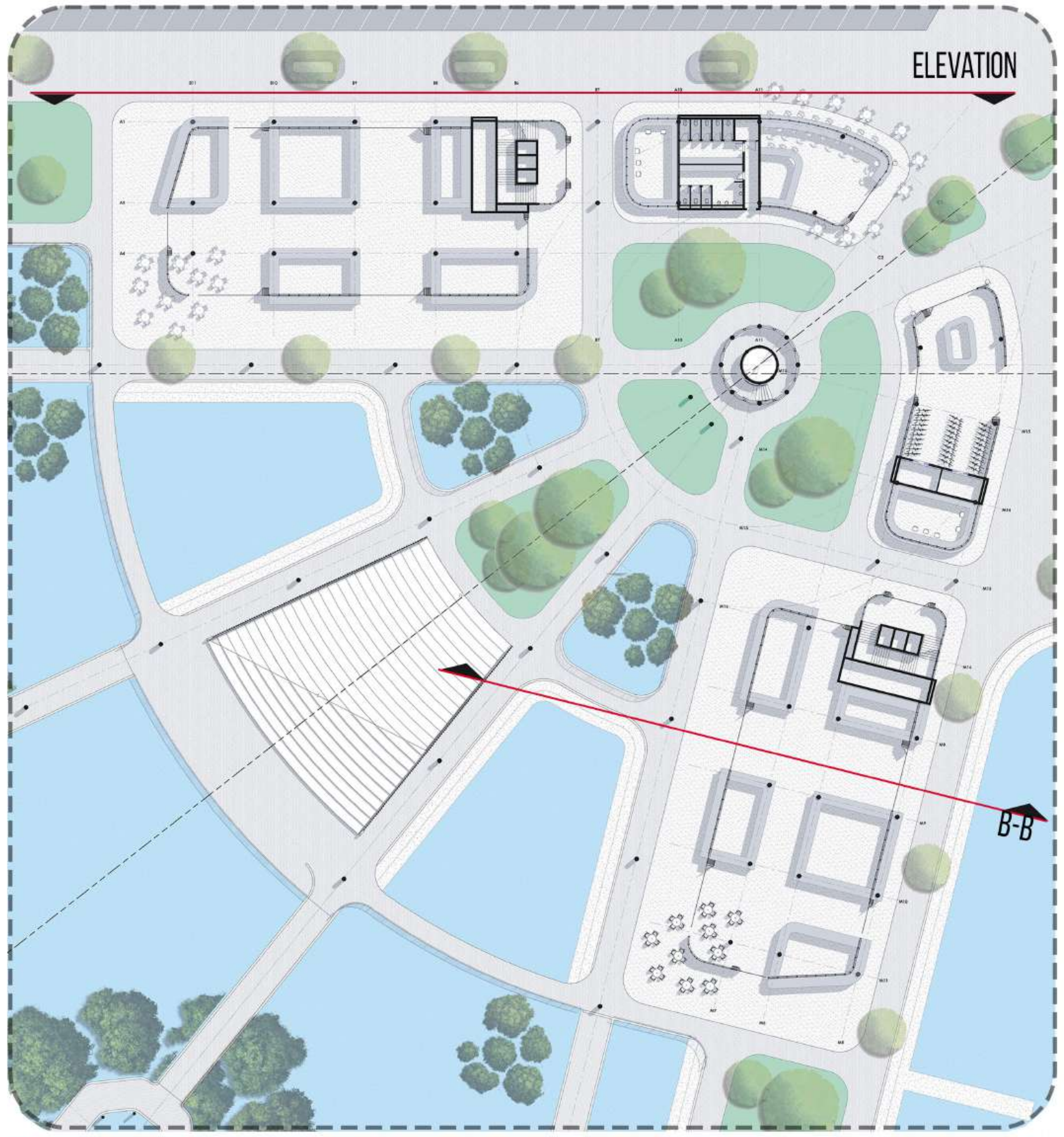
SECTION A-A ISOMETRIC



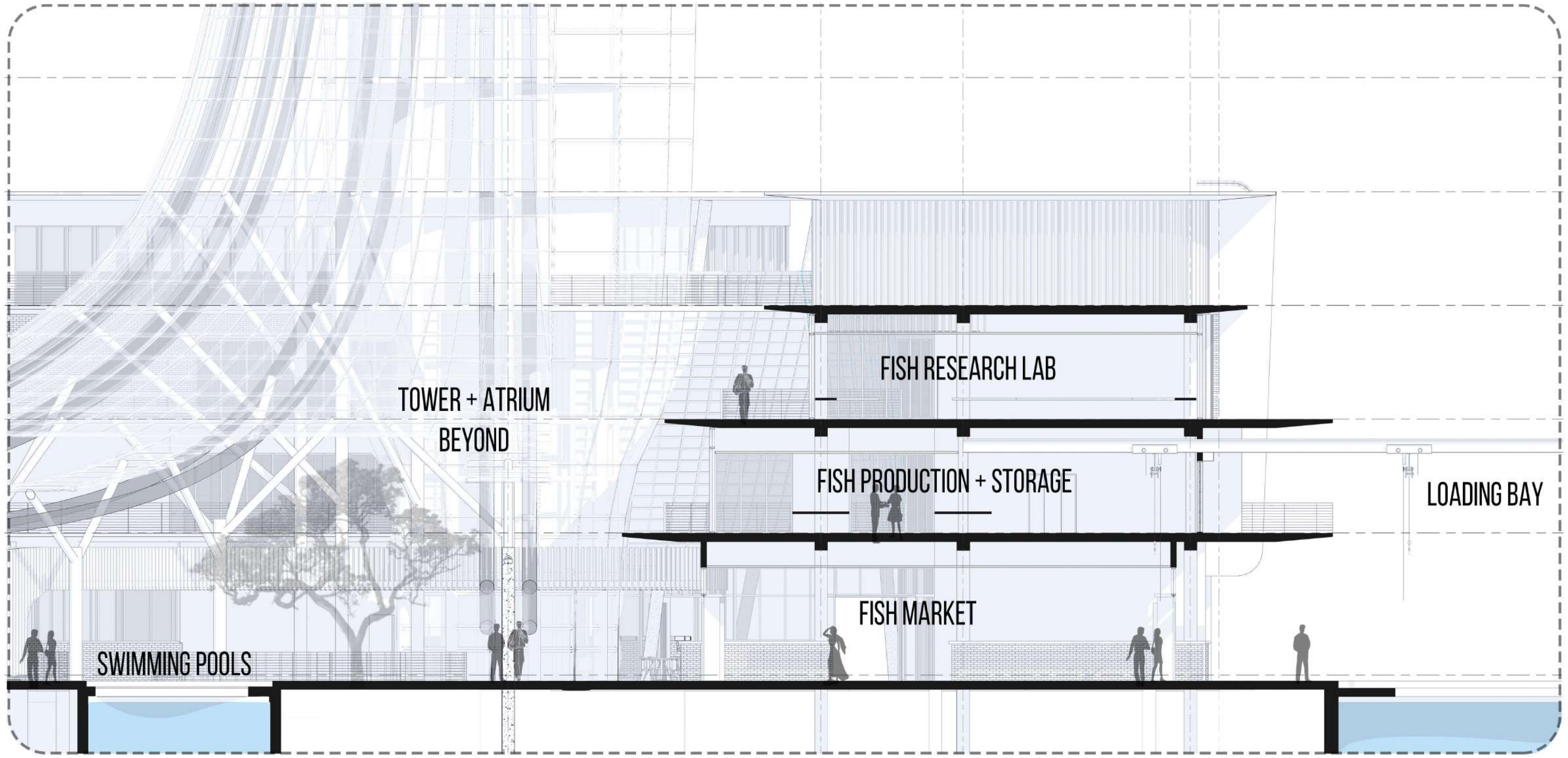
SECTION A-A [CENTRAL AXIS]1:100

BUILDING ELEVATION & SECTION

NORTH FACING ELEVATION

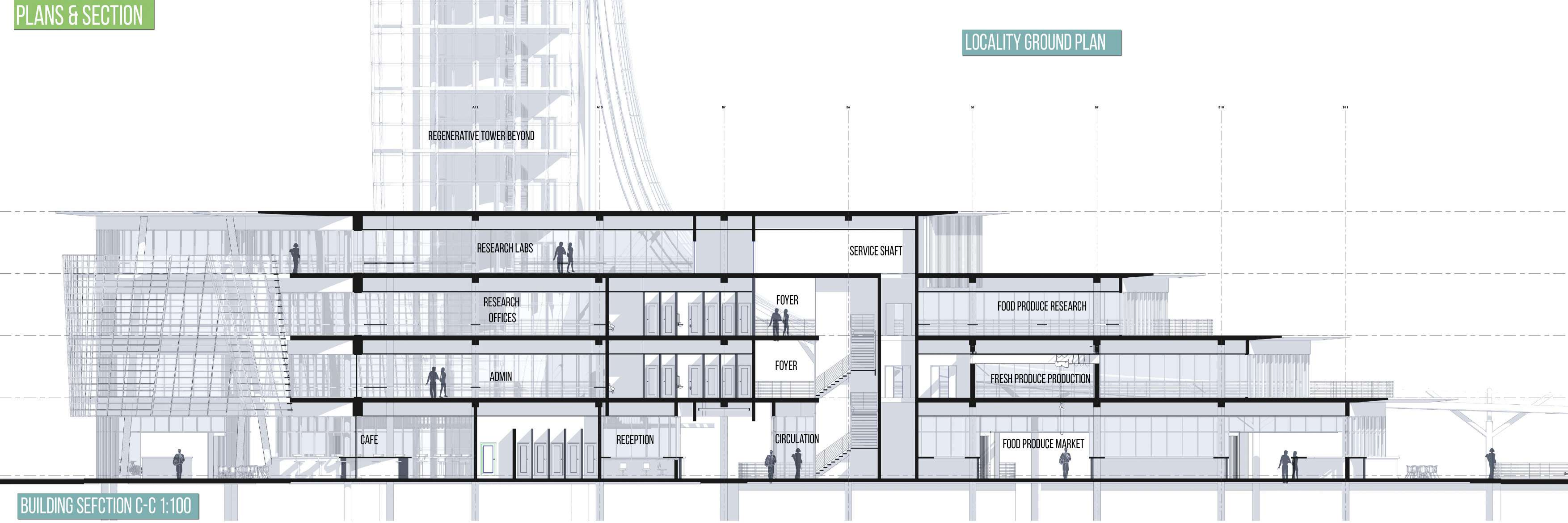


LOCALITY GROUND PLAN

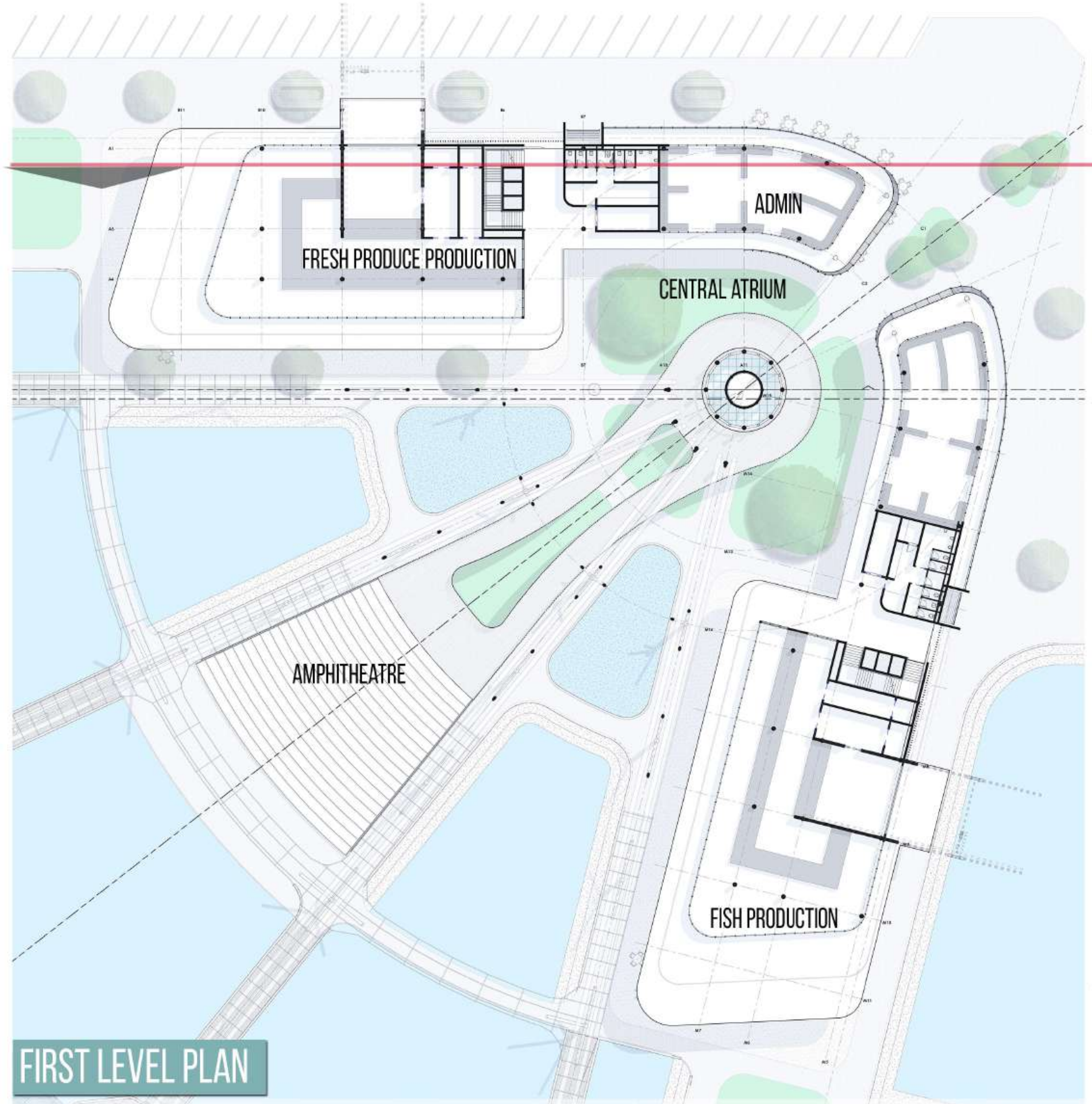


SECTION B-B MARKET WATERFRONT INTERFACE

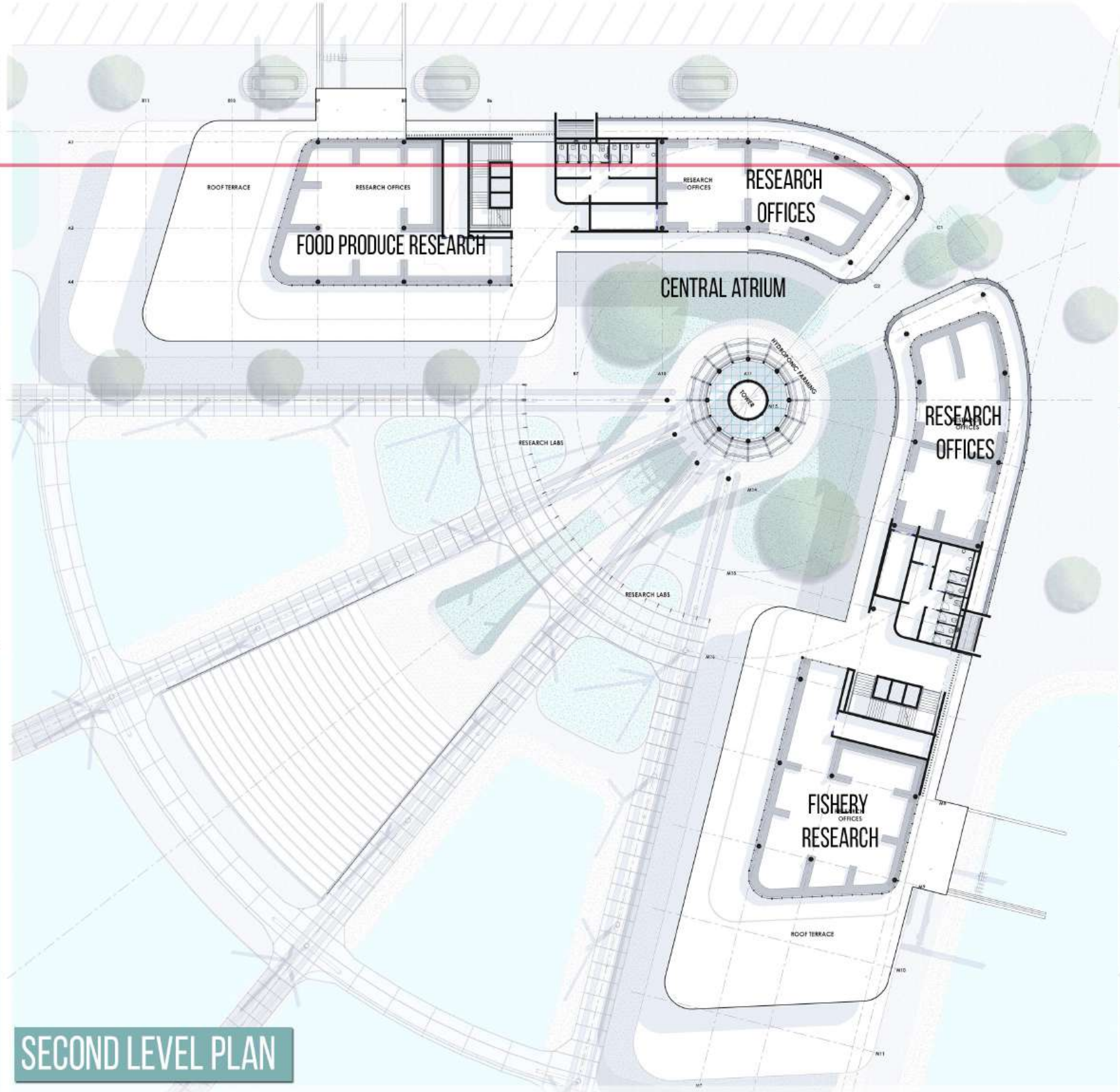
LOCALITY GROUND PLAN



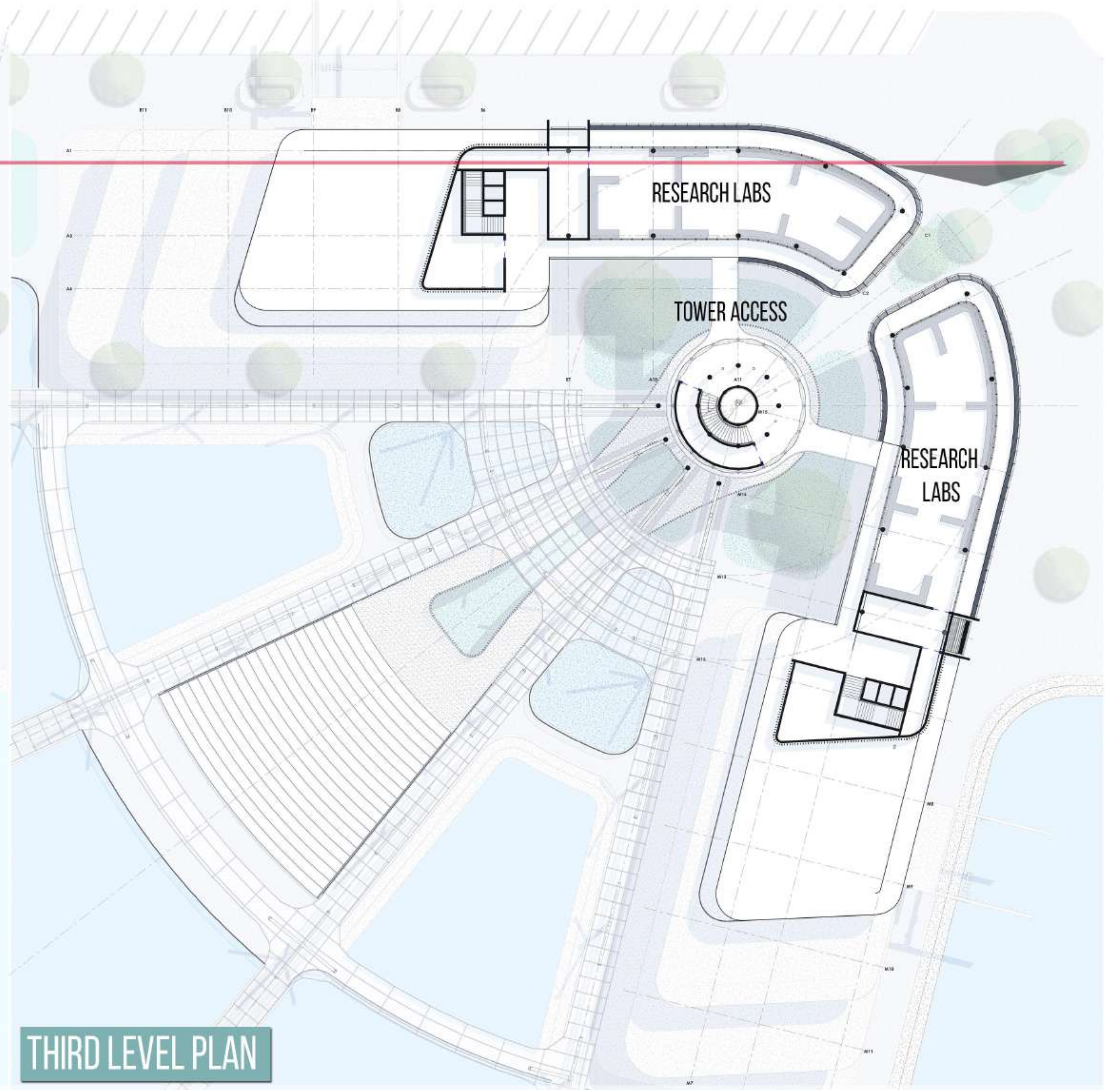
BUILDING SEFCTION C-C 1:100



FIRST LEVEL PLAN



SECOND LEVEL PLAN



THIRD LEVEL PLAN

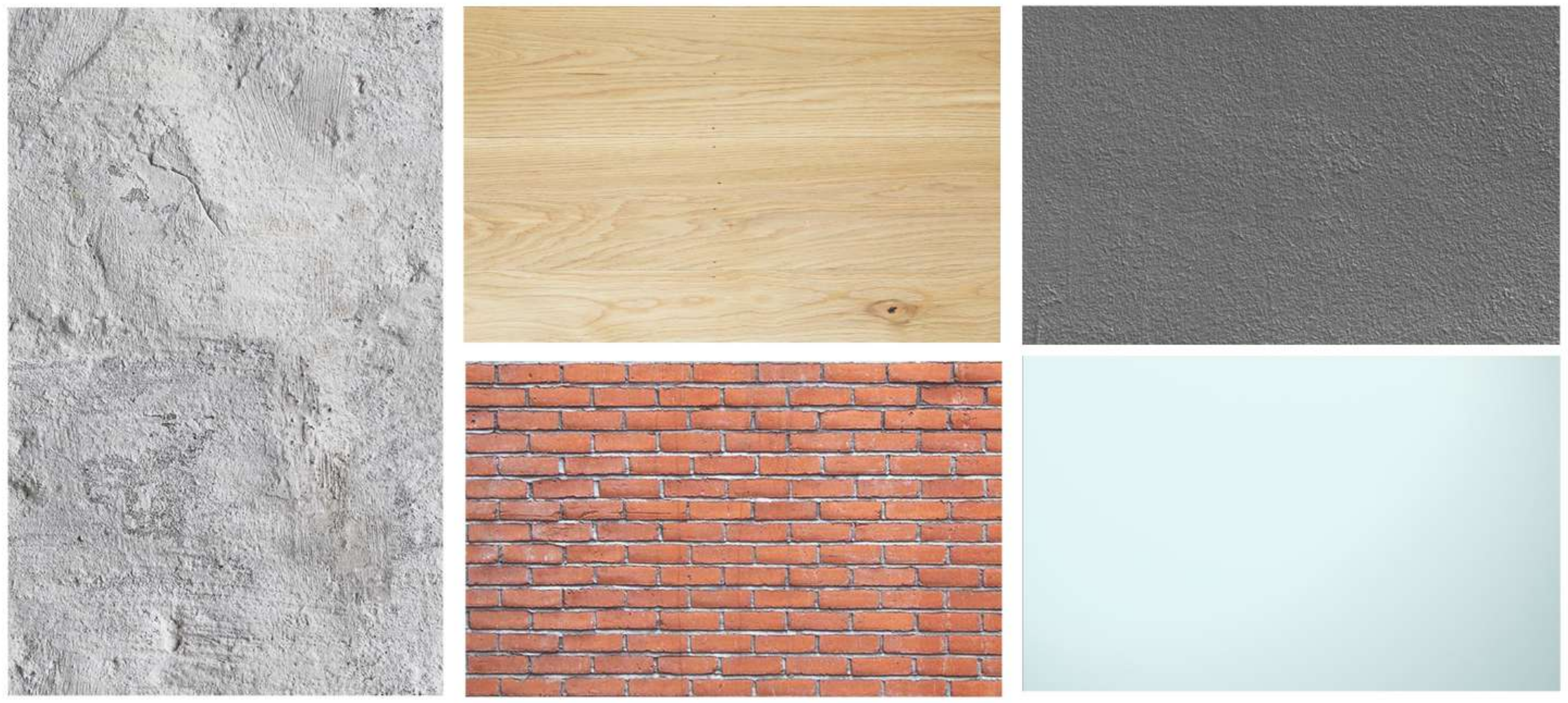
ARCHITECTURAL MATERIALITY + CONSTRUCTION

- LOCALLY SOURCED
- RECYCLE-REUSE-REGENERATE
- SUSTAINABLE
- DURABLE
- SUITABLE FOR SEAFRONT CONDITIONS

MATERIAL CRITERIA

LOCALLY SOURCED PINE

PLASTER & PAINT



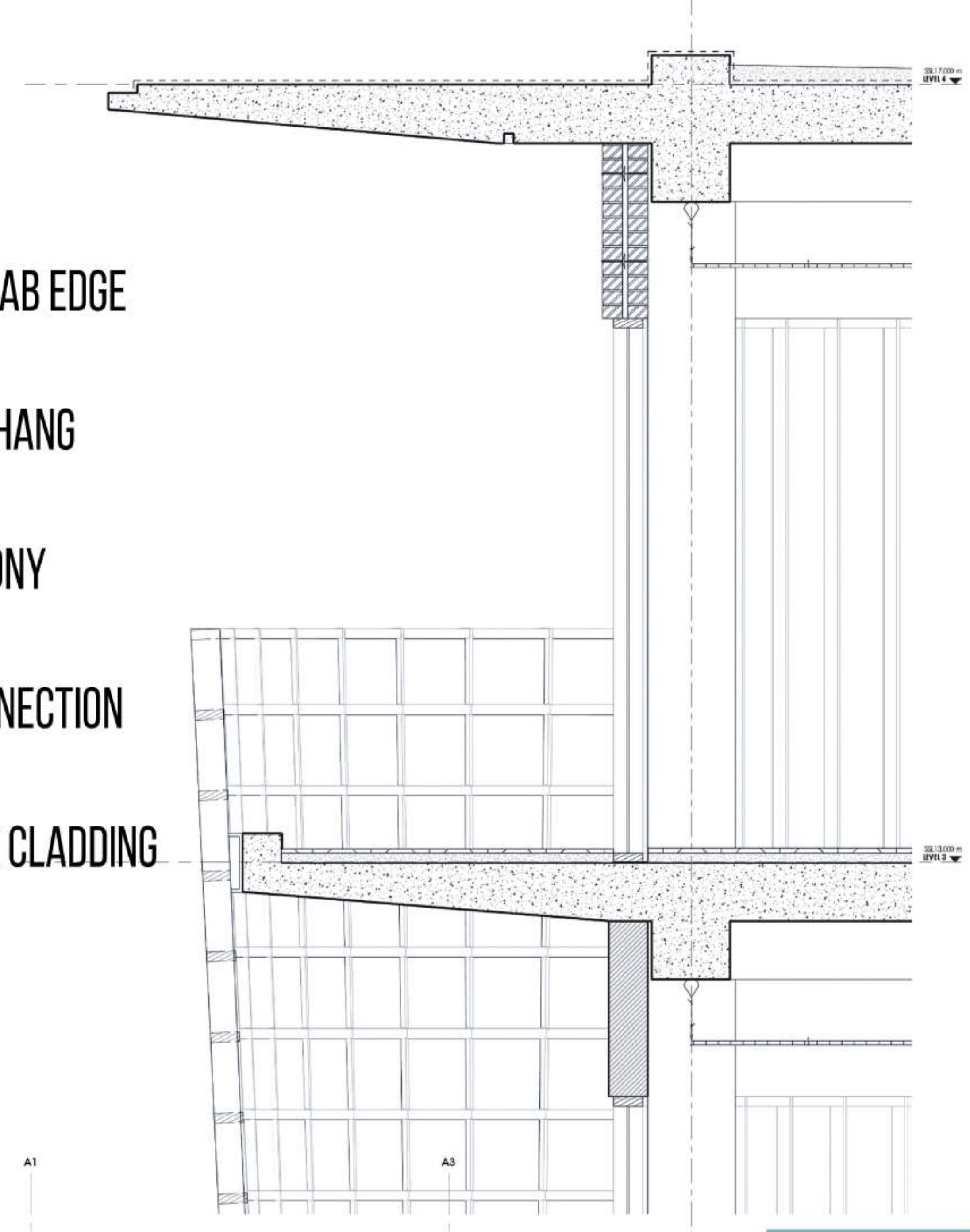
RECYCLED CONCRETE

RE-USED FACEBRICK

SUITABLE GLAZING

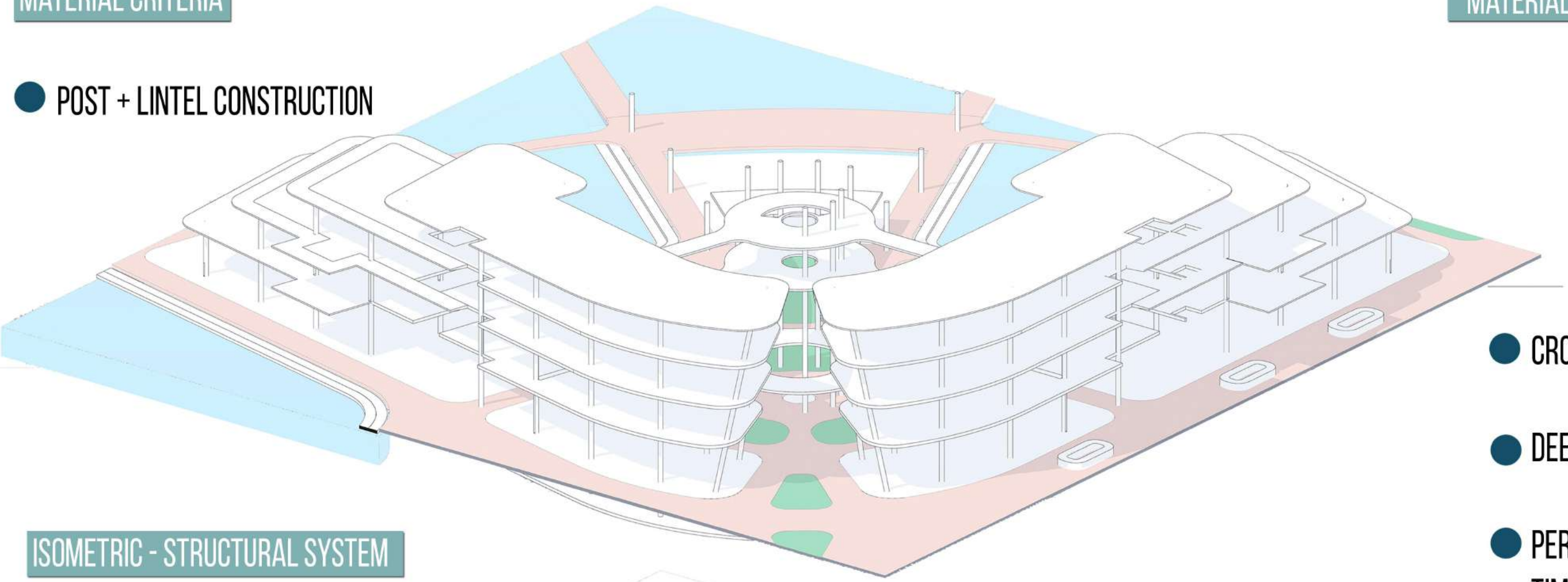
MATERIAL PALETTE

- TAPERED SLAB EDGE
- DEEP OVER HANG
- OPEN BALCONY
- VISUAL CONNECTION
- PERMEABLE CLADDING



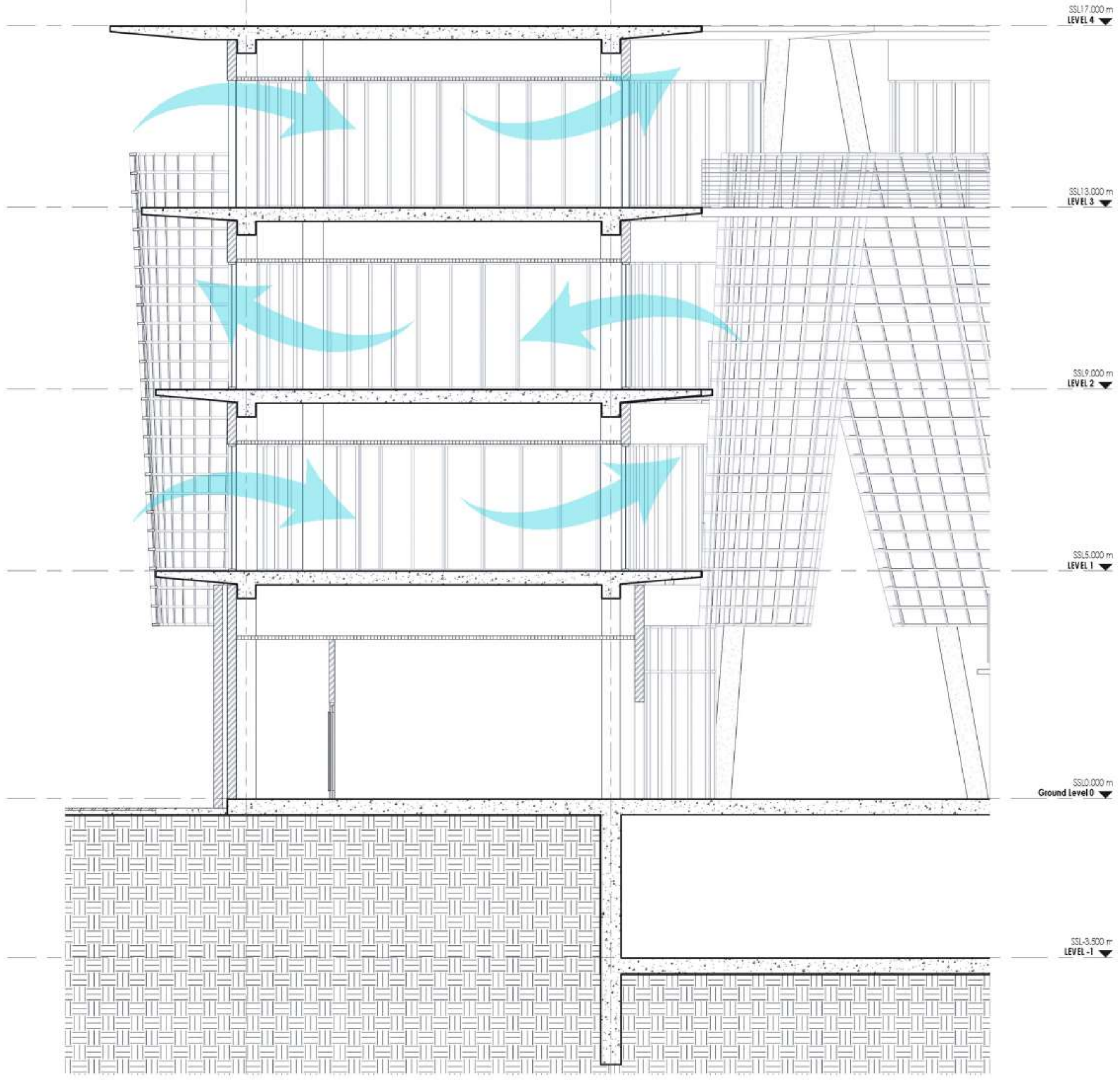
DETAIL SECTION 1:10

- POST + LINTEL CONSTRUCTION

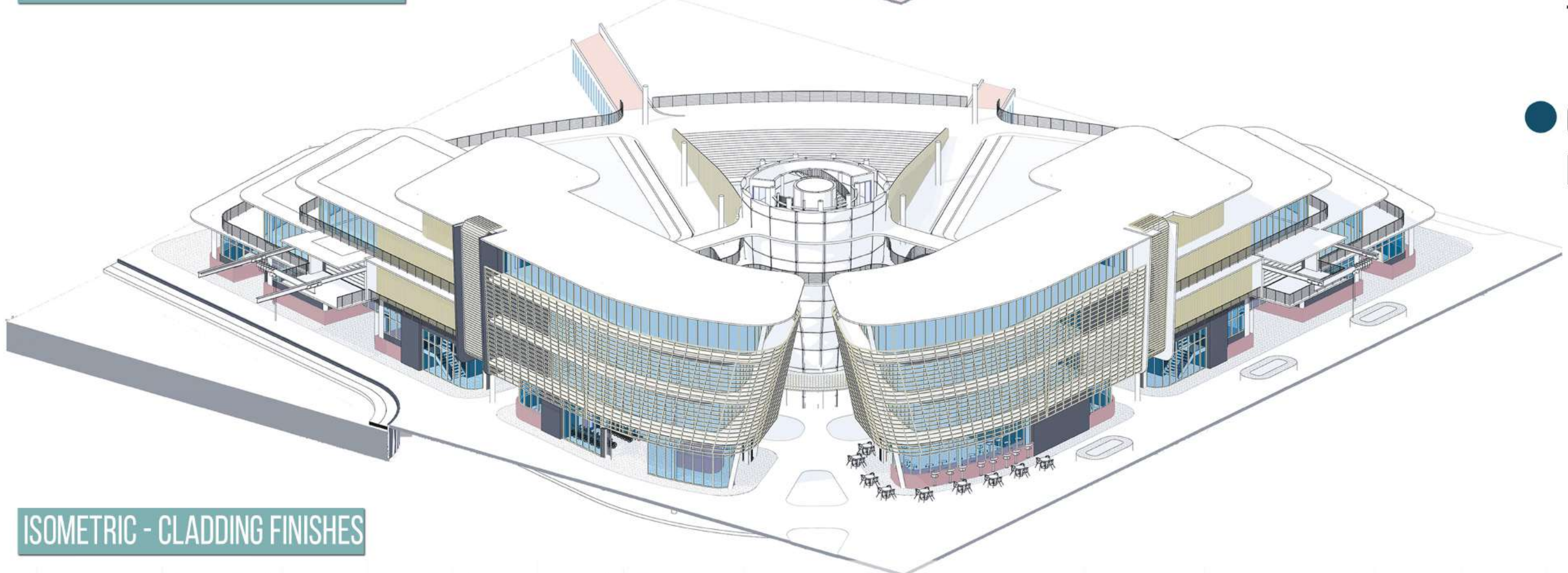


ISOMETRIC - STRUCTURAL SYSTEM

- CROSS VENTILATION
- DEEP OVERHANGS
- PERMEABLE TIMBER SOLAR SHADING
- GLAZING - MAXIMISES DAYLIGHTING

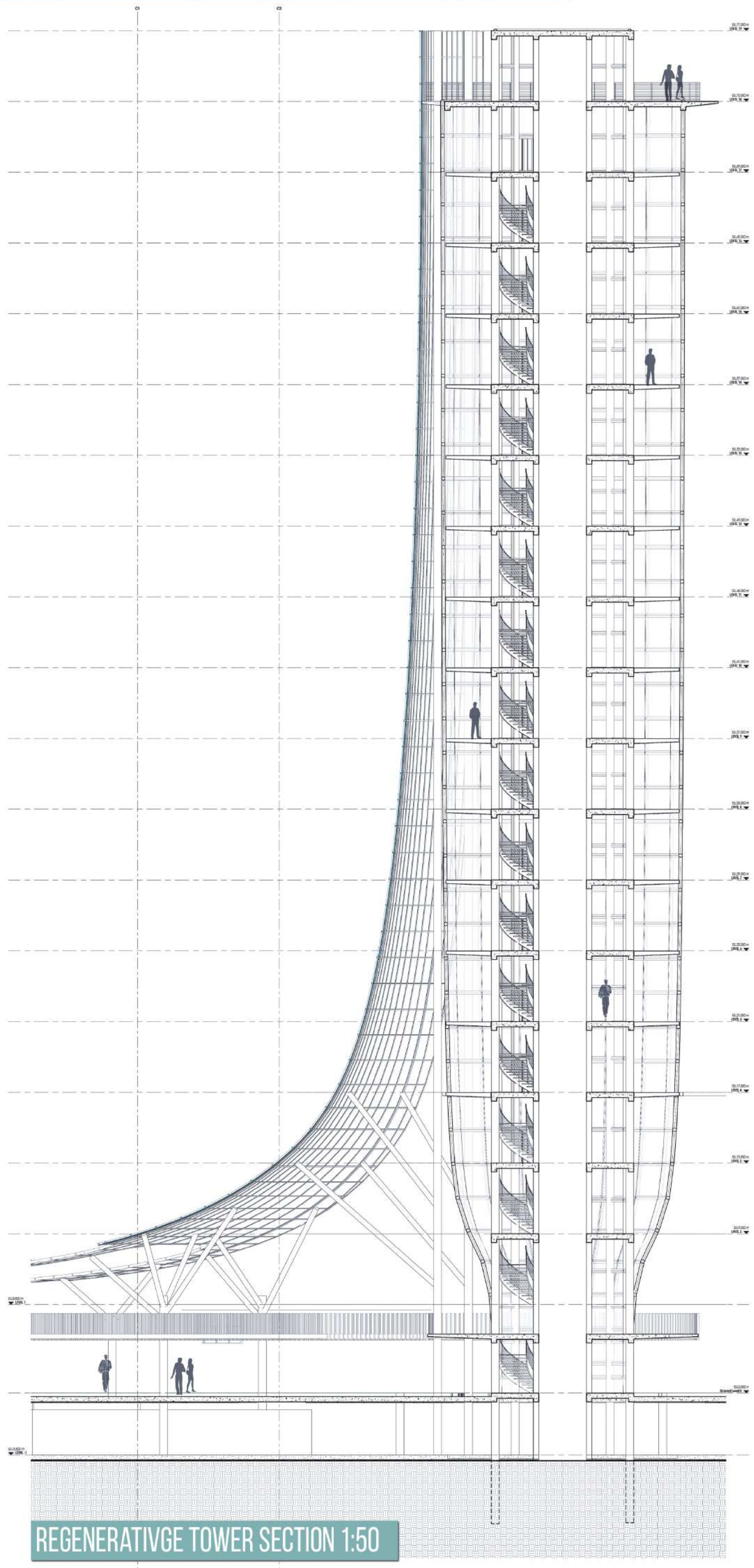


STRIP SECTION 1:50



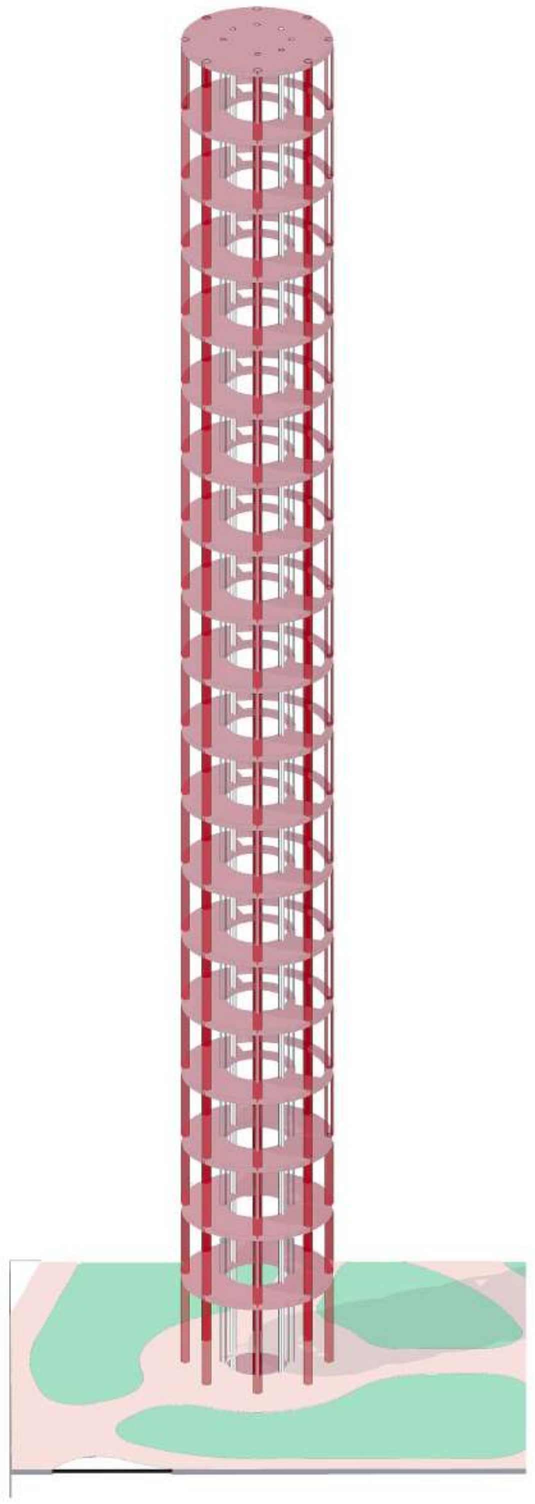
ISOMETRIC - CLADDING FINISHES

ARCHITECTURAL MATERIALITY + CONSTRUCTION

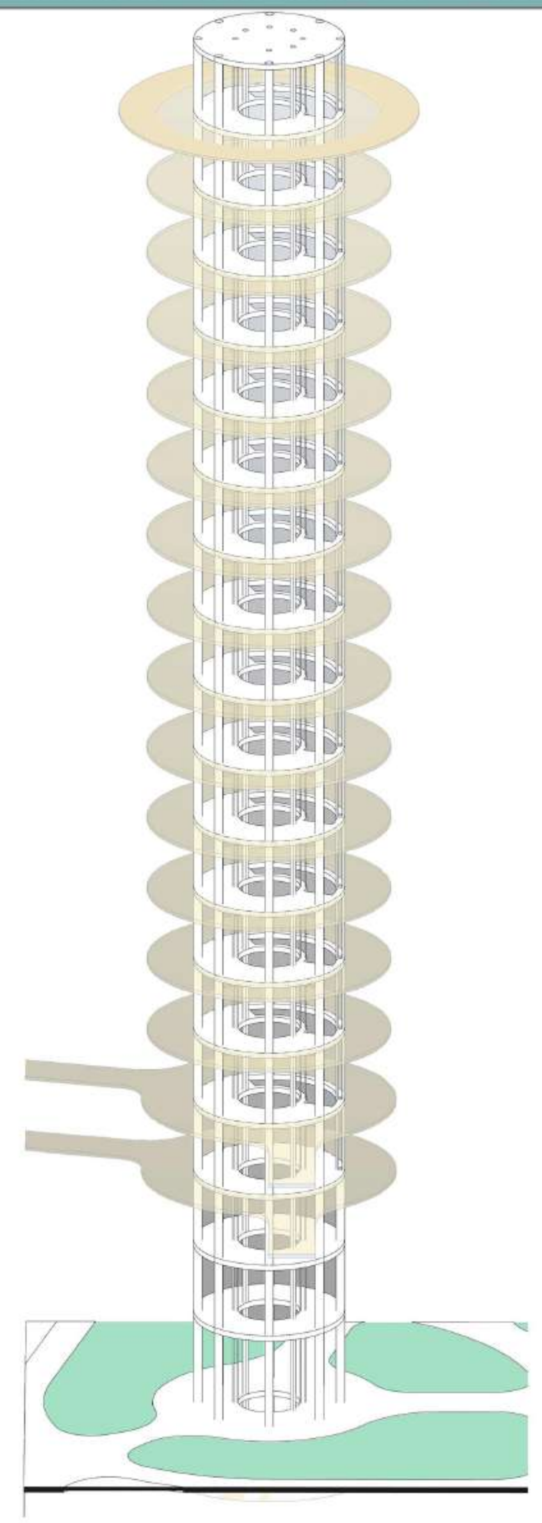


REGENERATIVGE TOWER SECTION 1:50

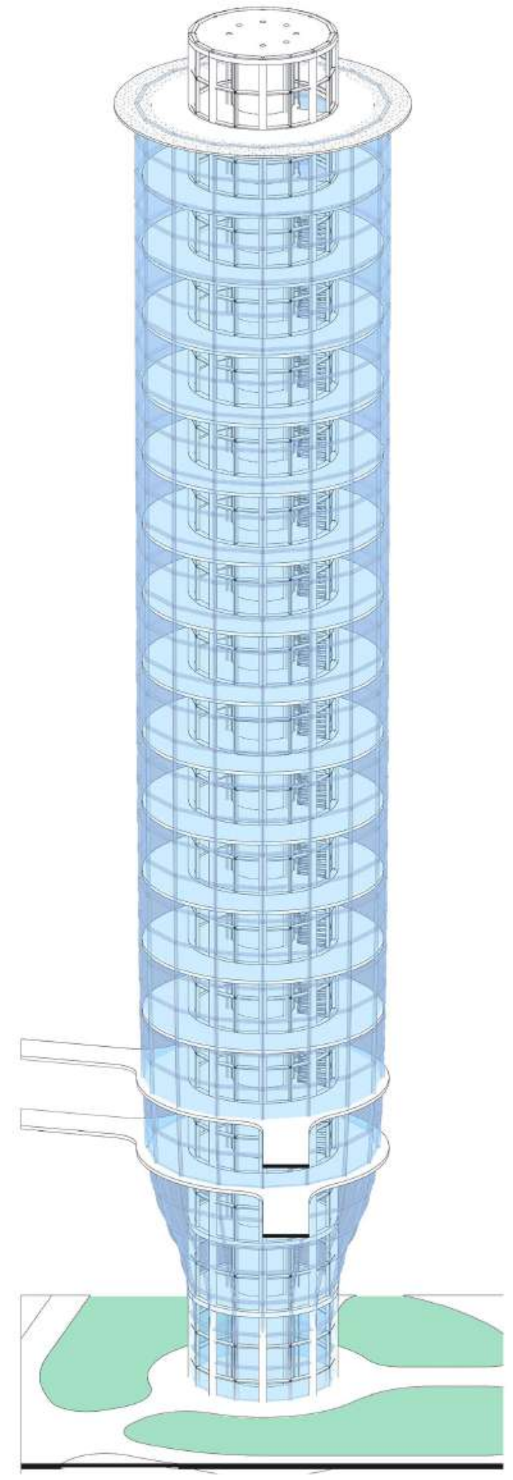
ROBUST CONRETE STRUCTURAL CORE

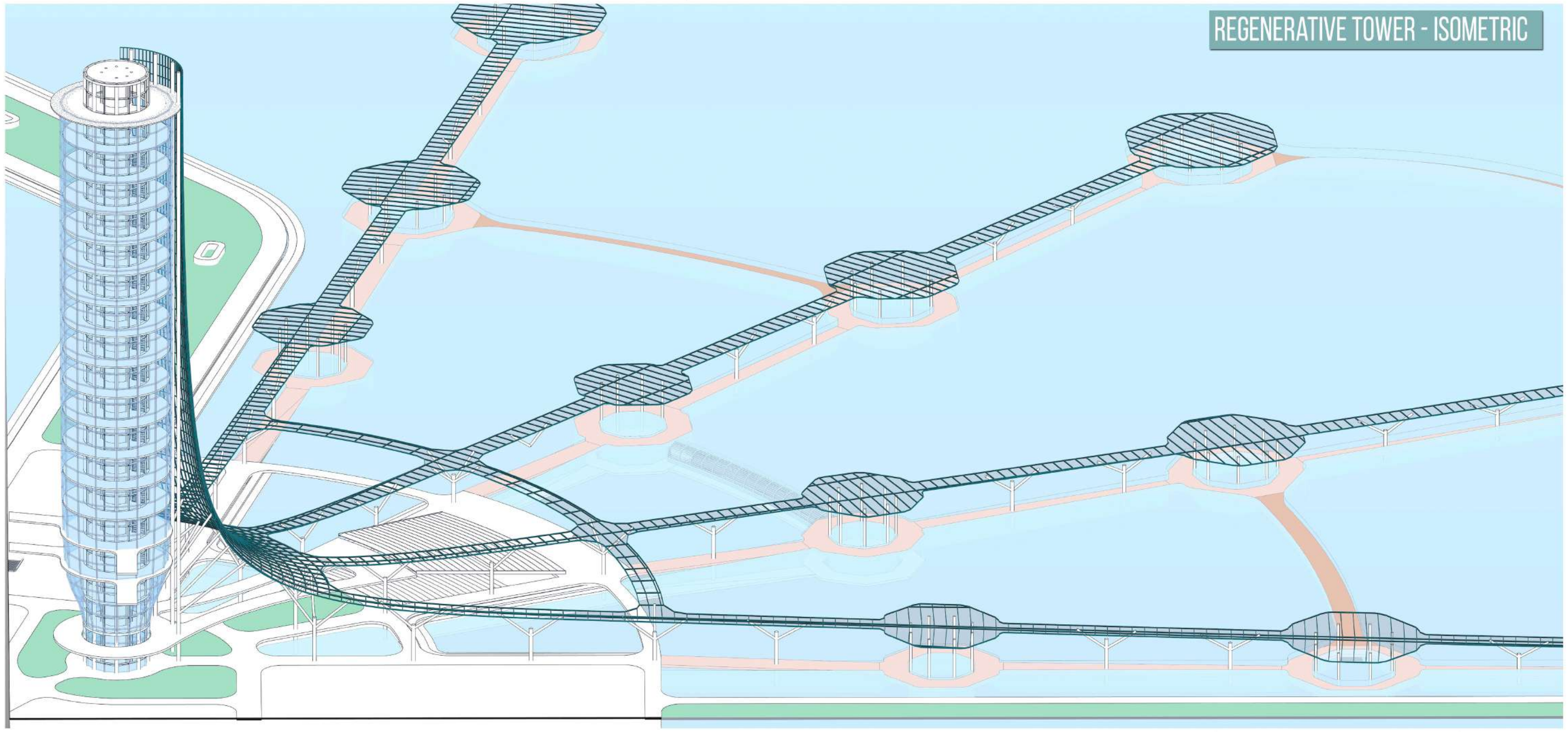


PREFABRICATED GALVANISED STEEL FLOORING



STRUCTURAL STEEL BRACING SHELL



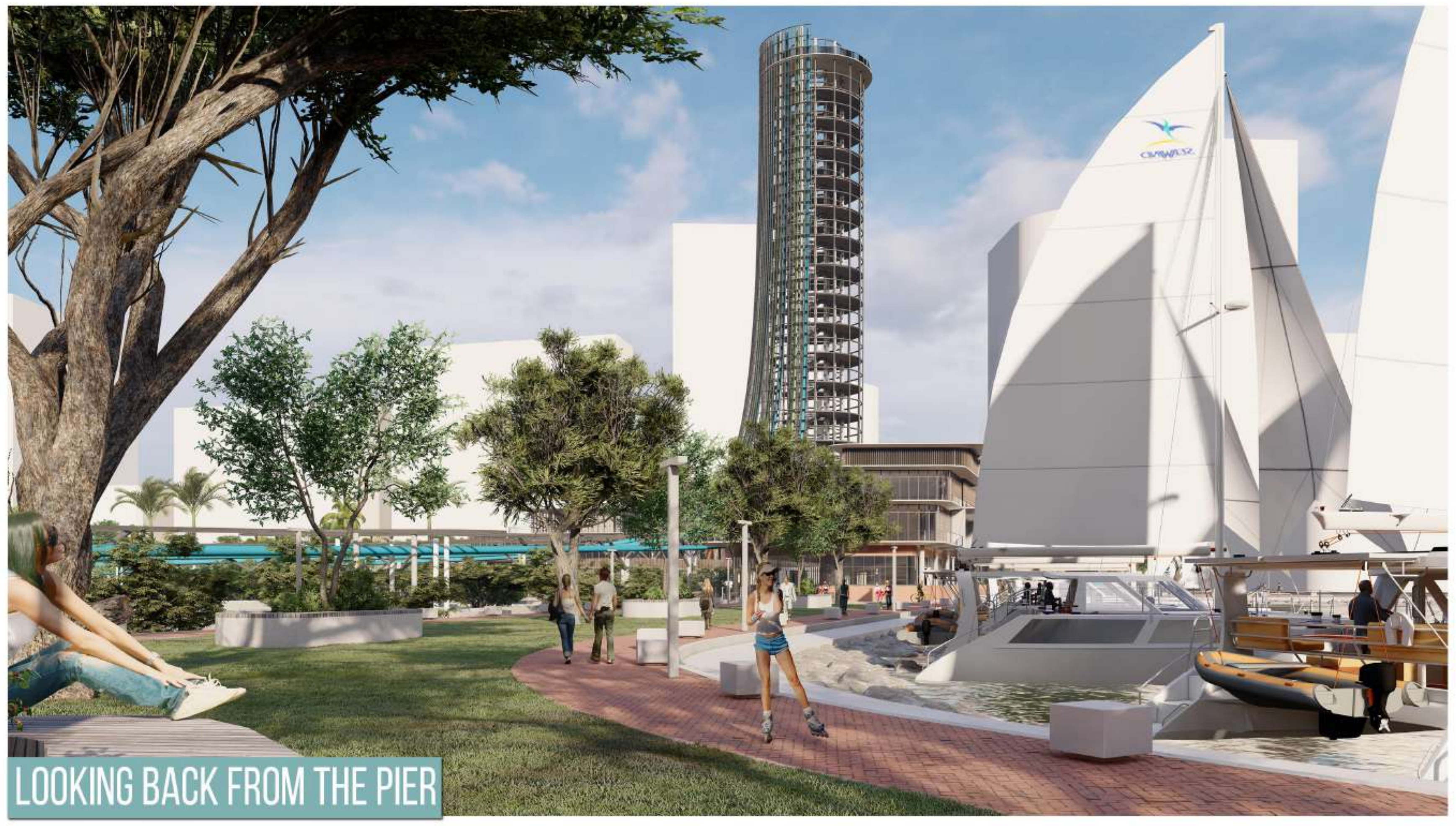


REGENERATIVE TOWER - ISOMETRIC

ARCHITECTURAL EXPERIENCE FROM AFAR

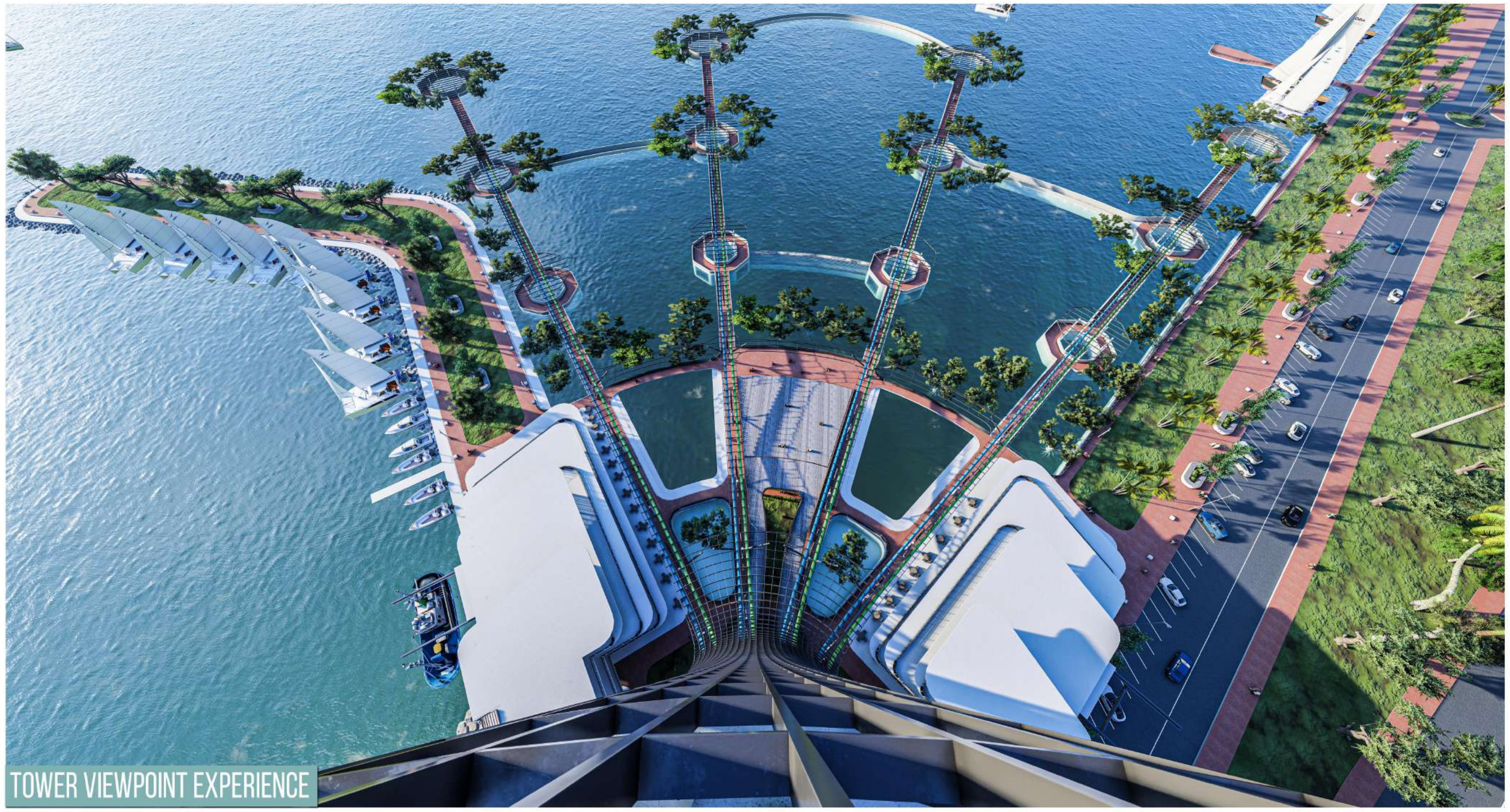
AERIAL EXPERIENCE

VIEW FROM MANGROVE WALKWAY



LOOKING BACK FROM THE PIER

VIEW FROM OUT IN THE BAY



TOWER VIEWPOINT EXPERIENCE

URBAN INTERFACE EXPERIENCE

VIEW FROM EAST WATERFRONT

WATERFRONT INTERFACE

URBAN WATERFRONT INTERFACE

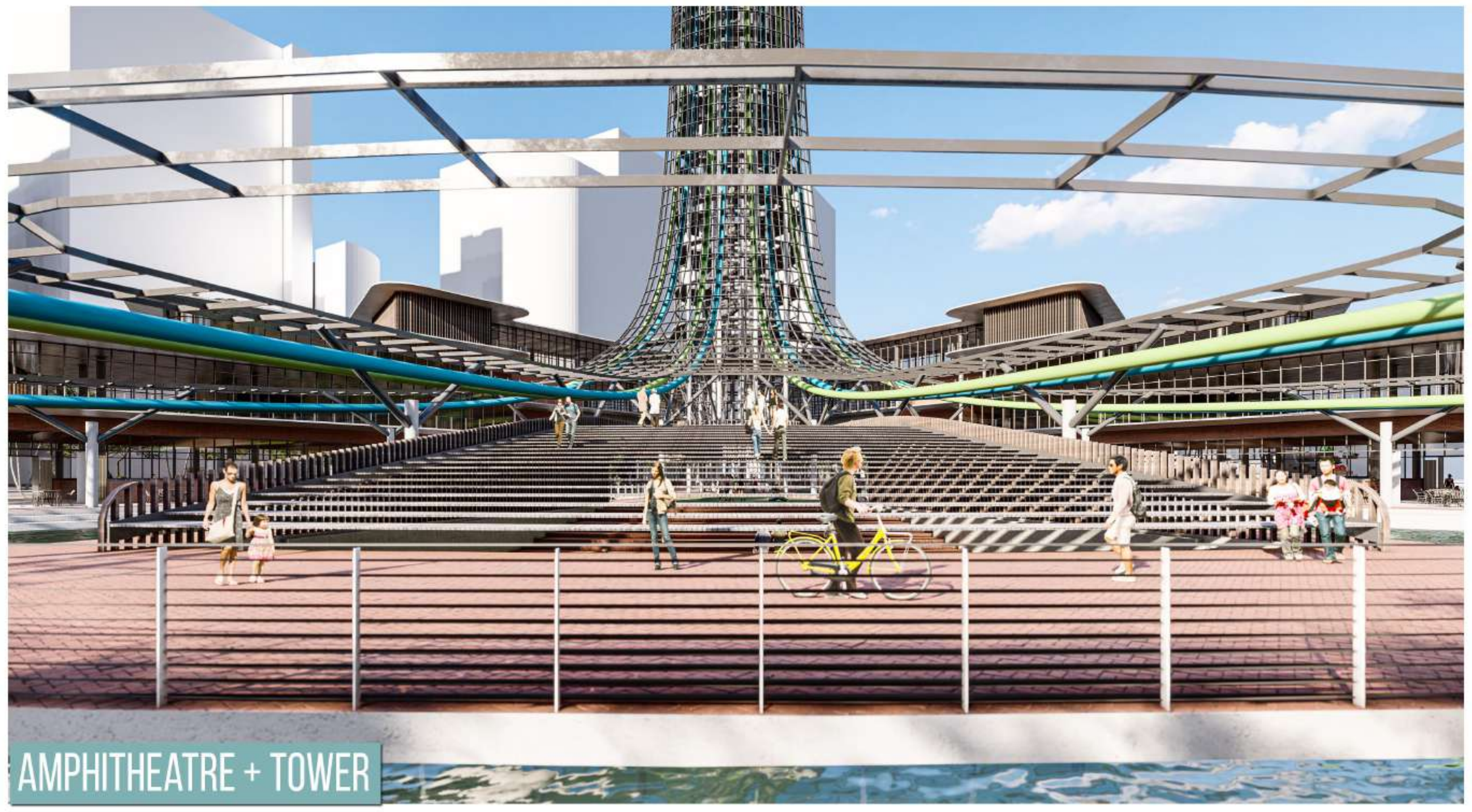
URBAN EDGE INTERFACE

MAIN ENTRANCE FRAMING THE TOWER + ATRIUM

ARCHITECTURAL ECOLOGICAL EXPERIENCE

VIEW FROM MANGROVE WALKWAY

UNDERWATER MANGROVE AMPHITHEATRE



AMPHITHEATRE + TOWER

SWIMMING POOLS + MARKET

REGENERATIVE TOWER + ATRIUM EXPERIENCE