UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

# **AN EXPLORATION OF WATER SECURITY THROUGH ARCHITECTURE**:
Towards a Learning Centre in Durban.

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216006406

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
University of KwaZulu-Natal
Durban, South Africa
May, 2022

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**Supervisor**

**Juan Solis-Arias (33012)**

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# Abstract

South Africa faces a challenge in ensuring clean water for its people as a consequence of exploiting its water resources (Donnenfeld, et al., 2018). Furthermore, a recent study conducted expressed the gap in public awareness and knowledge of water harvesting and recycling in South Africa (Slabbert & Green, 2020). The research aims to investigate water security, the conservation and control of water, through architecture to ensure a sustainable water supply for Durban whilst creating awareness and education on the importance of water. The research explores the relationship between water security and architecture to develop the principles of a learning centre. An interpretivism research philosophy was used through qualitative data collection to gain insight into the themes surrounding the topic using both primary and secondary sources.

# Declaration

I declare that this dissertation is my unaided work under the supervision of Mr Juan Solis-Arias. All references, references and borrowed ideas have been duly acknowledged. It is submitted for the degree of Masters in Architecture at the University of KwaZulu-Natal, Durban, South Africa. None of the presented work has been submitted previously for any degree or examination in any other university.

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Kreolin Lyle Naicker

13 January 2023

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## 1.1 Introduction

### 1.1.1 Background

Water is a crucial resource for human beings, thus, ensuring optimum hydration for the body promotes a healthy lifestyle and overall well-being. The average adult human body comprises 60% water (Sissons, 2020), with an advisable consumption of approximately 2 litres per day. In South Africa, the increased rate of urbanization, economic growth, and the demand for clean, freshwater resources put the water treatment sector under duress.

Another major contributor is climate change, producing unpredictable precipitation resulting in droughts or flash floods. The mean annual rainfall in the world is 860mm. In South Africa, the average is notably lower at 450mm per year, leading to the Department of Communication and Information Systems acknowledging the country as the 30$^{th}$ driest country in the world (Mnisi, 2020). Furthermore, the current ageing water supply infrastructure is prone to vandalism and leakages resulting in 54% of water loss (Govender, 2022). The destruction and contamination of river catchment areas in regions affect water quality, which harms people, wildlife, and the natural environment. The country has taken steps towards improving the accessibility to clean water and sanitation post-1994, implementing programs such as the Reconstruction and Development Program (RDP). Moreover, the country has fallen in line with many others to respond to Goal 6 of

the Sustainable Development Goals (SDG) to ensure clean water and sanitation for all South Africans by 2030. These improvements are recognized; however, 21 of 60 million South Africans either can't obtain clean water or their water source is contaminated, thus negatively impacting their livelihoods (Kings, 2020).

Global warming is a world-renowned phenomenon that negatively impacts planet Earth, and the greenhouse gases emitted result in increased global temperatures. Human beings are the main contributors to global warming, with the demands for food and water exceeding the availability due to population growth. The depletion of the natural environment as cities expand creates a disconnect between built form, humans and the natural environment (Moghadam, et al., 2015). The increase in the built environment creates impervious surfaces, which intensify the surface runoff of water, and contribute to flash floods which affect people's lives and cause environmental degradation (Xu, et al., 2020). The disconnect between man and nature hinders the relationship between the two as the built form and nature are designed as two separate entities.

The recent El Nino phenomena in 2015 caused an extreme heatwave across the country, leaving most areas with dry conditions and putting a strain on water resources and food production. The heatwave resulted in high demand for water and food across the country, with many water systems unable to facilitate the water required to serve various communities and industries (South African Government, 2015). In 2018 the "Day Zero" countdown that occurred in Cape Town due to the significant drought resulted in low levels of freshwater in the city, which sparked an interest in the country's insecure water security and management system and identified the weakness and challenges faced (Booysen & Gerber, 2021).

### 1.1.2 Motivation/Justification of the Study

South Africa faces a challenge in ensuring clean water for its people as a consequence of exploiting its water resources (Donnenfeld, et al., 2018). KwaZulu Natal is one of many provinces affected by the insufficient availability of clean water. The city is still feeling the effects of the 2015 droughts, which reduced dam storage levels to less than 50% of its total capacity within the province (eNCA, 2015). Research involving the climatic conditions of Durban between 1970 and 2017 shows a decrease in rainfall throughout the region, resulting in frequent droughts in various areas that strain the water resources (Ndlovu & Demlie, 2020). The unpredictable rain concurrently

reduces the amount of groundwater, negatively impacting industries such as the agricultural industry reliant on a constant water supply for food production.

The gap in public awareness and knowledge of water harvesting and recycling is evident in South Africa (Slabbert & Green, 2020). Educating people and bringing awareness to water conservation is crucial and relevant as water is a precious resource for societal needs. The research looks to contribute to the academic debate by presenting the opportunity to recycle and harvest water sustainably through Architecture, improving the water structure and livability with visible water (Muller, 2018). Moreover, contribute to improving the public's awareness and education on water security through multi-sensory and lived experiences with nature and the built form.

## 1.2 Definition of the Problem, Aim and Objectives

### 1.2.1 Definition of the Problem

The built environment has formed a disconnect between humans and nature through the city's development. The built form dominates the natural environment, destroying habitats without compensating and incorporating nature. The increase in population growth requires the built form to expand, creating impervious surfaces contributing to flash floods, environmental degradation, loss of biodiversity and climate change (Xu, et al., 2020; Wilby, 2007; McGrane, 2016). The development of the built form disrupts the relationship between water and urbanity (Carlo, et al., 2020), channelling water into pipes away from the built form instead harvesting and recycling it within urban environments.

Durban faces challenges surrounding water security due to climate change, urbanization and ageing infrastructure that strain current water resources in the province (Ndlovu & Demlie, 2020). Moreover, insufficient water supply negatively affects various regional production industries, such as agriculture and increases the ever-growing poverty rate and demand for food in the city (Gumbi & Rangongo, 2018).

To further expound on the problem, there is insufficient knowledge transfer and communication surrounding water security and the promotion of water recycling and harvesting in the public realm. Moreover, there is inadequate interaction and connectivity within communities to share, educate and create awareness of safeguarding water resources and management for the country's

sustainable growth (Sershen, et al., 2016). The quantity of knowledge and skills is depleting, as many experts are leaving the country; concurrently, there is a failure to produce skilled water engineers and educators to transfer knowledge and skills to improve and develop the sector (Government Communication and Information System, 2021).

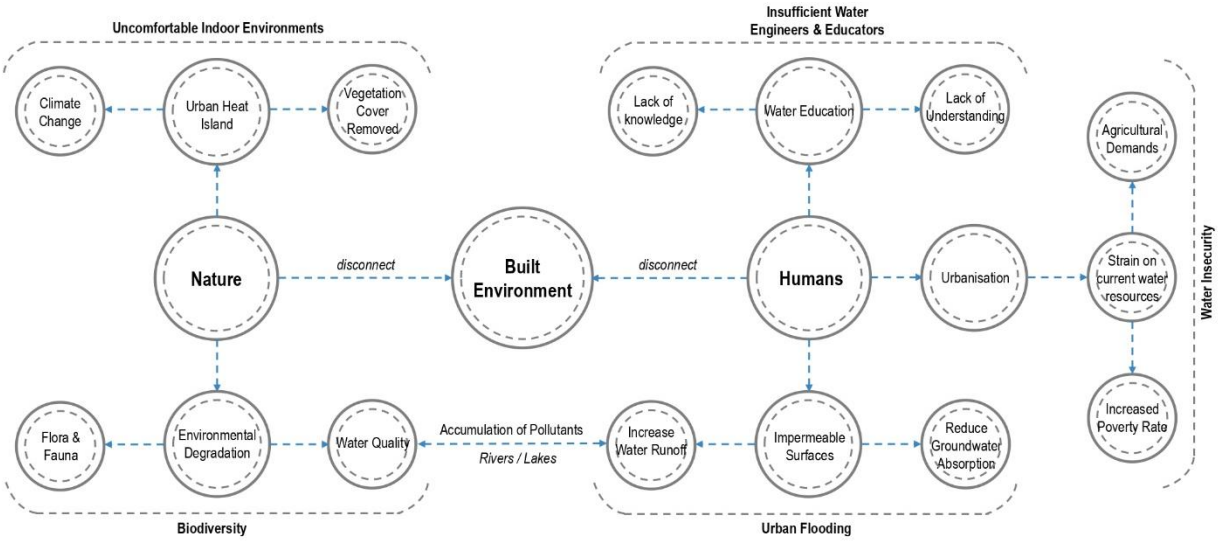



*Figure 1. Research Problem Diagram (Author, 2022)*

### 1.2.2 Aim

The research aims to explore the relationship between water security and architecture to develop principles of a Learning Centre in Durban.

### 1.2.3 Objectives

- To investigate the global-local state of water security and the built environments' impact on water security.
- To identify water security approaches through the built and natural environment.
- To explore and determine types of spaces to promote effective learning environments.
- To identify architectural principles of a Learning Centre.

## 1.3 Setting Out The Scope

### 1.3.1 Delimitation of Study

The research will be conducted within Durban and explores water security as a whole. The study will focus on the importance of water through architecture and identify strategies for sustainable water recycling and harvesting. The research aims to facilitate integrated active and informal learning environments to increase public awareness and meet societal water needs.

The proposal will not redefine the water management systems but rather contribute to and improve the current condition of conserving and controlling water in Durban through architecture. The research will seek the community's involvement in forming social bonds whilst being a vibrant social space engaging with learning on water security. Furthermore, the study will explore the influence of nature through interaction between humans and the natural environment to enhance learning outcomes.

### 1.3.2 Definition of Terms

**Water Security**
The conservation of water for society and the control of water through the built and natural environment as a climatic response.

**Sustainable**
Meeting the current generation's needs without disregarding the needs of future society.

**Awareness**
The ability to know, perceive, or be conscious of something.

**Conservation**
To preserve or protect something.

**Water Harvesting**
The collection of runoff water in order to provide for people, animals or crops.

**Integrated Learning**
A concept that allows students to use prior knowledge and experiences to sustenance new knowledge and experiences.

### 1.3.3 Stating the Assumptions

The study makes the following assumptions:

1. Water is exploited worldwide without sufficient recycling and harvesting to ensure its sustainability.

2. There is minimal public knowledge and awareness regarding water conservation and control.

3. Architecture can (re)connect people with nature (water) through multi-sensory encounters.

### 1.3.4 Key Questions

- What is the global-local state of water security and the built environments' impact on water security?

- What are the water security approaches within the built and natural environment?

- What types of spaces promote effective learning environments?

- What are the architectural principles of a Learning Centre?

### 1.3.5 Hypothesis

A Learning Centre can provide the city of Durban with the knowledge and ability to harvest and recycle water sustainably through informal and active learning environments. The Centre will create awareness of the importance of water for the locals and visitors while being a vibrant, social space that connects the community, wildlife, and the natural environment.

## 1.4 Conceptual and Theoretical Framework

### 1.4.1 Introduction

The section focuses on the relevant theories and concepts that explain and underpin the themes of the study. The concepts and theories and concepts discussed form the framework and support the design decisions. These, in turn, will assist in developing an understanding of the research, forming a base of knowledge that responds to the problem, aim, objectives, precedent studies and case study.

The three concepts explored are **Water Security**, **Water and Architecture** and **Nature and Learning Environments**. The three theories explored are **Phenomenology, Environmental Sustainability** and **Experiential Learning Theory.** These were chosen to create environments that promote comfortable learning and social spaces that invite users to engage and interact, creating memorable experiences through interactions with water. Relevant principles will be extracted through the research and implemented within the design development.

### 1.4.2 Water Security

Water Security in the context of the research refers to the conservation and control of water through the recycling and harvesting systems to provide non-potable and potable uses in the built environment. The key objectives are to ensure water sustainability and resilience, addressing the research problem of the water challenges faced in South Africa (US EPA, 2019). Authors suggest that the concept provides opportunities to create a decentralized approach by investing in non-conventional methods that increase water availability and provide environmental and human health benefits (Gulamussen, et al., 2019; Swartz, et al., 2022).

### 1.4.3 Water and Architecture

Water and Architecture focus on the relationship between the two and on integrating water into the built environment. Authors stress the impact of the built form on the natural environment, which contribute to water-related challenges (McGrane, 2016; Environmental Protection Agency, 2001; Wilby, 2007). The work of Professor Brook Muller (2017) envisions architecture as a living system using a water-centric approach to harvest, recycle, store and treat water through the built

form. In their books, Booth (1990) and Alexander et al. (1977) express man's desire to connect with water and Kellert & Calabrese (2015) expounds on the buoyant impact water has on human beings in spaces through sensory experiences.

### 1.4.4 Nature and Learning Environments

Nature and Learning Environments explore incorporating and interacting with nature to enhance the learning spaces for the users. Kuo et al. (2019) assert that by nurturing an emotional connection to nature, users tend to express a deeper affiliation with pro-environmental behaviour. Authors suggest that nature-orientated learning environments through experiences with direct, indirect and symbolic connections to the natural environment holistically improve students' performance (Acar, 2014; Mirrahimi, et al., 2011; Chrakas, 2020). The concept strongly links Experiential Learning Theory and Biophilic Design to supplement water education and awareness through experiences with water and nature.

### 1.4.5 Phenomenology: Multi-sensory Experience

The theory of Phenomenology is a philosophy that finds application in architecture through a multi-sensory experience. The manipulation of space perception, materials, light and shadow impact the human sensory experience when encountered (Kraus, 2011). The prominent thinkers in the research context are Peter Zumthor and Juhani Pallasmaa. Peter Zumthor (2006) explains how the atmosphere created by architecture shapes the perception in which one views it. Juhani Pallasmaa explores the concept of multi-sensory experiences and haptic, sensuous architecture. Pallasmaa (1994) states every meaningful experience of architecture, including materiality, scale and space, is multi-sensory. The theory will guide the researcher in organizing meaningful connections to water through an architectural lens allowing the users to develop a deeper relationship with water by activating multi-sensory experiences, creating a water-centric atmosphere.

### 1.4.6 Environmental Sustainability

Environmental Sustainability is one of the three pillars of Sustainability Architecture, focusing on conserving and preserving the natural environment. Environmental Sustainability, within the research, is associated with the connection between society and the natural environment (Morelli, 2011). Biophilic Design forms an approach to ensure the co-existence between humanity and the natural environment through built form. Biophilia was first introduced by Edward O. Wilson (1984), suggesting that humans have a natural affiliation and interest in nature. Stephen R. Kellert, a pioneer of the theory of Biophilia, emphasizes the need for human-nature interactions and the effects of nature on human well-being (Kellert, 2005). The theory will direct the researcher on approaches to improving the learning environment by connecting the users to nature and bringing water within the built form.

### 1.4.7 Experiential Learning Theory

John Dewey (1938) created a foundation for the Experiential Learning Theory in his book Experience and Education. He argues that traditional and progressive education systems are hindering the development of students as neither applies the principles of the philosophy of experience (Dewey, 1938). Dewey states that the social environment is crucial to education development through lived experiences that involve human contact and communication (Roberts, 2003). David A. Kolb (1984) further expounds on Dewey's ideology that experience is critical in ones learning development and the human adaptation process to the social and physical environment involving thinking, feeling, perceiving and behaving (Kolb, 1984). Paulo Freire (2005), an educator and philosopher, critiques the current education system stating that the narrative approach declines the quality of the current education system as students lack creativity, critical thinking and new knowledge because there is no opportunity to inquire and gather information. The theory is strongly linked to Phenomenology and Environmental Sustainability and will assist the researcher in creating lived experiences of water security to enhance learning about the importance of water.

The table below unpacks the conceptual and theoretical framework, identifying each theory's related concepts and goals. The goal is the overall outcome of what the theory and concept will achieve through the built form.

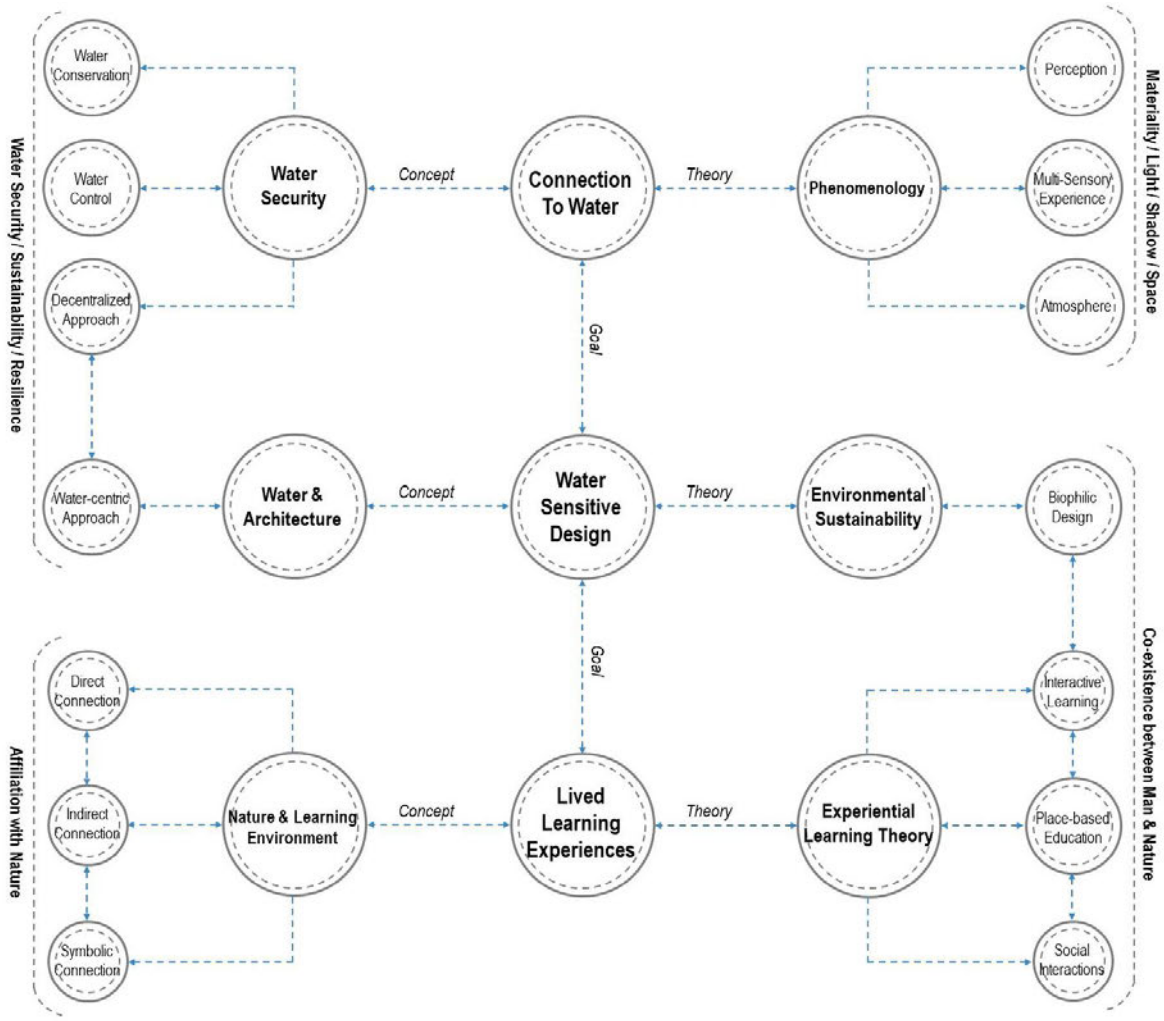



*Figure 2. Conceptual & Theoretical Framework (Author, 2022)*

## 1.5 Research Methodology

### 1.5.1 Introduction

This section of the dissertation discusses the Research Philosophy, Strategy, Data Analysis and Methods of obtaining information regarding the topic. The data will be collected through primary and secondary sources, with water, education and architecture at the forefront of the research.

### 1.5.2 Research Philosophy and Strategy

The research is set within an Interpretivism Research Paradigm consisting of Qualitative data collection. The study will be examined through the lenses of empirical and non-empirical research approaches. The empirical analysis will gather primary data, and the non-empirical analysis will gather secondary data. The data will be analysed through thematic and textual analysis, consisting of diagrams, images, sketches, mapping and text.

### 1.5.3 Secondary Data Collection

**Literature Review** - The theories of Phenomenology, Environmental Sustainability and Experiential Learning will underpin the Literature Review to fulfilling the Research Objectives and respond to the Research Questions. The current knowledge topic will be unpacked and critically analyzed to develop a comparative summary of the findings and build an argument in response to the Objectives and Research Question. The data will be collected using published books, scholarly articles, journals, thesis documents, and online sources.

**Precedent Studies** – A critical analysis of the existing buildings and the architectural principles used to develop sensory spaces that promote learning environments and sustainable methods to harvest and recycle water. The buildings investigated will identify concepts used in the design process to gain insight into typology, character, expression, and spatial arrangements. The Theoretical Framework will be central to identifying the relevant building focused on water resilience, awareness, and learning environments stimulated through sensory experiences. The buildings can be chosen in any location worldwide and will be a similar typology as a Learning Centre.

### 1.5.4 Primary Data Collection

**Sampling** – The semi-structured interviews and case study will use non-probability sampling of the **purposive sampling technique**. The researcher will identify individuals and a building based on the researcher's judgment that best suits obtaining the knowledge and information on the research problem and questions.

**Semi-Structured Interviews** – Depending on the interviewee's availability, the semi-structured interviews will be conducted via an online platform or in person. The interviewees will be one to five individuals from Siza Water, with each interview approximately 15-20 minutes regarding questions on the themes of the study. The individuals were selected due to their understanding and experience of water recycling and harvesting. The semi-structured interviews will be transcripted by the researcher and conducted formally with audio recordings signed with consent by the interviewee. The attached **Appendix One** entails the Interview Schedule and the Consent Form.

**Case Study –** The case study consists of an observation and analysis of a local facility that recycles water and incorporates educational activities. The Siza Water Recycling Plant will be investigated by observing the spatial arrangements, indoor and outdoor relationships, and approaches to recycling and harvesting water. The attached **Appendix Two** states the permission from the Gatekeeper of the particular building as per the Institutional Research Ethics Committee requirements.

**Site Analysis** (Movements, Observations, Sketches etc.) - The Site Analysis will increase the knowledge of the study area for the researcher, the pedestrian and vehicular movement and the buildings in and around the site identifying their functions and character and the potential of stormwater harvesting.

### 1.5.5 Research Materials

The research materials to gather data from the relevant sources on the research topic are as follows:

- Secondary Data will be collected from published books, scholarly articles, journals, thesis documents, and online sources.
- Interviews will include 3 topics for discussion on the themes of the study,
- The author will use sketches, photographs and field notes to analyze the case study and the chosen site context.

### 1.5.6 Research Analysis

The qualitative data collected will be critically analyzed in response to the research objectives and questions to develop a comparative summary relating to the research problem. The tools used to analyze the data are thematic and textual analysis, and these findings are represented through text, images, sketches, diagrams and maps. The sampling method involves purposive and convenience samples with 5-10 literature sources per research question, four interviews, four precedent studies and one case study.

#### 1.5.7.1 Summary (Research Matrix)

Objective 1 is *to investigate the global-local state of water security and the built environment's impact on water security;* data will be collected via semi-structured interviews with individuals at Siza Water and existing literature sources. The data collection instruments comprise journal articles, published books, online sources, thesis documents and an interview schedule with 5-10 references and 5 interviewees. The sampling technique will be purposive sampling technique, and the data will be analysed through a thematic and textual analysis consisting of text, images and diagrams.

Objective 2 is *to identify water security approaches through the built and natural environment*, data will be collected via semi-structured interviews with individuals at Siza Water, a case study and existing literature sources. The data collection instrument comprises journal articles, published books, online sources, thesis documents, precedent studies and an interview schedule with 5-10 references, 2 precedents, 5 interviewees and observations. The sampling technique will be purposive sampling technique, and the data will be analysed through a thematic and textual analysis consisting of text, maps, images, sketches and diagrams.

Objective 3 is *to explore and determine types of spaces to promote effective learning environments,* where secondary data will be gathered through a critical analysis of existing literature sources. The data collection instrument comprises journal articles, published books, online sources, thesis documents and precedent studies with 5-10 references and 2 precedents. The sampling technique will be purposive sampling technique, and the data will be analysed through a thematic and textual consisting of text, images and diagrams.

Objective 4 is to *identify architectural principles of a Learning Centre,* where secondary data will be gathered through a critical analysis of precedent studies. The data collection instrument includes online sources and images, with 3 precedent studies. The sampling technique will be purposive sampling technique, and the data will be analysed through a thematic and textual consisting of text, images and diagrams.

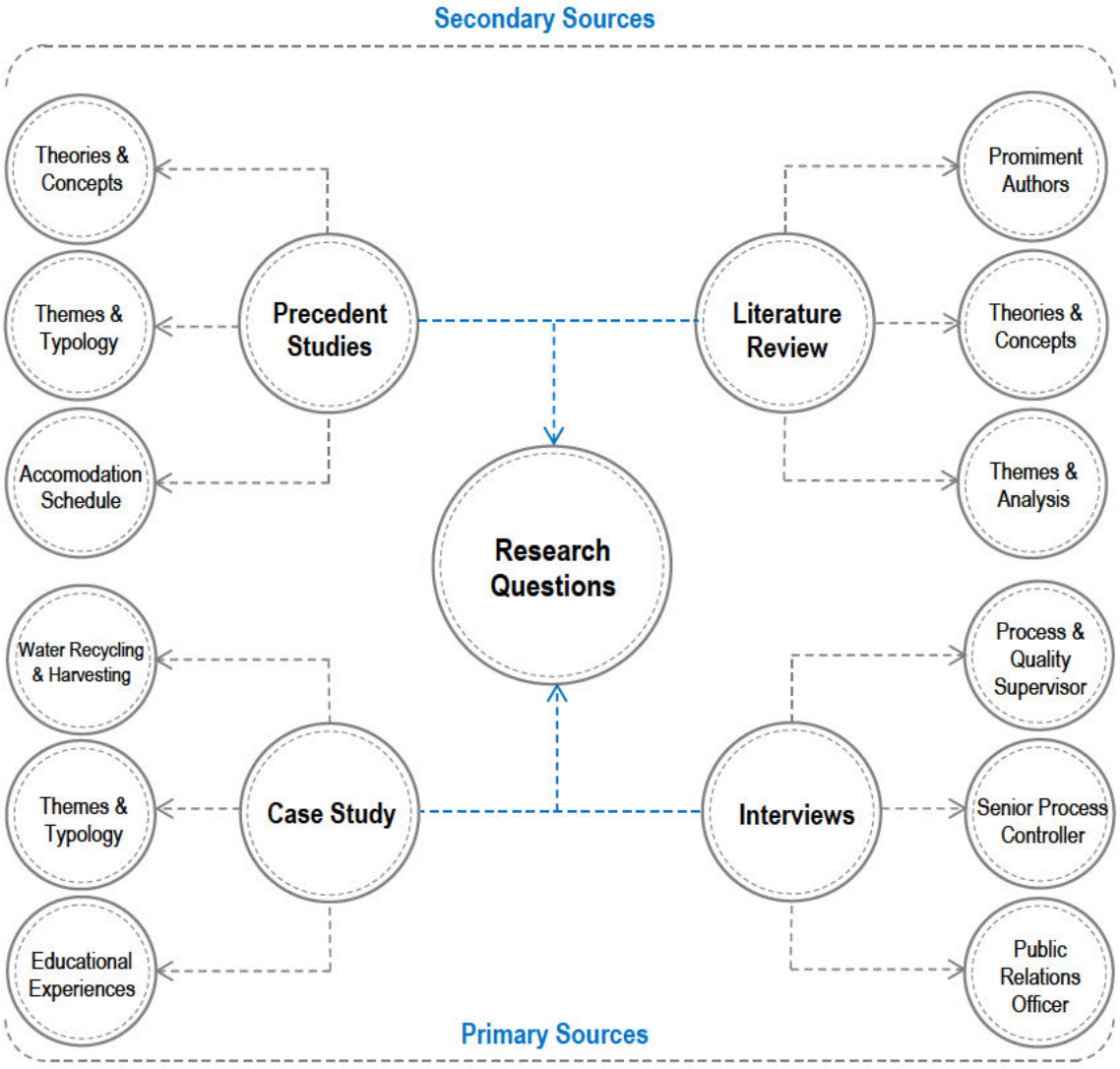



*Figure 3. Summary -Methodology (Author, 2022)*

### 1.5.8 Conclusion

Multiple research approaches will be used throughout the study to improve the research's reliability, validity and rigour. All data collected through the different research approaches will be evaluated and analyzed to ensure that all potential outcomes have been considered. A triangulation of various data methods and personnel will be developed to produce a complete set of findings and improve the research's credibility. All data will be collected formally with full consent and permission from the Ethical Committee, academic leaders, supervisors, participants, and published authors will be referenced accordingly.

## 1.6 Conclusion

Chapter 1 outlines the concerns regarding water security through the preliminary literature review and stresses the built environment's impact on the relationship between humans and the natural environment. Furthermore, identifying insufficient awareness and education regarding the topic in the local context enhances the problem. The accumulation of the problems motivates the research toward water security through an architectural lens. The study will consider water harvesting and recycling to address the issues through built form and stresses the necessity of water education. The Conceptual and Theoretical Framework explores the concepts and theories which form the lenses through which the literature review will be critically analyzed in the next chapter. The research will be conducted through an Interpretivism Research Paradigm, collecting Qualitative data and thereafter identifying the necessary architectural principles towards a Learning Centre.

# Chapter 2: Literature Review

## 2.1 Introduction

The dissertation chapter outlines and unpacks the current body of knowledge through the conceptual and theoretical framework lens. The chapter explores the works of prominent authors as a response to the research objectives and questions. The chapter begins by exploring Water Security and progress toward Architecture, developing principles through critical analysis in response to the research problem.

## 2.2 Water Security

The chapter expounds on the research problem and extracts the factors and contributors to water insecurity. The issues and challenges faced in South Africa and Durban are identified to gain insight into the research problem in the local context. The current gaps in knowledge on water security and education are explored in South Africa and the Durban Inner City Plan to respond to the city's future-proofing of water resources.

### 2.2.1 Overview of the Water Security

Water Security is a global phenomenon that can be defined in numerous ways depending on its relationship with water and the desire to manage water resources effectively. The phenomenon promotes environmental protection, social justice and a country's sustainable growth leading to the overall well-being of people and the natural environment (Mishra, et al., 2021). Issues surrounding the topic are a growing concern for countries that must implement holistic strategies to alleviate the problem. The United Nations have identified the importance of water security on a global scale through Goal 6 of the 17 Sustainable Development Goals stressing that there is an increase in countries experiencing water insecurity issues (United Nations, 2015). The relationship between these goals goes back to the initial point of water security being essential to a country's sustainable growth and development.

According to Young et al. (2021, p. 1059), the definition of water security often relates to one or more of four themes: *Availability, Accessibility, Use and Stability*. Figure 4 below depicts the four themes related to water security, with the stability of water resources without change across time impacting and ensuring *Availability, Accessibility* and *Use.* Furthermore, the themes towards the image's right depend on the themes toward the left. For example, the *Use* is dependent on *Availability* and *Stability* across time.

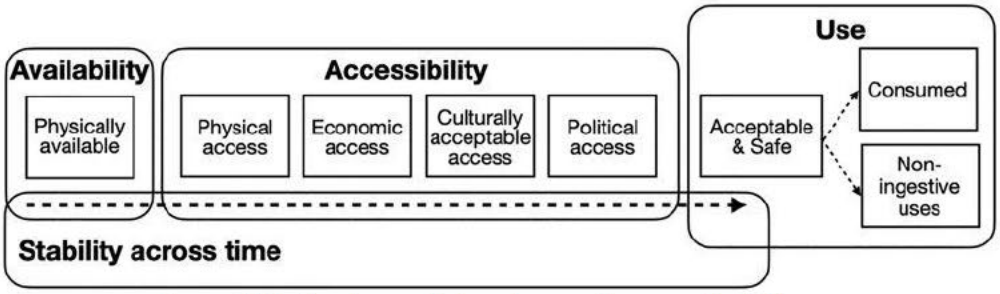



*Figure 4. The four themes of Water Security (Young, et al., 2021)*

The challenges surrounding water insecurity have been a concern for many countries around the globe and proposed a threat to the global economy, food security, societal needs, biodiversity and the livelihood of human beings and communities (Chakkaravarthy & Balakrishnan, 2019). The United Nations further highlight the problem as they predict a 40% deficit in freshwater resources by 2030 (United Nations, 2015).

According to various authors, the two main factors contributing to water insecurity are *Population Growth* and *Climate Change* (Mishra, et al., 2021; Guppy, et al., 2017; Yannopoulos, et al., 2019). In an article by Falkenmark et al. (2007), the authors categorized the factors into two main headings: *Physical* and *Economic Water Scarcity*. Physical Security refers to the inability to meet the demands of water needed and, according to Falkenmark et al. (2007), it is divided into four drivers:

*Demand-driven water scarcity* – A significant disparity between supply and demand for water.

*Population-driven water scarcity* – Increases in urbanization puts a strain on the physical supply of water.

*Climate-driven water scarcity* – Unpredictable rainfall and droughts result in limited amounts of water runoff.

*Pollution-driven water scarcity* – Chemicals and toxic waste pollute water sources to the point of them being unusable.

Economic Water Scarcity is the country's insufficient investment in water technology and infrastructure development which puts a strain on the existing, ageing infrastructure to perform beyond its capabilities (Mnisi, 2020). Demand and Population-driven water scarcity are closely associated with this factor.

### 2.2.2 Water Insecurity in South Africa

South Africa is a water-scarce nation with its sources under duress as it continues to over-exploit the freshwater supply. In the global context, domestic water use averages 173 litres per person per day (Ngobeni & Breitenbach, 2021). However, South Africa's average household water consumption is 237 litres/person/ day. Moreover, in 2018, the non-revenue water was 41% (Department of Water and Sanitation, 2018), which is considerably higher for a country in a water crisis. These statistics indicate a lack of knowledge surrounding the exploitation of water within the country. The mean annual rainfall received in the country is 500mm, 360mm less than the world average (Department of Water and Sanitation, 2021).

Furthermore, the country is heavily dependent on surface runoff which constitutes 77% of the water supplies (Mutamba, 2019). The above statistics show the need to use non-conventional approaches to capture and harvest water to ensure water security in the future. Many authors expound on the water crisis in the country, stressing that there is extensive river pollution from anthropogenic activities, an increase in droughts and flooding, budget constraints to improve existing infrastructure and negatively impacting food security, health and well-being (Thakur, et al., 2019; Mutamba, 2019; Fisher-Jeffes, et al., 2017). The accumulation of the contributing factor leading to water insecurity in South Africa shows that the country is facing both *Physical and Economic Water Security* which is a significant problem, and the inability to address these situations is affecting sustainable growth and development.

The Department of Water and Sanitation (DWS) is responsible for the control of South Africa's water resources. It works in tandem with the Sustainable Development Goals (SDG), formulating strategies to mitigate water insecurity. The National Water Security Framework (NWSF) is one of

the frameworks developed as a response to ensuring water conservation. Although the framework sets out many strategies concerning the research problem, one of the suggested possibilities is proposing specialized water intelligence centres with shared services in the country for producing research, knowledge, information and water monitoring to address the issues of water insecurity and management as well as developing technology and different systems for the medium and long term future (National Planning Commission, 2020).

### 2.2.3 Water Education in South Africa

Water Education is a critical component in the strides toward achieving global water security. The municipality needs to be transparent with the public regarding water-related difficulties in the country and the steps towards responding to the problem. A study by Sershen et al. (2016) in South Africa consisted of semi-structured interviews with experts in the field of water and sanitation. These individuals enunciated their concerns regarding public awareness and water reuse. They stress that communication and collaboration to share information and increase awareness of the need for water management and conservation are crucial across communities (Sershen, et al., 2016).

To further support the argument, a report on public knowledge concerning water-related aspects by Sarah Slabbert and Nadja Green (2020) concluded that water terminology amongst South Africans regarding reuse and recycling is minimal. The score obtained was 12 out of 20, and due to the basic level of questions, an average result would be 14. Moreover, even people with post-grade 12 qualifications scored 12,65, and the highest Living Standard Measure (LSM) group scored 13.05, both below the average, signifying that public water education is essential for all demographic groups (Slabbert & Green, 2020). According to the findings, 68.7% of people do not believe that the country is dealing with water scarcity issues (Slabbert & Green, 2020).

As a result of the findings, key points were derived to address the gap in knowledge and understanding of water-related aspects (Slabbert & Green, 2020):

- The various terminology of water and wastewater.
- Principles of the water cycle.

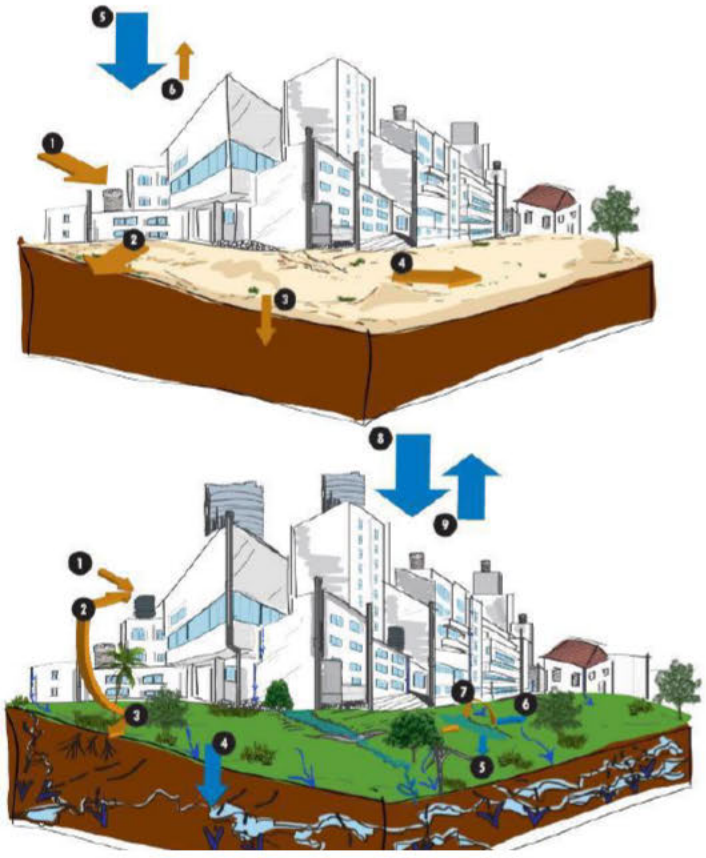
- The characteristics that ensure safe domestic water reuse.

The lack of knowledge from the statistics above expresses the need to transfer knowledge regarding the topic. The shortage of water engineers and educators in the country poses a further problem in sharing skills and expertise with the public (Government Communication and Information System, 2021). Authors suggest that interactive training and methods through an interdisciplinary learning approach can ease the knowledge and skills gap (International Hydrological Programme, 2014; Larson & Redman, 2014; Harrison, 2018). The process engages experts/students from multiple disciplines to create new knowledge by addressing water security through critical thinking and innovation, which supports Experiential Learning Theory and Place-Based Education. The implementation of said methods actively involves and educates the community whilst advancing the knowledge and training of water professionals.

### 2.2.4 Durban Water Development Plans

Durban is rich in history and heritage and has a variety of diverse cultures that give meaning and identity to the city. However, the province has been dealt a bad hand over the past few years, with climate change impacting its growth and development. The city was one of many provinces in South Africa affected by the El Nino phenomenon in 2015, which triggered an intense heat wave over the nation, leaving most regions dry and straining water supplies and agricultural production (South African Government, 2015). Heavy rains and high winds inflicted chaos across the city in October 2017 and recently in April 2022, causing significant flooding that affected many lives. Subsequently, after the flooding, most areas were left with no water for days and weeks due to damage to the ageing water infrastructure, which significantly impacted people's mental and physical health. In some cases, individuals experience post-traumatic stress disorder, depression and anxiety caused by the floods (Keipopele, 2022). A contributing factor that aids the damage caused by flooding is poor stormwater management which cannot drain the vast amount of water efficiently due to blockages from litter and impervious surfaces, which accelerates runoff. Moreover, leakages of toxic and hazardous waste residue in wastewater, groundwater pollution, and leachate runoff resulted in significant environmental and health issues (Palfreman, 2022; Govender, 2022).

The eThekwini Inner City Local Area Plan (2016) provides an overview of strategies to regenerate the inner city of Durban to create a safe, accessible and sustainable city that celebrates the different cultures, heritage and art. Moreover, future development is structured to create a walkable, livable, and connected public realm where all users can live, work and play cohesively. The city cannot achieve these goals and outcomes if the emphasis is not placed on the critical aspect of humanity: water. A reliable and constant water supply is essential for a city to promote economic growth, ensure public health, protect the environment and support the population (Stoker, et al., 2019). The eThekwini Inner City Local Area Plan (2016) highlighted vital challenges faced by the municipality, which are all interlinked to ensuring water security: low economic growth, poverty, food security and adequate water supply/ water shortages. The eThekwini Water and Sanitation (EWS), in collaboration with the International Water Ambition of the Netherlands, have developed a partnership to provide new solutions to solve the water challenges in the city. The increasing droughts and flash floods have led to the collaboration of developing a framework to create a Water Sensitive City integrating Sustainable Urban Design Strategies (Meulen, 2020). The goal is to ensure water resilience, reduce the impact on the natural environment and enhance the city's overall aesthetic, as depicted in figure 5 below.



1. Imported potable water and virtual water.
2. Wastewater Dsicharge
3. Reduced Infiltration.
4. Large Volumes of poor quailty runoff.
5. Precipitation.
6. Reduced evapotranspiration.

1. Reduced portable water consumption.
2. Wastewater reuse.
3. Reduced wastewater discharge.
4. Enhanced Infiltration.
5. Stormwater treatment.
6. Runoff.
7. Stormwater reuse
8. Precipitation.
9. Evapotranspiration.

*Figure 5. Sustainable Urban Design Strategies to create a Water Sensitive City (Meulen, 2020)*

The framework identifies Stormwater Harvesting as the broad term used to respond to water conservation with different application methods. The concept of a Sponge Town through Retention, Recharge and Re-use is advocated through the built environment to absorb and retain water, with the intention of it being attainable during periods of water scarcity. Meulen (2020) states that the vast array of non-permeable surfaces results in more than 80% of surface runoff in relation to the quantity received in urban settings. The eThekwini Local Area Plan (2016) supports the above statement stressing majority of the city consists of hard surfaces, and future development needs to implement innovative urban surface designs that incorporate permeable pavements combined with greenery (IPPU Consortium, 2016).

Understanding the context's topography is essential before implementing stormwater harvesting strategies. The development of the inner city was constrained in the early 1800s due to the uMgeni River's original path, which flowed to Durban Bay, as seen in figure 6. The stream known as the Cato Creek, coupled with Western and Eastern vleis, brought about regular flooding challenges for the early colonizers (IPPU Consortium, 2016). Dense forestry and dune ran along the coastline from the uMgeni River to the Point and mangrove forests along the bay. The first plans were to formally layout Durban in 1835 and consisted of a grid-iron street pattern near Durban Bay. However, the development of the Northern areas was restricted due to the flat, low-laying, swampland and occasional flooding (Harborth, 2010). As the years passed, the city's development expanded due to land reclamation programs which drained the Western vleis and removed the mangrove forests along the bay by 1905. The late 1920s to early 1930s saw the drainage of the Eastern vleis, and development in the Sports precinct started towards the early 1960s (Harborth, 2010). Today, residential and mixed-use buildings surround the Western Vlei and are home to the Greyville race course, which is utilized as a stormwater attenuation structure. The Eastern Vlei consists of a flood plain with lush, open green spaces surrounding the uMgeni River; future construction in this area will need to respond effectively to flooding events and be designed with high durability (IPPU Consortium, 2016).

Figure 7 depicts the current stormwater networks, and it is evident that the terrain has changed since the 1800s to accommodate the city's expansion. Most of the inner city consists of hard surfaces, such as buildings and roads, increasing surface runoff that contributes to flash floods. The Northern region consists of attenuation into the uMgeni River. The central and South areas

attenuate into the harbour, and the beach fronts consist of attenuation points below the dunes to gradually released stormwater into the ocean (IPPU Consortium, 2016). The identification of these zones which contribute to the stormwater attenuation is vital for positioning the proposed building in the correct area to harvest and capture the runoff water.

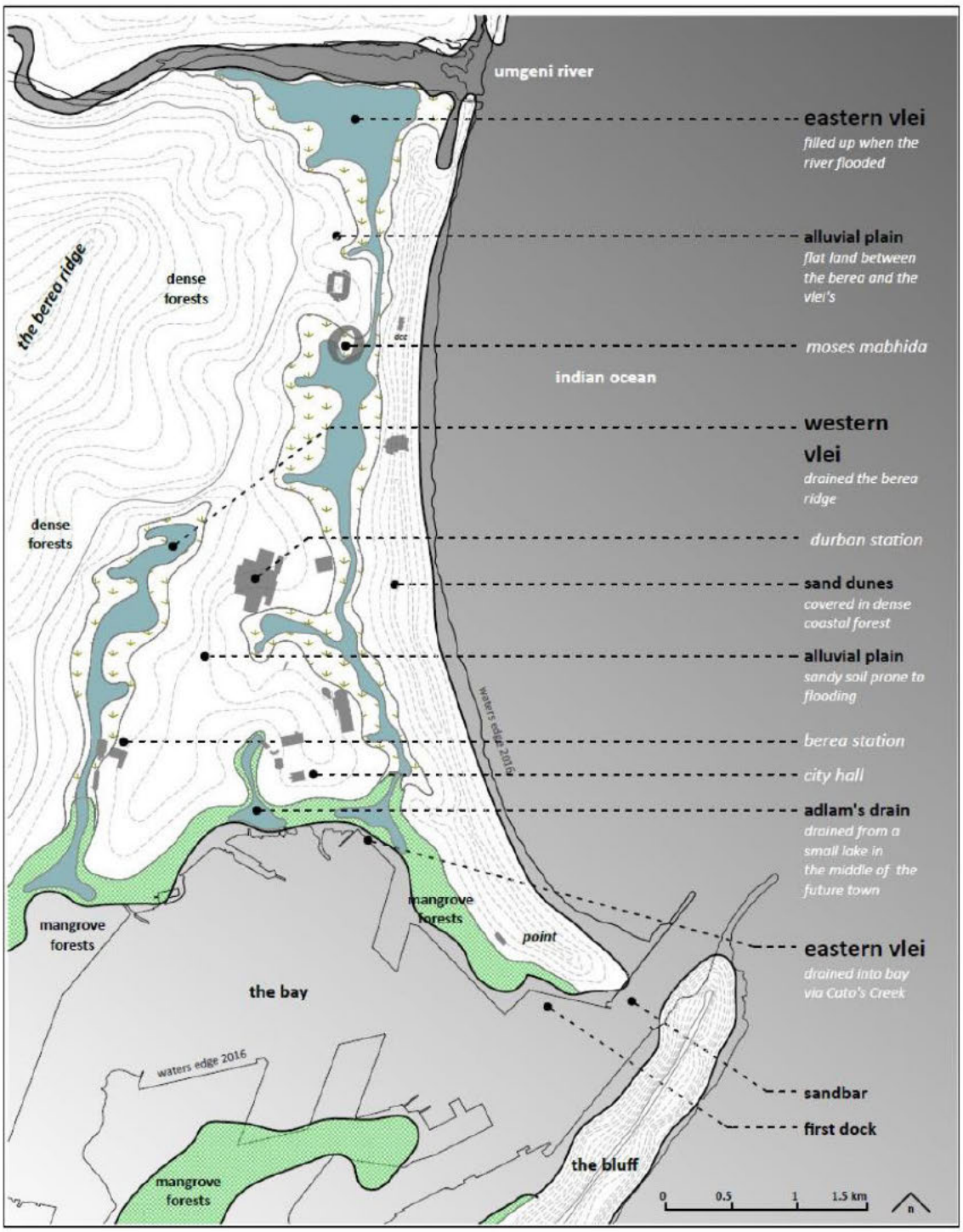



*Figure 6. eThekwini Inner City 1983 (IPPU Consortium, 2016)*

*Figure 7. Existing Stormwater Networks (IPPU Consortium, 2016)*

Legend: **Green** – Stormwater Channels; **Red** - Culverts

Although there are many challenges the city faces in ensuring water security, the plan is to promote and improve water conservation by implementing new technology and smart infrastructure whilst improving existing infrastructure. Therefore, creating co-existence between the new and existing infrastructure develops a holistic system in which, by 2040, 90 buildings in the inner city are expected to incorporate recycling and water conservation technology and systems (IPPU Consortium, 2016).

### 2.2.5 Conclusion

To conclude, water security is evident worldwide, with many authors signifying the issue surrounding the phenomena and the contributing factors. The factors were categorized into *Physical* and *Economic Water Scarcity.* The exploration of water insecurity in South Africa concluded with the country facing both types of water scarcity.

The analysis by Sarah Slabbert and Nadja Green (2020) on water education in South Africa brought about a concern regarding the lack of knowledge on waters importance and the need to educate local citizens regarding water conservation. Moreover, identifying the knowledge gap can assist going forward; however, further concerns regarding the lack of skilled engineers and educators expounded on the research problem.

The devasting recent climate changes in Durban have negatively impacted the city and its people.. The analysis of the history of the topography of Durban and the current stormwater networks was crucial in locating possible sites for the proposed building to collect and harvest from the existing outlets. The analysis of the section enhances the research problem and provides detailed observations on the conditions of water security. Furthermore, ensuring the need to address these problems and bridge the gap through an architectural response.

## 2.3 Water and Architecture

This section focused on the relationship between water, humans and architecture. Furthermore, an investigation of design principles to integrate water into the built environment, which positively impacts humans and the environment. Thereafter, an exploration of how the built form can contribute to water security through water conservation and control.

### 2.3.1 Connection to Water

Earth comprises 70% water; of that amount, 97% is salt water located in the ocean, and the remaining 2.5% is freshwater frozen in the ice caps (Baker, et al., 2016). The remaining 0.5% is accessible to humans. The accessible water is located in rivers, lakes, streams, rainfall and surface runoff. It is evident how precious water is for societal needs; therefore, it is essential for architecture to contribute to its sustainability. Figure 8 represents the hydrological cycle of water through the Earth's system, which is determined by solar radiation. The process is composed of two phases. The first phase occurs when water is converted from its liquid state to its gaseous state by transpiration and evaporation, rises into the atmosphere, cools, and then condenses before being released back to Earth as precipitation (Easton & Bock, 2015). The second phase involves groundwater and surface water flowing over and through the surface, moving towards the ocean due to gravitational forces.

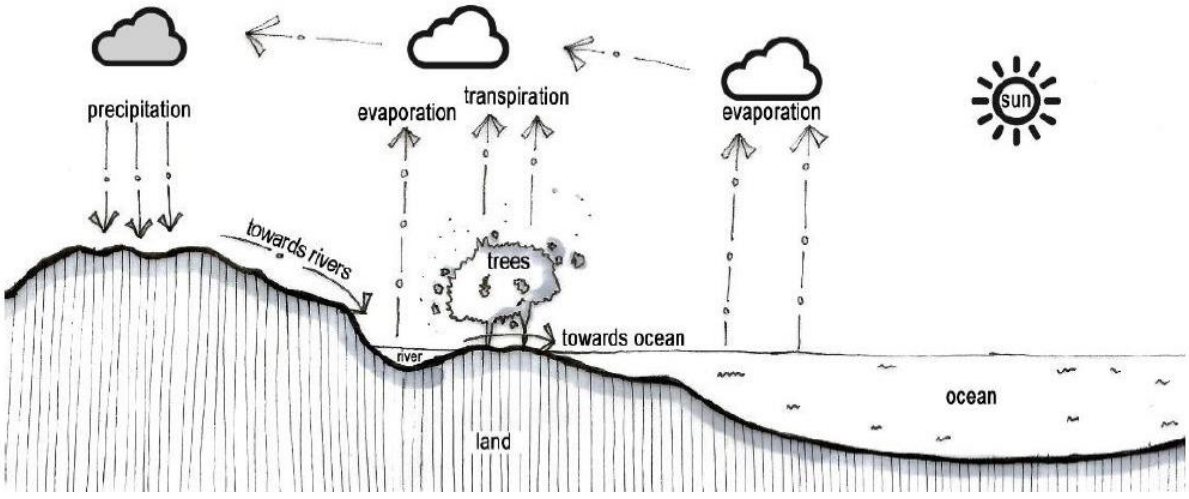



*Figure 8. The Hydrological Cycle (Pillay, 2018)*

Alexander et al. (1977) state that people have a natural desire for bodies of water and must be treated with great respect for preservation. They further affirm the increasing disconnect between our emotional needs to engage with the water through reservoirs, ponds, etc., as our primary contact is turning on taps that are often taken for granted. Additionally, they encourage connecting people with water collection where people can learn about their water supply, viewing and celebrating the water through small pools, gardens and along pedestrian paths (Alexander, et al., 1977). The implementation of water can play a role in architectural environments by evoking users' emotions and allowing them to (re)connect to nature. The built environment is perceived as a static structure in the context, whilst water is fluid and energetic; the contrast creates an opportunity for dynamic design interventions that can positively contribute to architecture and the users of the spaces (Kuhn, 2007). Kuhn (2007) stresses that Architecture and Water need to co-exist as modern designs tend to negate the integration of water. Rizky et al. (2021) further affirm that humans need to rethink the relationship with the natural environment stating that water is a fundamental part of life, providing food and sanitation, and the presence of water can create a sustainable future for the community. Thus, designers need to reconsider the possibilities that water presents as it is not merely a physical element but is symbolic and recognized for its social, cultural, economic, emotional and spiritual impact on users (Ženko & Menga, 2019). Therefore, the built environment possesses the potential to shape how people experience and perceive water, allowing it to be the mediator between the built form and the natural environment.

Juhani Pallasmaa (1996) states, "Architecture is the art of reconciliation between ourselves and the world, and this mediation takes place through the senses." The interaction with water creates a psychological response that stimulates the human sense as they experience a space responding to the theory of Phenomenology. The use of wind and light can evoke a peaceful and calm feeling, like the serene sound of the waves crashing on the shoreline or an invigorating and exciting feeling, like the roaring sound of a waterfall (Booth, 1990). In learning environments, incorporating water produces tranquillity, enhancing concentration and memory restoration within a space by activating the senses (Kellert & Calabrese, 2015) and is an environmental strategy to regulate temperatures through passive design. In its social and economic settings, such as Recreation and Tourism, water attracts people towards it, creating a sense of intrigue relating to the principle of Mystery in Biophilic Design (Browning, et al., 2014). Booth (1990), in his book *Basic Elements of Landscape Architecture,* states that people desire to feel and touch the water, which comes

almost intuitively to humans. He further explains the therapeutic effect water has on beings as water's rhythmic and sensory movement transforms an individual's state of mind into a more tranquil and passive mindset (Booth, 1990).

### 2.3.2 Water and The Built Environment

Cities in the early 1900s were compact and structured around the central business district, with amenities and employment within walking distract from different mixed-use buildings. The development of cities has changed since then, growing over large areas and forcing the reliance on vehicles to access various services and employment (Environmental Protection Agency, 2001). The city's rapid growth increased the number of buildings to cater for the population as people sought better jobs and living standards. According to the United Nations (2018), by 2050, the population worldwide is predicted to grow to 68% in urban areas, showing the required increase in built form. Although the built environment is crucial for the progression and development of a city, the adverse influence it presents on the natural environment and resources is a significant concern.

Petrovic (2021) asserts the two contributing factors that affect the hydrological process are climate and land use change, driven by human activities. Figure 9 expresses the factors of the built environment on environmental quality. The most significant impact concerning the research is the direct effects on habitats, ecosystem species and water quality. Many Authors stress that the expansion of urban forms removes the natural landscape resulting in the implementation of large impervious surfaces and artificial drainage networks, which increase surface runoff and alter the natural flow of drainage routes (McGrane, 2016; Environmental Protection Agency, 2001; Wilby, 2007). Carlos et al. (2020) express that the development of built form disrupts the relationship between water and urbanity, channelling water into pipes away from the built form instead of implementing it within urban environments.

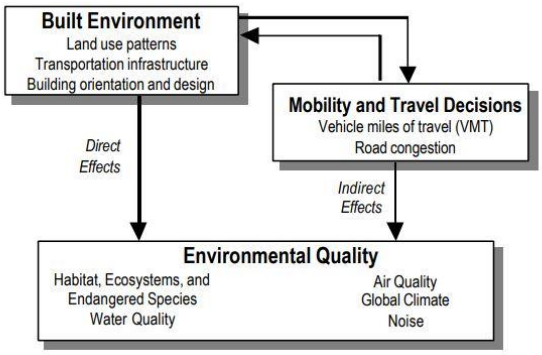



*Figure 9. Built Environments impact on Natural Environment (Environmental Protection Agency, 2001)*

The indirect effects, global climate, air quality and noise pollution, are as crucial as the direct effects, impacting one's mental health. Stephen Kellert (2005) describes the effects as a threat "not only to human physical and material security but also to nature's role as an essential medium for people's emotional, intellectual and moral development." (Kellert, 2005). The increased concentration of built form with heat-absorbing materials that retain solar energy and insufficient cooling from vegetation cover contributes to the development of heat islands in cities (McGrane, 2016). As a result, the area's atmosphere is affected, which impacts the intensity and consistency of precipitation, leading to flash floods, droughts and reduced comfort and productivity of people in their workplaces due to the excessive heat (Wilby, 2007).

The materiality of buildings and landscapes is critical to ensuring a balance between surface runoff and groundwater absorption. McGrane (2016) states that the type of material which faces the wind-driven building façade can either absorb or transfer the rain. He uses the example of a glass façade which contributes to the runoff due to the smooth surface, whilst a brick façade has porous properties. He explains the types of materials utilized on the ground for surface runoff, stating that concrete is considerably high, ranging between 69% and 93%, depending on the inclination of the surface. In contrast, brickwork only allows for 9% (McGrane, 2016). The diagram on the left of figure 10 depicts the current state of water runoff due to extensive hardened surfaces and piped stormwater that leads to an artificial network creating a disconnect between nature and built form. The diagram on the right demonstrates a method to respect the natural environment, implementing porous surfaces to reduce runoff whilst maintaining the water table through a swale and french drainage, as well as a detention pond to store stormwater runoff, releasing it slowly. The diagram on the right shows a harmonious connection between built form, water and the natural environment.

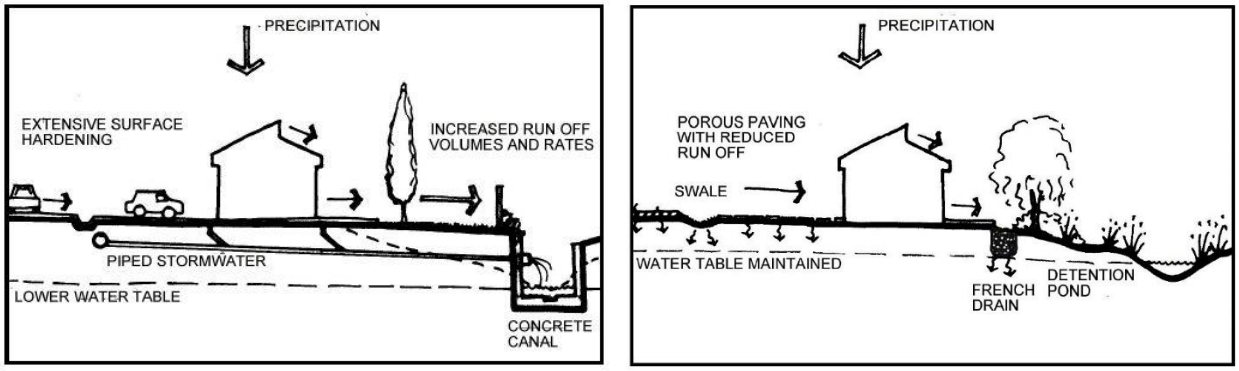



*Figure 10. Irresponsible and Responsible approach to stormwater management (SAWE, 2002)*

Professor Brook Muller, Dean at the University of Oregon, has written broadly on the relationship between built form and the water system. He has established a framework designed to create a water-centric approach to architecture to respond to urban societies' hydrological challenges. He envisions a decentralized water system through the built form that integrates harvesting, recycling, storage, treatment, and recharge of water bodies (Muller, 2017). The approach visualizes architecture as a living system that uses water as the medium to create a meaningful response to environmental and humanistic needs.

Muller states that a hydro-logical approach to architectural design can sustainably improve the water structure by enhancing livability with visible water (Muller, 2018). He further articulates that through passive design, buildings are currently designed as "thermal batteries" to absorb heat during the day and release it at night when temperatures are lower to achieve optimal human comfort. He proposes that the built environment be designed as "hydro-logical batteries", as seen in figure 12, to capture stormwater, collect rainwater, use gravity to filter and treat it then distribute it to the community and adjacent wetlands (Muller, 2018). Tracing water's journey through the landscape is crucial in developing a relationship between the built form and the landscape to ensure the collection and harvesting of water such that the recycling loop is continuous. Muller asserts that water storage tanks should become part of the architectural identity, as seen in figure 11. He suggests that the tanks in the central atrium, clad with reflective material, reflect light into the darker spaces and spaces below through the skylight (Muller, 2017). Combining the aspects forms a holistic approach to water security from a larger contextual perspective without relying on municipal connections. Water becomes expressive and integral to the learning environment through visual and physical connections of the harvesting and recycling process.

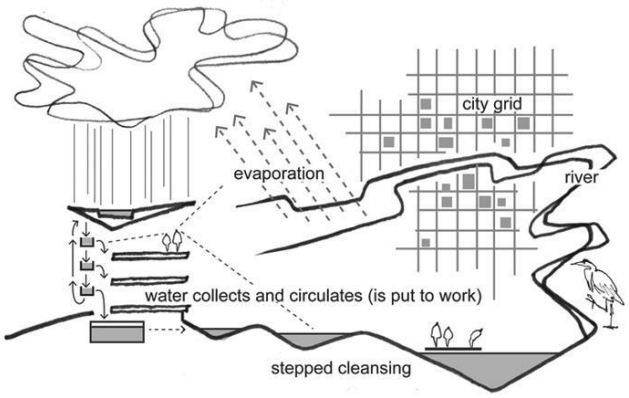



*Figure 12. Architecture as a Living System (Muller, 2017)*

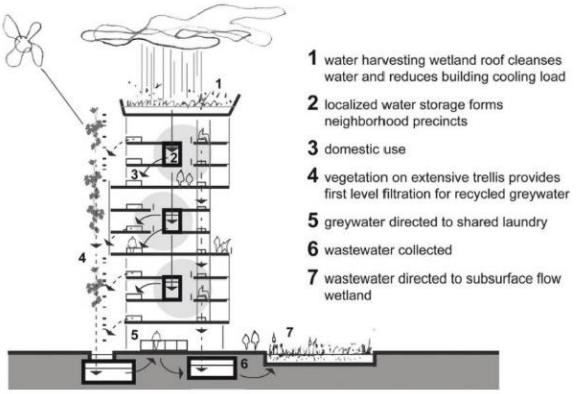



*Figure 11. Water Centric Approach to Urban Architecture (Muller, 2018)*

### 2.3.3 Water Conservation and Control

The following section will investigate ancient cities' to learn about the conservation strategies used to mitigate water insecurity and explore modern technological advances to educate individuals on water conservation and control through the built environment, contributing to society.

The conservation and control of water have been used throughout history, dating back to pre-historic times in China, Egypt and Pakistan, where archaeologists found evidence of stormwater and wastewater collection systems (Angelakis, et al., 2018). Ancient Greece was the first to use wastewater for agricultural purposes and channelled rainwater to storage tanks. The Roman Period implemented techniques such as aqueducts to transport water to various parts of the cities as water harvesting became a part of art and architecture (Aslan & Selçuk, 2018). The middle ages in India saw the rise in expanding the built form to capture, collect and store water through numerous irrigation facilities due to the severe drought conditions faced by the country (Aslan & Selçuk, 2018).

Communities were encouraged to construct water harvesting structures which brought the people together, forming strong cultural and social bonds whilst enhancing the importance of water (Gupta & Agrawal, 2014). Identifying these ancient methods shows that water conservation and control was crucial for communities and villages to meet water demands and protect the cities as they developed. Modern water harvesting approaches in the built environment should integrate these ancient methods to form holistic strategies to ensure sustainable water security.

#### 2.3.3.1 Learning from the Past

Ancient India regularly faced flood and drought conditions, forcing the Indian government to develop water harvesting systems to conserve water and reflect the geography and culture of the country (More, 2020). Communities implemented several traditional water harvesting strategies; however, the research identifies the integral ones through built form. One of the most popular water conservation and control strategies was the Stepwells. This subterranean water-related monument exemplified the beauty and aesthetic value of western Indian Architecture (Piplani & Kumar, 2019). In Indian mythology, water is the essence for purifying the body and soul and the bridge between Heaven and Earth (Chandna, 2019).

The step wells adopt various shapes and sizes, figure 13, but comprise descending steps and landings that reach a pool of water at the lowest position. The original function was to serve as reservoirs and storage tanks and allowed the series of steps to act as rainwater channels that guided the water to the bottom of the well serving as a catchment area (Aslan & Selçuk, 2018). Moreover, water was directed to the well from exterior water bodies, or water was acquired from underground aquifers due to the depth of the stepped well, which also creates a cool environment. A variety of materials were used to construct the stepped wells depending on the location, including stones, bricks, lime and mud (Selvaraj, et al., 2022). The monument further serves the community as a social space for religious and tourism gatherings and interactions, which expresses the multi-functionality of the design (Chandna, 2019). Local artisans designed ornamentations of sculptures, niches and friezes, which create a sense of place and a historical and cultural atmosphere whilst functioning as a water source for the community (Singh & Mishra, 2019).

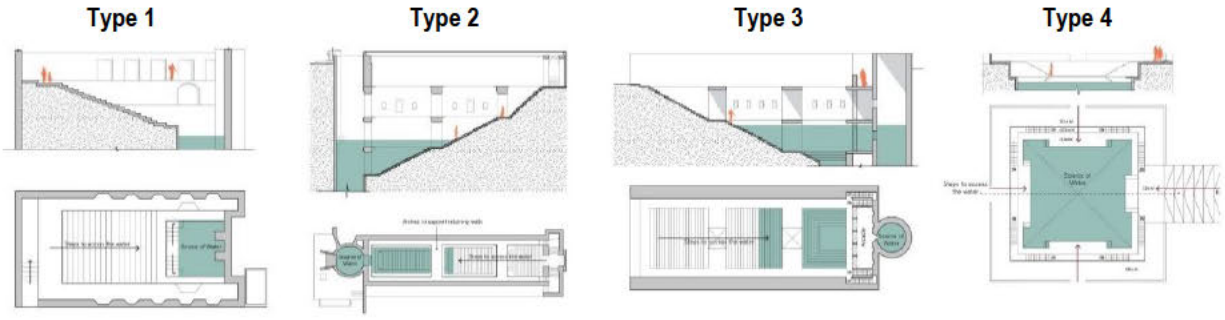



*Figure 13. Stepwell Typologies (Chandna, 2019)*

The Indus Valley Civilisation was renowned for its advanced hydrological knowledge and urban planning through its various water management systems that were revolutionary for ancient times (Singh, et al., 2020). The cities were divided into the raised upper town called the Citadel, consisting of the public buildings, and the lower residential town, which was built on plinths to prevent flooding. Large tapered mudbrick embankments and solid fire brick walls surrounded each city to monitor trading and defence strategy and divert water to control flooding (Dales, 1965; Naveed, 2014).

The civilisation developed along the banks of the Indus river, engaging with the water from the river and surrounding tributaries, building several stone dams that collected the water and diverted it to the inner city through channels. Moreover, smaller check dams and bunds were used to capture surface water, decelerate it and redirect it to reservoirs in the city (Khan, et al., 2020). The dams further provided water for irrigation, transferring to designated agricultural fields through canals (Singh, et al., 2020). Tightly packed, wedge-shaped bricks were used to build wells in the cities, making fresh drinking water accessible to the public and were functioned through a hand-operated lever system (Khan, et al., 2020). One of the prestigious features of the Citadel was The Great Bath, situated at the centre of the courtyard. According to archaeologists, the structure served as a public water tank and was used to purify the individual for religious rituals (Ananth, 2018). The innovative construction and joinery showcased the skills of the masons, as inner walls were laid in stretcher bond formation, closely compacted and filled with gypsum plaster. A thin layer of bitumen was applied to the base, side walls and outer walls to waterproof the structure (Jansen, 2013). The Great Bath form part of water conservation and control by capturing and diverting water to the base of the structure, where the materiality ensures no water percolation.

*Figure 15. Wedge Shaped Bricks used for Wells (Forman, 1968)*

*Figure 14. The Great Bath (Marshall, 1931)*

The ancient Romans expounded on a water conservation technique adapted from ancient Greece and expressed their architectural aesthetic and advanced engineering abilities. The Roman aqueducts channelled water from fresh springs on the city's outskirts to the urban centres and distributed it for drinking, baths and ornamental fountains through a series of terracotta pipes from the *castellum* (water distribution system) (Deming, 2020). The aqueducts provided abundant

water, allowing the city of Rome to develop and flourish whilst enhancing the Romans' deep affiliations with water through their decorative fountains, baths and encouraging civic projects.

The aqueduct functioned through gravity, where water flow was consistent. If the gradient were too steep, the speed of the water would damage the channel walls and erode the mortar waterproofing material. If too gentle, the water would stagnate, increasing the risk of pathogens and bacteria affecting the water quality. The systems channelled the water from catchment areas through underground semi-circular vaults inspected through artificial vertical shafts (Angelakis, et al., 2021). The shafts further provided aeration of the water, increasing the water quality. Sedimentation tanks allowed for water filtration, slowing it down to discard sand and debris. Challenges occurred when the water needed to move across valleys, and the design of the aqueduct bridges was developed. The bridges expressed the architectural style of the Romans with a series of arches initially built from cut stone laid with mortar, whilst modern versions were constructed with concrete cores with face brick externally laid with cement (Aicher, 1995). The aqueducts revolutionised the city's water supply as well as improved the city's physical fabric. As mentioned, the Romans naturally desired to engage with the water, and monumental public baths were used to urbanise open areas using water from the aqueducts (Aicher, 1995).

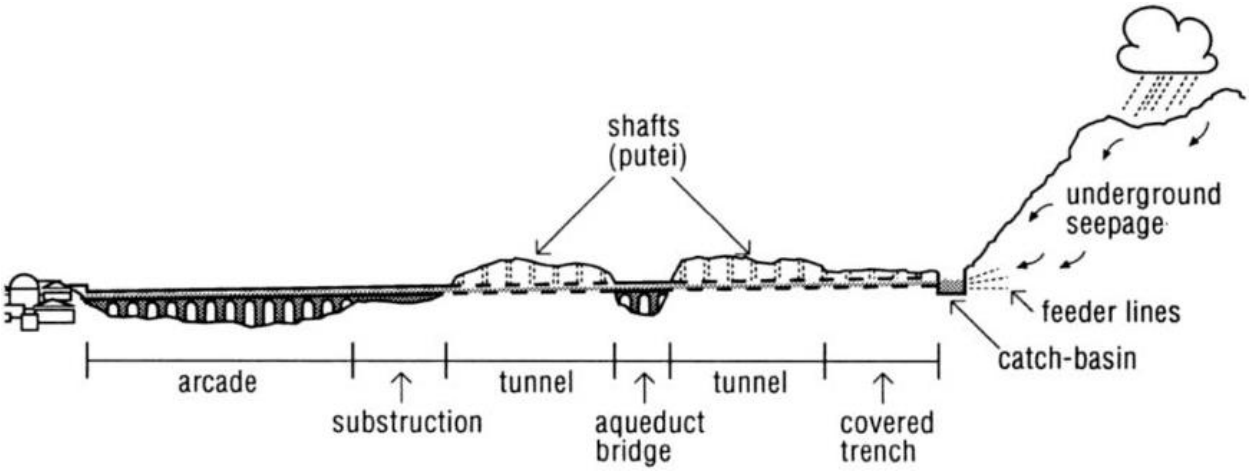
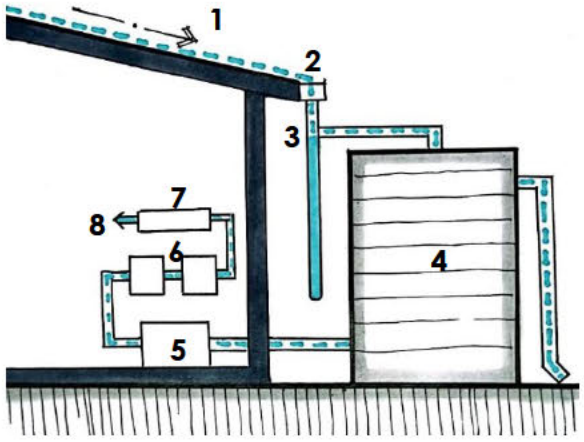



*Figure 16. Aqueduct System (Aicher, 1995)*

### 2.3.3.2 Rainwater Harvesting

Rainwater harvesting systems have developed in modern society and are a viable option to ensure water security in cities. The systems form part of a decentralized approach to water conservation and reduce the quantity of surface runoff by capturing, diverting and storing precipitation from on-site rooftops, positively impacting the natural environment and reducing the demand on centralized infrastructure (Medina, 2016; de Sa Silva, et al., 2021). Rainwater harvesting systems produce potable and non-potable water, provided it receives the correct treatment and purification.

The rainwater journey starts at the rooftops, as seen in figure 14, where gutters and downpipes divert it to storage tanks. Studies show that the most suitable roofing material to produce potable water is aluminium sheeting and concrete tiles due to the low number of bacterial contaminants collected through the process (Olaoye & Olaniyan, 2012; Mendez, et al., 2011). The pre-filter phase of the filtration system starts with removing leaves, pollutants, sediments, etc. Aluminium gutter guards prevent larger leaves and other debris from entering the gutter. The first flush device sends the contaminated water into a chamber consisting of a floating ball; when it is full, the floating ball rises and seals the top of the chamber, allowing cleaner water flows into the storage tank (Quadros, 2010). The storage tank consists of an overflow pipe and a pipe that leads to a pump within the building. The water moves to the treatment section and is purified into potable water using the 3-prong method. The 5-micron cartridge sediment filter removes sediment metals, and the 3-micron activated carbon filter absorbs organic contaminants (Capehart, et al., 2021). Finally, ultraviolet light kills bacteria and viruses, allowing the water to flow to faucets as clean, drinkable water.




1 – Collection Surface: Aluminium Sheeting / Concrete Tiles.

2 – Gutter with Aluminium Guard and Downpipe.

3 – First-Flush device.

4 – Storage Tank and overflow pipe.

5 – Pump.

6 - 5-micron cartridge sediment filter & 3-micron activated carbon filter.

7 – Ultra violet disinfection.

8 – Clean water to faucets.

*Figure 17. Rainwater to Potable Water Process adapted from Carpehart et al. (2021)(Author,2022)*

In the 21st century, technological advances have allowed designers to push the boundaries of water harvesting. Architect and Bio-designer Shneel Malik has created a water purification technique that forms a symbiotic relationship with nature.

She stresses the impact of water pollution on climate change and the natural environment, which sparked an interest in alleviating the phenomena. She collaborated with the Bio-Integrated Design Lab members to conceptualize a modular wall cladding system composed of made-made ceramic tiles inspired by a leaf structure with vein-like channels to mimic nature's ability to dispense water evenly (Simpson, 2021). The vein-like channels filled with a hydrogel contain a combination of microalgae and seaweed that breaks down pollutants to purify the water as it passes over the tile (Aldeghi, 2019). The microalgae are grown by absorbing carbon dioxide and sunlight, producing photosynthesis and allowing them to capture heavy metals found in water (TEDx Talks, 2020). Seaweed has natural filtration properties; combining the two products leads to cleaning the polluted water through the process of bioremediation (Hahn, 2019).

From the lenses of Biophilic Design, the tiles form a strong visual connection to nature through their shape and texture, allowing people to feel in touch with nature. The tiles are produced on-site, engaging in community development, social interaction and upskilling local artisans. The strategy ties in with Experiential Learning Theory by people interacting with a solution to solve a real-world water security problem and expanding their knowledge through lived experiences.

*Figure 19. Indus ceramic tile and microalgae (Hahn, 2019)*

*Figure 18. Wall panel system (Hahn, 2019)*

Green Roofs are a rainwater harvesting system that provides a sustainable strategy with multiple benefits, including decelerating water movement, reducing urban heat islands and increasing wildlife habitats, that respond to the aspects of the research problem (Shafique, et al., 2018). Typical green roof systems consist of a vegetation layer with a growing medium, a filter fabric, a drainage layer and a root-resistant membrane (Raimondi & Becciu, 2020). There are two types of green roof systems that respond to small or large-scale planting, namely: Extensive and Intensive systems. Extensive systems are for small planting, consisting of a lightweight, thin substrate layer that covers a large area, suited for rooftops. The Intensive system is suited for smaller spaces and requires a thick substrate layer for deeper root percolation, promoting the growth of trees and larger plants (Poptani & Bandyopadhyay, 2014).

Greensquared, a South African-based company, has designed a modular roof planting system, advancing the technology of green roofs. The R3 system is a 450x450mm pre-planting structure set within a recycled polypropylene planter box consisting of 4 water reservoirs that capture rainwater (greensquared, 2022). A pedestal is used to lift the planter via a clip-in system, allowing ventilation and placing the 15mm irrigation pipe. If root hairs grow below the planter through the drainage hole, the air will dry up the root, mitigating the possibility of roof damage. The extensive system ensures the possibility of creating a modern rooftop garden as it can withstand an individual weighing 120kg (greensquared, 2022). The technology provides an innovative method to ensure water conservation and control whilst responding to environmental concerns through the green roof structure.

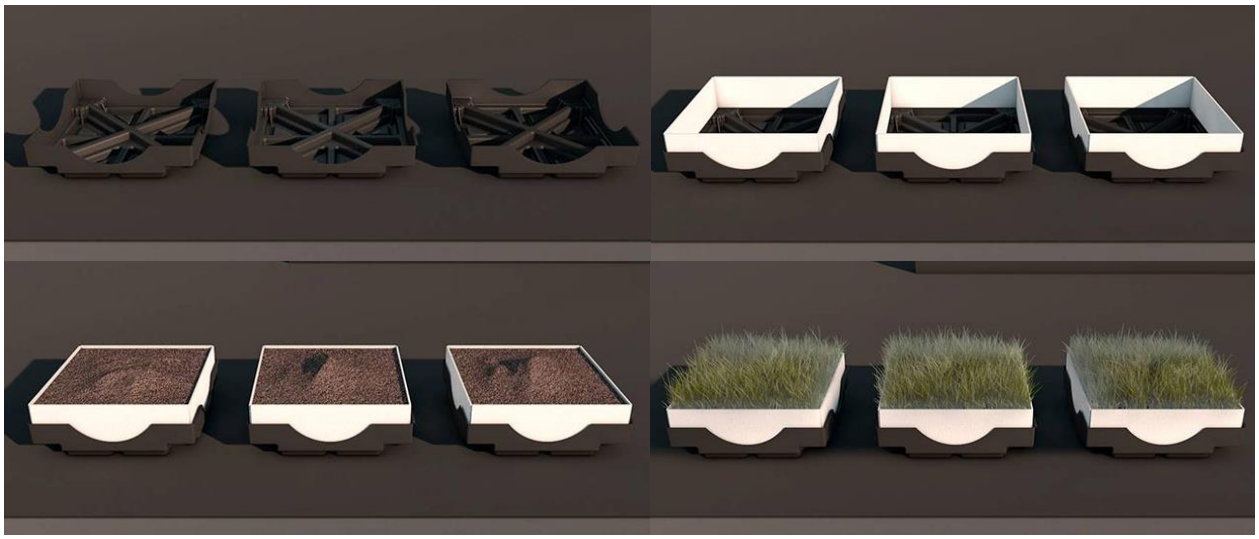


*Figure 20. Greensquared R3 System (greensquared, 2022)*

### 2.3.3.2 Stormwater/Surface Runoff Harvesting

Stormwater harvesting provides a design strategy to collect, store and treat surface runoff in urban landscapes. The harvesting method responds to Environmental Sustainability, preserving the natural environment by reducing flood risks and pollutants and improving water quality in urban settings (Zhang, et al., 2019). In water-stressed cities, recycling stormwater is a practical option for providing potable or non-potable water for irrigation or use in buildings through filtration and purification. It also improves the local climate when paired with rainwater collection by lessening the impact of the urban heat island due to higher moisture levels and evapotranspiration (Campisano, et al., 2017).

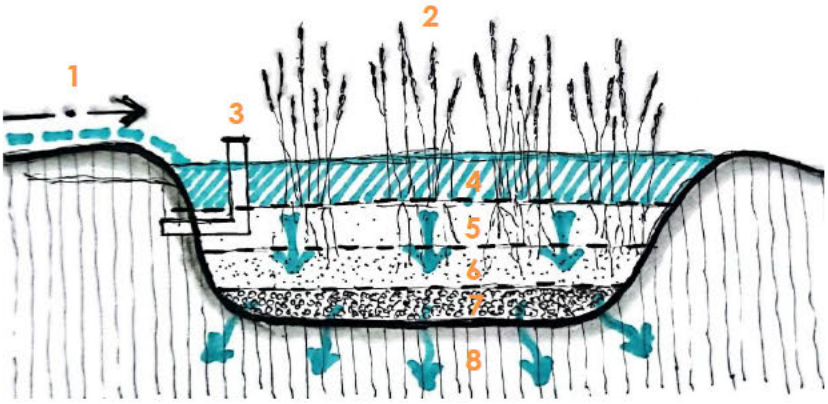
Yu Kongjian, a prominent thinker and landscape architect, developed the **Sponge City** concept and implemented the idea in Chinese cities to combat seasonal flooding from monsoon rains (Wong, 2021). The sustainable design concept seeks to absorb, retain rainwater and decelerate surface runoff water using Green Infrastructure technologies and porous surfaces. Kongjian refers to ancient Chinese approaches over 2000 years ago that managed stormwater and flooding using ponds as the source of his concept (Green, 2021). The nature-based system creates a harmonious relationship between man, nature and the built environment, enhancing the city's greenery and creating habitats for wildlife. The connection with the natural environment activates the haptic and sensual experience through the materials, textures, scent and sight of nature, alluding to the meaningful experiences stated by Juhani Pallasmaa (1994).

*Figure 22. Harbin Qunli Stormwater Wetland Park (Turenscape, 2011)*

*Figure 21. Haikou Meishe River Greenway and Fengxiang Park (Turenscape, 2019)*

A series of Green Infrastructure technology form an inclusive design to holistically achieve the Sponge City concept. **Biofiltration systems** are catchment areas designed to improve water quality by incorporating a topsoil layer coupled with vegetation to remove pollutants through a mechanical and chemical process. Thereafter a porous soil-based purification medium filters the stormwater to the transition layer that attenuates the water's flow and volume and moves to the gravel layer to improve drainage; the water then percolates into the ground, recharging groundwater and aquifers (Lim, et al., 2014).

Similarly, **Bioretention systems** provide the same function of collecting and decelerating stormwater; however, these systems store and retain the water for recycling purposes. The system consists of **retention ponds**, **rain gardens** and **planter boxes. Bioswales** are channels or paths containing vegetation that may either absorb or divert the water to ponds, depending on the water flow (Clark, 2008). The design of the systems mimics the natural hydrological cycle and promotes Environmental Sustainability.




1 – Stormwater Inlet.

2 – Vegetation Cover.

3 – Overflow.

4 – Pond Zone.

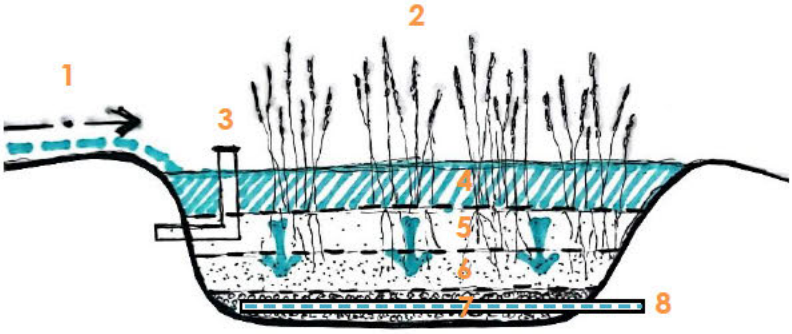
5 – Filter Medium (San-based).

6 – Transition Layer (Course Sand).

7 – Drainage Layer (Gravel).

8 – Infiltration to recharge Groundwater.

*Figure 23. Biofiltration System adapted from Payne et al. (2015) (Author,2022)*




1 – Stormwater Inlet.

2 – Vegetation Cover.

3 – Overflow.

4 – Pond Zone.

5 – Filter Medium (San-based).

6 – Transition Layer (Course Sand).

7 – Drainage Layer (Gravel).

8 – Collection Pipe with impermeable liner below.

*Figure 24. Bioretention System adapted from Payne et al. (2015) (Author,2022)*

### 2.3.3.3 Greywater and Blackwater Recycling

Greywater and Blackwater recycling form part of a decentralised approach toward water conservation in modern cities by providing treated non-potable water uses to alleviate the use of freshwater sources. Greywater is all wastewater from buildings that excludes toilet water and can be harvested to improve food security and reduce pollutants from entering rivers, lakes and estuaries (Albalawneh & Chang, 2015). Blackwater is contaminated water from water closets and urinals. Recycling both types of water incorporates biologically active soils and plants that filter the organic nutrients and bacteria, creating natural water treatment and forming a lush, healthy landscape (Brain, et al., 2015).

The first natural recycling method is **Constructed Wetlands**, consisting of various wetland plants that provide on-site water treatment. Wastewater fills into a basin filled with gravel or mulch and planted with wetland plant species. The structure's base has a waterproof lining to prevent water absorption into the ground, and the water flows below the gravel or mulch to avoid contact with humans or animals. The water is forced up and down through the system using baffles (rigid obstructions), allowing maximum contact with the plant roots to filter and cleanse the water (Millison, 2021). At the end of the system, an outlet pipe directs the cleaner water for irrigation use, flushing of toilets and sprinklers etc.

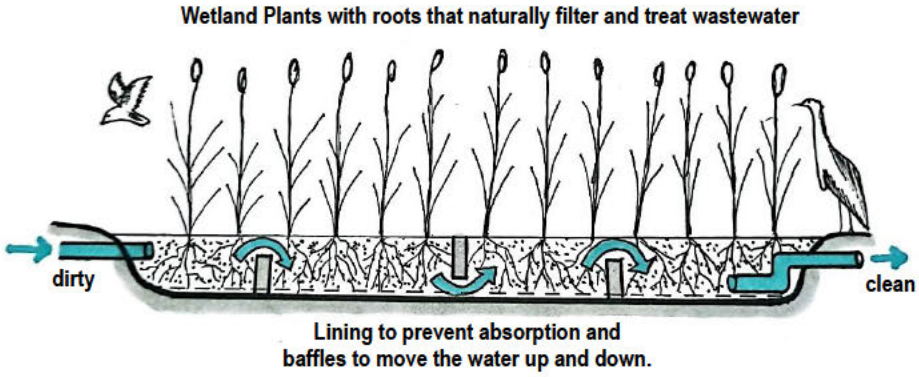



*Figure 25. Constructed Wetlands adapted from Millison (2021) (Author, 2022)*

Similarly, the **Living Machine concept** uses living organisms and plants to break down and remove substances in wastewater as part of a nature-based bioremediation system (Hung, et al., 2014). The system consists of a series of tanks or ponds, starting with a septic tank for blackwater

to remove the solids. The water then travels to an oxygen-free anaerobic tank which further breaks down the sludge. From there, a drastic environmental change occurs as the water moves into a series of oxygen tanks filled with aquatic plants and animals (Millison, 2021). The water flows into the bottom of the tank and out through the top, creating a biologically active system that breaks down the waste and absorbs the water's nutrients. Both systems positively impact the natural environment and complement the landscape's aesthetics.

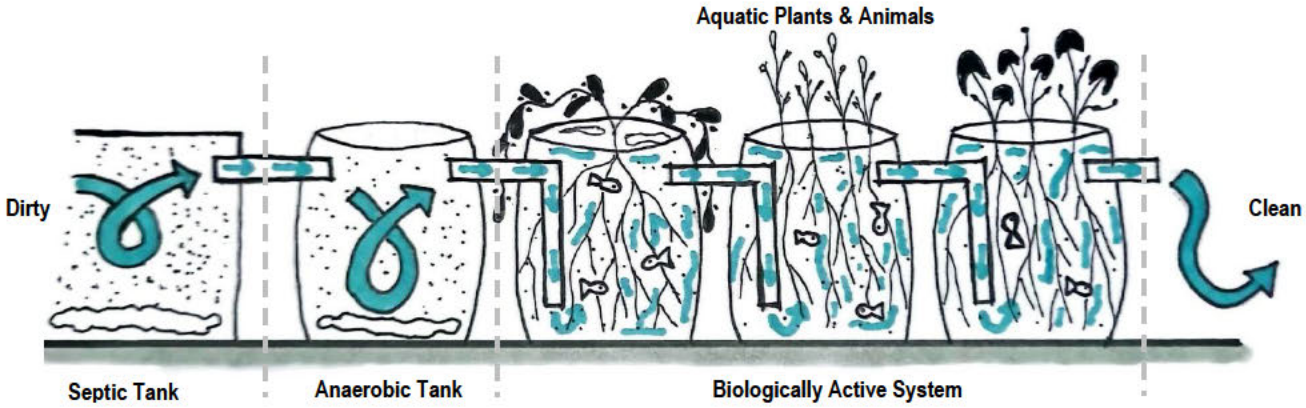



*Figure 26. Living Machine Concept adapted from Millison (2021) (Author, 2022)*

### 2.3.3.4 Atmospheric Water Harvesting

The traditional concept of atmospheric water harvesting is achieved through fog collection and dew collection. The fog collection system comprises an exposed mesh structure that captures water droplets and is perpendicular to the prevailing winds. The droplets are channelled to storage tanks through gravity. According to Olivier et al. (2015), international fog harvesting research was conducted in South Africa in 1904 and 1907 on Table Mountain in Cape Town. The best-suited mesh is a Raschel weave high-density polyethylene mesh used to shelter crops in arid areas, providing 35% shading properties (Jarimi, et al., 2020; Hadba, et al., 2020).

Modern advances in fog collection adopt a Biomimicry approach, mimicking nature to develop solutions to water insecurity. Namibia Hydrology Center consists of a nylon structure façade facing the ocean and captures the wind-driven fog. The concept of the nylon surface was inspired by the shell of the Namibia beetle, which resides in desert conditions and captures moisture by tilting its body toward the wind (Kaya, et al., 2018). The bumpy structure collects the water and,

through gravity, falls to the mouth of the bug. Similarly, the water moves from the irregular nylon mesh to underground storage tanks.

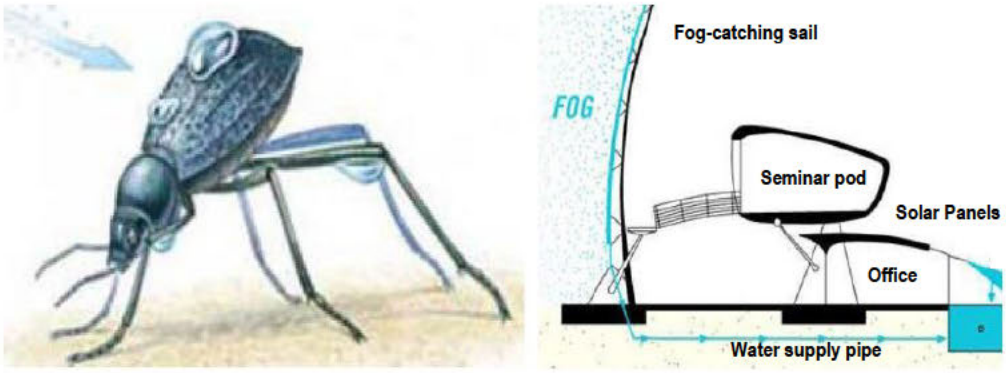



*Figure 27. Namibia Hydrology Centre (Aslan & Selçuk, 2018)*

SOURCE has developed an alternate water harvesting technique that combines water security and solar energy to form the Hydropanel. The innovative hydropanel uses the sun's power to produce clean, pollutant-free drinking water from the air (SOURCE, 2022).

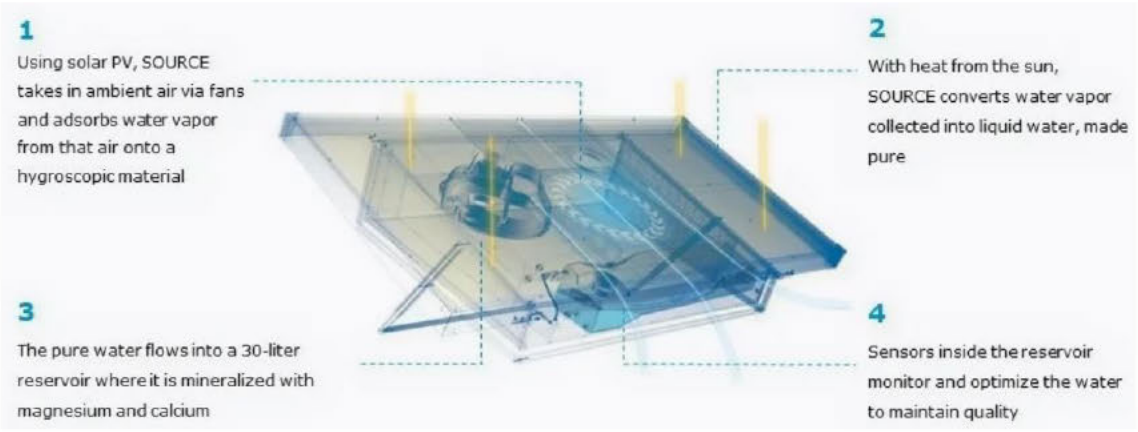



*Figure 28. SOURCE Hydropanel Process (Poverty Pollution Persecution, 2020)*

The size of one Hyrdopanel is 1.2 x 2.4m and produces 5 litres of water per day with a 15-year life span (SOURCE, 2022). The built-in air filter prevents contaminated particles and debris from entering the panel, and the hygroscopic material only attracts water molecules creating pure water from the air. The integrated magnesium and calcium cartridges mineralise the water, producing drinkable water. The on-site water harvesting establishes a sense of place by using the site's environmental conditions to make water and can serve as an educational tool for visitors on the advances in technology on water security.

### 2.3.4 Design Strategies

The literature presents design strategies, as seen in figure 29 below, to implement within the built environment (re)connecting humans to water using strategies that foster informal interactions.

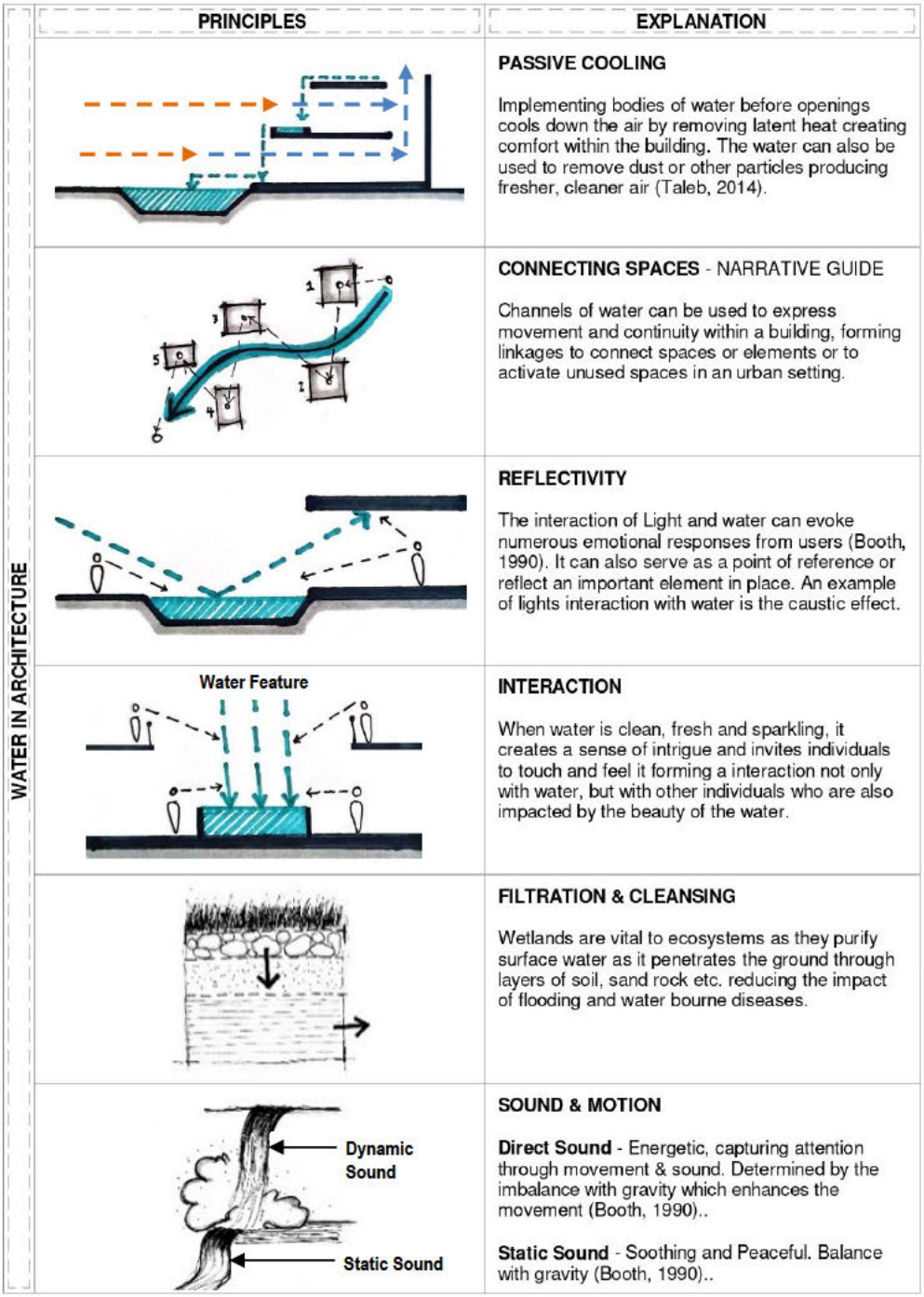



*Figure 29. Water in Architecture adapted from Moller (2015) (Author, 2022)*

### 2.3.5 Conclusion

To conclude, the section expresses the importance of water to humans through sensory encounters with the element. However, through the research, it has been evident that the built form negates the implementation of water in indoor environments, channelling it away from the building. Moreover, the built environment's impact, directly and indirectly, negatively impacts the natural environment and society. These problems lead to the research exploring Professor Brook Muller's writings on a water-centric approach to modern architecture, deriving a (re)connection to water through visual and physical encounters. These encounters become an educational source for visitors and showcase the water security process. The water security process was identified through the built and natural environment via four different harvesting and recycling strategies to implement into the design process and design principles in response to the research problem.

## 2.4 Nature and Learning Environments

This section explores and determines the types of spaces to promote effective learning environments. The human-nature relationship through the built and natural environment will be investigated to understand how the inclusion of nature impacts ones learning ability. The work of prominent author and architect Herman Hertzberger in his book *Space and Learning* will examine ways to redevelop the ideology of traditional educational spaces through the articulation of spaces (Hertzberger, 2008).

### 2.4.1 Human-Nature Relationship

The natural environment has influenced the evolution of humankind for thousands of years. Humans are living structures that formed a deep connection with nature through the years, impacting the physical, mental and behavioural processes we experience daily, known as our circadian rhythm (Meira, 2022). Nature-led environments, both in built and unbuilt forms, complement one another and become spaces for teaching and learning. Biophilic Design is the mediator that links Architecture and Nature. Prominent author Stephen Kellert (1997) asserts that humans have a deep affiliation with nature and, when in contact physically, emotionally and intellectually, benefit their lives. He states that the current built environment deprives sensory experience due to inadequate contact with nature; however, the principles of Biophilic Design

establish a concept that creates quality indoor environments and satisfactory experiences of nature for the users (Kellert & Calabrese, 2015). *Nature-Deficit Disorder*, devised by Richard Louv (2010), stresses that modern society and technology isolate humans from experiencing nature due to more time spent indoors. He expounds that the term expresses the growing disconnect between humans and nature, negatively impacting their health and well-being (Louv, 2010). The inward approach to education spaces negates the inclusion of nature indoors and contact with the outdoors, with reduced school excursions and outdoor learning experiences. Moreover, the poor design of urban environments, lack of open spaces and parents' fear of threats from strangers enhances the disconnect with nature leading children to find enjoyment in technology as opposed to the natural environment (Louv, 2010). In support of the statement above, Kellert (2005) stresses that the depletion of the natural landscape discourages humans from interacting with nature and suggests that the built environment recreates the experience of nature through the design process (Kellert, 2005). The analysis above emphasises the importance of nature, motivating the incorporation of nature-based design as part of the learning environment.

The vertical school design encapsulates a  multi-level building with outdoor mediation spaces such as elevated terraces, courtyards and green rooftop spaces, which creates transparency between the boundaries of the classroom and the outdoor environment, allowing students to engage with nature at different levels of the building (Duffy, 2019). These semi-open mediation spaces and informal in-between spaces facilitate social interactions by chance encounters and offer peer-to-peer learning opportunities (Salari, et al., 2020).

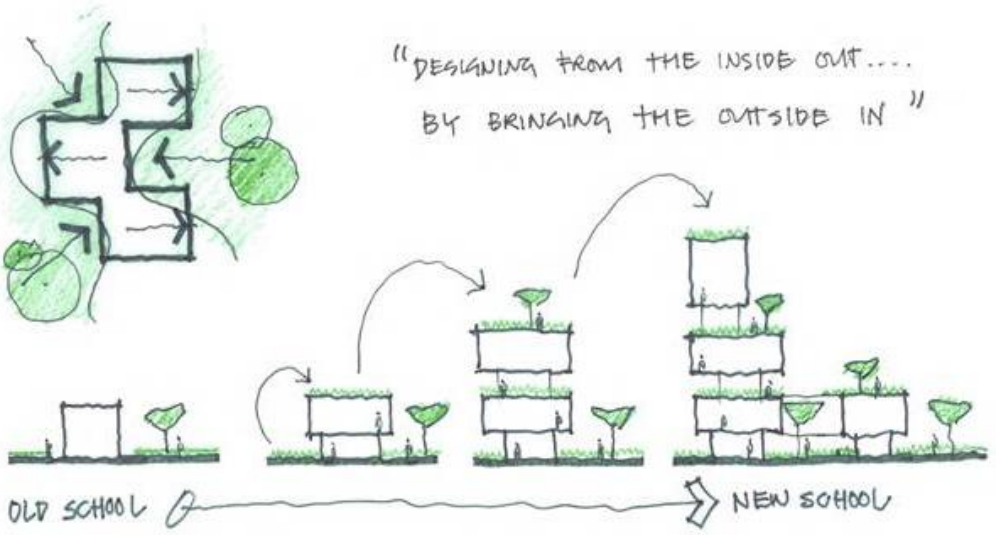



*Figure 30. The Vertical School (Duffy, 2019)*

The strategy is best suited in dense inner-city urban areas to meet educational demands due to minimized land coverage to accommodate the horizontal formation of traditional schools. The modern development towards a livable city forms strong community bonds, and the implementation of the vertical school design within these precincts offers different learning opportunities for diverse cultures, enhancing the community's social fabric and cohesion (Reid, 2018). The design can implement shared spaces that the public could use or occupy after hours as part of community development, further strengthening the social ties of the surrounding neighbourhood (Aminpour, 2020; Swinburn, 2017).

The integration of nature within learning spaces of education environments increases students' ability to focus, expands their creativity, and improves their cognitive skills. Incorporating nature into the learning environment through materiality, textures, pattern, and colours positively impact a user, creating comfort within the space (Heath, et al., 2018). Moreover, external learning spaces offer a different source of knowledge related to Experiential Learning Theory and Place-Based Education. John Dewey (1938) affirms that education systems should be arranged around real-life experiences to give the information context; this allows students to develop skills and knowledge needed to sustain the local community. It will enable students to connect strongly with the environment and create awareness and preservation of their surroundings. The outdoors stimulates the senses, creating adventure and exploration for the students and allowing them to inquire and investigate particular problems such as water insecurity. In support of this statement, Charkas (2020) states that when learners' curiosity is heightened, it encourages them to seek answers and explore solutions. Biophilic Design and Experiential Learning Theory are intertwined as the former introduces direct, indirect and symbolic connections to nature within the built form that sparks learners' interest and curiosity to actively engage with nature, leading to the latter's ideology (Chrakas, 2020).

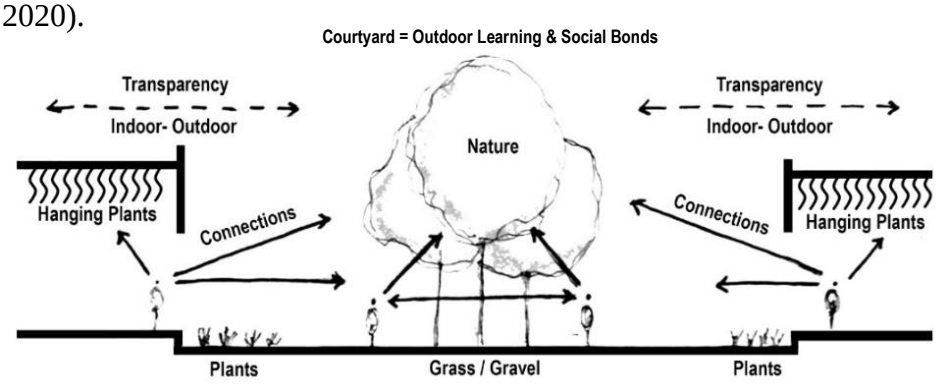



*Figure 31. Nature in Learning Environments (Author, 2022)*

### 2.4.2 The Articulation of Learning Spaces

A positive classroom environment allows students to explore and engage with challenges, develop social bonds and partake in educational activities as part of their learning process (García-Bullé, 2018). Herman Hertzberger (2008) states the learning environment should go beyond the borders of the classroom, where learning is visible throughout the building, enticing and encouraging students to partake in the different lessons and activities. Adedokun et al. (2017) and Osborne (2016) affirm that a learner-centric approach allows students to learn independently or in groups in flexible, open spaces with teachers supporting the learning process, achieving further exploration and improving learning outcomes.

Traditional learning environments are articulated by a series of classrooms accessed through a service or doubled-loaded corridor that teachers supervise as the students move from one classroom to the next. Nair & Fielding (2005) relate conventional learning settings to a factory production line which transfers information from the teacher to the learners through a linear process. A teacher-centric approach dictates most classroom environments where the teacher is present at the front of the class, and the student sits in rows unilaterally grasping knowledge from the teacher. The evolution of the traditional classroom design involves the expansion of the service corridors as an educational space, forming a "Learning Street" or "Educational Promenade" as described by Hertzberger (2008), in which the classroom becomes a part of the corridor and includes an operable interior dividing wall to allow for flexibility and shared learning spaces (Nair & Fielding, 2005).

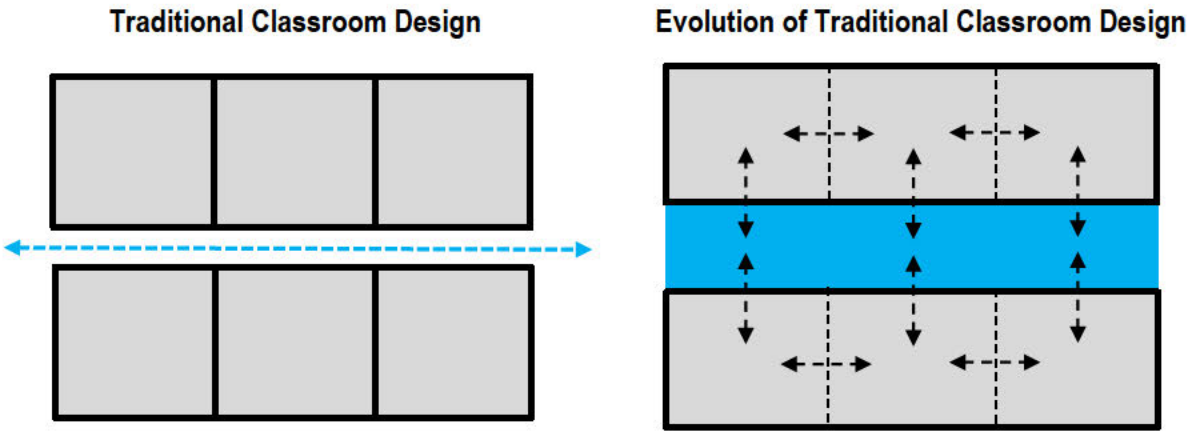



*Figure 32. Traditional and Evolution of the Classrooms Design adapted from Nair & Feilding (2005) (Author, 2022)*

The ancillary space for circulation becomes a vibrant, communal working space balanced between individual and collaborative learning, including nooks and niches to work, allowing the students to decide how to use the space (Hertzberger, 2008). A glazed dividing wall between the classroom and corridor creates transparency, increasing visual connections and inquiry into the areas whilst still forming a sense of belonging to the classroom. Expanding the classroom into the corridor forms a transition space where workstations and benches can be enclosed with low walls to define the spaces. These areas require adequate daylighting to create a comfortable, quality space that attracts students (Hertzberger, 2008).

The large, unarticulated rectangular form of traditional classrooms isn't ideal for facilitating the modern methods of student-orientated education that require nooks, bays and corners where students can work independently or in smaller collaborative groups (Hertzberger, 2008). In an article by James A. Dyck and Douglas Amedeo (2003), they analysed different forms of classroom layouts, where they derived the "L" shaped classroom as the best option that offers teachers more flexibility for innovative lessons and the development of various learning activities (Dyck & Amedeo, 2003; Lippman, 2016). The shape allows smaller learning groups to prevent students from being distracted and enables them to concentrate on their activities and tasks. Nair & Fielding (2005) describe the "L" shaped form as a Learning Studio, which can evolve into a Learning Suite with both forms placed alongside outdoor learning terraces. The development of the classroom formation offers a variety of smaller learning spaces, with break-out areas, movable walls, and mobile furniture that create flexibility and fluidity in the rooms (Nair & Fielding, 2005).

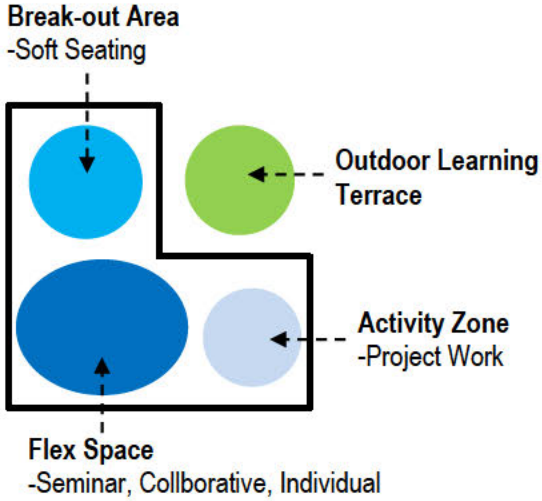



*Figure 34. Learning Studio Nair & Feilding (2005) (Author, 2022)*

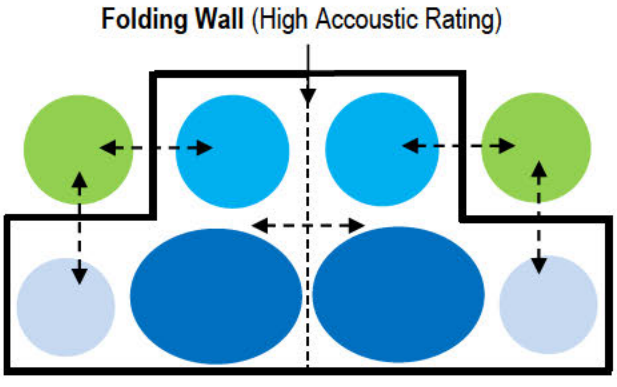



*Figure 33. Learning Suite (Author, 2022)*

Herman Hertzberger (2008) compares educational facilities to a micro-city, where the built form depicts the components of the city: the corridors become the streets, the classrooms become the surrounding buildings, and the communal areas become the public squares (Hertzberger, 2008). He further states that by adopting this ideology, the design of each component within the educational facility is critical to ensure a positive holistic outcome in which, similarly to an urban community, the learning community feels a sense of belonging and strengthens social connections (Hertzberger, 2008).

The design of a learning environment as a micro-city structured similarly with streets and public squares increases social contact between individuals, complementing the learning process and promoting peer interaction (Hertzberger, 2008; Bickford & Wright, 2006). As mentioned before, the Learning Streets or Education Promenade become an expansion of the classroom into the corridor. Alexander et al. (1977) suggest shortening and widening passages to encourage social interactions, including furniture along the way to create informal gathering points. Moreover, implementing alcoves along the widened routes allows small groups of people within a small space to create more intimate interactions and a sense of protection and security (Alexander, et al., 1977). The arrangement of learning environments alongside one another blurs the lines between formal learning and social activities, encouraging social relations through visible, active education.

Public squares in cities form a focal point for recreational activities, gatherings and lingering, with a series of streets leading to the public squares. Communal areas form the public squares in schools with high visibility, where students gather and interact (Hertzberger, 2008). In support, Alexander et al. (1977) assert communal areas for all social groups are located at the centre of all activities, and the passages should lead in and out of the space in tangent to it. They further explain the concept of activity pockets, which are situated on the edges of public spaces and can be natural spots to linger and interact. By activating the edges, these activities can spill over and overlap into the central space (Alexander, et al., 1977). Hertzberger (2008) introduces “steps” as a design element within communal areas that allows users to determine the function of the space through their interactions with the steps. It provides a natural lingering spot, and widening the treads creates a place for people to sit and interact, a platform for students to work and encourages spontaneous events such as performances, presentations and teaching lessons (Alexander, et al., 1977;

Hertzberger, 2008). Although the area beneath a staircase is typically used for storage, it has the potential to be designed into a peaceful reading nook or activity space by reducing the floor level.

Hertzberger (2008) explains that the spatial development of the built form to express social relations should enhance the visual connections through continuity between storeys. He negates the design of buildings as horizontal slices, suggesting using split levels or vertical voids, capturing the natural light through skylights to evoke the feeling of being outdoors. Moreover, increasing the floor-to-ceiling heights along corridors creates a street-like atmosphere that relates to his point of the school as a micro-city (Hertzberger, 2008).

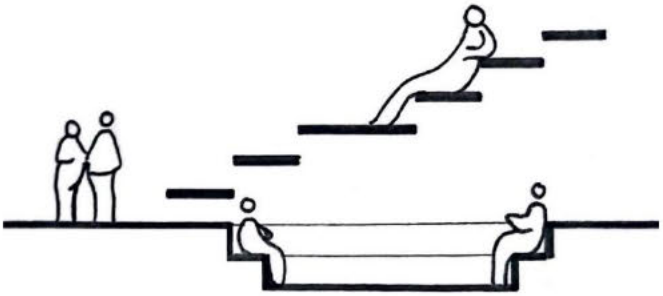


*Figure 36. Stair Seating (Author,2022)*

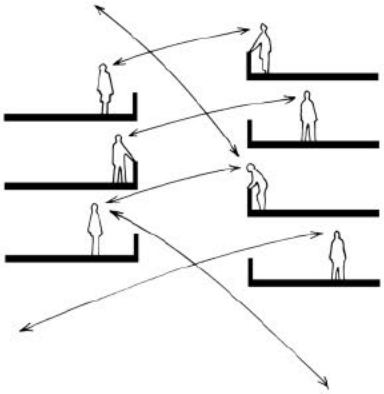


*Figure 35. Split Level & Visual Connections (Hertzberger, 2008)*

### 2.4.3 Conclusion

In conclusion, many authors expound on the importance of nature in learning environments that positively contribute to one's educational development due to humans' affiliation with nature. The vertical school design offers individuals constant interactions with nature on various levels of the outdoor environments.

The writings of Hertzberger (2008), Alexander et al. (1977) and Nair & Fielding (2005) form the foundations of the analysis to articulate learning spaces. These authors express expanding the corridor as part of the classroom, incorporating seating spaces, nooks and alcoves as part of the design. Moreover, regarding Dyck & Amedeo (2003) and Lippman (2016), the L-shaped classroom evolving into a Learning Suite best suits the needs of teachers and offers flexibility and fluidity to the space. Lastly, the school as a micro-city concept presents strategies towards the design of the learning environment to encourage visual and social interactions similar to ones in the city to enhance the quality of the learning facility.

## 2.5 Phenomenology

The phenomenon was first introduced in a philosophical setting and brought into focus through the writings of philosopher Edmund Husserl, in the early 19th century, as an approach to studying ones lived experiences through their conscious state, including sensory experiences, perception, memory and so forth (Qutoshi, 2018; Moran, 2013). The term has evolved, with many philosophers expounding and interpreting the phenomena through their ideologies developed from Husserl's writings.

Martin Heidegger, a student and associate of Husserl, brought the theory into the architectural setting in 1952 through his seminal essay, “Building, Dwelling, Thinking”, stating architects disregard the existential dimension in architecture which is the ability of humans to relate to the built form through lived experiences (Patil, 2017). This led to many prominent authors and architects investigating the connection between the experience of humans and the built form, notably in the works of Juhani Pallasmaa, through multi-sensory architecture and Christian Norberg-Schulz expressing the creation of meaningful places (Van de Vijver, 2018).

The way spaces are perceived is subjective to the user; however, integrating multi-sensory experiences creates meaningful spaces the user can (re)connect through their lived experiences. Juhani Pallasmaa (1996) states, "Architecture is the art of reconciliation between ourselves and the world, and this mediation takes place through the senses." The role of all the senses through architecture, i.e. Sight (visual), Smell (olfactory), Hearing (acoustic, auditory), Taste (oral), and Touch (haptic, tactile), enhances the association between humans and the built environment.

Juhani Pallasmaa (1994) says every meaningful experience of architecture, including materiality, scale and space, is a part of the multi-sensory experience. These experiences do not need to be tangible. He expounds that one's memory is the recollecting of past experiences within places we relive, reshape and reimagine depending on our behaviour as individuals and is achieved through the activation of our various senses. Therefore, memory can impact and influence our perception of space through the built environment. However, Modern Architecture is seduced by the visual representation of architecture through form and function instead of enhancing the other sensory effects through the experience of space (Lee, 2022). Although the aesthetic experience of

architecture is essential, it has dominated the built environment, disregarding the uses of the other senses, which impacts one's ability to experience the space entirely.

Peter Zumthor (2006) explains how the atmosphere created by architecture shapes the perception in which one views it. He further asserts that quality architecture is the ability to "move" someone through the atmosphere it presents (Zumthor, 2006). However, the human body is an essential part of experiencing spaces through the activation of the sense creating an integration with the surroundings, allowing one to shape their perception of the space. Philosopher Maurice Merleau-Pony supports this statement in his book *Phenomenology of Perception,* describing the human body as the source of human perception (Soltani & Kirci, 2019).

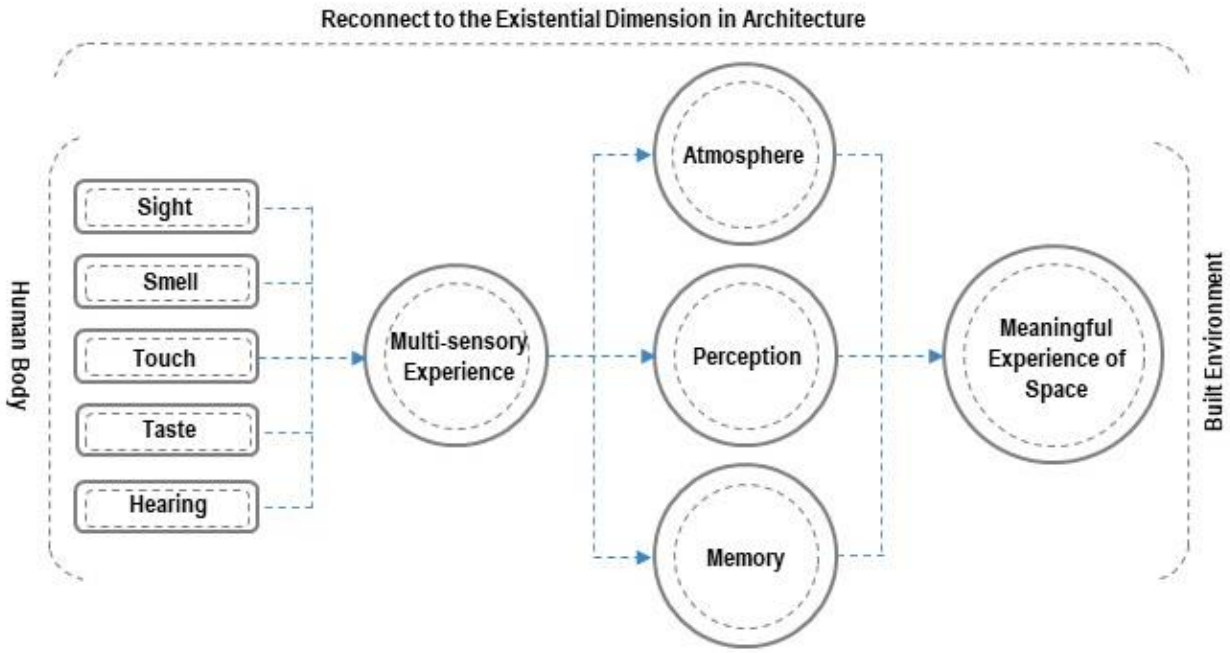



*Figure 37. Phenomenology Diagram (Author,2022)*

Activating multi-sensory stimulation within learning environments enables individuals to absorb and retain information effectively (Shams & Seitz, 2008). Thus, the theory of Phenomenology within the research is crucial to the user experience of the proposed design, creating an atmosphere by activating human senses, evoking memorable encounters and creating spatial perception, which promotes comfortable environments where users can learn, interact and obtain knowledge on water security.

## 2.6 Environmental Sustainability

Architecture and the Natural Environment co-exist through built form; man-made structures begin where nature ends; thus, architects must understand the relationship between nature and architecture to achieve a holistic outcome. Environmental Sustainability is a subdivision of Sustainability, coupled with Social and Economic Sustainability, which overlap. The focus is on Environmental Sustainability within the research because it is associated with the relationship between humans and the environment and the impact of humans on the environment (Morelli, 2011). The term is defined as *"the responsibility to conserve natural resources and protect global ecosystems to support health and well-being, now and in the future"* (Sphera, 2021).

The sustainability of water is a crucial aspect of Environmental Sustainability due to the impact on the country's socio-economic development, health and well-being of people and wildlife. Many people lack fresh water because the current water systems can't meet the city's demands. Moreover, there is an impairment of the natural ecosystem due to pollution and exploitation of water systems caused by human beings. Therefore, preserving the natural environment is crucial for the future of a city. The design of spaces needs to integrate with the natural environment to compensate for and incorporate nature and, regarding the research, sustainably recycle/harvest clean water and create human comfort and well-being for future generations.

### 2.6.1 Biophilic Design

The natural environment has influenced the evolution of humankind for thousands of years. Humans are a living structure that forms a deep connection with nature, impacting the physical, mental and behavioural processes we experience daily, known as our circadian rhythm (Meira, 2022). However, technological advancements and the development of societies and cities disconnect humans from nature, leading to many health problems. Predictions show that by 2050, 66% of the world will be urbanized, growing the disconnect between humans and nature (Heath, et al., 2018). The increase in urbanization results in dense urban environments with high-rise buildings taking over cities, leading to compact structures disconnected from the outdoors, negatively impacting one's mental health and well-being.

In his book Biophilia, Edward O. Wilson (1984) first introduced the term suggesting that human beings have a natural affiliation and interest in nature. Other theorists continued this study in response to Wilson's conception of Biophilia, leading to the identification and understanding of the advantages to human well-being that Biophilia provides. Stephen R. Kellert, a pioneer of the theory of Biophilia, emphasizes the importance of the interaction between humans and nature and the effects on human well-being (Kellert, 2005). He further states that there is a divide between man and nature in modern society, and civilization is unaware of the impact of the natural environment on one's state of mind.

Biophilic Design attempts to create sensory environments inside interior spaces that allow individuals to feel physically and emotionally at ease by connecting with nature (Dalay, 2020). The direct link to nature for humans shows why the sound of a crashing wave or rustling leaves is intriguing, why the views of the natural landscape heighten our creativity, and why the interplay of light and shadows creates an attraction and appeal (Browning, et al., 2014). People may engage with nature through architecture by bringing nature inside the building or creating direct views of nature from interior spaces. Because of nature's benefits on physical and mental well-being, Sjoquist (2003) claims that persons in contact with nature are healthier than those who are not.

The integration of nature within learning spaces of education environments increases students' ability to focus, expands their creativity, and improves their cognitive skills. Incorporating nature into the built environment through materiality, textures, pattern, and colours positively impact a user, creating comfort within the space. The following colours impact the environment accordingly: **Blue** – calming and relaxing, **Green** – calming and therapeutic, **Yellow** – happy and welcoming, and **Red** – energizing and exciting (Heath, et al., 2018). Biophilic Design is strongly linked to the multi-sensory experience of beings, and it creates a sensory awareness through the connection with nature that reduces stress and anxiety. In addition, the incorporation of water creates tranquillity, enhances concentration and memory restoration within a space by activating the senses (Kellert & Calabrese, 2015) and is an environmental strategy to regulate temperates through passive design similar to the Stepped Wells in India.

Applying Biophilic Design principles is beneficial to achieving human comfort within a space, increasing visual comfort and reducing stress and anxiety. It also improves productivity and creativity and improves mental health & well-being (Pranjale & Hejiib, 2019). Biophilic Design in architecture holds the potential to create positive spaces where people feel comfortable interacting and learning whilst being in contact with nature.

The Biophilic Design Principles: **Nature in Space, Natural Analogues** and **Nature of the Space,** have been adapted from the 14 Patterns of Biophilic Design to implement in interior and exterior environments (Browning, et al., 2014). The design principles create a sensory atmosphere through the various techniques discussed below to stimulate comfortable environments.

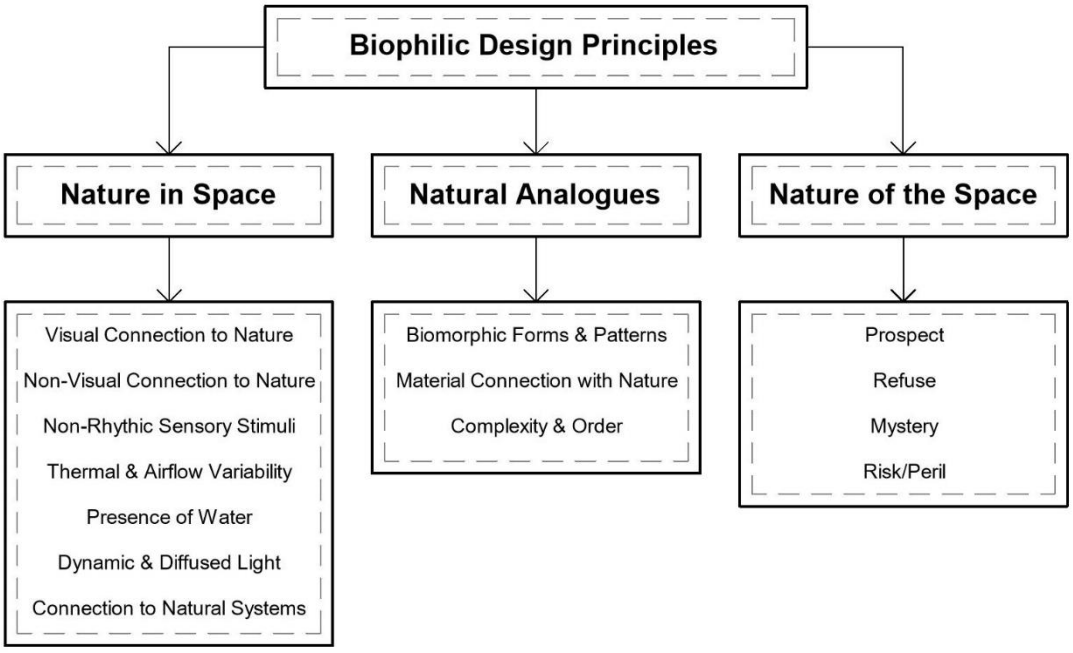



*Figure 38. Principles from Browning et al. (2014) (Author, 2022)*

The principle of Nature in Space implements nature within the built environment resulting in direct physical contact with nature (Interface, 2020). This includes adding plants, trees, water, scents, etc., that bring nature within the building and activate the human senses, bringing humans closer to nature. The patterns for Nature in Space, adapted from Browning et al. (2014), begin with the Visual Connection to Nature that implements direct views of nature in the built environment, including green roofs, green walls, light wells, internal courtyards and landscaped areas. The

following pattern is the Non-Visual Connection to Nature, which stimulates the other senses that connects one to nature, including sound masking, scent diffusers, furniture materials and texture. Non-Rhythmic Sensory Stimuli create consistent yet unpredictable motion similarly found in nature through kinetic sculptures, caustic effects from water and digital screens. Passive design strategies through stacked ventilation or passive cooling using water bodies mimic the changes in temperature, humidity and airflow in the natural environment. The presence of water through sight, sound or physical touches, including seating near water features, fountains, bouncing light, and different tones of blue, enhances humans' affiliation with water. The interplay of light and shadows mimics natural patterns and cycles and is seen in the built environment through louvres, skylights and vertically planted screens.

The principle of Natural Analogues refers to objects, colours, shapes, forms and patterns that are indirect or non-living representations found in nature reflected through furniture, textures, artwork etc., within the built environment.. Browning et al. (2014) assert that "while they are real, they are only analogous of the items in their 'natural' state." The patterns of Natural Analogues adapted from Browning et al. (2014) include Biomorphic Forms and Patterns that adopt patterns, shapes, and textures found in nature, such as organic-shaped furniture, cell-like facades, curved paths and spaces. The Material Connection with Nature and Complexity and Order patterns create a connection to the space through textures, symmetries and geometries that reflect the natural environment through timber cladding, nature-inspired wallpaper, exposed structures and furniture and plants to designate areas.

The principle of Nature of the Space refers to the experience of space through spatial arrangements in nature that enhance our well-being. This reference to one's desire to have uninterrupted views of the immediate surroundings, the intrigue of the unknown, partially obstructed views that produce a pull factor or the intentional creation of fear through informed safety elements (Browning, et al., 2014). The Nature of the Space patterns adapted from Browning et al. (2014) includes Prospect, which ensures clear views of the surrounding environments and is seen in the built form through balconies, large windows or skylights, transparent materials and mezzanines. Refuge refers to a protected place for withdrawal, such as places to retreat or restore energy, winter gardens and raised platforms. The Mystery pattern evokes a sense of intrigue by partially obstructing views via gently curved pathways and pull factors towards a space through sensory

stimulation. The pattern of Risk/Peril creates a sense of visual threat coupled with reliable safety, including hanging chairs, glass flooring, hanging walkways and double-height atriums.

### 2.7 Experiential Learning Theory

Education is a fundamental quality as beings, enhancing our personal development and social skills and possessing the potential for a better quality of life. The current education methods adopt a narrative approach, where the teacher is the narrator and the students are the subjects that listen and receive the information (Freire, 2005). The narrative approach dominates the teacher-student relationship in modern society, with students obtaining information, memorizing it and then regurgitating it in their examinations. Frier (2005) asserts that the narrative approach declines the quality of the current education system as students lack creativity, critical thinking and new knowledge because there is no opportunity to inquire and gather information.

John Dewey created a foundation for the Experiential Learning Theory in his book Experience and Education. He argues that traditional and progressive education systems are hindering the development of students as neither applies the principles of the philosophy of experience (Dewey, 1938). These principles are Continuity and Interaction. Continuity refers to an individual's past and present experiences that will impact their future experiences, whilst Interaction refers to how an individual's current circumstances influence their experiences (Elkjaer, 2000). Dewey states that the social environment is crucial to ones educational development through lived experiences that involve human contact and communication (Roberts, 2003). Nurturing students' social relationships that facilitate social interactions between different age groups creates a broader range of lived experiences leading to greater knowledge production. He affirms education systems should be arranged around real-life experiences to give the information context; however, this depends on the student's readiness and capabilities (Roberts, 2003). The most significant aspect of the theory is the quality of the experience (Dewey, 1938). Once obtained, students can apply it in different settings, developing new information.

David A. Kolb further expounds on Dewey's ideology that experience plays a central role in ones learning development and is the process of human adaptation to the social and physical environment involving thinking, feeling, perceiving and behaving (Kolb, 1984). Kolb argues that the term "Transaction" is better phrased than Dewey's principle of "Interaction" as it describes a

more fluid relationship between the objective conditions and the subjective experiences; however, he notes that knowledge is achieved by merging these entities resulting in the learning (Kolb, 1984). Therefore, knowledge is obtained from one's experiences, which is the foundation for learning.

### 2.7.1 Placed-based Education

Place-Based Education connects to the Experiential Learning Theory as it uses the environment and local community to learn, (re)connecting humans to nature. The concept focuses on real-world experiences to develop a connectedness to the place and engages with the local community. Implementing this concept makes the learning process engaging and meaningful with regard to the students' daily lives. David A. Gruenewald & Gregory A. Smith (2014) state that Place-Based Education assists learners in developing skills and knowledge needed to sustain the local community. The overall vitality and preservation of the environment improve as students develop stronger ties to the natural world and their surroundings. The concept focuses on all aspects of the environment, including culture, history, social, political and the built environment (Elfer, 2011)**.**

The design principles of Place-Based Education adopted from the publication by Getting Smart (2017) demonstrate the importance of the connection to place and the development of student-centred learning experiences. A Learner-Centred approach identifies the strengths of the students and allows them to grow in accordance with their capabilities. An inquired based curriculum is built on the premise of observations, informed questions and data collection to comprehend real-world problems. The community as a classroom principle expands the learning environment, involving the community, such as members explaining their experiences, informative places within the area etc., as a source of education. This point interlinks with an interdisciplinary approach where the curriculum is designed to reflect the real world, with conventional academic material and skills taught in an environment that supports project-based, multidisciplinary learning aimed at challenging students. Implementing these principles forms a meaningful connection between the students and locals towards their community.

## 2.8 Conclusion

In conclusion, the three theories of Phenomenology, Environmental Sustainability and Experiential Learning Theory were critically analysed to identify each theory's critical approaches through prominent authors' writings.

The theory of Phenomenology in architecture is centred around the humanist experience of the built environment. The key approaches of the theory encapsulate the multi-sensory experience of humans, leading to their perception of the built environment based on past memorable encounters coupled with the atmosphere created by the architecture. The experience begins with the human body and the activation of the senses to reconnect people to the existential dimension of architecture. The increasing disconnect between humans and nature is ever-growing, and one can reconnect to nature by implementing biophilic design principles in architecture.

Moreover, the principles create human comfort in interior spaces and improve the productivity and ability of students in learning environments. Experiential Learning Theory expresses the importance of lived experiences and social interactions to enhance students' learning abilities, and including principles of Place-based Education encourages active and informal learning settings.

The critical approaches discussed will be explored through the precedent studies in the next chapter that depict the activation of multi-sensory experiences and learning environments that encourages people to engage with water through the built and natural environment.

# Chapter 3: Precedent Studies

## 3.1 Introduction

The chapter investigates and explores precedent studies of existing built forms that respond to water security, natural environment and learning spaces. The three precedents will be analysed through the lenses of the conceptual and theoretical framework as a response to the research problem. The analysis will further explore principles of *Multi-sensory Experience*, *Biophilic Design* and *Place-based Education* in the selected buildings. This analysis aims to develop architectural principles to aid the connection to water, the natural environment and built form.

**The chosen Precedent Studies:**

1. **Frick Environmental Center**

- Phenomenology and Water Security.
- Environmental Sustainability and Water and Architecture.
- Experiential Learning Theory and Nature and Learning Environments.

2. **VUC Syd Education Centre**

- Experiential Learning Theory and Learning Environments.
- Accommodation Schedule: Openness, Flexibility and Transparency of Learning Spaces.

3. **Sydney Park Water Re-Use Project**

- Phenomenology and Water Security.
- Environmental Sustainability and Water and Architecture.
- Experiential Learning Theory and Nature and Learning Environments.

## 3.2 Frick Environmental Center

*Figure 39. Frick Environmental Center (COMCAST, 2020)*

### 3.2.1 Project Description

**Location:** Pittsburgh, Pennsylvania

**Architect:** Bohlin Cywinski Jackson

**Completion Year:** 2018

**Client:** Pittsburgh Parks Conservancy

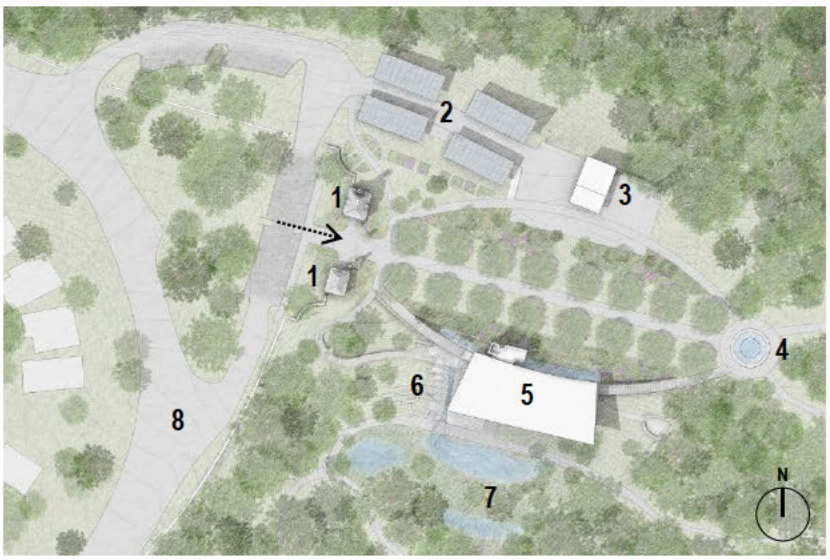
**Area:** 1530m²

**Category:** Environmental Education Centre

### 3.2.2 Brief Background + Locality

The Frick Environmental Center is a three-story, experiential education building that serves as the gateway to the 644-acre Frick Park in Pittsburgh and symbolizes the concept of "Neighborhood to Nature" (Castro, 2018). The Net Zero facility achieves net-zero energy and water, meeting Leadership in Energy and Environmental Design (LEED) Platinum certification requirements and the **Living Building Challenge** (LBC) requirements. The Centre and the surrounding site serve as the city's primary source of environmental education, forming an active educational experience for learners of all ages with indoor and outdoor learning spaces and guided and independent exploration activities and tours (AIA, 2019). The building consists of open-plan classrooms, offices, a reception area, ablution facilities, a public "living room", and gallery spaces designed to encourage community learning about the environment and develop a deeper connection with nature.

The site was once home to a nature centre; however, in 2002, a fire destroyed the building and the surrounding landscape. The new center is located in the footprint of its predecessor to reduce environmental impact. After removing invasive plants, 7000 new native plants and 200 native trees were planted throughout the site to restore the biodiversity and ecosystems lost from the fire (AIA, 2019). The new plants positively impact the natural habitat and deepen human-nature interaction as one moves through the site.




1 – Gatehouses.

2 – Parking Lot with Canopy for Solar & Raiwater collection.

3 – Barn and Service Yard.

4 – Fountain Feature.

5 – Environmental Center.

6 – Woodland Amphitheater & Watershed Interactive Sculpture

7 – Wetlands.

8 – Beechwood Blvd.

*Figure 40. Site Plan (Bohlin Cywinski Jackson, 2016)*

### 3.2.3 Connection to Water

The Center celebrates water through the various stormwater and rainwater collection techniques and uses a water feature, rain veil, and rain ravine as works of art. The process of collecting water begins at the Northern end, where solar canopies capture the water and transfer it to a rain barrel, which is then used to irrigate the demonstration garden. The overflow water moves to the 15000-gallon underground storage tank and is treated using a 5-micron stainless steel filter and two UV treatment units (Gonzalez, 2020). The water is directed to the building and is used as potable and non-potable water, ensuring water security. The parking lot flooring consists of permeable concrete pavers that allow stormwater to filter into the underground infiltration system.

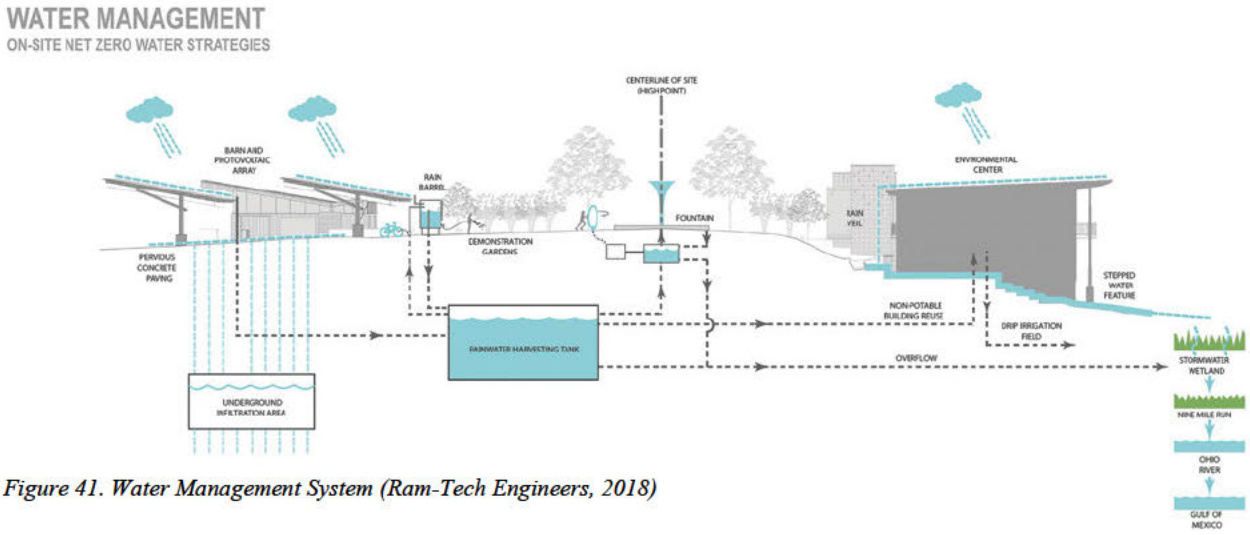



*Figure 41. Water Management System (Ram-Tech Engineers, 2018)*

The Center, situated in the southernmost part of the site, is where phenomenological encounters and artistic exchanges with water occur. The rain veil, seen indoors and outdoors, is a curtain of water cascading down the northern roof edge onto the catchment area. The water moves to the rain ravine, a stepped sandstone feature adjacent to the amphitheatre and then to the constructed wetlands that manage the flow (AIA, 2019). Visitors may access the amphitheatre and rain ravine to interact with the water, which enhances their sensory experience through physical touch, visibility, and audibility of the water. The design of this system displays the flow of water, providing visitors with a visual demonstration of how water is collected and transported, forming a source of education whilst creating a playful atmosphere and deepening the connection through interaction with it as it meanders down the hillside. These water design features relate to the Non-Rhythmic Sensory Stimuli pattern of the Biophilic Design principles creating a consistent yet

unpredictable motion of water similarly found in nature. The water fountain at the site's highest point further links one to the water and produces a focal point where people can gather and interact in the presence of water. One drawback is that greywater and blackwater are not recycled within the building; instead, they are treated locally and used in drip irrigation systems to cultivate crops. (Shuqair, et al., 2020).

*Figure 42. Rain Ravine (NRPA, 2019)*

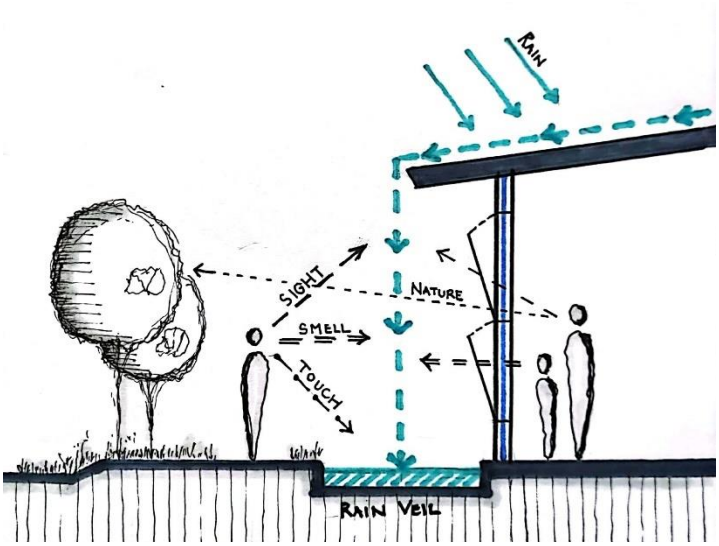



*Figure 43. Rain Veil (Author, 2022)*

### 3.2.4 Design Approach

The approach to the design was nature orientated, with biophilic design at the heart of the process. Patricia Culley, a senior associate at Bohlin Cywinski Jackson, stated, "The center nurtures exploration of and connection with the natural world" (Binsacca, 2019). The relationship between the indoor-outdoor transitions smoothly with the operable floor-to-ceiling glazing allowing abundant natural light and ventilation to filter into the spaces and showcase panoramic views of nature relating to the pattern of Prospect from the Biophilic Desing principles. The outdoor classroom, balcony and private staff porches further enhance the engagement with the natural environment. The permeable amphitheatre serves as an outdoor education space and an area to relax and socialize. The building adopts passive design strategies to improve the learning environment with the structure orientated to receive optimal prevailing winds through a stacked ventilation system and large overhangs to reduce solar gain. A post-occupancy survey expresses the overall happiness and productivity of the staff as they highlighted that indoor air quality had led to a more comfortable working environment (AIA, 2019).

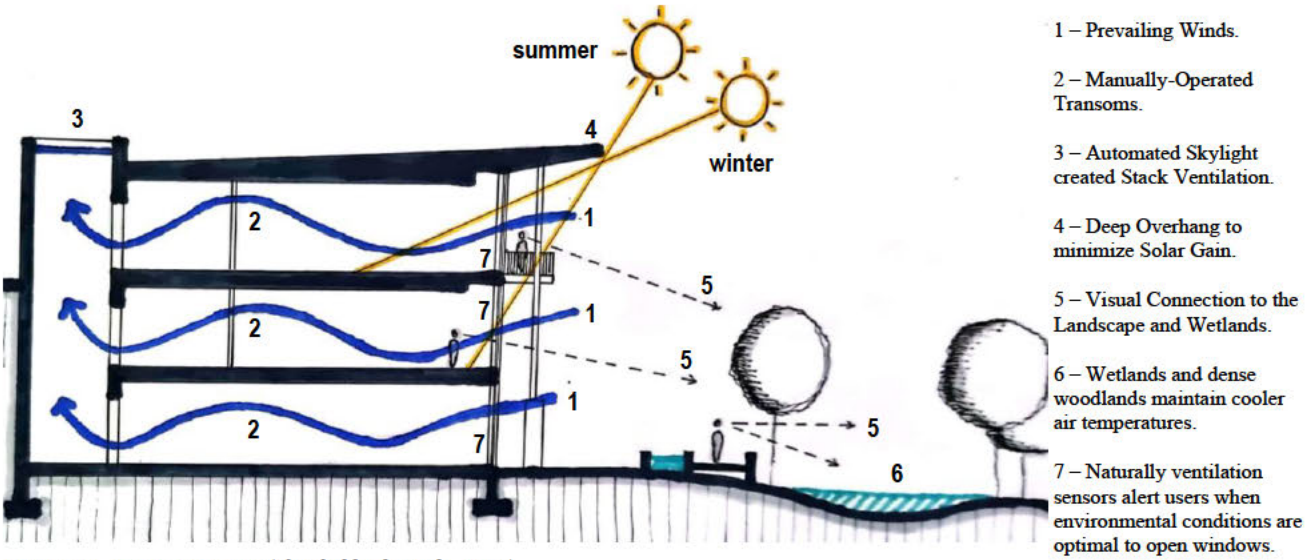



*Figure 44. Passive Design (Shackelford, et al., 2022)*

The material palette is simple and consists of wood, concrete, steel, stone and glass. The facade is treated with black locust siding, which is meant to weather naturally over time and blend in with the surroundings without needing any treatment or sealant, representing a material connection to nature and the site (Shuqair, et al., 2020). A local carpenter made the furniture from invasive trees removed during construction, expressing the site's intimate relationship to the surrounding natural environment. The slender steel columns, exposed steel structure, and steel entrance bridge define the tectonic nature of the building, showcasing how the structure is composed. The entrance bridge is nestled into the treescape so that guests may view the park from the height of the forest canopy. The slender steel columns are placed irregularly to resemble the dense woodlands surrounding the structure and create a floating effect of the roof (World-Architects, 2016).


*Figure 45. Elevation from Wetlands (Lehoux, 2016)*


*Figure 46. Internal Connection to Nature (Denmarsh, 2016)*

## 3.3 VUC Syd Education Centre

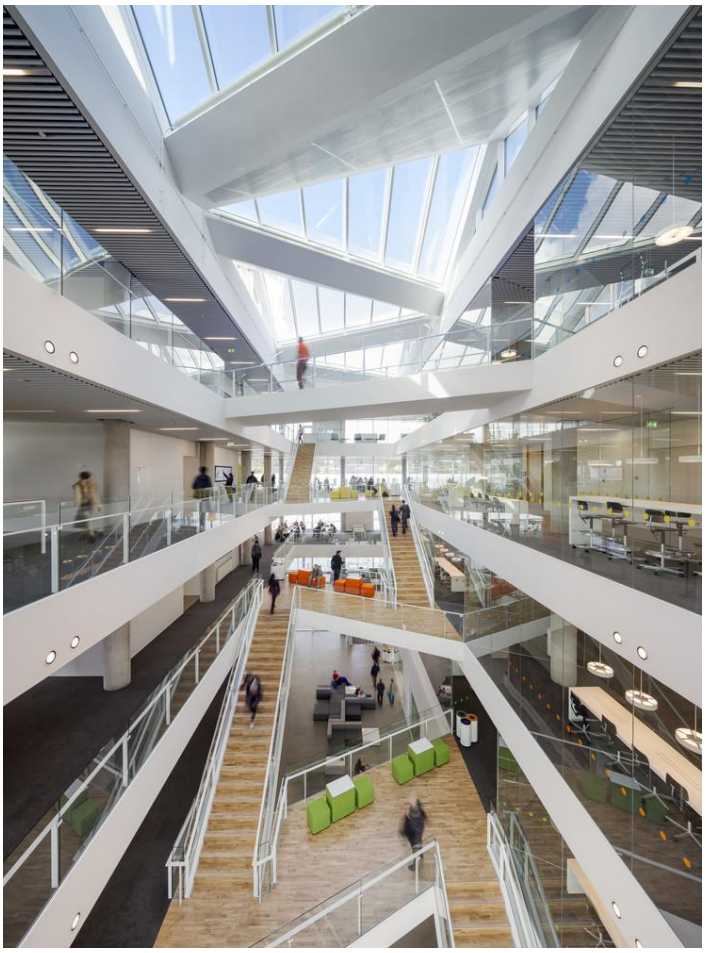


*Figure 47. VUC Syd Education Centre (Moerk, 2013)*

### 3.3.1 Project Description

**Location:** Haderslev, Denmark

**Architect:** AART Architects + ZENI Architects

**Year:** 2013

**Client:** VUC

**Area:** 8600m²

**Category:** Education Centre

### 3.3.2 Brief Background + Locality

The VUC Syd Education Centre sits on the waterfront of Haderslev in Denmark, with 360-degree picturesque views of the harbour and city. It gives young students who have grown tired of conventional learning environments an opportunity to experience a new perspective of education and thereafter gain employment. The Centre challenges the traditional idea of a school and provides a constructive approach to learning through vibrant and flexible educational spaces (AART Architects, 2013). According to the statistics, The Center drew 53% more students than other VUC facilities. Once their studies were complete, 70% more students pursued vocational education while 200% chose further higher education, which translates to 1000 young people each year (Sattrup, 2019).

The future-oriented building adopts two core approaches toward a new education strategy: modern information technology and innovative teaching methods (AART Architects, 2013). As part of the modern information technology strategy, enrolled students receive either an iPad or a MacBook for their studies, and 165 digital touch screens are inserted into the learning spaces as part of the innovative teaching methods.

### 3.3.3 Design Approach

The design moves away from conventional learning environments, with permanent classrooms and fixed uses of spaces, and adopts an open learning environment with flexible spaces to augment the learning experience. As you move up the building, the levels are arranged according to the subject area, from science to culture to language.

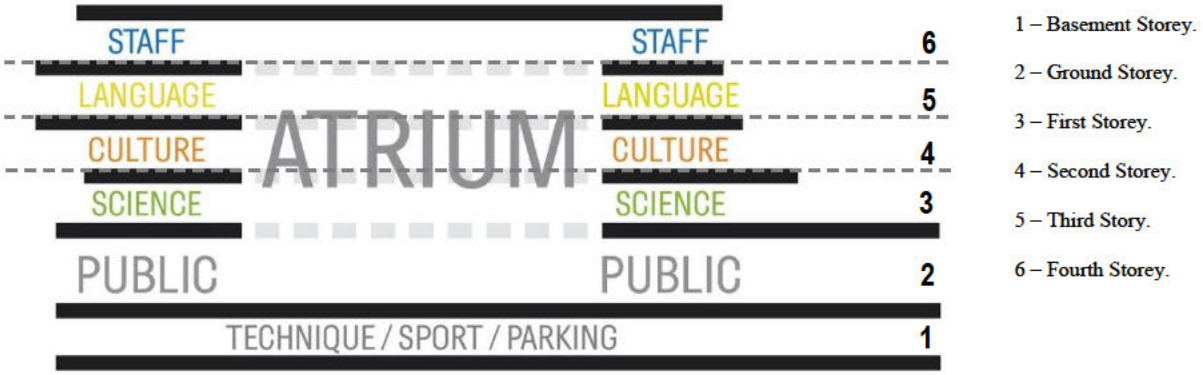
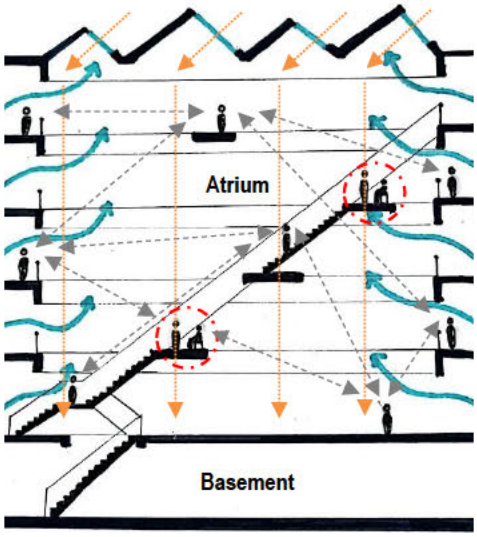



*Figure 48. Different Levels depend on subject area (AART Architects, 2013)*

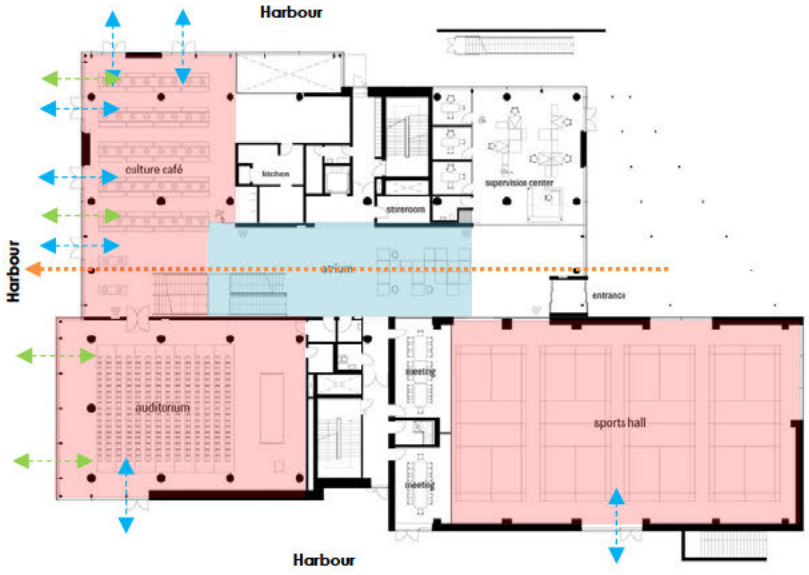
The organization of these spaces are structured around a central atrium consisting of a series of bridges with staircases and seating areas. The atrium includes multiple skylights, evoking vertical visual connections from different levels and filtering natural light into the space. The seating space arrangements and the atrium offer a comfortable central gathering space where students can relax, socialize and develop informal learning interactions.




- Natural Light filtering into the atrium through the skylights.
- Stack Ventilation created in the atrium.
- Seating areas promoting social interactions.
- Visual connections linking to different people and spaces.

*Figure 49. Diagram of the Interactions in the Atrium (Author,2022)*

The design engages with the public at the ground level incorporating complementary spaces such as the culture café, auditorium and lecture and sports hall available for large-scale events (AART Architects, 2013). The open-plan atrium forms a central access point with views of the harbour as one enters, inviting people into the space. Views and access to the harbour can be made from the cultural café, auditorium and sports hall through the double doors, offering the public and students a visual and physical connection to the water, enhancing humans' affiliation with water.




- Central axis from the Entrance to Harbour.
- Physical connection to the harbour/water.
- Visual connection to the harbour/water.
- Engaging Public spaces.
- Central atrium linking the buildings entrance and harbour.

*Figure 50. Ground Floor Storey (AART Architects, 2013)*

The spaces along the passages have floor-to-ceiling glazing, creating visual connections and offering inquired learning as one moves to their destination, responding to the concept of openness and transparency (Coughlan, 2015). For private classes, futuristic igloo-shaped structures called dialogue cubicles are placed within the open space creating a different approach to standard classrooms. The balconies are vital in the design to achieve indoor and outdoor cohesion. Starting on the ground floor and moving to the floors above, the balconies spiral around the built form, offering a release from the learning environment by connecting to the surrounding city and harbour (AART Architects, 2013).

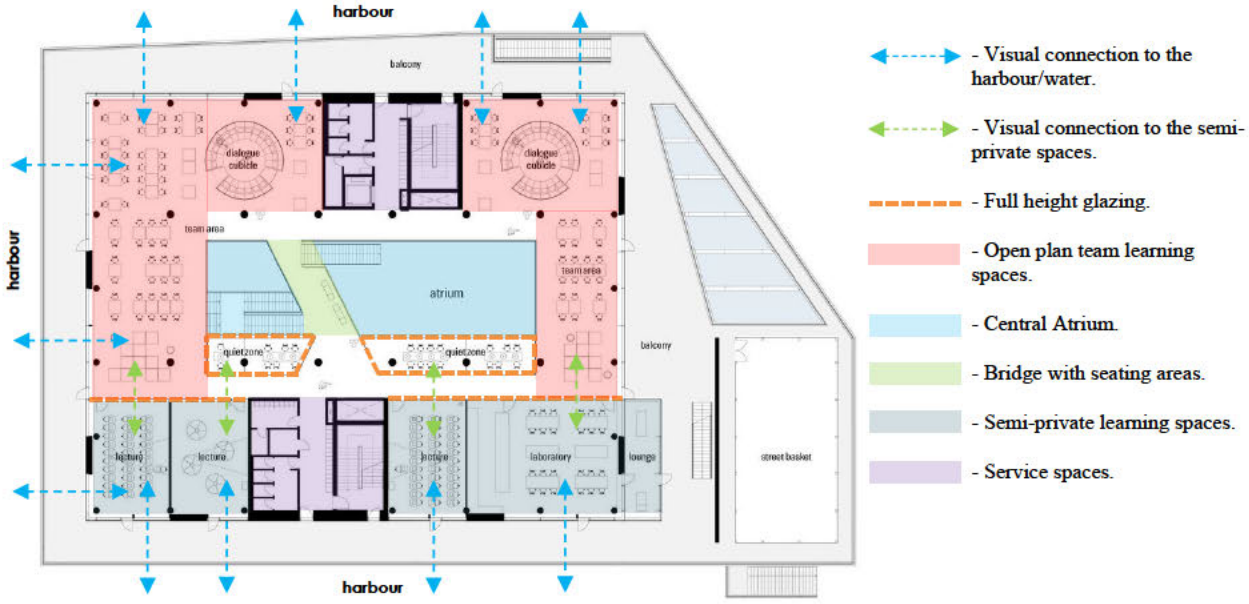



*Figure 51. First Floor Storey (AART Architects, 2013)*

### 3.3.4 Accommodation Schedule

The accommodation schedule forms an integral part of the research analysis to identify the spaces and sizes within a modern education centre. The contemporary approach to flexible and digital education environments adopted by the VUC Syd Education Center underpins diverse opportunities to learn and interact with others. The teaching areas encourage various activities and interdisciplinary exchanges (Sattrup, 2019). The concept of openness and transparency encourages social interactions related to Experiential Learning Theory, with Dewey stating that the social environment is crucial to education development through lived experiences that involve human contact and communication (Roberts, 2003)

| ACCOMMODATION SCHEDULE | | | | | |
|---|---|---|---|---|---|
| | ROOM NAME | APPROX. AREA | | ROOM NAME | APPROX. AREA |
| BASEMENT STOREY | Store Rooms | 155m$^2$ | GROUND STOREY | Auditorium + Store Room | 280m$^2$ |
| | Technical Room | 185m$^2$ | | Culture Cafe | 190m$^2$ |
| | Kitchen + Store Room | 130m$^2$ | | Kitchen + Store Room | 30m$^2$ |
| | Locker Room | 100m$^2$ | | Atrium | 255m$^2$ |
| | Changing Room | 45m$^2$ | | Supervision Center | 120m$^2$ |
| | Sports Hall | 375m$^2$ | | Meeting Room 1 | 35m$^2$ |
| | Office | 30m$^2$ | | Meeting Room 2 | 30m$^2$ |
| | Circulation | 80m$^2$ | | Circulation | 120m$^2$ |
| | Parking + Refuse | 380m$^2$ + 15m$^2$ | | Ablutions | 15m$^2$ |
| FIRST STOREY | Lecture 1 | 55m$^2$ | SECOND STOREY | Lecture 1 | 55m$^2$ |
| | Lecture 2 | 53m$^2$ | | Lecture 2 | 53m$^2$ |
| | Lecture 3 | 50m$^2$ | | Lecture 3 | 50m$^2$ |
| | Labratory + Lounge | 105m$^2$ + 25m$^2$ | | Labratory + Lounge | 105m$^2$ + 25m$^2$ |
| | Quiet Zone 1 | 20m$^2$ | | Quiet Zone 1 | 30m$^2$ |
| | Quiet Zone 2 | 35m$^2$ | | Quiet Zone 2 | 35m$^2$ |
| | Open Plan Team Areas | 465m$^2$ | | Open Plan Team Areas | 465m$^2$ |
| | Ablution 1 | 25m$^2$ | | Ablution 1 | 25m$^2$ |
| | Ablution 2 | 35m$^2$ | | Ablution 2 | 35m$^2$ |
| | Circulation | 170m$^2$ | | Circulation | 170m$^2$ |
| | Sky Bridge | 35m$^2$ | | Sky Bridge | 40m$^2$ |
| THIRD STOREY | Lecture 1 | 55m$^2$ | FORTH STOREY | Office 1 | 40m$^2$ |
| | Lecture 2 | 53m$^2$ | | Office 2 | 25m$^2$ |
| | Lecture 3 | 50m$^2$ | | Management Group | 30m$^2$ |
| | Tellepresence | 35m$^2$ | | Open Plan Management Group | 25m$^2$ |
| | Quiet Zone 1 | 25m$^2$ | | Flexible Meeting Room | 65m$^2$ |
| | Quiet Zone 2 | 35m$^2$ | | Staff Lounge + Open Plan SL | 75m$^2$ + 65m$^2$ |
| | Open Plan Team Areas | 565m$^2$ | | Open Offices | 380m$^2$ |
| | Ablution 1 | 25m$^2$ | | Ablution 1 | 25m$^2$ |
| | Ablution 2 | 35m$^2$ | | Ablution 2 | 35m$^2$ |
| | Circulation | 170m$^2$ | | Circulation | 230m$^2$ |
| | Sky Bridge | 30m$^2$ | | Sky Bridge | 40m$^2$ |
| | Lounge | 125m$^2$ | | Meeting Room 1+2+3 | 15m$^2$+20m$^2$+20m$^2$ |

*Figure 52. VUC Syd Accommodation Schedule (Author,2022)*

## 3.4 Sydney Park Water Re-Use Project

*Figure 53. Sydney Park Re-use Project (Rohloff, 2016)*

### 3.4.1 Project Description

**Location:** Sydney, Australia

**Architect:** Turf Design Studio, Environmental Partnership, Alluvium, Turpin+Crawford, Dragonfly and Partridge

**Year:** 2015

**Client:** Local Government, City of Sydney

**Area:** 16 000m²

**Category:** Park Renovation / Stormwater Management Facility

### 3.4.2 Brief Background + Locality

The Sydney Park Water Re-use Project forms a decentralised approach to water conservation in the city. Australia had its most significant drought at the beginning of the 2000s, forcing the city of Sydney to rely on remote river catchment to meet the water demands (Yang & Wang, 2017). The Sustainable Sydney 2030 initiative started after the country was declared drought-free in 2012 and aimed to fulfil 10% of local potable water demands by 2030 through water collection and reuse, ensuring future water security. The government saw an opportunity to revitalise the city, transforming the former industrial wasteland site into a vibrant recreation park that invites families to interact with nature whilst learning about water security. The new waterscape lies on a sub-catchment area named Alexandra Canal that buffers the industrial area and growing residential development, consisting of 4 constructed wetland areas that harvest 850 million litres of stormwater from the Munni Channel annually (Holmes, 2016).

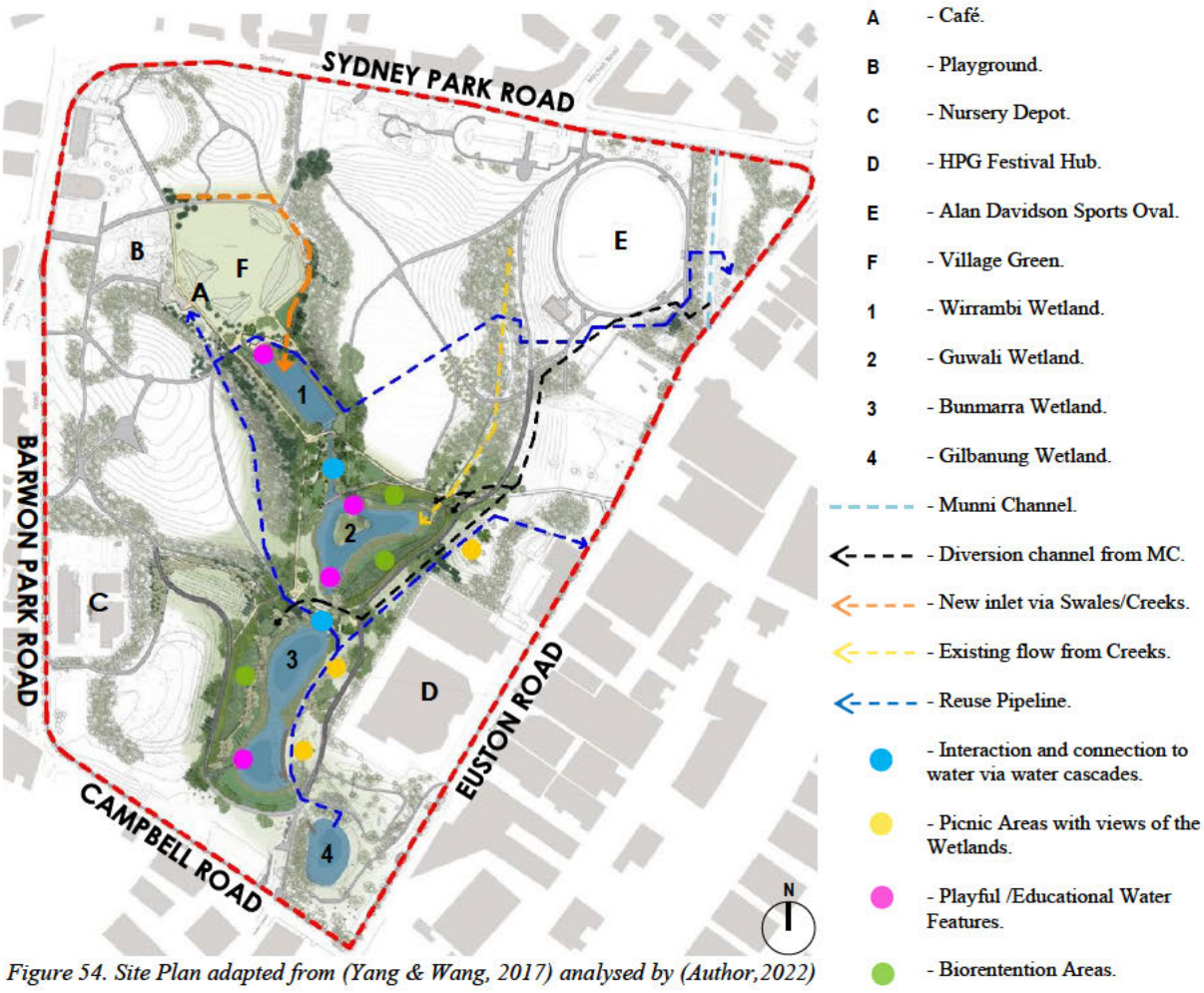



*Figure 54. Site Plan adapted from (Yang & Wang, 2017) analysed by (Author, 2022)*

### 3.4.3 Connection to Water and Nature

The concept of the project is to celebrate the water story through the visual engagement of the water capturing and cleaning processes, which informally educates the community within a leisure environment. The water storey is conveyed through art, science, ecology and green infrastructure that stimulates the multi-sensory experience of the public as they move through the park (Architecture & Design, 2016). The system consists of gross pollutant traps, 500m2 of bio-retention systems, and constructed wetlands that improve water quality and provide an aesthetic appeal and educational resource (Turf Design Studio, 2016). The water for irrigation is treated with filters and UV disinfection before being transferred. The bio-retention areas are densely populated with native plants that filter pollutants, clean the water, and provide spaces for natural habitats to thrive. The landscape design encourages interaction with the water treatment system, structuring walkways, bridges and seating areas in strategic locations that intersect with the wetlands and allow visitors to explore, learn and gather, strengthening the community's social ties and water education.

An essential source of water education in the project was the water sculptures designed by Turpin + Crawford Studios. The artists collaborated with landscape designers and water specialists to develop three sculpture features as part of the design, intertwining public art as part of the relationship between people, nature and water. The artwork forms part of the learning experience and celebrates the role of water by activating the human sensory experience, beginning with the "Water Falls" artwork placed in the Wirrambi Wetland, the system's source, capturing the purified water from the bioswales and transferring it into the wetland ponds. The sculpture's materiality reminisces the site's industrial history using terracotta channels arranged in a zig-zag formation raised above the water on black steel columns expressing the recycling process through the wetlands and serving as perches for birds (Turpin Crawford Studio, 2013). The sound of the splashing water moving from one channel to the next attracts people to the sculpture, where they can visually engage with the artwork from the surrounding viewing and seating areas.

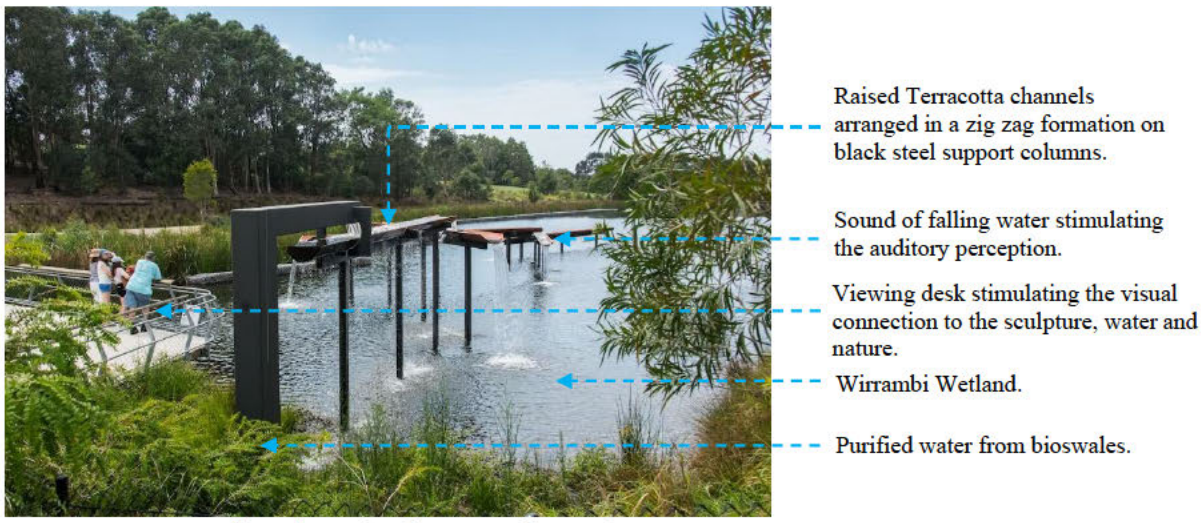



*Figure 55. "Water Fall" Sculpture (Turf Design Studio, 2016)*

The next feature is "The Cascades", located between Wirrambi Wetland and Guwali Wetland, supplemented by the water from the "Water Fall", forming part of the physical experience with water. "The Cascades" consists of a series of 5 stepped pools that aerates and stores water and are built with recycled gabion stones and concrete retaining walls. On either side of the stepped pools are enclosed forests called "The Gulley", with terraces and benches to allow views of the water feature (Landscape Architecture Foundation, 2016). Sandstone steps form pathways from one end to the other and create a nature-based play area for children. The materiality of the features expresses a tectonic nature through the art of its construction, and visitors can see, hear and interact with the water as it moves to the next wetland. The pools of water create a cool atmosphere that the users can enjoy whilst interacting with the water.

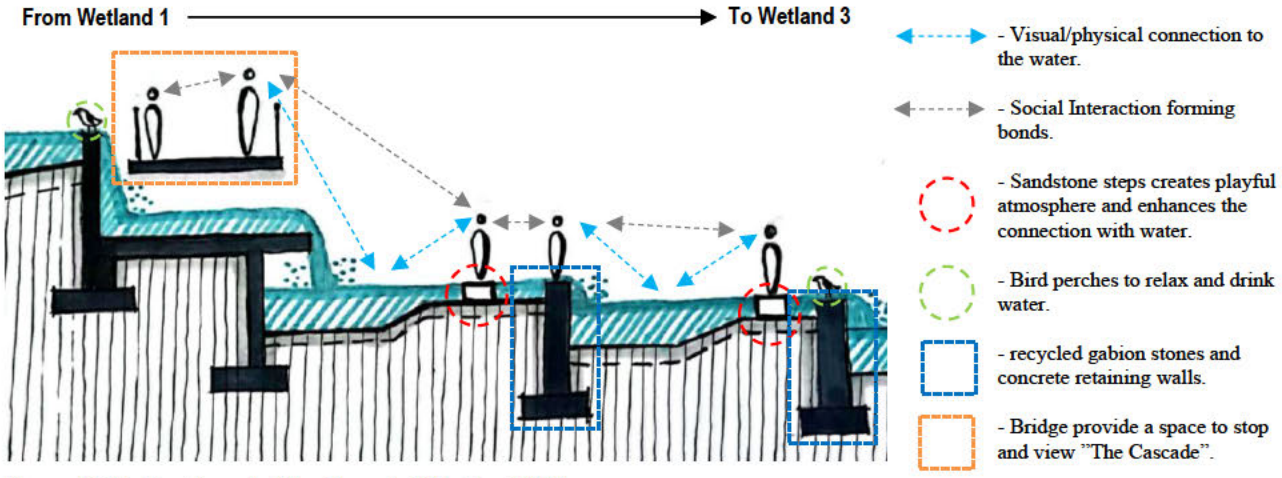



*Figure 56. Section through "The Cascades" (Author,2022)*

The "Exhaust Fans" shaped in a fan structure are the final component, and they are situated in the bio-retention regions where bioremediation for eliminating contaminants from stormwater occurs. The sculptures capture the essence of the relationship between water and the natural landscape as they convey water from the bio-retention area to the wetlands via elevated terracotta channels in an equal manner (Turf Design Studio, 2016). The artwork's materiality is the same as the "Water Falls" sculpture to enhance the relationship with the existing site.

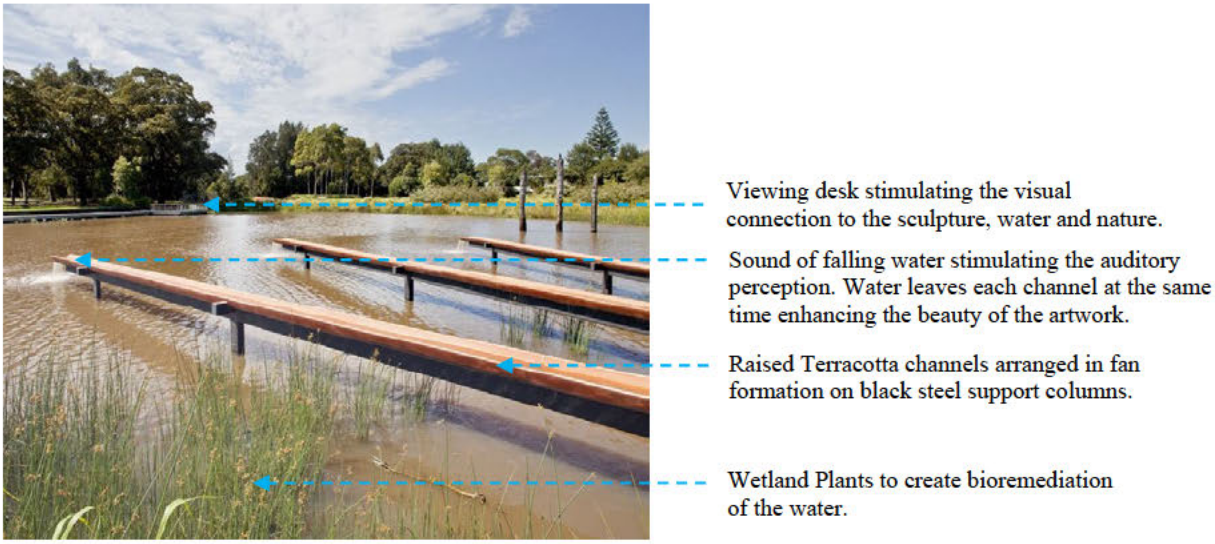



*Figure 57. "Exhausted Fan" Sculpture (Wood, 2016)*

## 3.5 CONCLUSION

In conclusion, the chapter unpacked three precedent studies of existing built forms that respond to water security, natural environment and learning spaces. The precedents were analysed through the conceptual and theoretical framework lenses to identify architectural principles that respond to the research objectives and questions. The buildings and landscapes reveal that architecture can form an intrinsic relationship between man, nature and built form. The interactions with water and nature can create human comfort and productivity within spaces and enhance social bonds. Additionally, articulating open learning spaces that promote conversation and provide a clear view of the outdoors and aquatic bodies enhances knowledge creation. Implementing sensory experiences through built form and landscape design by physical touch, sight and sound of water connects people to the element and improves their learning ability. Utilizing natural materials that depict nature and fostering a dynamic learning environment via art forms and sculptures further links individuals to their surroundings.

# Chapter 4: Case Study

## 4.1 Introduction

The Siza Water Recycling Plant in Ballito, Kwa-Zulu Natal, was the case study explored. The facility was investigated through physical observations, sketches, informal interactions and semi-structured interviews with employees to gain further information. Moreover, the spatial arrangements, water recycling and harvesting methods, and educational activities to increase public awareness were analysed on ensuring water security and learning opportunities for the Ballito region.

## 4.2 Siza Water Recycling Plant


*Figure 58. Overall View of the Recycling Plant (Siza Water, 2021)*

The Siza Water Recycling Plant sits adjacent to Zimbali Wedge, separated by the M4 roadway and accessed through a gravel slip road. The site is divided into the Wastewater Treatment and Potable Purification sections, with the main office building located centrally, forming direct views of the treatment and purification processes. The plant treats wastewater collected from Zimbali Estate,

Business Parks and parts of Simbithi Estate and recycles it back to potable water consumption for these places. However, pre-2015, the plant treated the wastewater and discharged it to nearby rivers as a response to ensure clean water entered the waterways and the safety of the environment. The droughts experienced in 2015 and Ballito's expansion and development forced Siza Water to develop the Potable Purification section, enabling the plant's water recycling portion to distribute potable water.

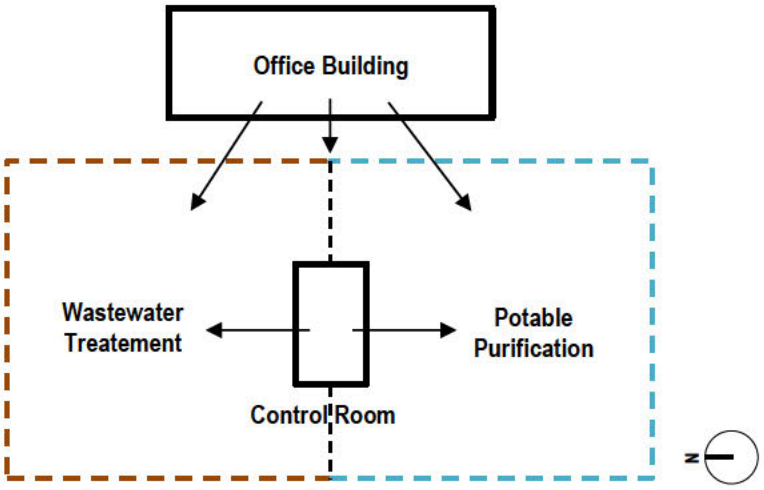



*Figure 59. Site Arrangement (Author, 2023)*

The rectangular, face brick office building is immersed within the natural environment, surrounded by nature, overlooking the entire plant whilst housing the offices, boardroom, ablutions, kitchen, laboratories and workshop facilities. A pathway leading towards the central entrance of the building from the parking lot is lined with rows of trees, allowing one to engage with nature upon arrival. A main staircase further allows one to enter the central entrance, offering various access routes to the building. The entry is flanked on either side by the multiple facilities mentioned above; however, once inside, one feels disorientated as there is no reception area or guided experience, and one is faced with a blank wall leading to a series of ablutions. The facility complies with the Blue Drop and Green Drop Certification, which refers to meeting the standards of the water treatment and distribution systems as well as sewage treatment and reticulation systems (Siza Water, 2021). The major accredited laboratories within the building conduct tests daily and weekly to ensure the water quality and PH levels are up to standard. Furthermore, the boardroom is used to host meetings, staff training and team-building courses, and the workshop facilitates the equipment, tools, fixtures etc., that the plumbers and pump station fitters require for onsite and offsite repairs as the Plant is the mother site for Siza Water.

### 4.3 Wastewater Treatment & Potable Purification Process

The wastewater treatment process begins with the small pump stations located around the Ballito region; these pump stations feed the big pump stations, which transfer the water to the head of works situated at the Plant. The head of works has two modules: a mechanical screen and a manual screen that traps debris, bottles, rags, etc., and consists of a large screen to trap the bigger dirt and a finner screen to catch the smaller dirt. A screen compactor gathers all dirt and grit and then pushes it into two separate skips for collection, or the process is done through a manual collection using a housekeeping team. The approach evades disrupting the flow of water and avoids blockages in the pumps as the water advances. The head of works also consists of a balancing tank used as a reserve tank due to the fluctuation of the flow from high to low peaks. When the inflow is at a high peak at the inlet, the sluice regulates the flow, and the water is diverted to the balancing tank and overflows into the emergency dam.

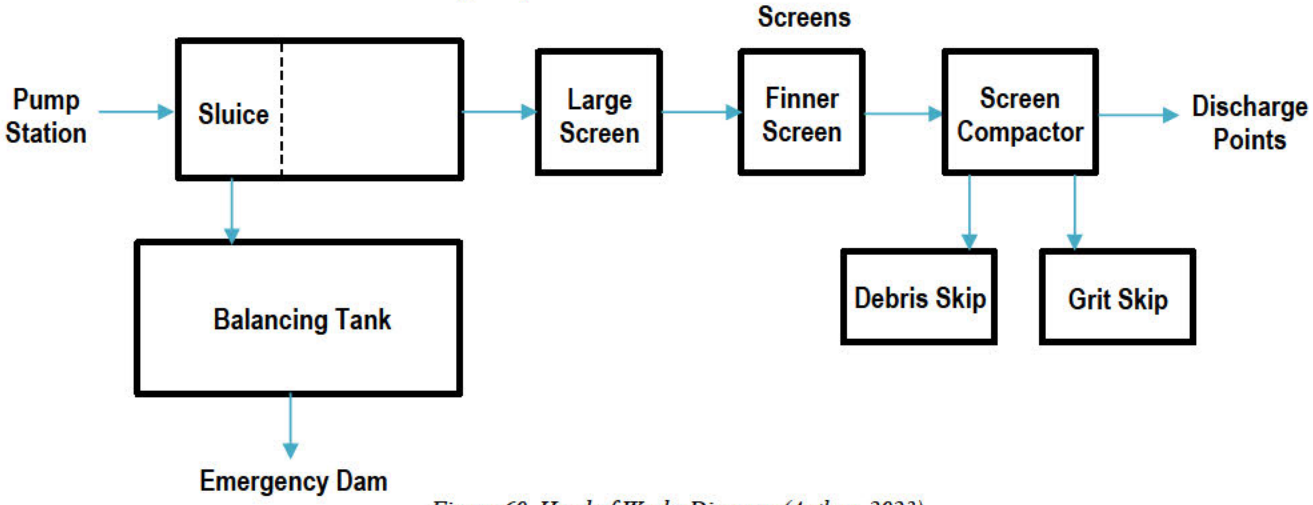



*Figure 60. Head of Works Diagram (Author, 2023)*

Once the water is rid of the debris, it moves to an inlet channel where the inflow meter measures the quantity of water that enters the system per second. The water passes to discharge points and into the three aeration tanks, where daily readings and analyses are taken to determine the amount of concentrated sewer, ammonia etc., needed to add to the tanks, ensuring the controlled bacteria are in good shape to clean the water. Turbines in the aeration tanks that are 10m deep constantly circulate oxygen, giving the bacteria enough air to live and thrive on the water's organic matter. The water moves to the eight clarifier tanks that trap the remaining solid particles at the bottom of the tank, which is 10m deep, and pump the solids back into the system as active sludge to break down ammonia. However, some of the active sludge is wasted and transferred to drying beds and

sludge ponds as part of the desludging process. The drying beds consist of stones at the bottom and river sand above, separating the sludge into water that percolates to the bottom and solids that remain on top. The drying beds emit an undesirable smell which discourages someone from approaching the beds; however, powdered lime sprinkled over the beds mitigates the scent. The clear water at the top of the clarifiers, known as supinated water, overflows and moves towards the final conduct tank, where chlorine chips are added to disinfect the water from the bacteria.

*Figure 62. Aeration Tanks (Author, 2023)*

*Figure 63. Drying Beds (Author, 2023*

*Figure 61. Clarifier Tank (Author, 2023)*

*Figure 64. Chlorine Chips (Author, 2023)*

The water is pumped into the final effluent tank, where chlorination occurs, and the structure is designed in a zig-zag formation due to chlorine needing contact time to function. Therefore, the zig-zag design creates a delay, increasing the retention time to allow the chlorine to make contact with the water particles. Pre-2015, the supinated water would enter a maturation pond for final polishing before entering the river system; however, the water transfers to the Water Re-use Plant from the final effluent tanks due to the new Potable Purification section developed post-2015. The chlorinated water from the final effluent tanks is stored in 2 tanks called Mini Apollo 1 and Mini Appollo 2 and then goes through sand filtration. Once complete, the water is filtered, and Ultra Filtration feeder tanks send it for Ultra Filtration processing, where the water flows to 2 reverse

osmosis tanks. The third reverse osmosis tank treats and filters the Brime and pumps it back into the system. The final stage uses Ultra Violet light to treat the water, and the now potable water is stored in 2 reservoirs, Appollo 1 and Apollo 2, ready to be distributed back to the Ballito area.

*Figure 65. Final Effluent Tank (Author, 2023)*

*Figure 66. Inside the Water Re-use Plant (Author, 2023)*

### 4.4 Conclusion

The Siza Water Recycling Plant provides the research with a clear understanding and insight into wastewater purification, demonstrating the various processes taken to ensure safe potable water for areas in Ballito. The guided tour of the Plant is informative and expresses the importance of treating the water before it enters the environment and mitigating water scarcity. The spatial organisation of the site is structured in chronological order creating a linear experience as one moves from the main office building at the top to the final effluent tank at the bottom. However, the Plant lacks a public interface and architectural infrastructure to attract and encourage visitors to experience the water treatment process. Furthermore, there is minimal visibility of the plant from the M4, which reduces the visual appeal to attract visitors, and the occasional smell of sewage creates an uncomfortable experience.

The principles extracted from the case study to inform the proposed design included the importance of considering the environmental impact of the water, the method of treating wastewater for potable use, the spatial organisation of the Plant and the facilities to cater for staff and visitors. The study shall consider the shortfalls of the Plant as a source for improvement within the design development, increasing the architectural infrastructure and facilities to create a public environment where learning about water can occur.

# Chapter 5: Analysis and Discussion

## 5.1 Introduction

This chapter of the research analyses and discusses the empirical data gathered through 3 semi-structured interviews of individuals at Siza Water in Ballito. The individuals were selected due to their understanding and experience in the water sector, as the research utilises a purposive sampling technique. The author recorded the interviews digitally and transcripted them as part of the data collection process with signed consent from the interviewees.

The interview questions were set on three themes, structured similarly to the literature review, to form a coherent link between the empirical and non-empirical data. The first theme discusses **Water Security in Durban**, obtaining information on the current water infrastructure, and their views on the concerns about water security. The next theme was the **Recycling Facility** to develop an architectural response to the research problem and identify the treatment processes and outcomes of water recycling. The last theme concluded with a discussion on **Water Education** that Siza Water provides by creating community awareness and educational activities for scholars at the Plant.

The collation of the data will be presented at the forefront of the chapter in order for the analysis and discussions to occur and, thereafter, for conclusions to be formed. This assists the reader in understanding the data collected and allows them to refer to the information during the analysis. The information gathered from the interviews will be analysed and compared to find similarities and differences regarding the themes in the interview schedule.

## 5.2 Summary of Interviews

**Research Interview A:**

**Icebreaker:**

Please tell me about yourself. Where did you study? What are your qualifications? What is your position at Siza Water? Etc.

- Process and Quality Supervisor at Siza Water.

**<u>Theme 1:</u> Water Security in Durban**

Topics Discussed:

Water Infrastructure, Water Technology, Water Scarcity, and Water Importance.

1. What are your views on the current water infrastructure in Durban?

- Unfortunately, we, as Siza Water, cannot speak on behalf of Durban as an entirety. However, following the recent floods it has highlighted areas that are in need of improvement.

2. Do you believe there are water security concerns in Durban?

- Yes, Water Security concerns the entire country and not just a particular province.

3. Do you think the importance of water is acknowledged among society in Durban? Explain your answer.

- Yes, it is especially following the recent floods that occurred in 2022, where numerous lives were affected throughout Durban.

**<u>Theme 2:</u> Recycling Facility**

Topics Discussed:

Spatial Arrangement/Requirement, Treatment/Recycling Processes, Challenges and Water Production.

4. What is the process of treating/recycling water to produce potable water?

- The process of treating wastewater and recycling it into potable water consumption involves sand filtration, ultrafiltration, reverse osmosis, ultraviolet radiation and chlorine dosing.

5. How much water does the plant produce on a daily average? Both potable and non-potable.

- On average, the plant produces 3 megalitres per day.

6. What are some of the challenges faced in treating/recycling water?

- We at Siza Water cannot disclose the challenges we face at the Plant.

7. Do you know of any innovative alternate water recycling methods that can contribute to improving the water supply?

- Sea Water Desalination.

8. What spaces are needed in a facility to treat/recycle water? E.g. Laboratory, Testing Station.

- A footprint for the recycling equipment.
- Laboratory.
- Control room.
- Chemical dosing stations,
- Storeroom and pump stations.

**<u>Theme 3:</u> Water Education**

Topics Discussed:

Community Involvement, Community Awareness, Educational Activities and Physical Involvement.

9. How does Siza Water create community awareness of water education?

- We create awareness concerning water-related matters via Social media platforms and community programmes.

10. Are educational activities offered for visitors/schools at the Recycling Plant? If Yes, are they physically involved? Please explain the activities.

- Plant tours are allowed for visitors; however, they will not be physically involved in activities due to safety risks.

**End of Interview A.**

**Research Interview B:**

Please tell me about yourself. Where did you study? What are your qualifications? What is your position at Siza Water? Etc.

- Senior Process Controller at Siza Water.
- Working at Siza Water for 14 years.
- Chemical Engineer Student with N5.
- Studied at eThekwini FET.

**<u>Theme 1:</u> Water Security in Durban**

Topics Discussed:

Water Infrastructure, Water Technology, Water Scarcity, and Water Importance.

11. What are your views on the current water infrastructure in Durban?

- Durbans water infrastructure is not efficient since last year, March 2022, during the floods, e.g. Tongaat area and surroundings had no water for months.

12. Do you believe there are water security concerns in Durban?

- As far as I know, the entire South Africa is facing water security concerns, not just Durban in particular.

13. Do you think the importance of water is acknowledged among society in Durban? Explain your answer.

- Well, I do not think Durban officials are doing enough to educate society in Durban regarding the importance of water.

**Theme 2:** **Recycling Facility**

Topics Discussed:

Spatial Arrangement/Requirement, Treatment/Recycling Processes, Challenges and Water Production.

14. What is the process of treating/recycling water to produce potable water?

- Treating wastewater and recycling it into potable water involves pressure sand filters, UF process, reverse osmosis and UV light.

15. How much water does the plant produce on a daily average? Both potable and non-potable.

- Recycling Water Plant – an average of 3 megalitres per day.
- Wastewater Plant - an average of 5-7 megalitres per day.
- The Plant capacity holds approximately 12 megalitres of water within the aeration tanks.

16. What are some of the challenges faced in treating/recycling water?

- Unfortunately, the challenges we face cannot be disclosed.

17. Do you know of any innovative alternate water recycling methods that can contribute to improving the water supply?

- Sea Water Desalination.

18. What spaces are needed in a facility to treat/recycle water? E.g. Laboratory, Testing Station.

- An accredited laboratory.
- MCC room to serve as a database to conduct readings and to store the equipment.
- Hazardous chemicals room and chemical pumping zone.

- Offices.
- Workshop
- Potentially standby houses to ensure someone is always on-site for emergencies.

**<u>Theme 3:</u> Water Education**

Topics Discussed:

Community Involvement, Community Awareness, Educational Activities and Physical Involvement.

19. How does Siza Water create community awareness of water education?

- We usually use social media platforms, e.g. local newspapers, Facebook, and Whatsapp.
- We have annual programs running where scholars get a chance to visit the plant, where we do induction and tour and are allowed to ask questions. From the Plant, the scholars are also taken to the pump stations around Ballito, where they are informed about how the pump stations work.

20. Are educational activities offered for visitors/schools at the Recycling Plant? If Yes, are they physically involved? Please explain the activities.

- Visitors get an opportunity to see our daily reclamation plant process and wastewater treatment works, where they become involved by asking important questions.

**End of Interview B.**

**Research Interview C:**

Interview C was conducted only on Theme 3, involving Water Education, to gain a further understanding of the programs offered by Siza Water.

**Icebreaker:**

Please tell me about yourself. Where did you study? What are your qualifications? What is your position at Siza Water? Etc.

- Public Relations Officer at Siza Water.
- Working at Siza Water for 14 years.
- National Diploma in Marketing.
- Studied through UNISA.

**Theme 3: Water Education**

Topics Discussed:

Community Involvement, Community Awareness, Educational Activities and Physical Involvement.

- Siza Water is a private-public partnership which signed a contract with the Elembe District Municipality to serve the Ballito district from Zimbali to Etete.
- As part of the agreement, we have to plough back the money to the community we serve. We have a number of community projects, one being compulsory, called the Siza Water Youth and Community Development Fund.
- A pool of money comes in every year that grows as the CPI increases every year, with 70% of the amount going towards student bursaries to produce graduates for the company and 30% going towards Ad Hoc organisations that request funding.

- We have annual school projects, and an event called Water Week that includes National Water Day, where we celebrate water in a very in-depth and thorough way, involving primary schools within our concession area.

- We invite 10 students selected from 7 public primary schools in the concession area and take them to a facility where we teach them about water education. We suggest to the schools that they send students that can grasp the information and take it back to educate their peers.

- We have activities in the form of competitions where we teach them about the water treatment process, for example, and get them actively involved in building a recycling plant from what they learnt.

- Every water week has a theme, so we hire individuals to teach the scholars about the theme of the year. For example, if the theme is trees, we hire an organisation suitable to provide in-depth information on trees.

- There isn't ample space to facilitate the students, so we have to book the boat house down the road for these events. Furthermore, there is no space to display or store the models the students build, so we ask them to take them back to the schools and take pictures of them.

- Another community awareness project is when we go out to areas where they have communal standpipes and speak to the community about water-saving tips due to the exploitation of the standpipes in these areas.

- We do road shows from time to time where we take a mater droplet mascot and go out and teach bystanders to save water; however, this idea is very time-consuming.

- For the close-knit community of Ballito, we have water-saving tips on our website, Facebook, and paper printing advertising in the North Coast Courier quarterly.

**End of Interview C.**

## 5.3. Analysis and Discussion of Findings

The following section seeks to engage with the responses from the discussions in relation to the literature review to find a correlation between the secondary data collected. The analysis will use the main topics of the interviews: Water Security, Recycling Facilities and Water Education as a basis of the discussion.

### Water Security

The theme of Water Security began with Interviewees A and B concurring with the lack of efficiency with the water infrastructure in Durban. Both respondents referred to the floods that occurred in March/April 2022, stating how they impacted people's lives in certain areas, with Interviewee B making an example of the Tongaat region that didn't have water for months. The floods mentioned further contributed to the degradation of the environment stemming from the water infrastructure. The second question posed to the respondents asked if they believe there are water security concerns in Durban. Interviewees A and B stated that not only does Durban have water security concerns, but South Africa as a country is struggling to meet water demands. The answers to both questions correlate with the literature review where the authors stress the water crisis faced by the country (Thakur, et al., 2019; Mutamba, 2019; Fisher-Jeffes, et al., 2017). The last question in this theme question of the importance of water is acknowledged among society in Durban. Interviewee A response affirmed the devastation of the floods where numerous lives were affected throughout the city, the importance of water is now acknowledged. Interviewee B suggested that Durban officials need to do more to promote the importance of water to the citizens. The literature review supported these answers in recognising the problem and showed the steps taken by the eThekwini Water and Sanitation (EWS), in collaboration with the International Water Ambition of the Netherlands, to develop a framework to create a Water Sensitive City by integrating Sustainable Urban Design Strategies (Meulen, 2020).

**Recycling Facilities**

The next topic of discussion was the Recycling Facilities at the Siza Water Plant. The first question was to identify the process taken to treat/recycle water to produce potable water. Interviewees A and B expressed the need for the water to go through different filtration processes, reverse osmosis, and UV light treatment. Although the process is regarding wastewater, similarities can be drawn from the rainwater harvesting process of producing potable water. Both needed a source of filtration, whether sand filters for wastewater or sediment filters for rainwater and UV light, as the last process of disinfecting the water before it is deemed potable. Interviewees A and B both stated the plant produces, on average, 3 megaliters of potable water per day. During the Plant tour, the tour guide informed the author that the plant must produce 2.3 megaliters per day. Unfortunately, both respondents could not disclose the challenges faced by the plant in the next question; however, they did suggest seawater desalination as an innovative water recycling method to consider. The last question was regarding the spaces needed at the Plant as part of the treatment and recycling process. From the responses, an accredited laboratory, control room and hazardous chemical room were similar spaces mentioned by the respondents. Interviewee B further elaborated on the need for support spaces such as offices, a workshop standby houses to ensure someone is always on-site for emergencies. The answers assist in developing the accommodation schedule and the experience of the space through a Phenomenological lens supported by the Precedent Studies.

**Water Education**

The final topic of discussion referred to Water Education provided by Siza Water as part of the development of water awareness. Interviewee C was best suited and recommended to provide in-depth information as the Public Relations Officer of Siza Water. The first question was how Siza Water creates community awareness of water education. All 3 interviewees mentioned social media as a form of education. Interviewee C expounded on examples of creating water awareness through road shows with a water droplet mascot, going out to communities, and providing them with talks on water-saving tips. Furthermore, Interviewee C explained Siza Water's agreement with the Elembe district municipality regarding initiating and implementing community-based programs. The last question asked if educational activities are offered to visitors or scholars. All 3 interviewees stated the Plant tour of the treatment process. Interviewee C explained the annual

school visits of the 10 students from the 7 public primary schools in the concession area during Water Week. The students engage in talks, tours, competitions and activities, such as building a recycling plant which gets the scholars actively involved and develops their understanding and knowledge of water and the surrounding environment, responding to Experiential Learning Theory and Place-based Education. However, Interviewee C mentions that Siza Water hires the boat house in Ballito to facilitate the scholars and Water Week as there is insufficient space at their premises. Furthermore, there is no display space for the models built by the scholars resulting in the schools taking it for display. The proposed design can learn from this and accommodate these spaces to display the models and facilitate many scholars or visitors.

### 5.4 Conclusion

In conclusion of the chapter, the primary data obtained from the semi-structured interviews provided in-depth information regarding the topics of the study. The findings correlated with the secondary data by affirming the water security concerns stated in the research problem and provided insight into the recycling facilities and processes to treat and recycle water. The identification of the spaces required assists in informing the facilities in the proposed architectural design. The various community-based programs and scholarly involvement offered by Siza Water promote water's importance, increase water awareness for citizens and develops a tight-knit community where everyone can learn together. The information gathered, analysed and synthesised from the findings will be concluded in the next chapter, and recommendations will be developed towards designing a Learning Centre.

# Chapter 6: Conclusion and Recommendations

## 6.1 Introduction

The research began with developing the topic's background information, leading to defining the research problem. The study aimed to explore the relationship between water security and architecture to develop principles of a learning centre in Durban. The exploration of the previous chapters set out to address the research questions and achieve the objectives instated in chapter 1 to ensure the aim of the study can be achieved. The dissertation's hypothesis: A Learning Centre can provide the city of Durban with the knowledge and ability to sustainably harvest and recycle water through informal and active learning environments, will be verified before the conclusion. The accumulation of the previous chapters has provided the information required through the research findings, which will be used to develop the design recommendations and the study's conclusion in this chapter.

## 6.2 Recommendations

The information gathered from the data collection process explored the concepts of Water Security, Water and Architecture and Nature and Learning Environments through the theoretical framework. The design drivers below were derived from the data collection to respond to the research problem.

The design drivers are as follows: Architecture as a Living System, Interactive Public Engagement, Water Sensitive Design and Connection between Man and Nature.

### 6.2.1 Architecture as a Living System

The driver was developed through the findings in the literature review to connect water and architecture, using water as the medium to create a meaningful response to environmental and humanistic needs. The water acts as the veins of the built form, creating fluidity between the spaces and showcasing the visible treatment of the water. The built form becomes a physical source of education for the visitors connecting them to the spaces by activating their multi-sensory experiences with water. Learning from the ancient methods of ensuring water for the community, the built form controls the water through materiality and conserves it through the various water

management systems explored in the literature review. The Frick Environment Center and Sydney Park Water Re-use Project express the interactions with the water through the rain veil and active park environment with constructed wetlands that educate and inform visitors on water treatment.

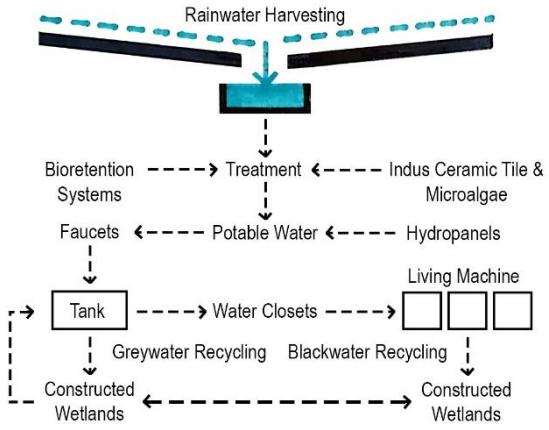



*Figure 68. Water Management Processes (Author, 2023)*

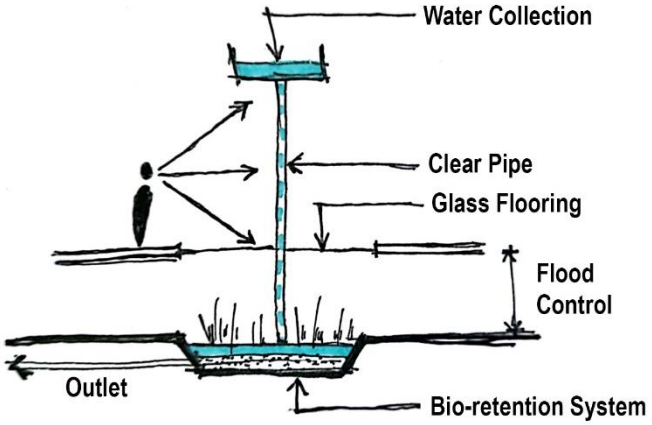



*Figure 67. The Built Form as a Learning Source (Author, 2023)*

### 6.2.2 Interactive Public Engagement

Experiential Learning Theory expresses the importance of the social environment and interactions between different age groups leading to greater knowledge production through lived experiences that involve human contact and communication. The driver is based on this ideology and promotes an environment where individuals can gather, relax and share knowledge. The literature review, 3 precedents and fieldwork depicted the importance of the social environment to evoke learning through visual connections, increasing chance encounter and the diversity of the learning spaces.

Furthermore, the driver promotes active learning by encouraging the public to learn about water management through physical engagement, such as interactive boards and displays or making a wetland adapted from the information gathered through the fieldwork on Siza Waters water education programs. Informal learning occurs through social interactions in the park setting, similar to the Sydney Park Water Re-use Project, engaging with the water treatment and purification process through leisure, creating memorable experiences. Increasing public engagement and community involvement will promote a tight-knit community similar to the Ballito region. The research showed that the flexibility of the spaces noted through the vertical school concept could integrate community development through events, workshops and markets.

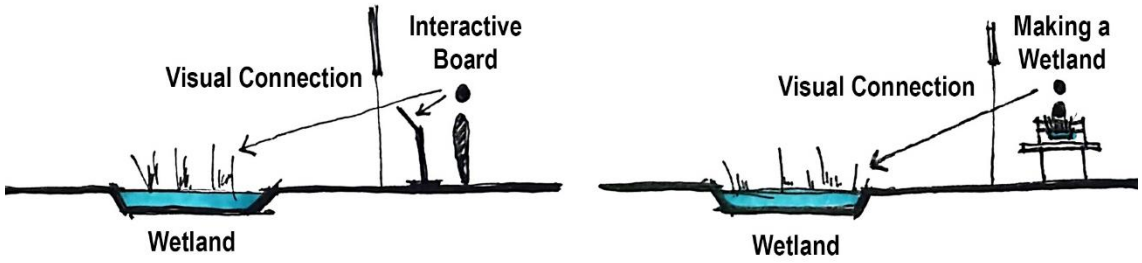



*Figure 69. Active Learning Environment (Author, 2023)*

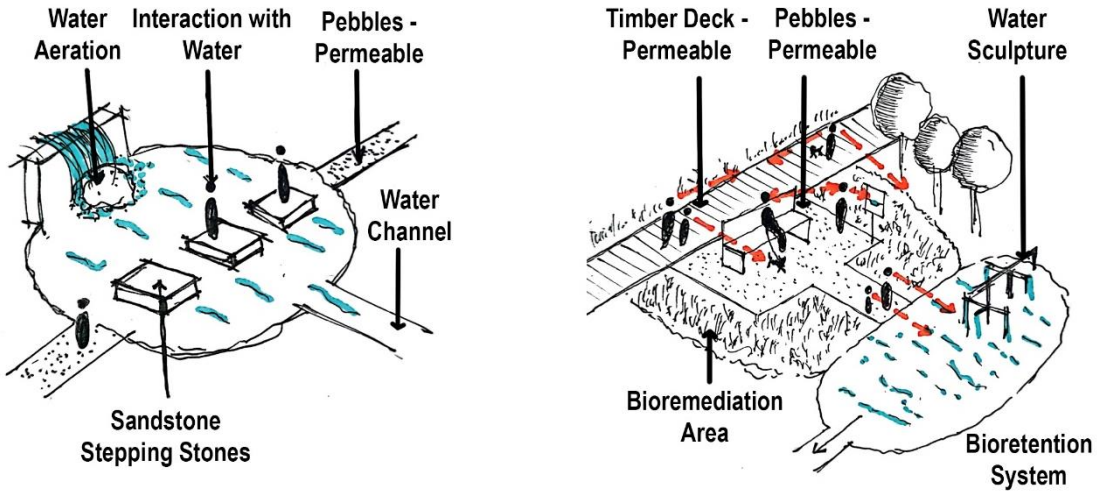



*Figure 70. Informal Learning Environment (Author, 2023)*

### 6.2.3 Water Sensitive Design

The Romans depicted the deep affiliation between humans and water through the baths and decorative fountains. Furthermore, the research explored the impact of water on humans expressing the therapeutic effects, the visual appeal and the sense of intrigue, creating a natural design to feel and touch the water. The research depicted the Sustainable Urban Design Strategies (SUDS), which include bioretention and biofiltration systems in the literature review that contribute to addressing the research problem.

Water Sensitive Design is a macro and micro design strategy that increases the blue and green spaces, improving the urban fabric. The Sydney Park Water Re-use Project promotes the driver by revitalising the lost space into a vibrant urban park for the surrounding community. The park used the affiliation to water to attract people by implementing a series of water bodies. The built form becomes a part of the driver, working in tandem with the driver Architecture as a Living System,

increasing the permeability of the surfaces to reduce surface runoff and diverting water to the different bioretention and biofiltration systems.

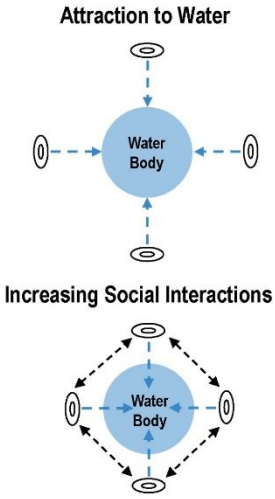



*Figure 72. Humans Affiliation with Water (Author, 2023)*

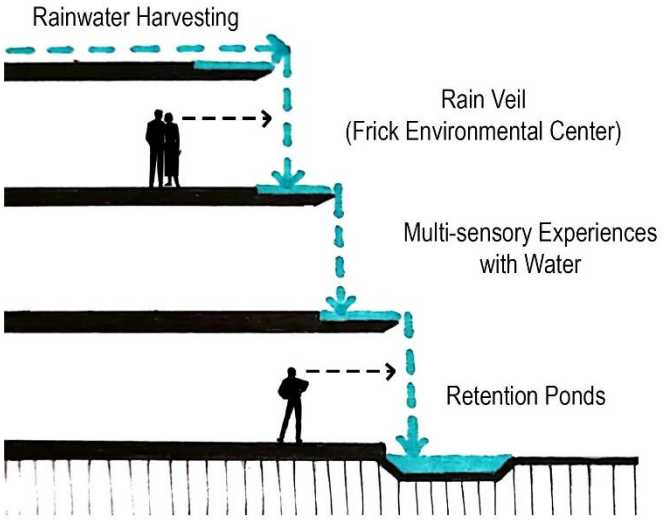



*Figure 71. The Built Form as a Water Senstive Design (Author, 2023)*

### 6.2.4 Connection between Man-Nature

The driver is supported by the writings of Stephen Kellert (1997), who asserts that humans have a deep affiliation with nature and, when in contact physically, emotionally and intellectually, benefit their lives. The theory of Environment Sustainability supported by Biophilic Design justifies the need for man and nature to reconnect, ensuring architecture that compliments the natural environment internally and externally. The VUC Syd Education Centre and Frick Environmental Centre both demonstrate the concept of openness and transparency between the indoor and outdoor environment. The vertical school concept explored in chapter 2 supports the design driver by allowing individuals to engage with nature at different levels of the building, creating a strong connection between the inside and outside.

The design driver can be implemented through the built form engaging with the outdoors, as seen in figure 74, creating open and transparent facades and using water for passive cooling and gatherings, similar to the stepped wells in India. Moreover, retention ponds can activate demonstration and vegetable gardens where the public can participate and understand the water's importance for food security, depicted in the Frick Environmental Centre. The Activity Pockets principle stated by Alexander et al. (1977) can be implemented within the design driver by

activating the edges of the site, providing a natural spot for people to linger and interact. These can potentially spill over and overlap the activities into the central space. The principle was adopted where the wetland park and leisure activities activate the edges of the site through these interactive areas and recreation spaces; the spaces overlap with the learning centre, linking the built form and the natural environment to ensure water security.

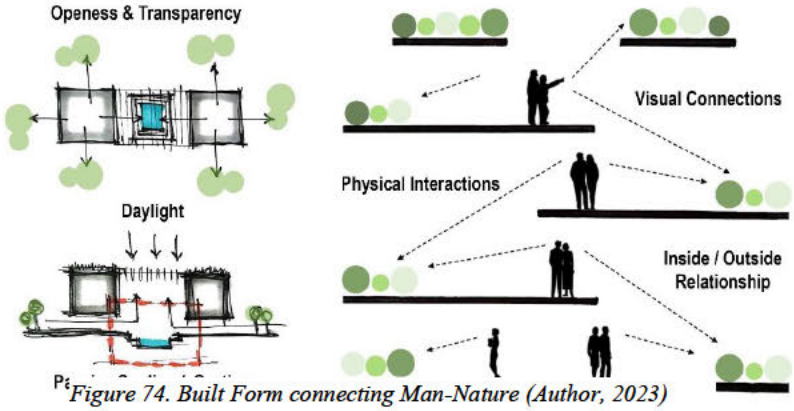



*Figure 74. Built Form connecting Man-Nature (Author, 2023)*

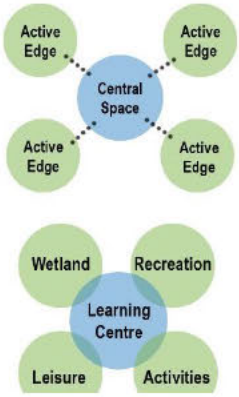



*Figure 73. Activity Pockets (Author, 2023)*

## 6.3 Conclusion

The research findings of the dissertation demonstrate the role of architecture and the natural environment as a response to the research problem. Furthermore, the findings portray the promotion of water's importance to society through awareness and education. Therefore, to conclude the study, the recommendations, based on the various research outcomes, prove the hypothesis stated by the researcher to be valid; thus, the design of a learning centre that ensures water security and promotes water education can be achieved.

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UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

14 December 2022

**Kreolin Lyle Naicker (216006406)**
**School of Built Env & Dev Stud**
**Howard College**

**Dear KL Naicker,**

**Protocol reference number:** HSSREC/00005129/2022
**Project title:** An exploration of water reclamation through architecture: Towards a hydrological education centre in Durban
**Degree:** Masters

## Approval Notification – Expedited Application

This letter serves to notify you that your application received on 06 November 2022 in connection with the above, was reviewed by the Humanities and Social Sciences Research Ethics Committee (HSSREC) and the protocol has been granted **FULL APPROVAL.**

**Any alteration/s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach and Methods must be reviewed and approved through the amendment/modification prior to its implementation. In case you have further queries, please quote the above reference number. PLEASE NOTE: Research data should be securely stored in the discipline/department for a period of 5 years.**

This approval is valid until 14 December 2023.
To ensure uninterrupted approval of this study beyond the approval expiry date, a progress report must be submitted to the Research Office on the appropriate form 2 - 3 months before the expiry date. A close-out report to be submitted when study is finished.

HSSREC is registered with the South African National Research Ethics Council (REC-040414-040).

Yours sincerely,

[redacted]

---

**Professor Dipane Hlalele (Chair)**

**/dd**

# COLLEGE OF HUMANITIES
## POSTGRADUATE AND RESEARCH OFFICE

*(THIS FORM IS TO BE COMPLETED THREE MONTHS BEFORE SUBMISSION OF MASTERS DISSERTATION, AND 6 MONTHS BEFORE SUBMISSION OF PHD THESIS, AND HANDED IN AT COLLEGE POSTGRADUATE OFFICE)*

**CONFIRMATION OF INTENTION TO SUBMIT THESIS/DISSERTATION**

**NAME OF STUDENT:** Kreolin Lyle Naicker

**STUDENT NUMBER:** 216006406

**DEGREE :** Master of Architecture (MARCP)

**SCHOOL:** Built Environment and Development Studies

**NAME OF SUPERVISOR:** Juan Solis-Arias

**NAME OF CO-SUPERVISOR:** n/a

**TITLE OF THESIS/DISSERTATION:** An exploration of Water Reclamation through Architecture: towards a Hydrological Education Centre in Durban.

**DATE OF INTENTION TO SUBMIT:** 16 January 2023

**POSTAL ADDRESS:** 37 Allenby Lane, 30 Evergreen Estate, Malvern, 4093

**TELEPHONE NUMBER:** n/a

**CELLPHONE** [redacted]

**E-MAIL ADDRESS:** 216006406@stu.ukzn.ac.za / kreolin4@gmail.com

**CANDIDATE'S SIGNATURE:** [redacted] **DATE** 2022/09/29

**SUPERVISOR'S SIGNATURE:** [redacted]

**DATE:**

CO-SUPERVISOR'S SIGNATURE:.....DATE:.....

# Digital Receipt

This receipt acknowledges that Turnitin received your paper. Below you will find the receipt information regarding your submission.

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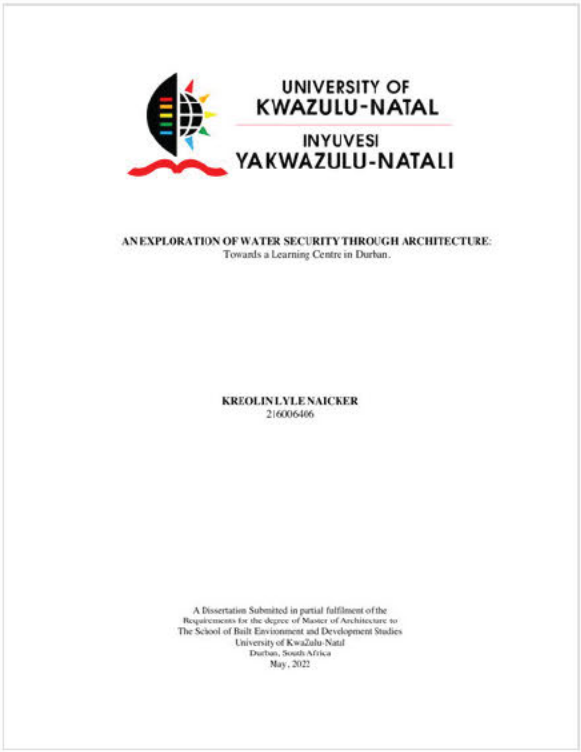

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

AN EXPLORATION OF WATER SECURITY THROUGH ARCHITECTURE:
Towards a Learning Centre in Durban.

KREOLIN LYLE NAICKER
216006406

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
University of KwaZulu-Natal
Durban, South Africa
May, 2022

siza water
A **SAWW** Company

21 September 2022
Ref. no: 1973/Tech/CK

Siza Water (RF) (Pty) Ltd
Co. Reg. No. 1998/19209/07
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PO Box 1635, Ballito, 4420, South Africa
Tel: +27 (0) 32 946 7200
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Fax (Customer Service): +27 (0) 32 946 3211
www.sizawater.com

**Reference**: An exploration of Water Reclamation through Architecture: towards a Hydrological Education Centre in Durban.

To Whom it May Concern

This letter is to indicate that I, Chenelle Kalopdeo, the Process & Quality Supervisor of Siza Water, have been in conversation with Kreolin Lyle Naicker about gatekeeper authorization at the institution. I can affirm that we have no objections to his carrying out his investigation on the condition that the appropriate times for the semi-interviews be evident in advance. He also requested clearance to use the recycling treatment plant as a case study to observe and photograph the facilities to assist with the research, which I acknowledge. We would also advise him on the interviewees relevant to his studies. Kreolin is welcome to schedule his research in the next three months, and we are pleased to assist him.

If you have any queries, please contact me directly.

Regards

[redacted]

**CHENELLE KALOPDEO**
**PROCESS & QUALITY SUPERVISOR**

**SIZA WATER RF (PTY) LTD**
**P.O. BOX 1635. BALLITO 4420**
**TEL:** 032 -946 7200
**FAX:** 032 -946 2188
**Co. Reg.** 1998 19209/07

**Appendix One: Semi-structured Interview Schedule**


**Researcher: Kreolin Lyle Naicker**

**Research Topic:** An Exploration of Water Security through Architecture: Towards a Learning Centre in Durban

**Interviewee:** Professionals at Siza Water, Ballito.

**Introduction**

I want to express my appreciation for taking the time to engage in this interview. The objective of the interview is to gather information for my master's research project based on your experiences, views, and insights. The research explores the relationship between water reclamation and architecture to develop principles of a Hydrological Education Centre in Durban. The enhancement of water education and awareness of water's importance is also critical to the research.

**Icebreaker:** Please tell me about yourself? Where did you study? What are your qualifications? What is your position at Siza Water? Etc.

**Questions**

*In the Literature Review, concerns pinpoint the issues of the availability of clean water in Durban for various reasons such as urbanisation, economic growth and climate change. The recent floods resulted in most areas being left with no water for days and weeks due to damage to the ageing water infrastructure, significantly impacting people's mental and physical health.*

**Theme 1: Water Security in Durban**

- **Water Infrastructure**
- **Water Technology**
- **Water Scarcity**

- **Water Importance**

**Type of Questions**

1. What are your views on the current water infrastructure in Durban?
2. Do you believe there are water security concerns in Durban?
3. Do you think the importance of water is acknowledged among society in Durban? Explain your answer.

**Theme 2: Recycling Facility**

- **Spatial Arrangement/Requirement**
- **Treatment/Recycling Processes**
- **Challenges**
- **Water Production**

**Types of Questions**

4. What is the process of treating/recycling water to produce potable water?
5. How much water does the plant produce on a daily average? Both potable and non-potable.
6. What are some of the challenges faced in treating/recycling water?
7. Do you know of any innovative alternate water recycling methods that can contribute to improving the water supply?
8. What spaces are needed in a facility to treat/recycle water? E.g. Laboratory, Testing Station.

**Theme 3: Water Education**

- **Community Involvement**
- **Community Awareness**
- **Educational Activities**
- **Physical Involvement**

**Types of Questions**

9. How does Siza Water create community awareness of water education?
10. Are educational activities offered for visitors/schools at the Recycling Plant? If Yes, are they physically involved? Please explain the activities.

**Conclusion:** Thank you for your time and insight on the topic. Do you feel there is any further information that can assist me with my research?

**INFORMED CONSENT**

**Information Sheet and Consent to Participate in Research**

Date:

Dear Interviewee

My name is Kreolin Lyle Naicker (Student Number - 216006406) from the School of the Built Environment and Development Studies. Programme of Masters in Architecture at the University of KwaZulu-Natal, Durban.

You are being invited to consider participating in a study that involves research on an exploration of water security through architecture, towards a learning centre in Durban. The aim and purpose of this research is to explore the relationship between water security and architecture to develop principles of a learning centre in Durban. Furthermore, the research looks to increase public awareness of the importance of water in society and promote the recycling and harvesting of water. The study is expected to enroll 1-5 participants from Siza Water based on their knowledge of water recycling. It will involve the following procedure of a semi-structured interview on the relevant themes of the study, including water security, recycling facilities and water education. The duration of your participation if you choose to enroll and remain in the study is expected to be 15-20 minutes via an in-person or online interview, depending on your availability.

There are no risks involved in the study. If you agree to partake in this interview, I hope that the information will be used to improve the built environment's ability to aid water recycling and improve the awareness and importance of water in society.

This study has been ethically reviewed and approved by the UKZN Humanities and Social Sciences Research Ethics Committee (approval number_____).

In the event of any problems or concerns/questions you may contact the researcher at **Cell:** [redacted]; **Email:** 216006406@stu.ukzn.ac.za / kreolin4@gmail.com or my supervisor, Mr Juan Solis-Arias, School of the Built Environment and Development Studies. University of KwaZulu-Natal, Durban. **Tel:** 031 260 2304; **Email:** solis@ukzn.ac.za or the UKZN Humanities & Social Sciences Research Ethics Committee, contact details as follows:

**HUMANITIES & SOCIAL SCIENCES RESEARCH ETHICS ADMINISTRATION**
Research Office, Westville Campus
Govan Mbeki Building
Private Bag X 54001
Durban
4000
KwaZulu-Natal, SOUTH AFRICA
Tel: 27 31 2604557- Fax: 27 31 2604609
Email: HSSREC@ukzn.ac.za

Please note:

- Your participation is entirely voluntary, and you are free to withdraw at any time. You will not be penalized for taking such an action.
- Your participation in the research is limited to this interview only, and there are no other expectations of you.
- There will be no costs or incentives for your participation in the research.
- Your views in this interview will be presented anonymously. Neither your name nor identity will be disclosed in any form in the study.

- The record as well as other items associated with the interview, will be held in a password-protected file accessible only to myself and my supervisors. After a period of 5 years, in line with the rules of the university, it will be disposed of by shredding or burning.
- You are aware that you have the option of allowing the interview to be recorded to ensure accurate recordings of your responses.
- You may be contacted for any possible follow- up queries, or to verify any interview transcripts.
- You are free to refuse to answer any question; or refuse to discuss a topic, without judgment or prejudice.
- You will be given access to all interview notes for verification, and all findings will be made available to you.
- If you agree to participate, please sign the declaration attached to this statement (a separate sheet will be provided for signatures)

---

**CONSENT**

I _____ (full name of participant) have been informed about the study entitled an exploration of water security through architecture, towards a learning centre in Durban by Kreolin Lyle Naicker.

I understand the purpose and procedures of the study.

I have been given an opportunity to answer questions about the study and have had answers to my satisfaction.

I declare that my participation in this study is entirely voluntary and that I may withdraw at any time without affecting any of the benefits that I usually am entitled to.

If I have any further questions/concerns or queries related to the study I understand that I may contact the researcher at (provide details).

If I have any questions or concerns about my rights as a study participant, or if I am concerned about an aspect of the study or the researchers then I may contact:

**HUMANITIES & SOCIAL SCIENCES RESEARCH ETHICS ADMINISTRATION**
Research Office, Westville Campus
Govan Mbeki Building
Private Bag X 54001
Durban
4000
KwaZulu-Natal, SOUTH AFRICA
Tel: 27 31 2604557 - Fax: 27 31 2604609
Email: HSSREC@ukzn.ac.za

Additional consent, where applicable

I hereby provide consent to:

Audio-record my interview / focus group discussion YES / NO

_____ _____
**Signature of Participant** **Date**

_____ _____
**Signature of Witness** **Date**
**(Where applicable)**

_____ _____
**Signature of Translator** **Date**
**(Where applicable)**

## INFORMED CONSENT

**Information Sheet and Consent to Participate in Research**

Date: 04/01/2023

Dear Interviewee

My name is Kreolin Lyle Naicker (Student Number - 216006406) from the School of the Built Environment and Development Studies. Programme of Masters in Architecture at the University of KwaZulu-Natal, Durban.

You are being invited to consider participating in a study that involves research on an exploration of water security through architecture, towards a learning centre in Durban. The aim and purpose of this research is to explore the relationship between water security and architecture to develop principles of a learning centre in Durban. Furthermore, the research looks to increase public awareness of the importance of water in society and promote the recycling and harvesting of water. The study is expected to enroll 1-5 participants from Siza Water based on their knowledge of water recycling. It will involve the following procedure of a semi-structured interview on the relevant themes of the study, including water security, recycling facilities and water education. The duration of your participation if you choose to enroll and remain in the study is expected to be 15-20 minutes via an in-person or online interview, depending on your availability.

There are no risks involved in the study. If you agree to partake in this interview, I hope that the information will be used to improve the built environment's ability to aid water recycling and improve the awareness and importance of water in society.

This study has been ethically reviewed and approved by the UKZN Humanities and Social Sciences Research Ethics Committee (approval number_____). HSSREC/00005129/2022

In the event of any problems or concerns/questions you may contact the researcher at **Cell:** [redacted] **Email:** 216006406@stu.ukzn.ac.za / kreolin4@gmail.com or my supervisor, Mr Juan Solis-Arias, School of the Built Environment and Development Studies. University of KwaZulu-Natal, Durban. **Tel:** 031 260 2304; **Email:** solis@ukzn.ac.za or the UKZN Humanities & Social Sciences Research Ethics Committee, contact details as follows:

**HUMANITIES & SOCIAL SCIENCES RESEARCH ETHICS ADMINISTRATION**
Research Office, Westville Campus
Govan Mbeki Building
Private Bag X 54001
Durban
4000
KwaZulu-Natal, SOUTH AFRICA
Tel: 27 31 2604557- Fax: 27 31 2604609
Email: HSSREC@ukzn.ac.za

Please note:

- Your participation is entirely voluntary, and you are free to withdraw at any time. You will not be penalized for taking such an action.
- Your participation in the research is limited to this interview only, and there are no other expectations of you.
- There will be no costs or incentives for your participation in the research.
- Your views in this interview will be presented anonymously. Neither your name nor identity will be disclosed in any form in the study.

- The record as well as other items associated with the interview, will be held in a password-protected file accessible only to myself and my supervisors. After a period of 5 years, in line with the rules of the university, it will be disposed of by shredding or burning.
- You are aware that you have the option of allowing the interview to be recorded to ensure accurate recordings of your responses.
- You may be contacted for any possible follow- up queries, or to verify any interview transcripts.
- You are free to refuse to answer any question; or refuse to discuss a topic, without judgment or prejudice.
- You will be given access to all interview notes for verification, and all findings will be made available to you.
- If you agree to participate, please sign the declaration attached to this statement (a separate sheet will be provided for signatures)

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**CONSENT**

I Sandile Shandu (full name of participant) have been informed about the study entitled an exploration of water security through architecture, towards a learning centre in Durban by Kreolin Lyle Naicker.

I understand the purpose and procedures of the study.

I have been given an opportunity to answer questions about the study and have had answers to my satisfaction.

I declare that my participation in this study is entirely voluntary and that I may withdraw at any time without affecting any of the benefits that I usually am entitled to.

If I have any further questions/concerns or queries related to the study I understand that I may contact the researcher at (provide details).

If I have any questions or concerns about my rights as a study participant, or if I am concerned about an aspect of the study or the researchers then I may contact:

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Additional consent, where applicable

I hereby provide consent to:

Audio-record my interview / focus group discussion (YES) / NO

[redacted] 04/01/2023

**Signature of Participant** **Date**

_____ _____

**Signature of Witness (Where applicable)** **Date**

_____ _____

**Signature of Translator (Where applicable)** **Date**

**CONSENT**

I Khosi Sihle Makenjwa (full name of participant) have been informed about the study entitled an exploration of water security through architecture, towards a learning centre in Durban by Kreolin Lyle Naicker.

I understand the purpose and procedures of the study.

I have been given an opportunity to answer questions about the study and have had answers to my satisfaction.

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Audio-record my interview / focus group discussion (YES) / NO

[redacted] 04/01/23

**Signature of Participant** **Date**

**Signature of Witness (Where applicable)** **Date**

**Signature of Translator (Where applicable)** **Date**

**CONSENT**

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Additional consent, where applicable

I hereby provide consent to:

Audio-record my interview / focus group discussion (YES)/ NO

[redacted]

**Signature of Participant** **Date**

**Signature of Witness (Where applicable)** **Date**

**Signature of Translator (Where applicable)** **Date**