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SPONGE PARK AS FLOOD-RESILIENT LANDSCAPE AT BERTAM LAKE, KEPALA BATAS, PULAU PINANG

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ABSTRACT

The research explores flood-resilient landscapes and the sponge city concept to address Malaysia's increasing urban flood risks due to climate change and rapid urbanisation. The lack of effective urban stormwater management in urban areas, especially in flood-prone regions, exacerbates both infrastructure damage and socio-economic impacts. Through the incorporation of blue-green infrastructure (BGI) and nature-based solutions (NBS) into urban design, this project investigates how sponge city concepts can alleviate these challenges. To find successful design elements such as permeable pavements, bioretention systems, rainwater harvesting, rain gardens, and green roofs, information was gathered through literature reviews and precedent studies. Results indicate that the sponge city concept provides strategies for a flood-resilient landscape. Thus, it promotes urban livability, sustain biodiversity, and increase flood resistance to Bertam Lake park. The research emphasizes that it is important for adaptive flood management techniques to be practiced to promote resilient and sustainable communities in Malaysia's urban landscapes.

Keywords: blue-green infrastructure (BGI), flood-resilient landscape, nature-based solutions (NBS), sponge city, urban stormwater management

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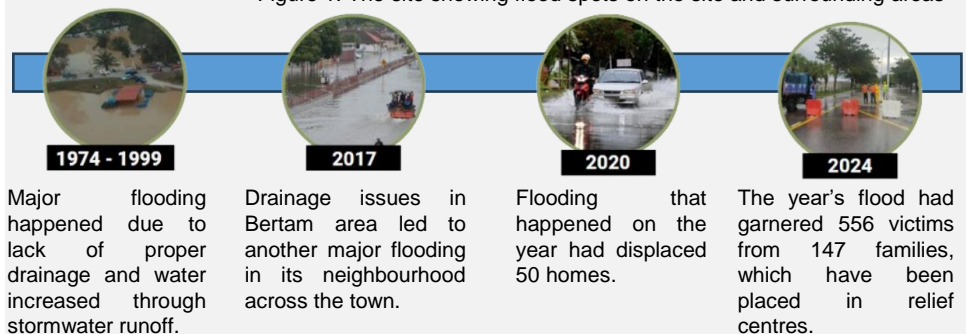
PROJECT INTRODUCTION

The project explores flood issues in an urban area of Malaysia and how a flood-resilient landscape, which is inspired by the sponge city concept can help mitigate the climate adversity. Two objectives are set for the research, which are to identify how flood-resilient landscape strategies can mitigate the impact of climate-related challenges, and second, to explore the integration of the sponge city concept into urban design, focusing on enhancing stormwater management. The site for the project is Bertam Lake park in Kepala Batas, Pulau Pinang. There is a significant benefit from this research as it is believed that sponge city can influence the future development of the urban landscape in Malaysia by enhancing its resilience against flooding (Ahmad & Ayob, 2023).

Flood Map and Timeline






Figure 1: The site showing flood spots on the site and surrounding areas



Site Issues

The followings are issues of the site and its surrounding area:

- 
RISING FLASH FLOOD
The site's surrounding has been noticing an increase of flooding.
- 
RAPID URBANISATION
Residential and commercial areas are being rapidly developed within Kepala Batas area.
- 
DAMAGED INFRASTRUCTURES
The flooding directly led to damage of important structures like highways and roads.

LITERATURE REVIEW

In response to increasing climate-related challenges, particularly urban flooding, the concept of flood-resilient landscapes has gained momentum as a sustainable approach to water-sensitive urban design. Central to this is the *sponge city* concept, which has emerged as a leading strategy in contemporary stormwater management. This literature review forms the theoretical foundation for the design proposal, which explores how sponge city principles can be adapted to the Malaysian context to develop a multifunctional, flood-resilient public space.

Drawing upon key studies, including Ferreira et al. (2021), Rau (2022), and Adedeji et al. (2019), this review examines the integration of nature-based solutions (NBS) such as permeable surfaces, wetlands, rain gardens, and green infrastructure to mimic natural hydrological processes in urban environments. These strategies aim to retain, absorb, and filter excess stormwater, ultimately restoring the urban water cycle to a more natural state. By emphasising both ecological performance and urban resilience, the sponge city model provides a practical and adaptable framework for landscape architecture in flood-prone areas like at Bertam Lake, Kepala Batas, Pulau Pinang.

RESEARCH METHODOLOGY

For the data collection, two methods were used: primary data and secondary data. The primary data is the on-site inventory using an observation checklist. An analysis from the observation was carried out to identify the site's opportunities and limitations. Meanwhile, the secondary data was taken from journal articles and government sources including the District Local Plan (RTD).

The collected data was analysed and synthesised to develop possible solutions or alternatives for the site to adapt a sponge park concept. Meanwhile, document analysis provides additional background and supporting information about the site (Figure 2). The analysis is presented in the following sub-sections according to the inventory attributes.

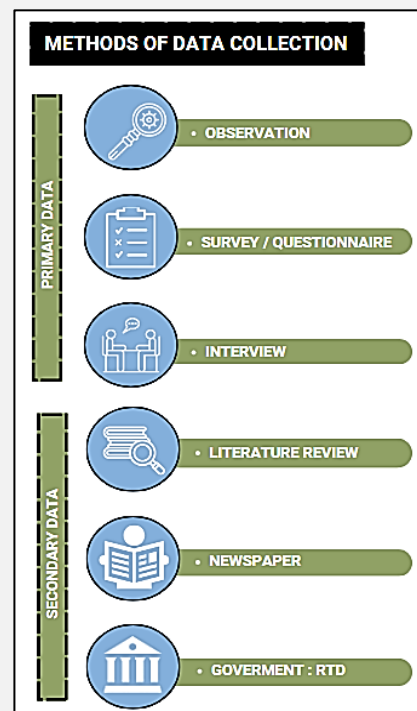


Figure 2: Data Collection Methods

PRECEDENT STUDIES

This section highlights landscapes that use the sponge city concept or the same design strategies.

i. Benjakitti Park is an urban park located on the site of a former tobacco factory. It has been transformed into a low-maintenance regenerative system that reduces the destructive force of stormwater, filters contaminated water, and offers much-needed wildlife habitat.



Figure 3: Benjakitti Park during dry season
(Authors, 2024)

ii. The Starry Sky Park in Shanghai is the world's largest sponge park. Located near the Shanghai Astronomy Museum in Lingang New City, it spans 54 hectares, including 16 hectares of water. The park features typical sponge city elements such as permeable pavements and green spaces that help purify, store, and reuse rainwater.



Figure 4: The Starry Sky Park
(<http://en.sasac.gov.cn/>)

SITE INVENTORY AND ANALYSIS

1. LANDSCAPE EVOLUTION

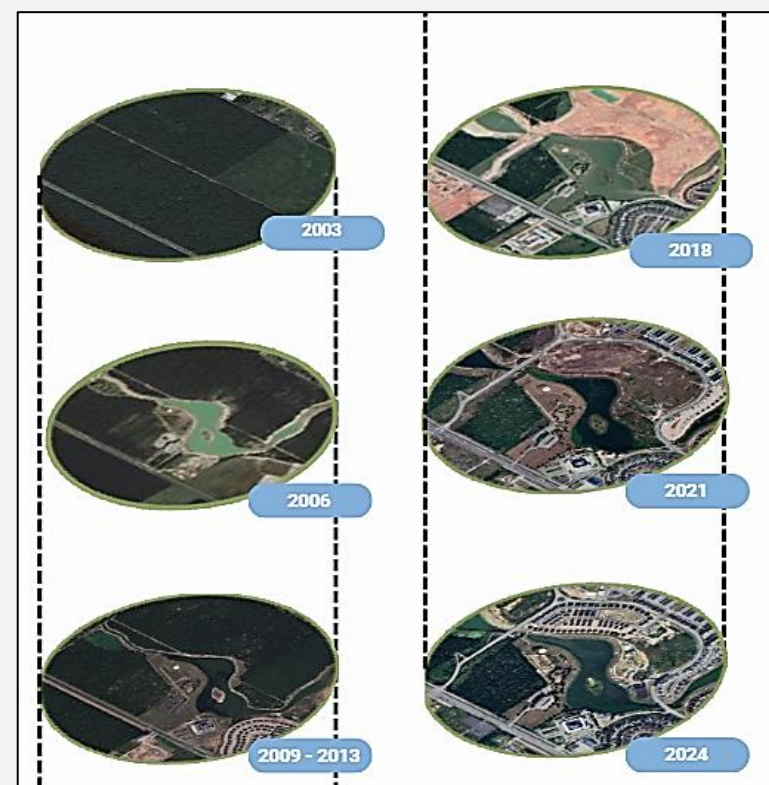


Figure 5: Landscape Evolution Timeline

SITE INVENTORY AND ANALYSIS

2. HYDROLOGY

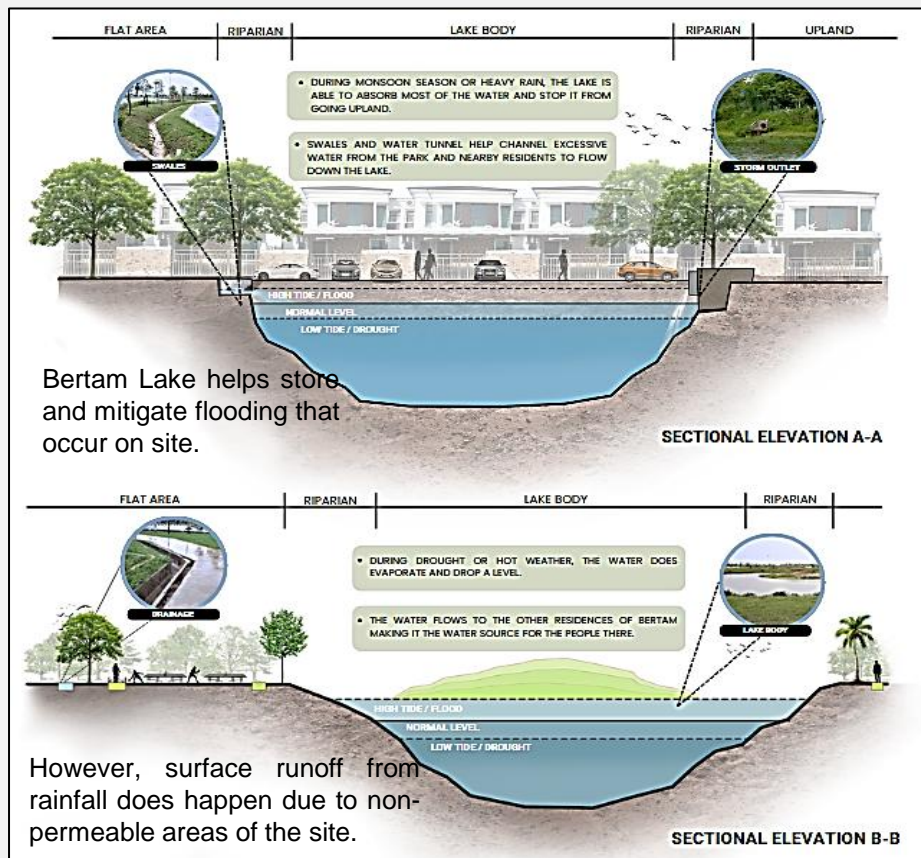


Figure 6: Sections showing the water level of the lake.

3. SOIL AND TOPOGRAPHY

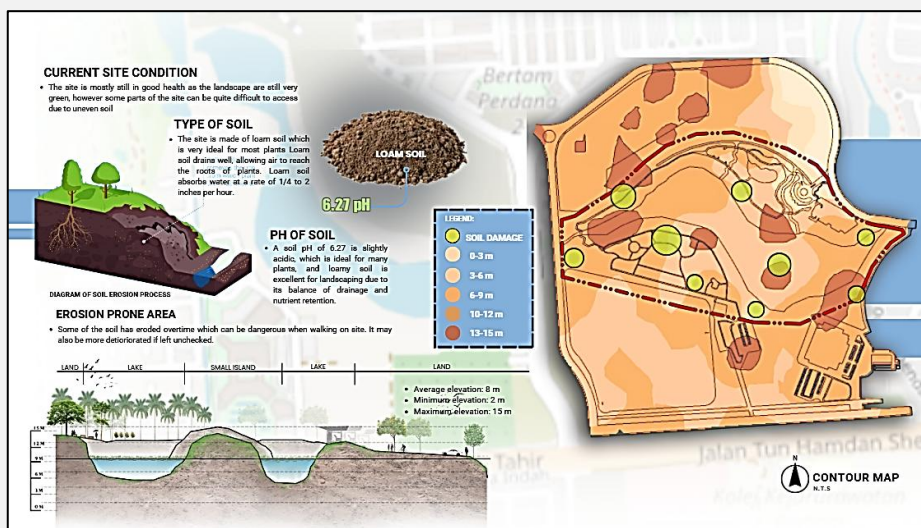


Figure 7: Diagram of Soil and Topography Analysis

The soil on the site appears healthy, supporting plenty of plant growth. The area is mostly flat, with pathways designed to meet the design standards. However, some parts are damaged or eroded due to usage and runoff water, which pose safety risks.

4. MICROCLIMATE

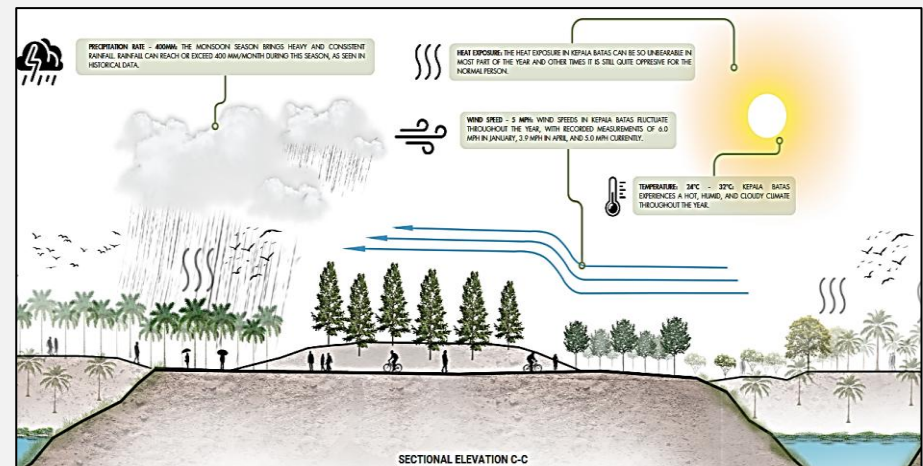


Figure 8: Section on Microclimate Analysis

Unpredictable weather poses threat to the site as flooding had occurred quite often in Kepala Batas town. Not to mention, the heat exposure before the monsoon season, which is quite unbearable and makes it harder for people to visit Bertam Lake park. In addition, the park lacks in comfortable spaces such as shaded trees and shading structures.

5. ACCESSIBILITY

The site is easily accessible, especially for nearby residents, with a direct entrance and available parking areas. However, it lacks inclusive design features for people with disabilities, such as tactile paving for the visually impaired and wheelchair-accessible paths in many areas. The materials should also be non-slip and permeable that aligned with the sponge city concept.

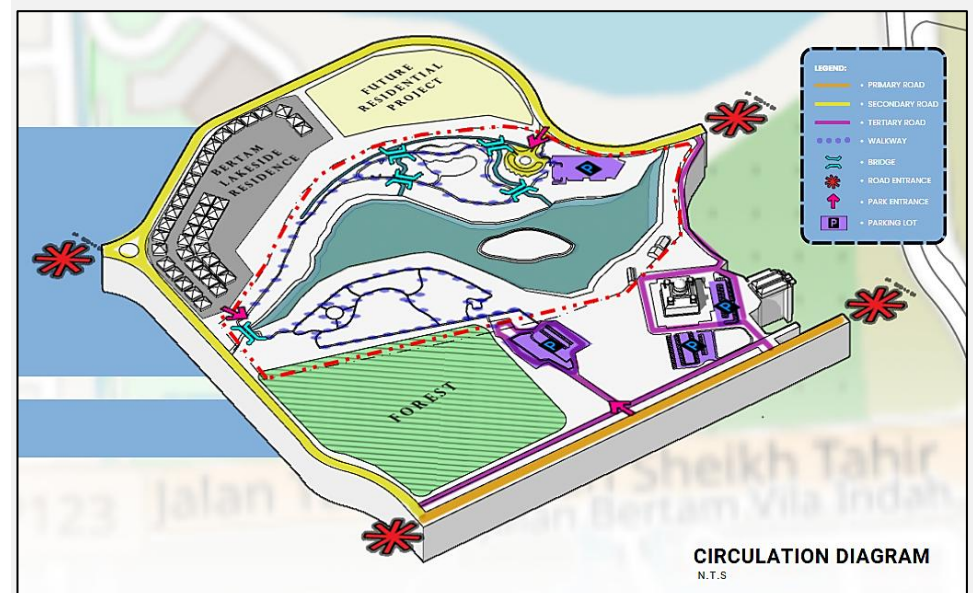


Figure 9: Accessibility analysis diagram

SITE INVENTORY AND ANALYSIS

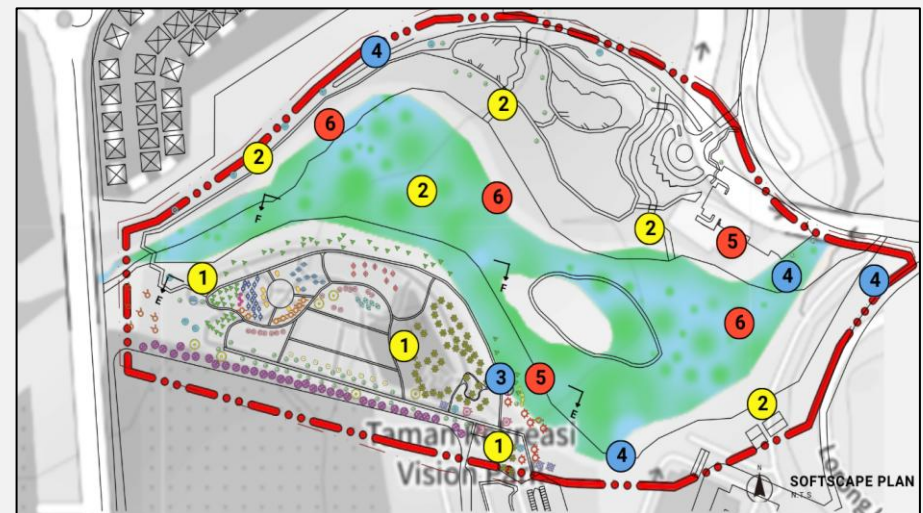
6. SOCIO-CULTURAL



Figure 10: Socio-cultural Analysis Map

The park provides spaces for recreation and leisure, promoting a healthier lifestyle for the community. Green areas, with a variety of trees, enhance the park's sense of place and visual appeal. The site is welcoming and inviting, and local residents, schools, and organisations often hold events and activities, making it a lively and enjoyable space.

7. FLORA AND FAUNA



PLANTED VEGETATION			INVASIVE PLANT
1. ANGSA NA	7. MAHOGANY	13. RHU BUKIT	19. JEMERLANG LAUT
2. GOLDEN PENDA	8. MERTAJAM	4. SAMANEA SAMAN	20. KELAPA
3. GOLDEN TRUMPET	9. PENAGA LILIN	13. SAWIT	21. BUCIDA TIKUS
4. JOHAR	10. PISANG KIPAS	16. TECOMA	22. HOPEA
5. KRIANG	11. PLUMERIA	17. TEMBUSU	
6. LIVISTONA	12. PULAI	18. KAYU RAJA	
			KIAMBANG



Figure 11: Existing Flora and Fauna and planting palette

The site has a mix of native and exotic trees, including *Tembusu* (*Cyrtophyllum fragrans*), *Merawan* (*Hopea odorata*), *Rhu Bukit* (*Gymnostoma sumatranum*), *Golden Penda* (*Xanthostemon chrysanthus*), and *Tecoma* (*Tecoma stans*). They provide shade, beauty, and support biodiversity. Large trees like Raintree (*Samanea saman*) and *Kayu Raja* (*Agathis borneensis*) offer canopy cover, while palms like Chinese fan palm (*Livistona chinensis*) and *Pisang Kipas* (*Ravenala madagascariensis*) add height and variety. This mix enhances both the ecological and visual value of the site. However, the main issue is the overgrowth of *Kiambang* (e.g. *Salvinia molesta*) in the lake, which needs to be addressed by ecological system, which is recommended in the sponge city concept. There is also a noticeable lack of wildlife in the area.

SITE INVENTORY AND ANALYSIS

8. FACILITIES AND UTILITIES

Most facilities on the site are still usable, though some, like broken benches and lights, need fixing. The upper park has more and better facilities, including a maintenance shed, since it is newer. A common complaint from users is the lack of shaded areas, especially in the lower park where gazebos are too far apart. Recreational facilities in the lower park also feel outdated compared to the upper park. Some areas, like the jetty and stepping-stone paths, seem neglected and are rarely used.

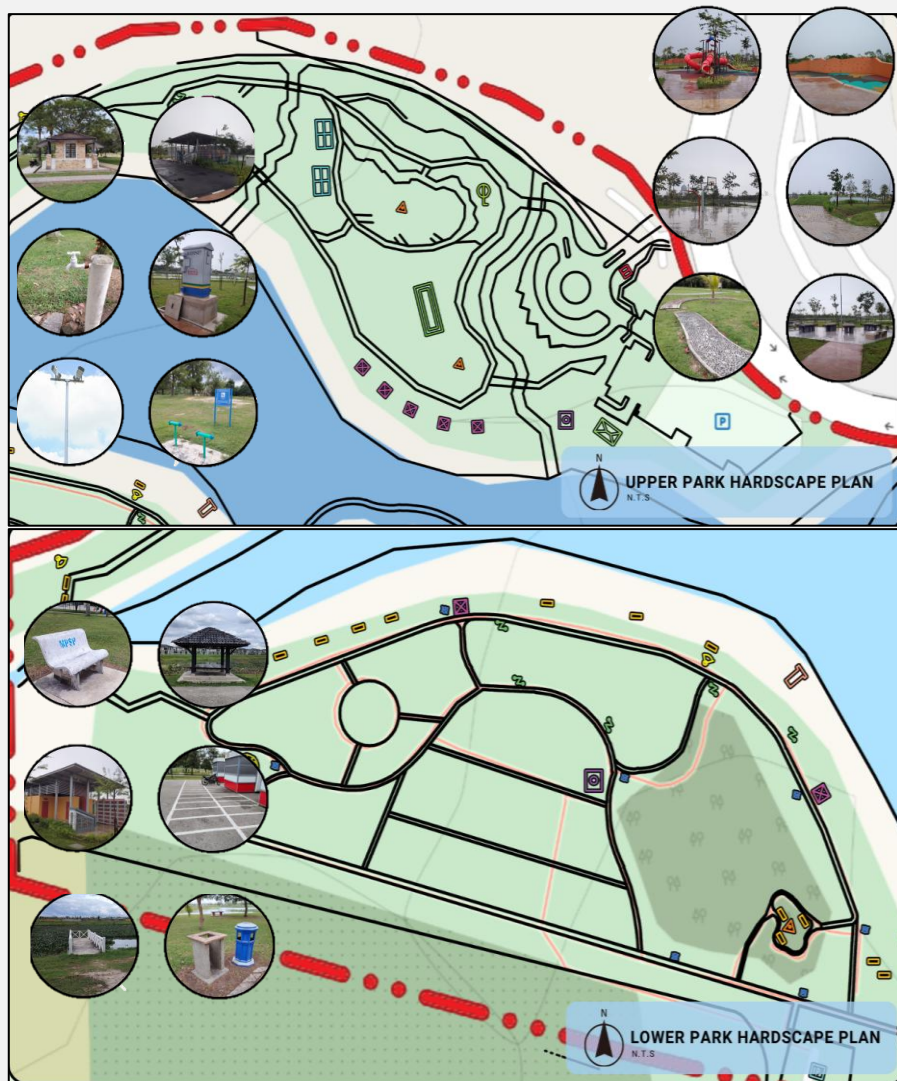


Figure 12: Facilities and utilities for Lower and Upper Park

9. VIEW AND SENSES

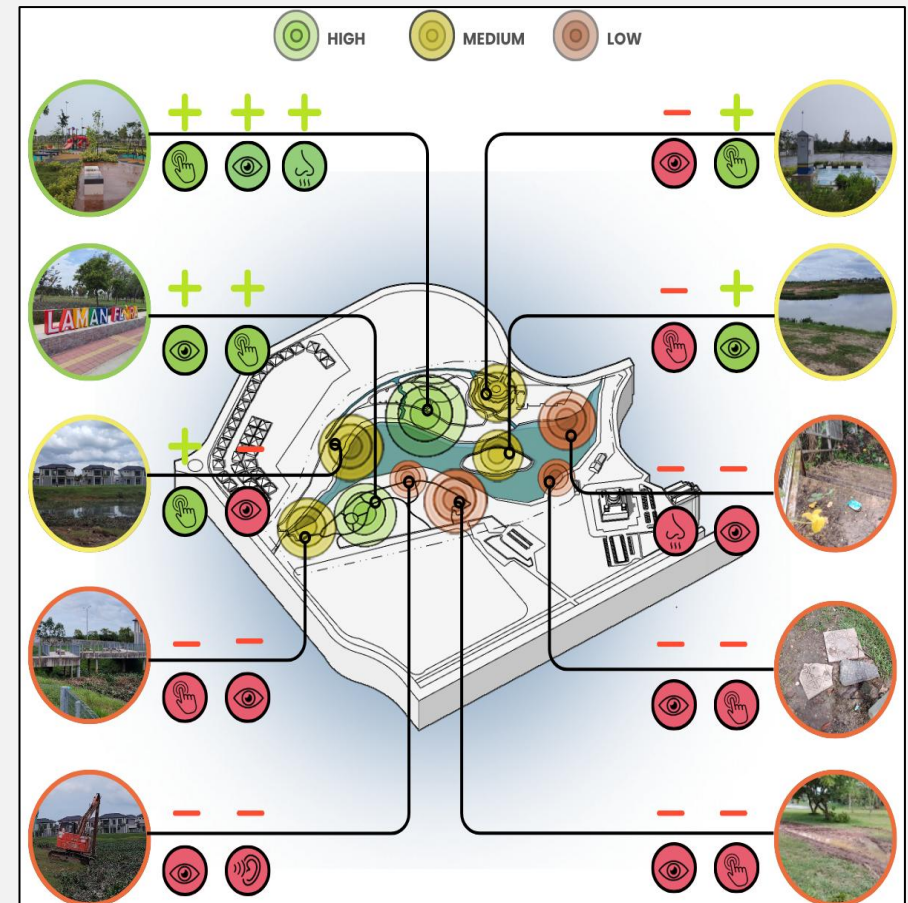


Figure 13: View and Senses Analysis Map

The site does not offer much visual or sensory appeal, except for a few nice spots. The smells and sounds are generally unpleasant due to traffic and water pollution from overgrown *kiambang* plants. Overall, the site needs more scenic views and sensory features to make it more enjoyable.

SITE SYNTHESIS

Based on the site inventory and analysis map, the site was synthesised according to its suitability to the sponge park concept, as follows:

SPONGE CORE - The heart of water retention and ecological balance. This central area acts as the main catchment zone.

POROUS CONNECTION – A network of trails that encourages water infiltration while guiding visitors through key areas.

STORMWATER GROVE – Act as a vegetated stormwater management hub, using trees, shrubs, and terraces to direct, filter, and slow stormwater runoff.

RESILIENT INTERACTIVITY– This area integrates interactive features for education and recreation, emphasising the site's resilience to flooding.

SITE SYNTHESIS SYNTHESIS

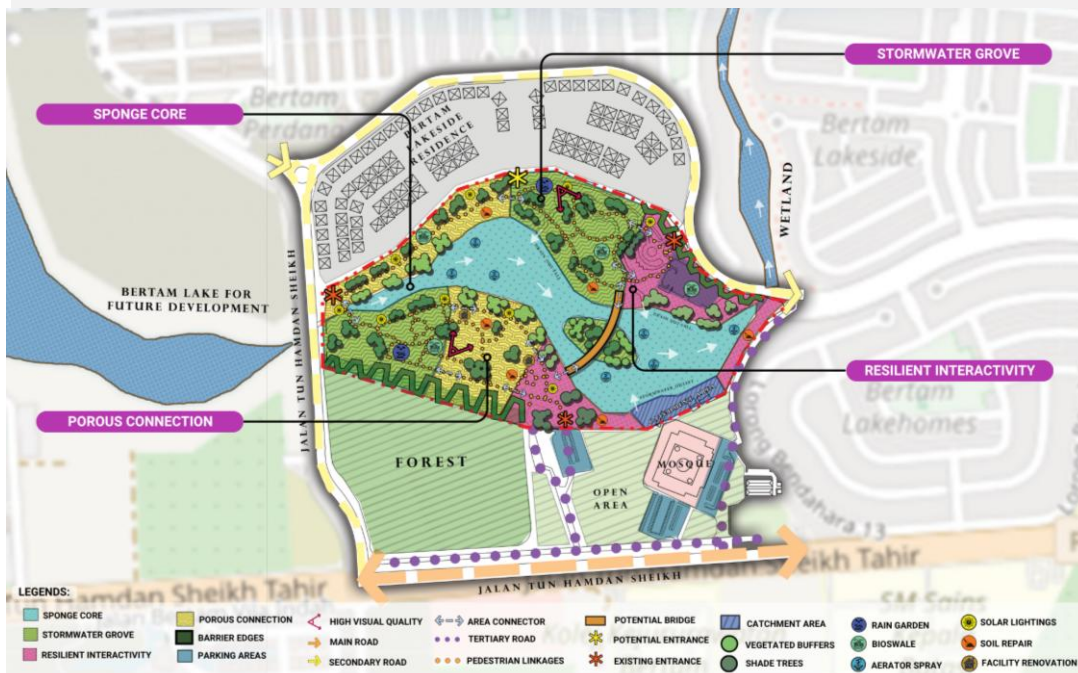


Figure 14: Synthesis Map

DESIGN STRATEGIES

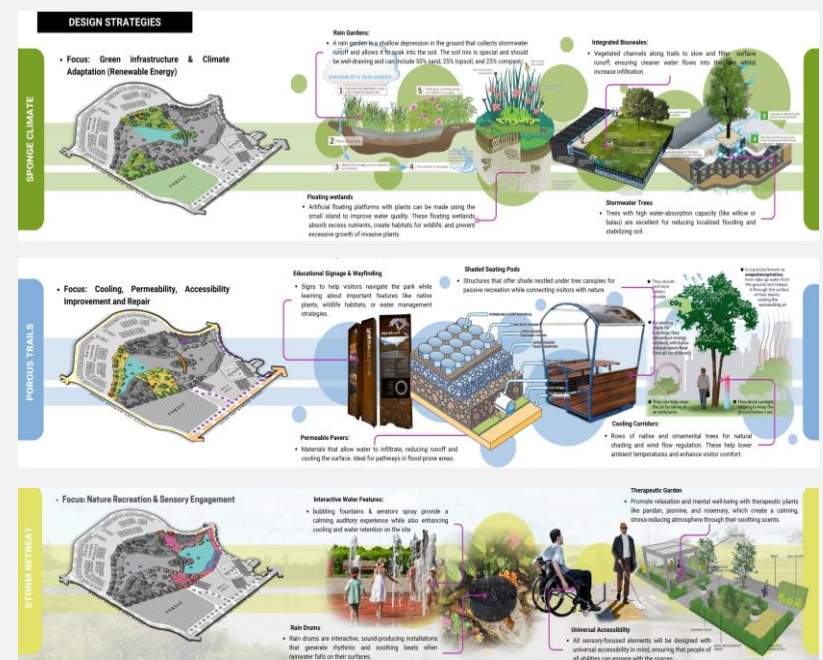


Figure 15: Design Strategies

LANDSCAPE MASTERPLAN

DESIGN CONCEPT

The design concept of this project is 'Porous-Scape', which means a landscape that can breathe and absorb water naturally. *Porous* represents the site's ability to soak up and filter rainwater using green features like wetlands and swales. *Scape* refers to the overall transformation of the area into a more livable and flood-resilient space. This concept helps reduce flooding, supports nature, and creates a healthier environment for the community.

CONCEPT BREAKDOWN



(Porous system) → mimics "sponge" by using natural hydrological cycles, allowing water absorption, filtration, and slow release.

DESIGN AIM

To develop a flood-resilient landscape at Bertam Lake, Kepala Batas, that enhances water retention, mitigates flooding, and promotes ecological sustainability through porous and adaptive design strategies, while integrating renewable energy and multifunctional spaces.

DESIGN OBJECTIVES

1. Enhance water resilience by implementing flood-mitigation strategies, optimising water retention, and integrating blue-green infrastructure.
2. Integrate climate-adaptive solutions through renewable energy, passive cooling, and adaptive design strategies for long-term sustainability.
3. Create a renewed multifunctional and connected landscape that balances stormwater management, biodiversity conservation, and recreation.

DESIGN PROCESS

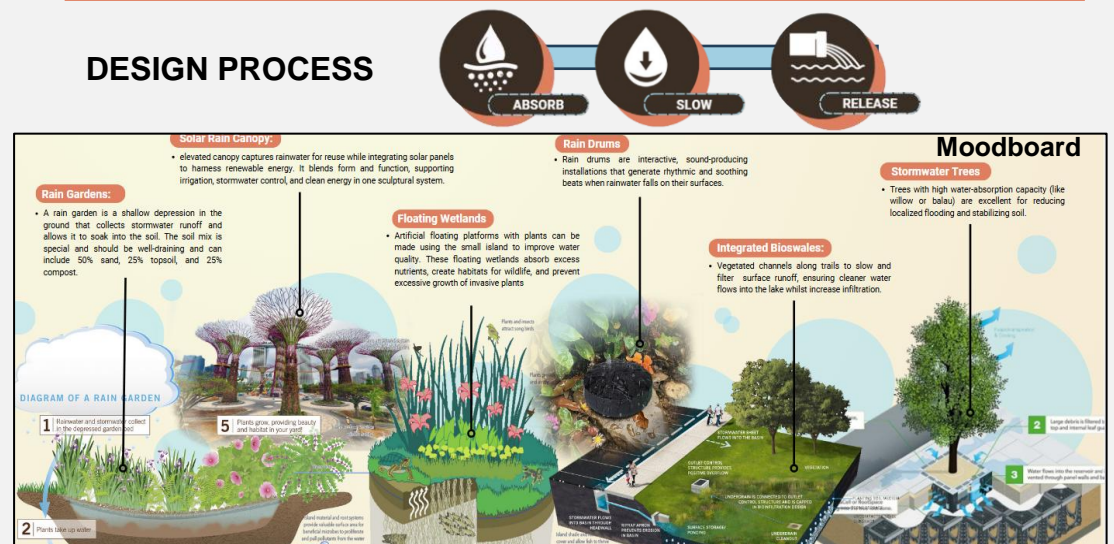
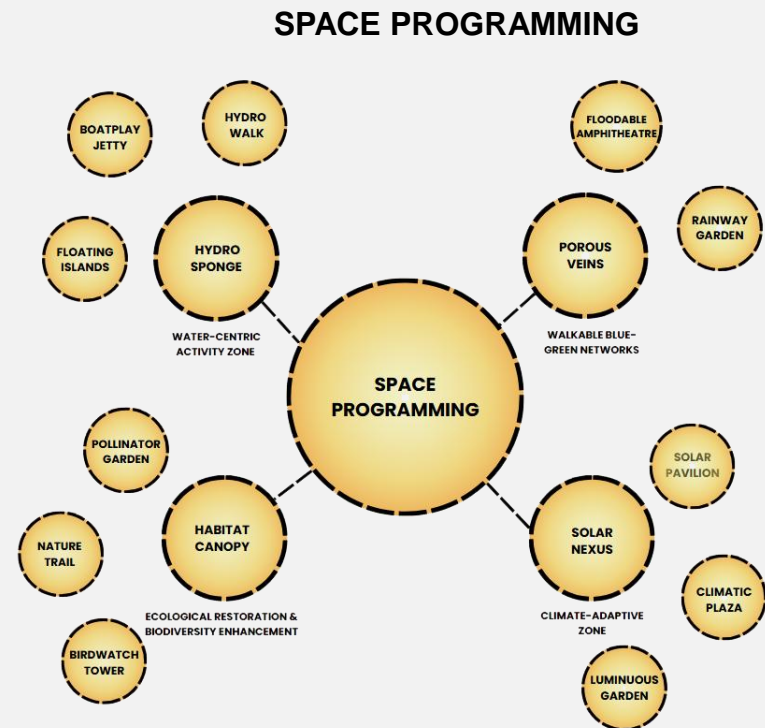
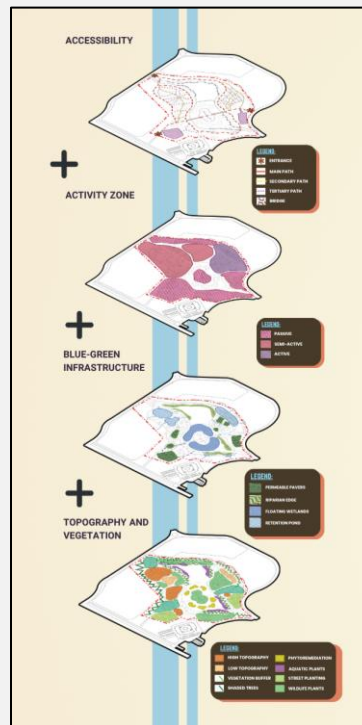


Figure 16: Mood board showing ideas in sponge park concept

LANDSCAPE MASTERPLAN



FUNCTIONAL DIAGRAMS



CONCEPTUAL PLAN

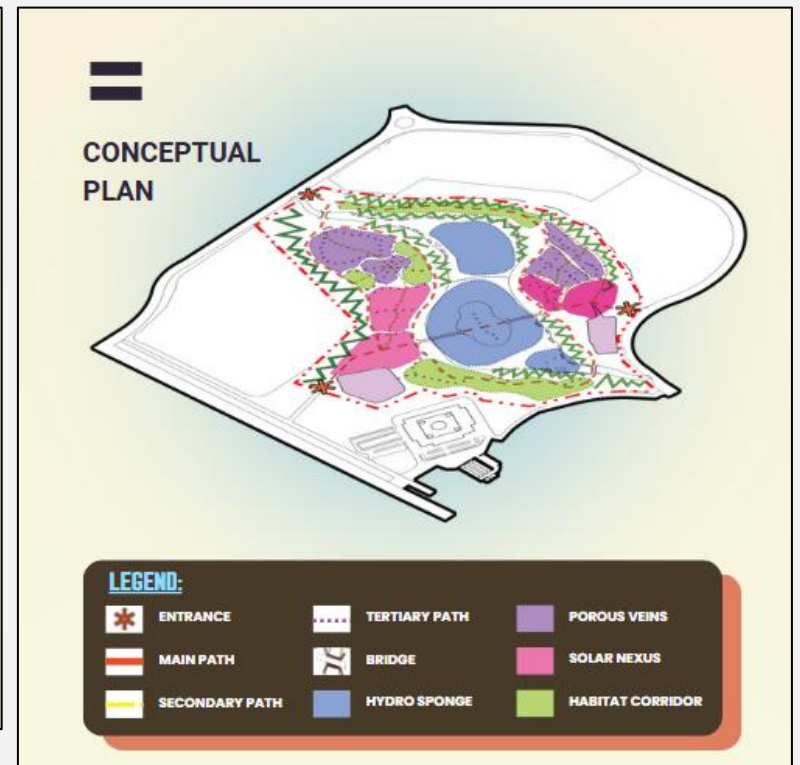


Figure 17 Layered Functional Diagrams

SCHEMATIC PLAN



PLANTING CONCEPT

The planting concept for the project is 'Verdant Sponge'. It is a multifunctional green infrastructure strategy that combines aesthetic planting design with hydrological performance. Acting like a living sponge, the park absorbs rainfall, filters pollutants, cools the air, and supports wildlife. Strategically planted layers slow down stormwater, allow it to percolate, and transform runoff into a resource.



Figure 19: Planting Concept and Arrangement

LANDSCAPE MASTERPLAN

PRELIMINARY MASTER PLAN



Figure 20: Preliminary Master Plan

SECTIONS AND PERSPECTIVES

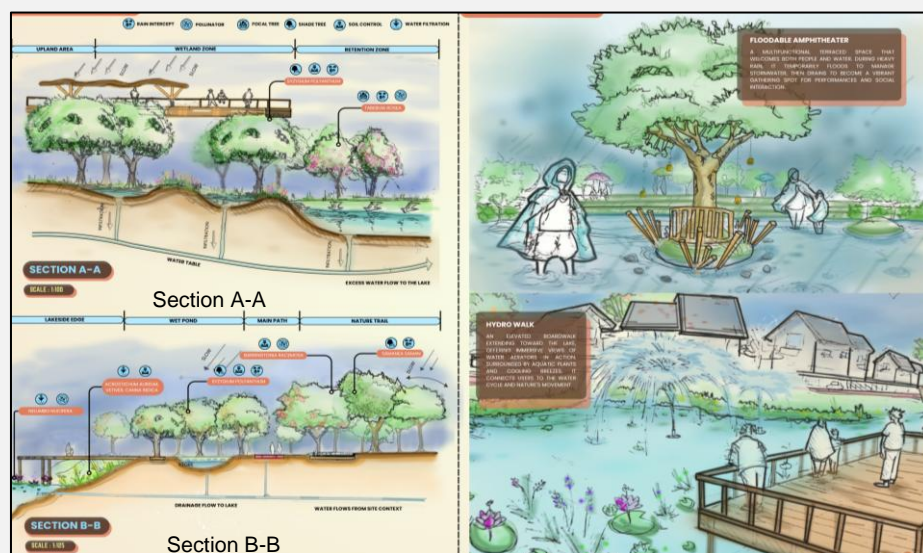


Figure 21: Sections and perspective drawings of the site

MASTER PLAN

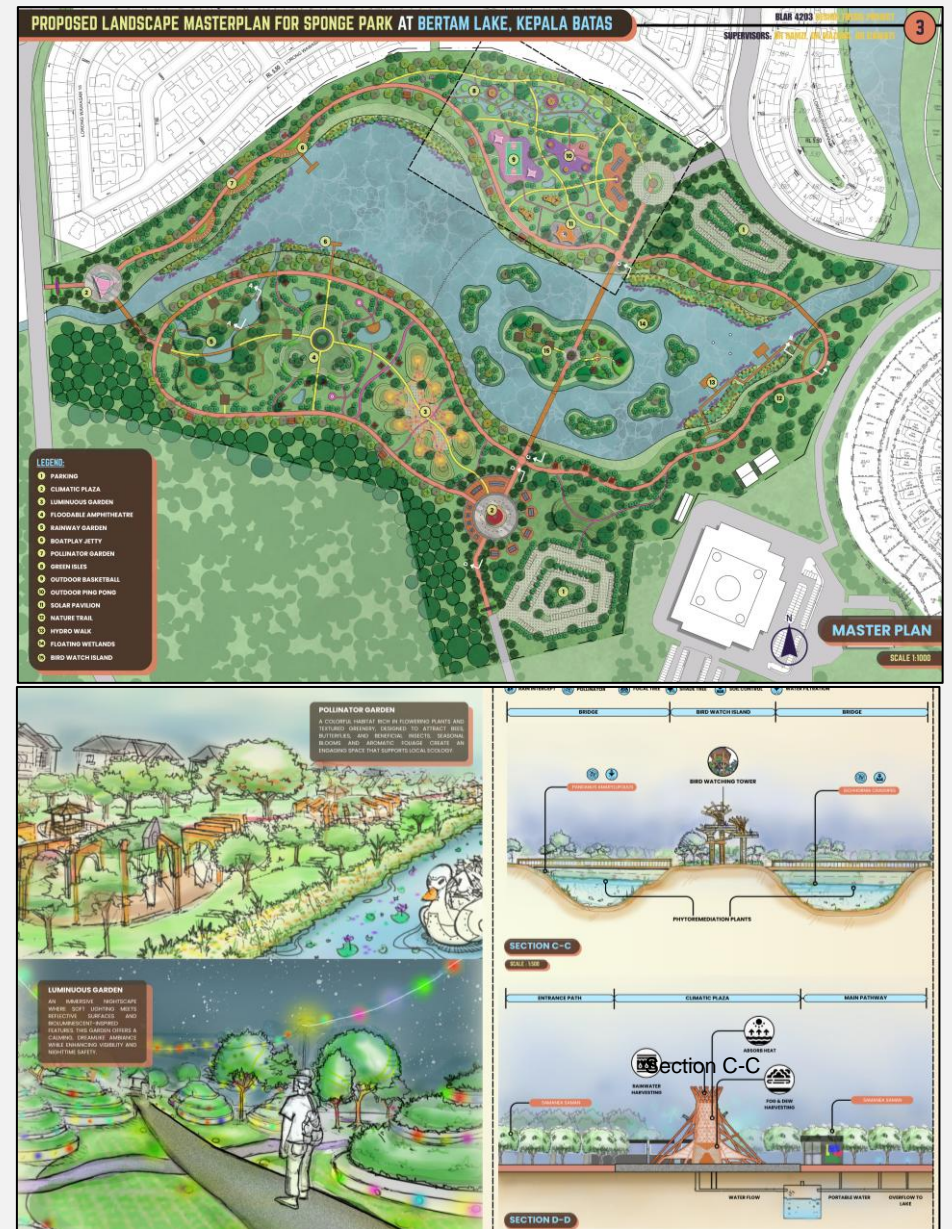


Figure 22: Master Plan andS

Section A-A is called Rainway Garden where terraces is created to help create a zone that will help flow runoff water into wetlands that are connected to the lake.

Section B-B is dedicated to the Nature Trail. There can be seen canopies of trees to slow down the water as well as wet pond as retention area.

Section C-C for the Bird Watch Island. It is surrounded by floating wetlands and a big tower on the island to oversee the natural beauty of the site.

Section D-D is for Climatic Plaza which acts as the main hub of the lower park, offering a central gathering space for visitors.

DETAILED DEVELOPMENT PLAN



Figure 23: The detailed development plan presents a refined layout of the proposed intervention, highlighting spatial hierarchy, functional zoning, user circulation, and ecological systems

STORMWATER MANAGEMENT

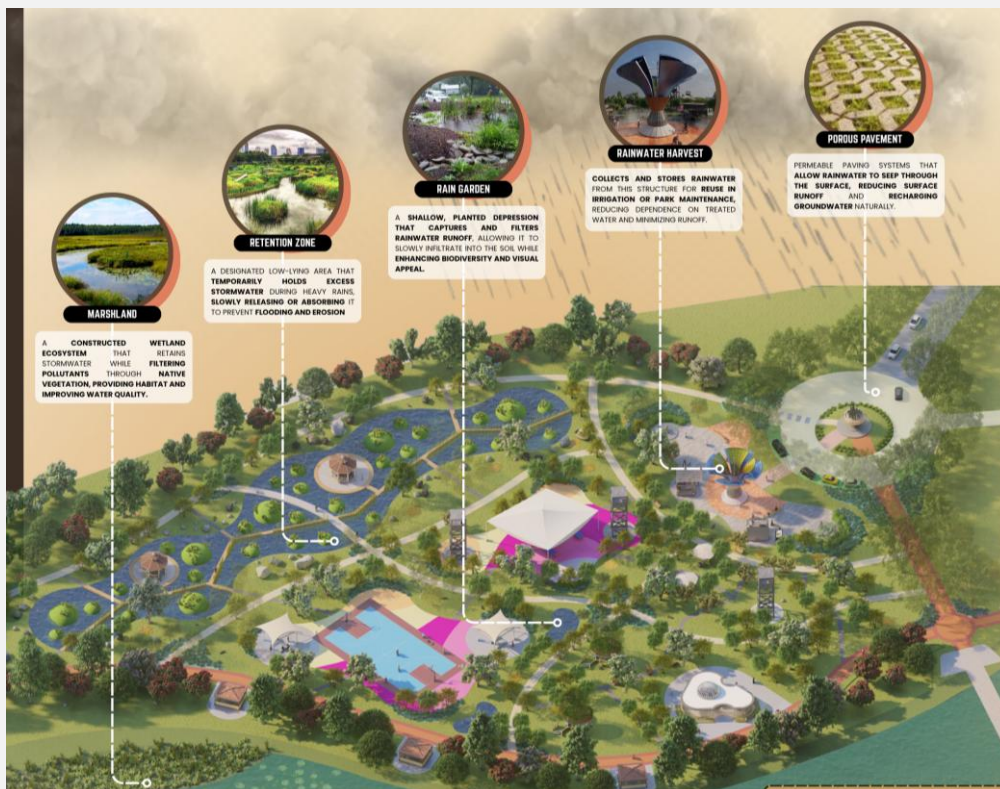


Figure 24: This section highlights how stormwater is managed on site using a sponge city approach. Following the "absorb, slow, and release" principle, the design uses green features like rain gardens, marshlands, retention areas, and permeable surfaces. For example, the proposed design will exceptionally increase the permeable surface of the site.

WATER FLOW DIAGRAMS

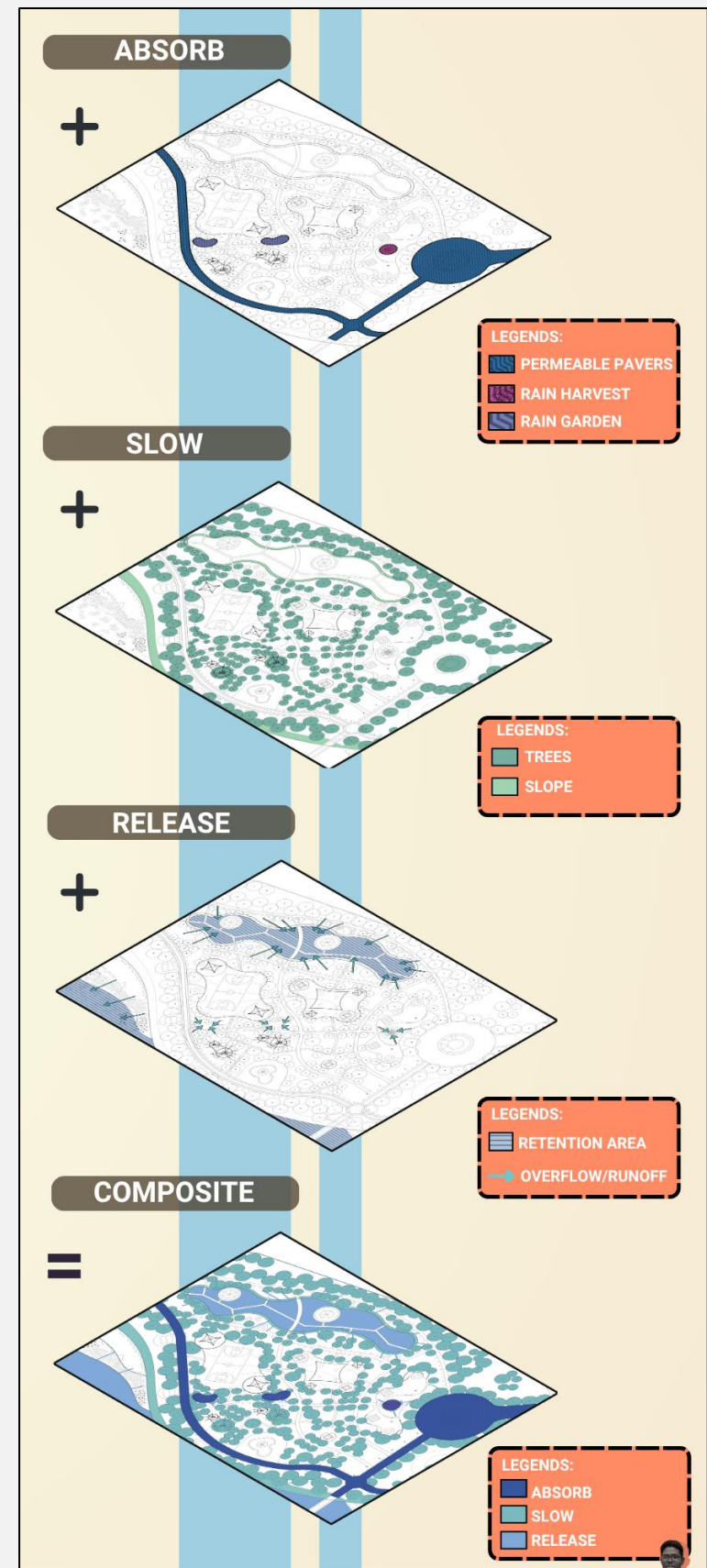


Figure 25: Layered Key Process Diagrams

SECTIONS AND PERSPECTIVES



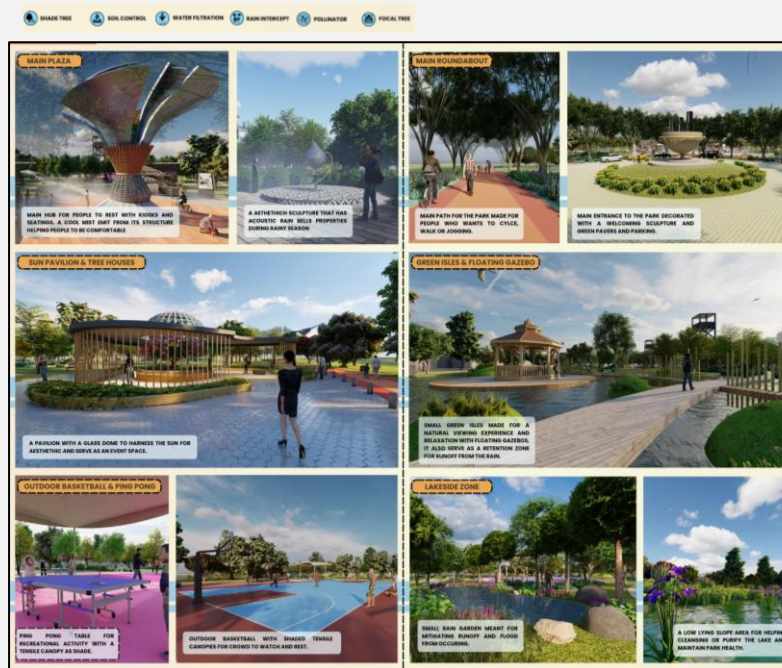
Section A-A is the main plaza. It functions as the main hub for the park, decorated with benches, kiosks, rainwater harvesting, and sculptures.



Section B-B shows the Sun Pavilion and Tree Houses. The pavilion is a relaxing spot with a sunlight dome and Tree Houses are a play area for kids.



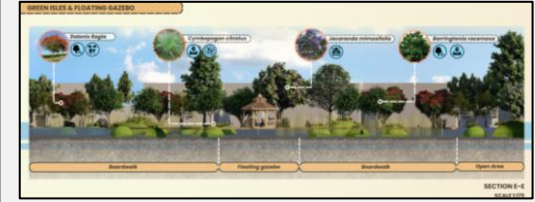
Section C-C has Outdoor Basketball and Ping Pong area. They are covered by tensile canopy for users' comfort and function as a highly active space



The perspective renderings visualise key experiential moments within the site, showing how people engage with various elements like vegetation, open spaces, and water features. These visual scenes help communicate the atmosphere and character of the design, giving a sense of how it feels to move through and experience the space.



Section D-D is Main Roundabout. It is a direct entrance to the site and is created with permeable pavers and act as drop-off point for the park.



Section E-E is called Green Isles. This area includes floating gazebos and green isles that offer peaceful spots for visitors to relax.



Section F-F is the Lakeside Zone. It features marshland and wetland plants that help clean the water through a process called phytoremediation. They help in nutrient uptake that starves invasive weeds and solve *kiambang* issue.

Figure 26: Compilations of Perspectives Images

INNOVATIVE DESIGN ELEMENT : SPIN DROP TOWER

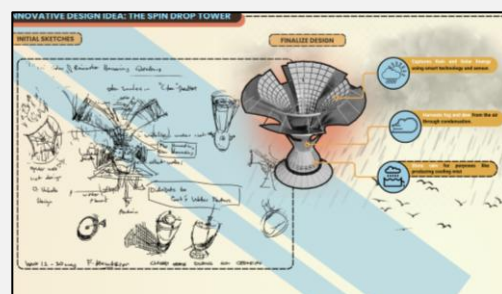


Figure 27: Design stage of Spin Drop Tower

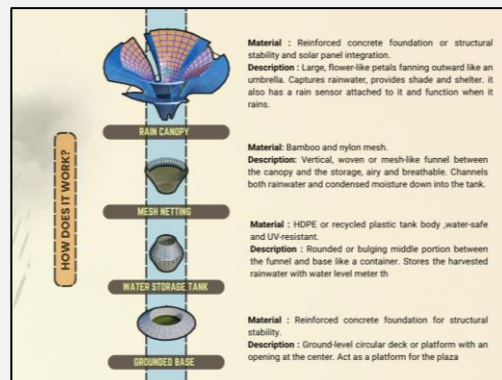


Figure 28: Material Breakdown

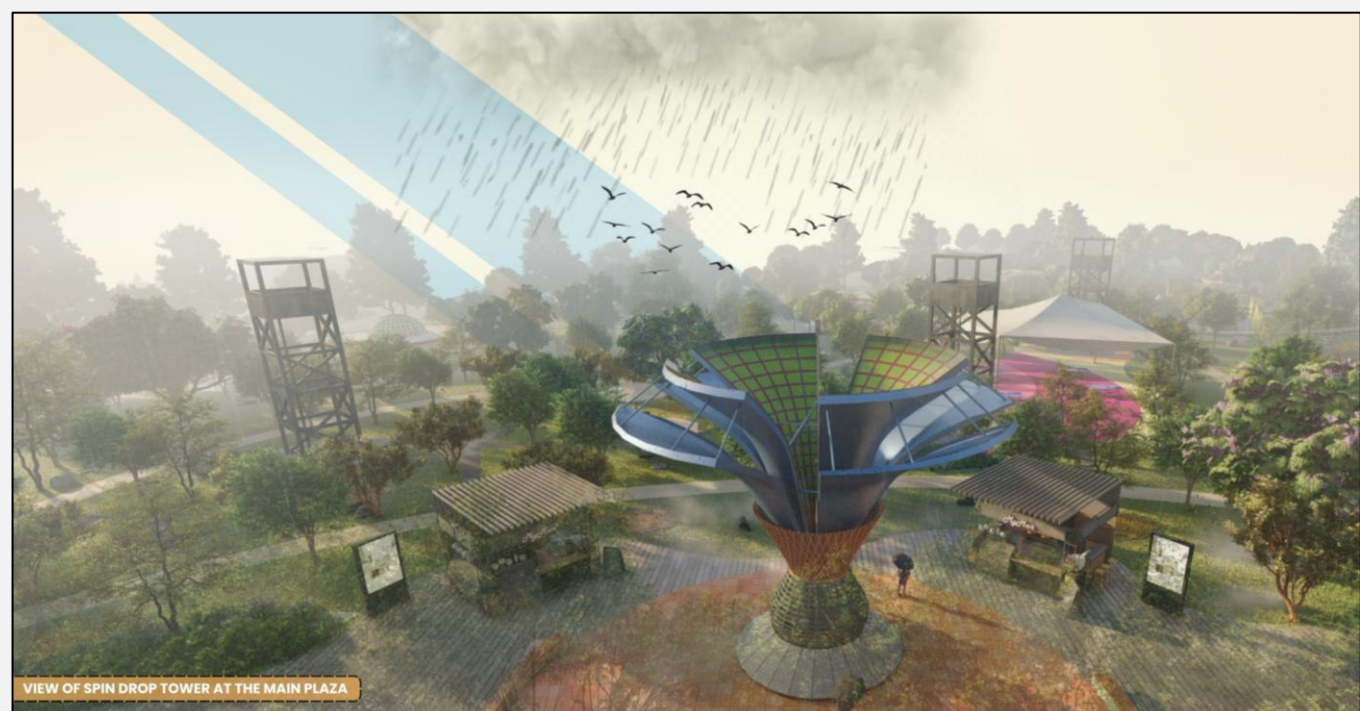


Figure 29 Perspective of Spin Drop Tower

SOFTSCAPE PLAN

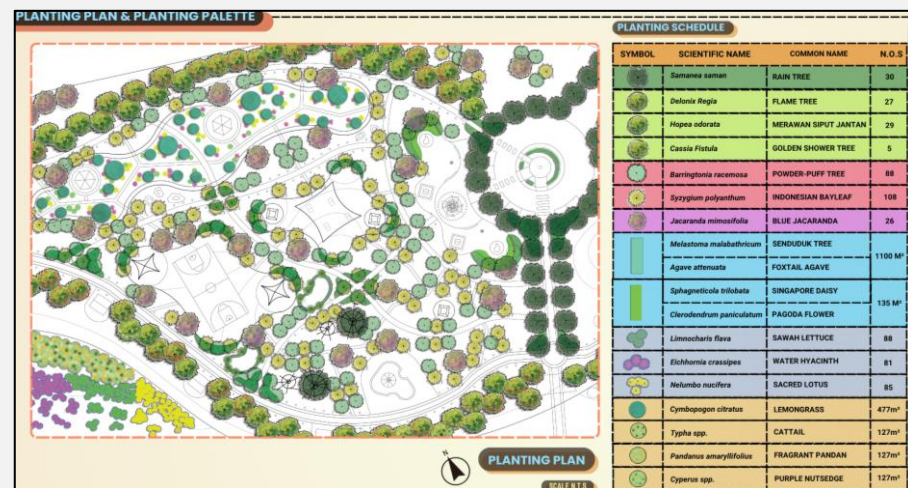


Figure 30: Softscape Plan and Softscape Schedule

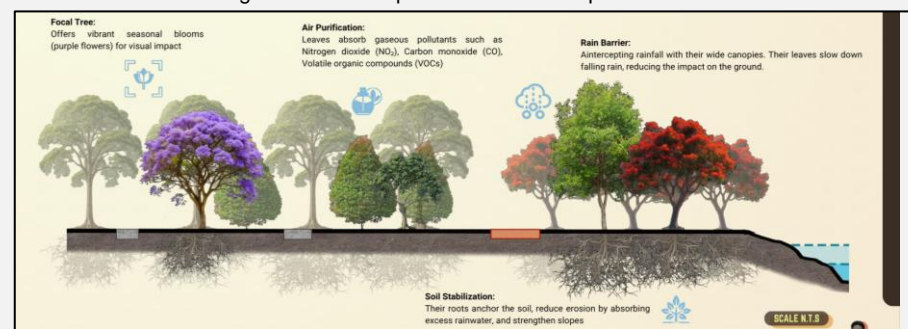


Figure 31: Typical Sectional Elevation for Tree Functions

HARDSCAPE PLAN

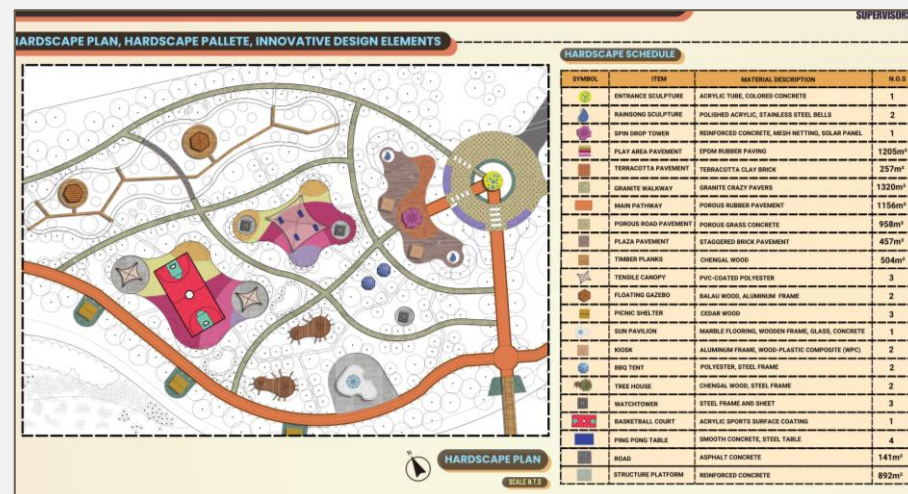


Figure 32: Hardscape Plan and Hardscape Schedule



Figure 33: Hardscape Palette



Figure 34: Aerial View of Current Bertam Lake park

CONCLUSION

This project began with an investigation into the ongoing flooding and ecological issues affecting Bertam Lake park and the surrounding area in Kepala Batas. Through primary and secondary data collection, the project identified key factors contributing to the site's vulnerability, including outdated drainage systems, altered land use, and poor water management. These findings laid the groundwork for a design approach using the sponge city concept centered on resilience, sustainability, and ecological healing.

The design process translated this research into a comprehensive master plan and detailed development strategy that reimagines the park as a climate-responsive, multifunctional landscape. By focusing on stormwater management, habitat restoration, and improved public access, the proposal not only addresses the immediate flooding concerns but also enhances long-term ecological health and user experience. This project aims to serve as a replicable model for other flood-prone areas, showing how thoughtful landscape interventions can turn degraded urban green spaces into vibrant, adaptive systems that benefit both the environment and the wider community of Kepala Batas, Pulau Pinang.

ACKNOWLEDGEMENT

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