SWAMPY URBANISM:

Make a Little Room for the Elbow River

by

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AUTHOR'S DECLARATION

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.
I understand that my thesis may be made electronically available to the public.

ABSTRACT

The City of Calgary is known for its flood issues, and the oldest flood recorded can be dated back to 1879. To reduce and potentially eliminate the inundation threats, the city has commissioned numerous dams and reservoirs to alter the hydrological cycle in exchange for security, electricity, and water supply. Thanks to the protection of these grey infrastructures, the city was able to develop and expand rapidly. However, despite the massive concrete barriers that were built to shelter the city from inundation, catastrophic events continue to occur within the city. In the case of the 2013 Calgary flood, the Bow River had reached eight times its regular flow and the Elbow River peaked at twelve times its normal flow rate. This was one of the largest floods in Canadian history which recorded four to six billion dollars of financial losses. Part of the reason for such severe overland flood damages was the increase in developments and urban growth in floodplain-designated zones during the periods when floods are managed. The infrastructural approach has become a double-edged sword that projected a false sense of security and encouraged developments adjacent to the river. With the pressing concerns of climate change and the increased frequency of floods in the past few decades, contemporary urbanism needs to find a new strategy to embrace the challenges of environmental shifts.

The fundamental cause of the problem is that current Canadian societies treat water and land as separate entities, where the land dominates over water. This is reflected throughout our maps and urban design approaches where water is limited within certain boundaries. However, this narrative does not necessarily represent reality as water exists everywhere, the only difference is in quantities and forms. This limited understanding of rivers has constrainted us from truly fostering a bond between nature and cities, where the current urban flood mitigation strategies attempt to shelter our societies from the forces of nature rather than adapting to the rhythm. Therefore, this thesis challenges the traditional view of water and aims to imagine a hydrological urban planning strategy that emphasizes on coexisting with water.

There are two types of floods in Calgary: river floods and stormwater floods. The Room for the River is a great strategy to create space for water to overflow, which was invented by the Dutch to manage flooding. On the other hand, Sponge City from China has proven to be effective for rainwater management by creating a more permeable landscape that will temporarily absorb the overflow and release it slowly over time. In addition to these landscape flood mitigation strategies, the core focus of this thesis centers on the Landscape of Retreat Theory— voluntarily vacating flood-prone areas— which addresses the root causes of vulnerability. Given the current circumstances, where both flood exposure and the costs of insurance are increasing, retreating from the floodplain provides long-term economic, environmental and social benefits. As a result, this

thesis will explore the creation of a more resilient urban terrain in Calgary by examining all the listed strategies. Additionally, local landscape projects by the O2 Planning + Design Firm will be referenced to ensure the design outcome of this thesis aligns with local contexts. By adopting the Retreat approach, the thesis will culminate into a proposal for urban strategies that integrate the exemplary practices provided, ultimately strengthening flood resiliency by adapting to the rhythm of the Elbow River in Calgary.

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0. PRELUDE

0.1 Introduction

Swampy Urbanism presents an urban flood mitigation approach that focuses on creating more room for the water to overflow in the landscape of Calgary. It reveals the complex social-hydrological relationship between urban centers and rivers, providing an in-depth understanding of how current human actions with water will influence the dynamics of water. This thesis then proposes a design intervention which retreats from the Elbow River's riparian zones in the city and challenges the current practices of using engineered infrastructure to control water flow and shelter the city from external natural forces. As a result, the design explores how to live with the rhythms of rivers by creating a landscape project designed to embrace flooding and enhance climate resiliency for the city.

The thesis uses the city of Calgary in Alberta as the context for exploration since the city has been frequently entrenched in flood-related catastrophes. In the case of the 2013 Calgary flood, the Bow River reached a speed of eight times its regular water flow and the Elbow River peaked at twelve times its normal flow rate.[1] This was one of the largest floods in Canadian history, resulting in four to six billion dollars of financial losses.[2] Part of the reason for such severe overland flood damage was the increase in building developments and growth in floodplain-designated zones during periods of no floods. About 28% of riparian zones in Calgary have been developed, and 11 % are specifically for residential. Of the remaining 72%, 50% is used for parks and recreation, and 22% awaits future planning and agricultural developments.

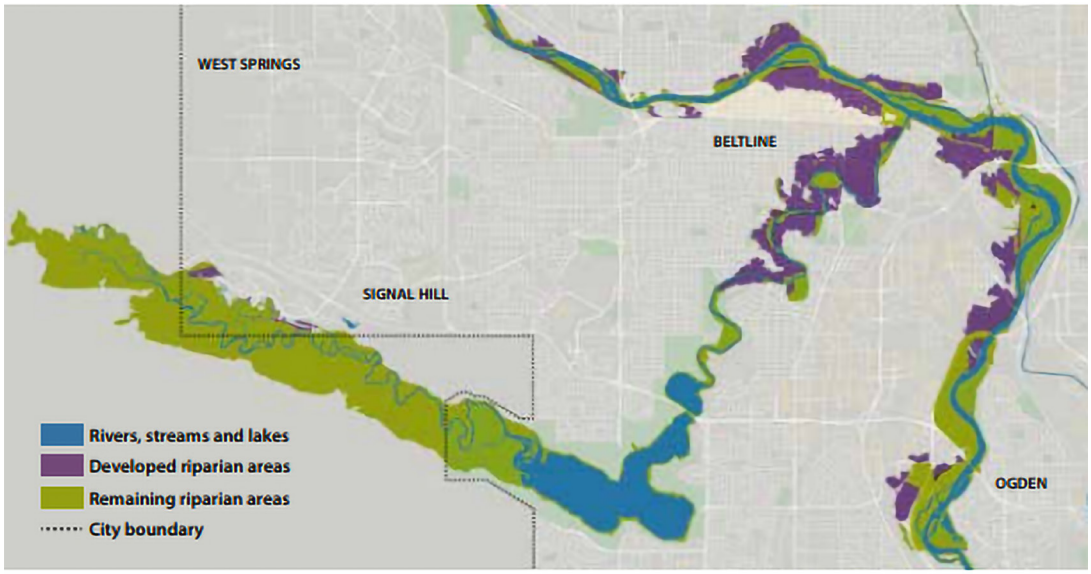


Figure.0.1. Map of Developed inner city riparian areas. O2 Planning +Design Inc.

After the 2013 flood, the Alberta Government announced the voluntary floodway relocation program across the province. While the program succeeded in the nearby towns, most of the Calgary homeowners refused to relocate. Despite the program's failure in Calgary, it is conceptually one of the most effective non-structural flood mitigation strategies, as it addresses the root cause of the problem. This has become more critical with the impact of climate change where the frequency of major floods has increased along with the cost of flood insurance. What if the projected 100-year scale flood now happens every few years? Will the government and insurance companies still be willing to pay for reimbursement? As a result, a change of culture that prioritizes "living with the rivers" is needed to unlock new design possibilities and create a more resilient cityscape that protects itself with a more effective long-term water management vision. The relocation example in Calgary provided the foundation for this thesis. If fully implemented, it would have provided a workable response to the scenario of extreme conditions and significantly reduced the exposure to substantial water damage and unsustainable financial liability.

Most of the Elbow River's riparian areas are part of an alluvial aquifer, a natural sponge that absorbs and discharges water based on the river's level and flows. Returning these lands to the river will promote diverse and healthy ecosystems that would also enhance the city's energy and quality of life. This design proposal will never be a complete solution but rather it is an acknowledgment that water exists everywhere, in different forms and quantities, and that natural forces can never be tamed. Therefore, rather than seeing land and water as separate entities where the land dominates over the water, the thesis challenges how water is perceived in traditional urban planning and aims to imagine a new type of urban design strategy - a hydrologic one. The approach focuses on the practice of retreating, voluntarily leaving flood-prone areas before an incident, letting nature and water reclaim those surrendered lands. The design outcomes evolve around phasing the retreat but also recognizing the social-political complexity of that move and recognizing that the entire process will require some time to achieve its final vision. Strategically, applying landscape solutions that can accommodate distinct phases will be critical to the success of the project. Landscape strategies such as Sponge City, Room for the River, and Patch Dynamic will be used to create artificial landscape frameworks to rewild the site, eventually generating a park.

0.2 Thesis Structure

The thesis is structured into four parts. *Chapter One: The Choking Rivers* provides an overview of the context and sets the stage for later research and design. It highlights how the City of Calgary has interacted with the two rivers throughout history and how that has led to current water challenges. The thesis positions riparian zone restoration and non-structural flood mitigation as the focus of the research. It highlights the importance of healthy river systems and examines the impact of humans on the overall hydrosphere. This is specifically discussed in subchapter 1.3, which examines how mankind's over-intervention in the water cycle has worsened the situation and the importance of restoring natural systems to better combat environmental crises. The research in this section ultimately shaped the direction and justified the focal point of this thesis.

Chapter Two: Landscape of Retreat & Strategies uncovers the significance of the retreat practices in Calgary's landscape and the potential mutual benefit it would bring to both the city and nature. This section dives in-depth into the Retreat theory framework and defines the difference between retreat and relocation. Then it breaks down some social-political movements after the 2013 flood event to reveal how the complex social values of different stakeholders, beliefs, and interests directly shape how these natural events are portrayed and hence impact the policies and outcomes. The original intention of the local government was to implement natural-based solutions like Room for the River, as their future flood mitigation approach. However, political interventions resulted in the construction of a massive dry reservoir on the Elbow

River. This thesis chapter aims to understand the potential of retreat practices in Calgary's metropolitan areas and the need to restore floodways to reduce vulnerability and enhance the ecosystems.

Chapter Three: The Site introduces the site chosen for the pilot landscape project. Roxboro and Rideau Park are two out of the three Calgarian neighborhoods that were offered the 2013 Floodway Relocation Program. There are existing cases of retreat on site where several homes have already been relocated by the program. The design will continue the retreat process on top of the previous example while analyzing the current site conditions, looking for land degradation and potential areas for improvements. Through understanding and mapping the multi-layers of the landscape conditions, this thesis will outline an artificial landscape framework to assist retreat and facilitate ecological restoration.

Finally, *Chapter Four: Design Synthesis* proposes a different type of landscape design that involves less spatial programming but a method that focuses more on edge conditions and dynamic landscapes. With the implementation and guidance of planning and architectural frameworks, the site will eventually generate a park. This approach does not provide a definitive outcome but an interactive proposition that will be constantly influenced by the users and environment. By doing so, it positions the ecosystem, flood memory, and community at the center of the design vision.

By analyzing social-hydrological relationships between human development and ecosystems in Calgary, *Swampy Urbanism* reveals the need to transition away from the traditional flood mitigation approach to adaptive non-structural landscape strategies in the Southern Alberta

metropolitan areas. The thesis emphasizes the importance of finding a balance between human developments and nature, shifting the culture from attempting to master nature to a mutually beneficial relationship. The thesis aims to establish practices that would facilitate resiliency in the landscape while opening new possibilities, allowing other practices and neglected relationships to flourish once again.

0.3 Literature Review

The following is a literature review that further contextualizes the theoretical framework on which this thesis is built. One of the key readings is "*Landscape of Retreat*" by landscape architect Rosetta S. Elkin, which helped shape the concept of 'unbuilding' properties in and adjacent to riparian zones. In the book, Elkin redefines the idea of retreat by suggesting that such an act is not a move of surrender, but rather an alternative path moving away from attempting to tame nature and acknowledging the importance of fostering a strong relationship with the environment.[3] The central message of the book evolves around the concept of respecting the environment and the ever-changing nature of the landscape. Through providing numerous case studies where communities have actively chosen not to develop in the riparian areas, the author has shown a different possibility where human societies and nature can co-exist. At the same time, the book also provided examples of how profit-driven stakeholders, such as foreign-invested logging companies, are changing the existing dynamic. Putting more emphasis on the Retreat practice would allow other practices and neglected relationships to flourish once again, forming a more resilient urban environment.

In connection with Elkin, the paper "*Making Room for Nature? Applying the Dutch Room for the River Approach to Flood Risk Management in Albert, Canada.*" by environmental sociologist Eva Angelyna Bogdan, shares a similar idea on shifting the current culture from controlling nature to working with nature to achieve goals. Bogdan looks at an interesting case study in Alberta where the government attempted

to implement the Dutch Room for the River program as a potential strategy for flood mitigation. During the process, the project also tried to relocate neighborhoods in Calgary that were adjacent to the river. She suggests that shifting away from using megastructures to natural-based solutions requires a change in perspectives from the residential to the governmental level.[4] Bogdan's paper offers a comprehensive insight into government movements, providing a broader view of the flood risk management framework, including the need for culture change, and policy transfer.

Similarly, *"Protect, Accommodate, Retreat or Avoid (PARA): Canadian Community Options for Flood Disaster Risk Reduction and Flood Resilience."* by professor Brent Doberstein, categorizes flood reduction strategies and case studies across Canada using the PARA framework. He points out that the Room for the River strategy in Alberta, which eliminates developments in flood plains, would fall into the avoid category.[5] Sorting case studies based on types reflects the broader flooding challenges in Canada and, at the same time, lists out other potential methods to be applied based on the contexts. To fundamentally understand the water challenges, one needs to trace back to the core definitions of city and water. However, water governance researcher Kelsey Leonard criticizes the PARA framework for its exclusion of indigenous knowledge which limits available adaptation options. In her paper, *WAMPUM Adaptation framework: eastern coastal Tribal Nations and sea level rise impacts on water security*, she argues that current Sea Level Rise adaptation frameworks like the PARA model are still economically driven,[6] prioritizing the cost-benefit analyses and engineering solutions. In response, the WAMPUM framework is created to integrate Indigenous knowledge into the current adaptation systems. The approach shares similarity to the core concept repeated in Rosetta S.

Elkin's work, which focuses more on the kinship between humanity and landscape, advocating for a more ecosystem-based perspective.

Dilip da Cunha, an architect and a planner, unpacks how the relationship between land and river is perceived and defined due to colonialism in his book *The Invention of Rivers: Alexander's Eye and Ganga's Descent.* In his writing, he challenges the reader to rethink the definition of rivers where the river is seen as the line that separates water and land. Instead, he suggests that urbanism should consider the different stages of water as relevant to understanding rivers, which ultimately would lead to a different design practice. On the other hand, urban landscape historian Thaisa Way said that "the role of the river as a coupled natural and sociocultural system, providing energy and resources as well as cultural identities, becomes essential to productively reimagining any future for both river cities and city rivers."[7] As she mentioned in her book *River Cities, City Rivers,* rivers have not yet been fully understood either as landscape components or as agents of urban formation despite the fact that over half of the world's population live in river cities. Both authors, Way and Cunha, fundamentally examine the cultural, environmental, and social relationships between rivers and cities which provides a unique basis for this thesis to expand on. Understanding how water and water-related challenges are being perceived will inform the design practices and policies of this thesis.

This thesis also references landscape architecture books such as *Design with Nature* by landscape architect Ian L. McHarg in 1969, to understand the ecological principles in land planning, as well as methods to incorporate natural processes over time. *Design with Nature Now* is a newer version of the book, which was released in 2019 and edited by Frederick R.

Steiner. This version points out that McHarg's previous vision of *Design with Nature* is too conclusive and fails to address the increasing human interventions in nature which influence outcomes.[8] The book suggests that designers need to shift away from the idea of seeing the world as full of problems and attempt to use design to resolve these issues. Instead, planners should create designs that consider all the possible interventions and leave space for future changes.

On the other hand, James Corner's introduction chapter of his book *Recovering Landscape: Essays in Contemporary Landscape Architecture* has provided some of the most fundamental thinking and knowledge of the field.[9] As the title suggests, the chapter emphasizes the importance of landscape recovery as landscape holds critical cultural habits and conventions so restoring them would be beneficial to ecosystems and societies. However, recovery does not simply mean restoration but should include renewal, invention, and transformation. Corner points out that beyond the aesthetic and prescriptive forms, the landscape holds complex relational values which are critical to all living beings. Therefore, landscape design should focus more on renewing and maintaining interactive relationships within the land rather than being visually oriented and problem-solving.

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1. THE CHOKING RIVERS

1.1 River Town, River City

Calgary began as a town of roughly 500 residents residing in temporary dwellings alongside the Elbow River.[1] Before the establishment of the township and the arrival of settlers, this land was used by the First Nations—the Siksika, the Kainai, the Piikani, the Nakoda, and the Tsuu T'ina—as the crossing point for the Bow River due to its gentler slope and shallow riverbed.[2] The Tssu T'ina called the location Kootsisaw, which meant "elbow", describing the geological location where the two rivers meet.[3] Despite being the place where the Bow and Elbow Rivers confluence, the area was unsuitable for water transportation due to the low water flow and drifting river channels. Instead, Calgary was used more as a navigational landmark and a major intersection for the First Nations due to its unique landscape features.[4] This relationship between humans and nature remained the same until the arrival of settlers, who introduced a different settlement pattern at a faster pace.

In 1875, Calgary became a fort due to the settler establishment which later transformed itself into a township and the gradual growth led to new developments. Similar to cities built on the West Coast of Canada, Calgary emerged along with the development of the Canadian Pacific Railway, which was the result of so-called C.P.R. Urbanism.[5] In the 1880's the C.P.R. selected the township as a major service depot, building along the flood plains of the Bow and Elbow River. This eventually became the nucleus of modern metropolitan life. Gradual growth led to new developments centred around the two waterways of the city, the Bow River and the Elbow River. In the Dominion survey map of 1884, homestead lands cleared

for development are shown to be within the boundaries of the two rivers.[6] Calgary's geographical location as a transportation hub also enabled it to become the center of the lumber industry.[7] With the supply of timber being abundant, the construction industry started to flourish. Housing was built around the nucleus, surrounding the business hub south of the Bow River and West of the Elbow River.[8] This development is shown in the land use pattern of 1961.

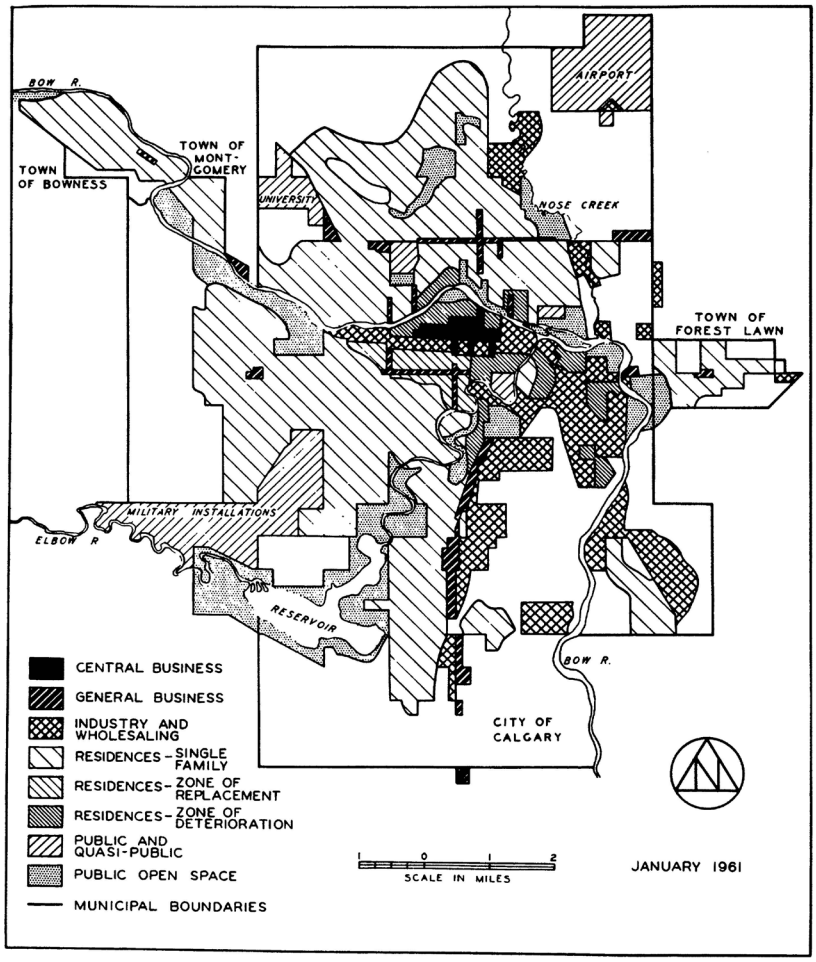


Figure.1.1. Generalized land use pattern of Calgary metropolitan area. January, 1961. Image from *Calgary: A Study in Urban Pattern* by P.J. Smith.

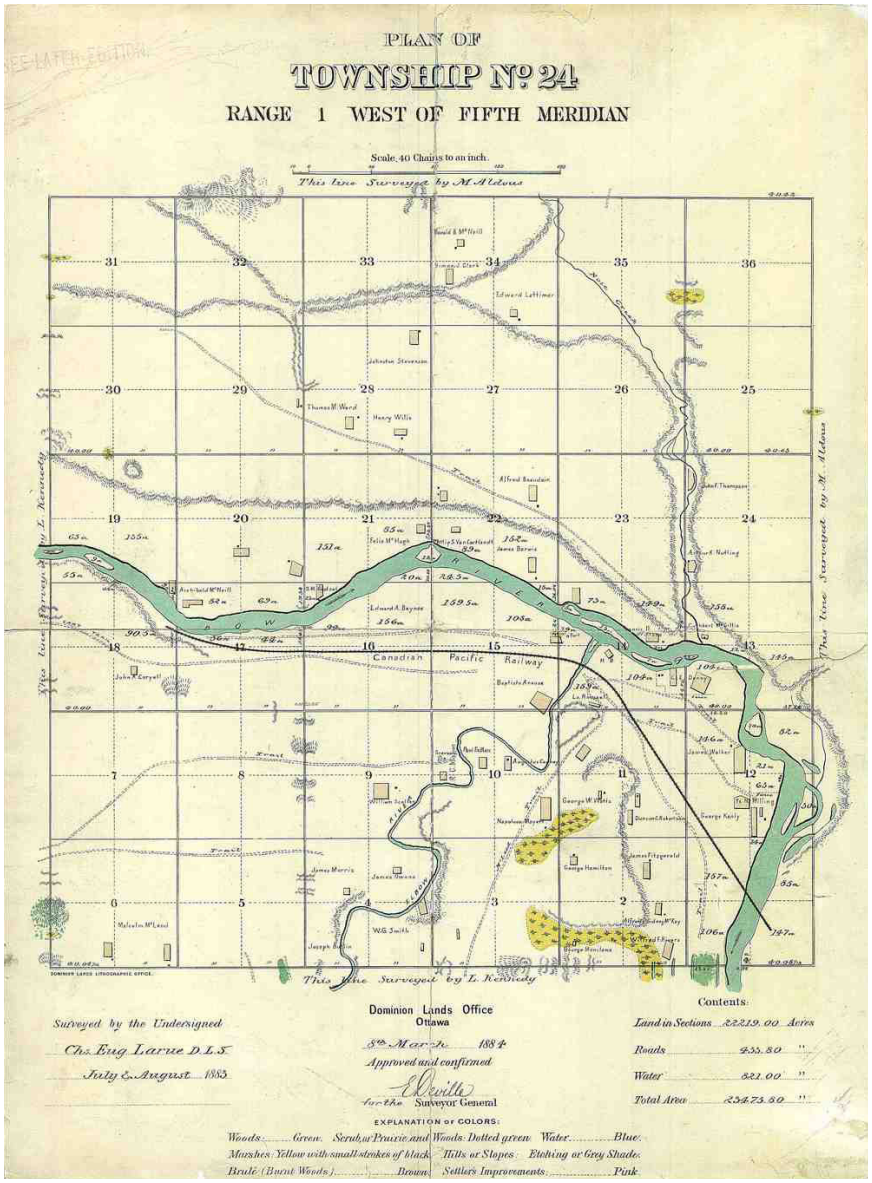


Figure.1.2. Map of Calgary, 1883. Digital Museums Canada.

High-quality residential developments such as single-family homes were mostly dispersed along the valleys of the two rivers, capitalizing on the valley views and majestic scenery.[9] Two specific communities that emerged from this phenomenon is Roxboro and Rideau Park. These communities, established in 1911, were marketed towards the desire to 'live by the river and amongst nature,' attracting high-earning residents to the city.[10] It was home to many important figures such as the first local Commissioner of the RCMP and famous author W.O. Mitchell, who had major impacts on the early developments of Calgary.[11]



Figure.1.3. Thomas Mawson's 1914 Plan for Calgary. Known as Vienna on the Bow. University of Calgary Archives.

Besides being an economic asset for the community, the Elbow River is considered an important watercourse for recreational activities. This pattern of residential development not only poses challenges to the ecology but also increases the risk of flooding and potential property damages. However, those risks have not discouraged the desire to live along the valley but rather encouraged the construction of water management infrastructures to control the water flow as the city develops.

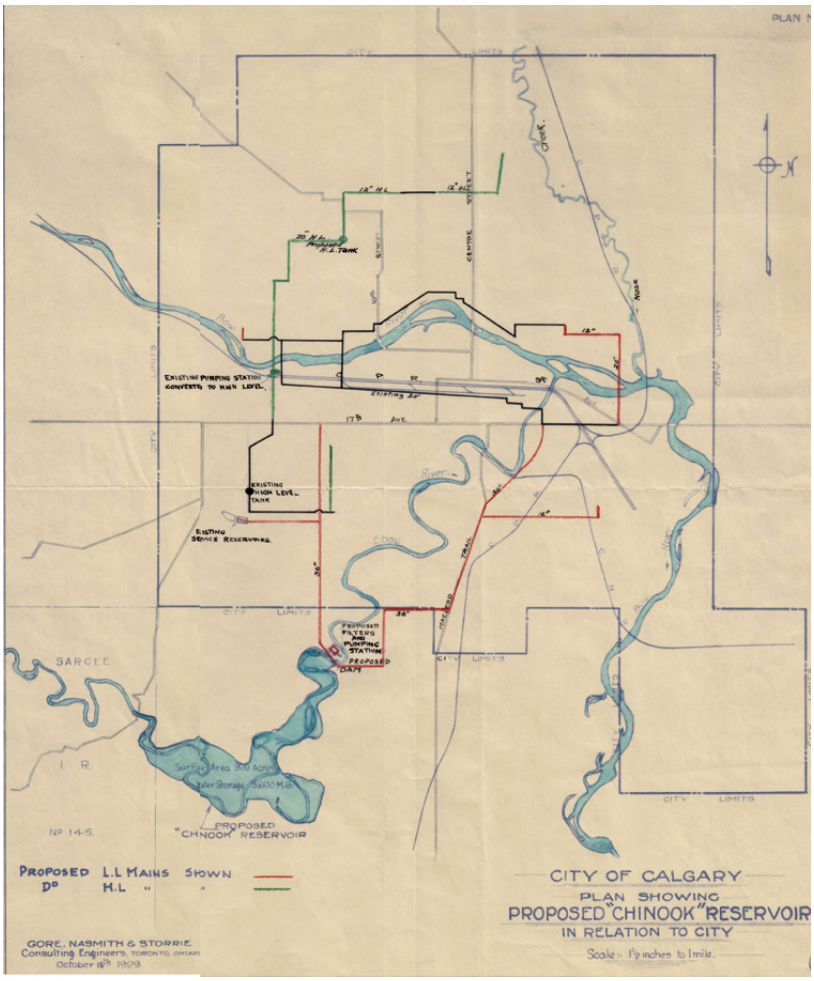


Figure.1.4. Proposed "Chinook" Reservoir" in Relation to City, 1929. City of Calgary Archives.

Waterworks have been critical infrastructure since the establishment of Calgary as the city relies on rivers to generate hydropower and water supplies. At the same time, droughts and floods constantly afflict the city. With rapid population growth and expansion between the 1910s to 1930s, the traditional infrastructure such as the gravity system, wasn't be able to meet demand; new utility infrastructure that can serve both the uplands and lower lands of the two rivers were required.[12] This was when the relationship between the two rivers and society started to change drastically, where the City attempted to master the two rivers through engineering applications to meet the population's needs.



ALGARY, ALBERTA, THURSDAY, JUNE 2, 1932 — 18 PAGES

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When Flood Waters Spilled Through New Dam

Spray cascaded 30 feet in the air when flood waters of the Elbow spilled through the new Glenmore Dam Thursday morning. Storage of millions of gallons of water in the new reservoir prevented a serious flood condition on the Elbow.
Bottom photograph shows the huge wave of water which carried away the temporary coffer dam below the dam proper. More than $4,000 worth of damage was done. Water was still pouring through at the rate of 9,000 second feet Thursday noon.—Photo by W. J. Oliver, Herald Staff Photographer.

Life of New
German Gov't
May Be Short

Reichstag Expected to B
Dissolved Within
Few Days

HITLER REGARDED AS
WINNER IN ELECTION

New Cabinet Remains
Power Until Will of Voters
Ascertained

(By United Press)
BERLIN, June 2.—Ger
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ment headed by Lieut.-Col
Franz von Papen, expelle
from the United State
during the world war, ap
peared destined today to
short life.
The new cabinet was regarde
generally as a stop-gap betwe
the recent government of Hei
rich Bruening and that to com
headed by Adolph Hitler.
The reichstag was expected to
dissolved in a few days, possi
by written order from Presid
Von Hindenburg without even c
vening, thus saving the cabinet
embarrassment of a certain def
in parliament.
The new regime includes few
landowners, military leaders,
influential industrialists. It wo
remain in power after dissolu
of the reichstag pending new e
tions in July or August. Hitl
party appeared certain to come
to power in the elections.

To Safe People

"President Von Hindenburg
now ready to conclude any alli
with Hitler to save the Germ
people," the Fascist newspa
Volkischer Beobachter said.
The new cabinet, with Von Pa
as chancellor, includes Forei
Minister Baron Constantine
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Curt Von Schiecher, chief of st
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departmental director of the
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Lacoste Is
Eliminate
By Brito

AUTEUIL, France, June
(A.P.)—Rene Lacoste, Fre
Davis cup veteran, who is
tempting a comeback after th
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ship play, was eliminated in
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Figure.1.5. Calgary Herald: "When floodwaters spilled through new dam" , June 2 ,1932. Calgary Flood Story.

In the 20th century, massive construction of dams and reservoirs began to take place along the two rivers to meet the demand of the city while reducing threats of floods and droughts.[13] One of the most prominent examples is the Glenmore Reservoir, also known as the Chinook Project back then, which began construction in July 1930. The project contained a sixty-foot-high overflow dam, a water purification plant, and excavation of about 900 acres of land to create the reservoir.[14] The design vision was that the reservoir would be capable of servicing a population of 200,000 people and become one of the major clean water sources for the City of Calgary.[15]

The Glenmore Reservoir played a vital role in the development history of Calgary as it served as the lifeline for the city and assisted the city's prosperity by reducing environmental risks in the lower Elbow River neighbourhoods. The project brought peace to existing communities along the river, and no major floods happened along the Elbow River from 1932 to 2005. People began to think that the Glenmore Dam would be able to save them from high water.[16] As a result, the recreational value of the Lower Elbow greatly increased, and more recreational facilities and parks that encouraged activities such as swimming and skating were built along the river.[17] With lessened flood risk and increased real estate values, areas within the floodplains were further developed during the absence of inundation.

However, rivers create opportunities, but they also push back, and history has proven it is impossible to tame a river. The 2005 and 2013 floods were harsh reminders that floods will never be permanently addressed. The Glenmore Reservoir is just one of the many dams that were constructed during the

early days, and it reflects the overall development patterns of the City. It is critical to learn from the lessons and understand that flood is not a problem but a force of nature that restricts human activities in certain areas. By learning how to respect ever-changing ways of rivers, the city can form a mutual relationship with nature, which will foster a resilient built environment.

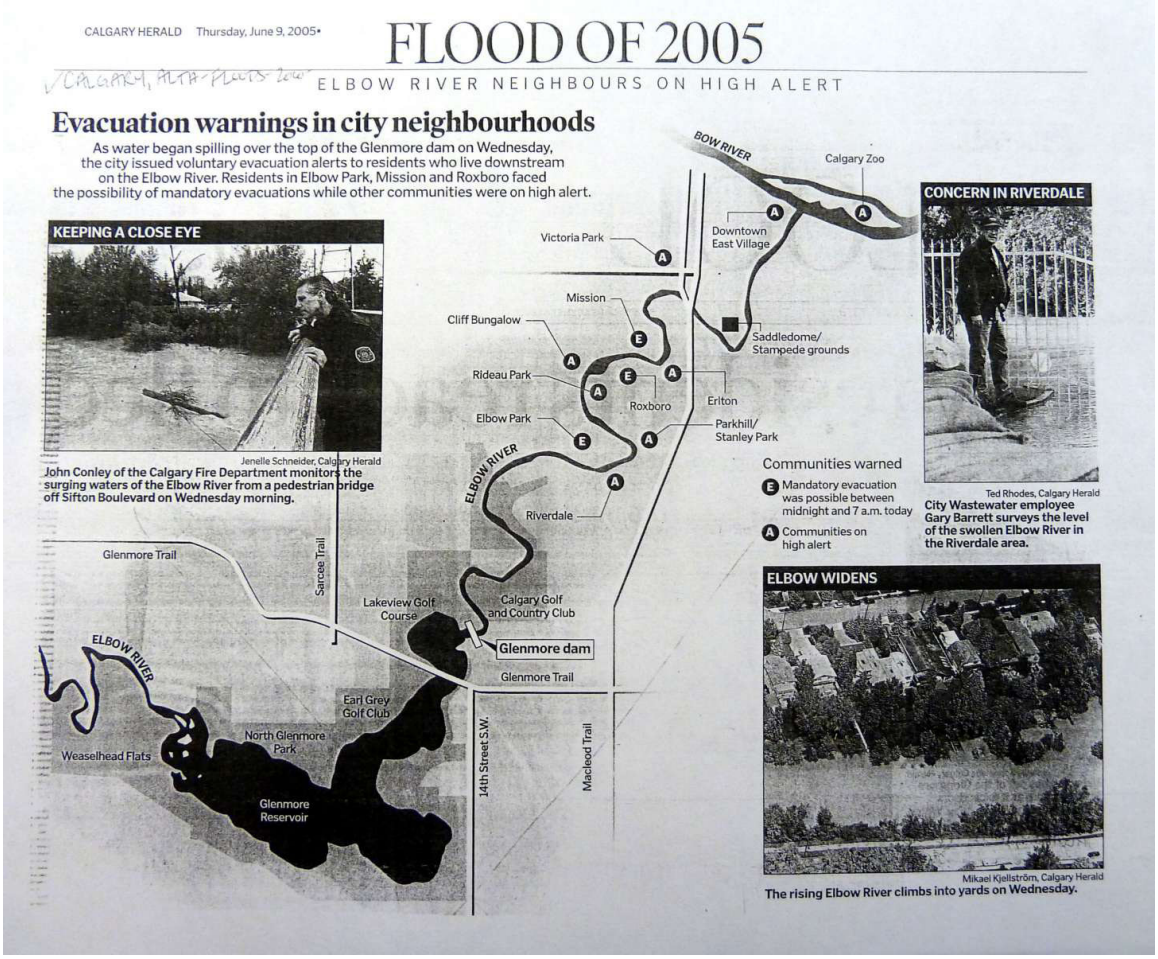


Figure.1.6. Calgary Herald: "Flood of 2005: Elbow River neighbourhood on high alert" , June 9 ,2005. Calgary Flood Story.

1.2 The 2013 Flood

The city of Calgary is known for having flood issues due to its early development scheme and unique geographical location, the oldest flood on record can be traced back to 1879.[18] River floods and stormwater floods are the two main flood types in Calgary. River floods usually happen from the middle of May to the middle of July when the heavy rainfall and snow melt in the Rocky Mountains rapidly drain into the two rivers.[19] This kind of flooding happens quickly and with little warning due to the short, steep path the rivers travel from the mountains to the city. The other type is local stormwater flooding which typically happens during the summer from excessive rainfall that overloads the local stormwater system.[20] With the increasing amount of hard surfaces in cities, how to navigate stormwater management has become an important urban design topic.

The 2013 flood was one of the most memorable floods in Calgary's history. It was one of the largest floods the city has experienced and solidified the definite risk of living in a floodplain. During the flood, the Bow River water flow peaked at 2,400 cubic meters per second, and the Elbow River peaked at 1,240 cubic meters per second.[21] The event cost a total of $6 billion in financial losses.[22] The images showcase the severity compared to the 2005 floods and the impact it had on residents, property and local infrastructure.

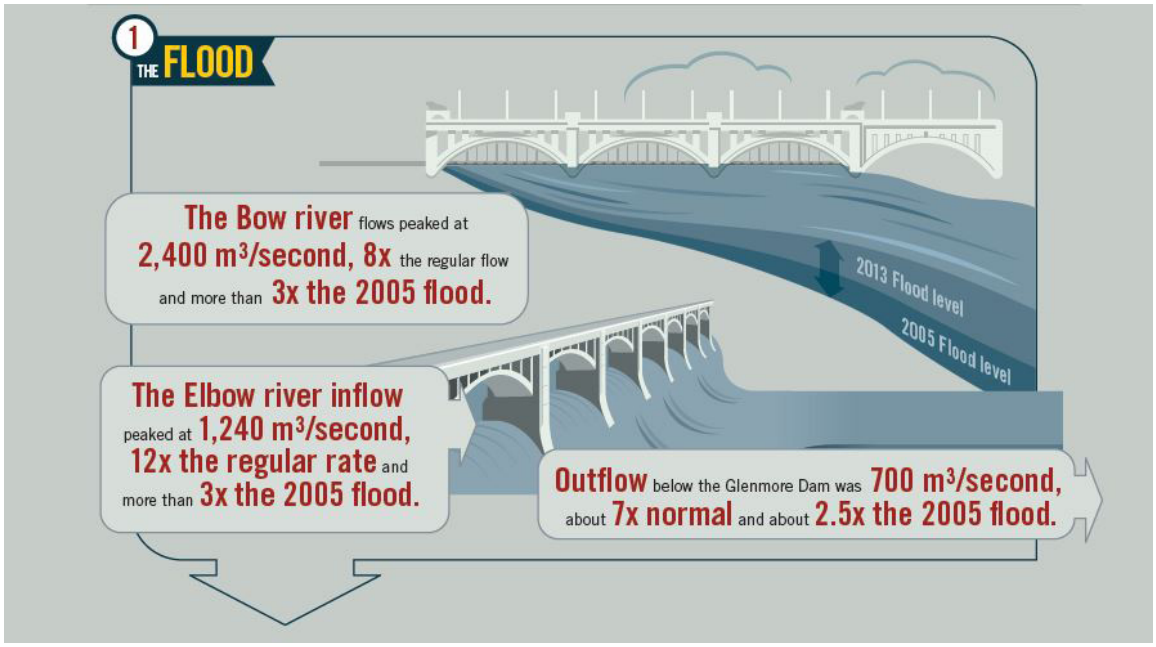


Figure.1.7. Flooding in Calgary -Flood of 2013. City of Calgary.

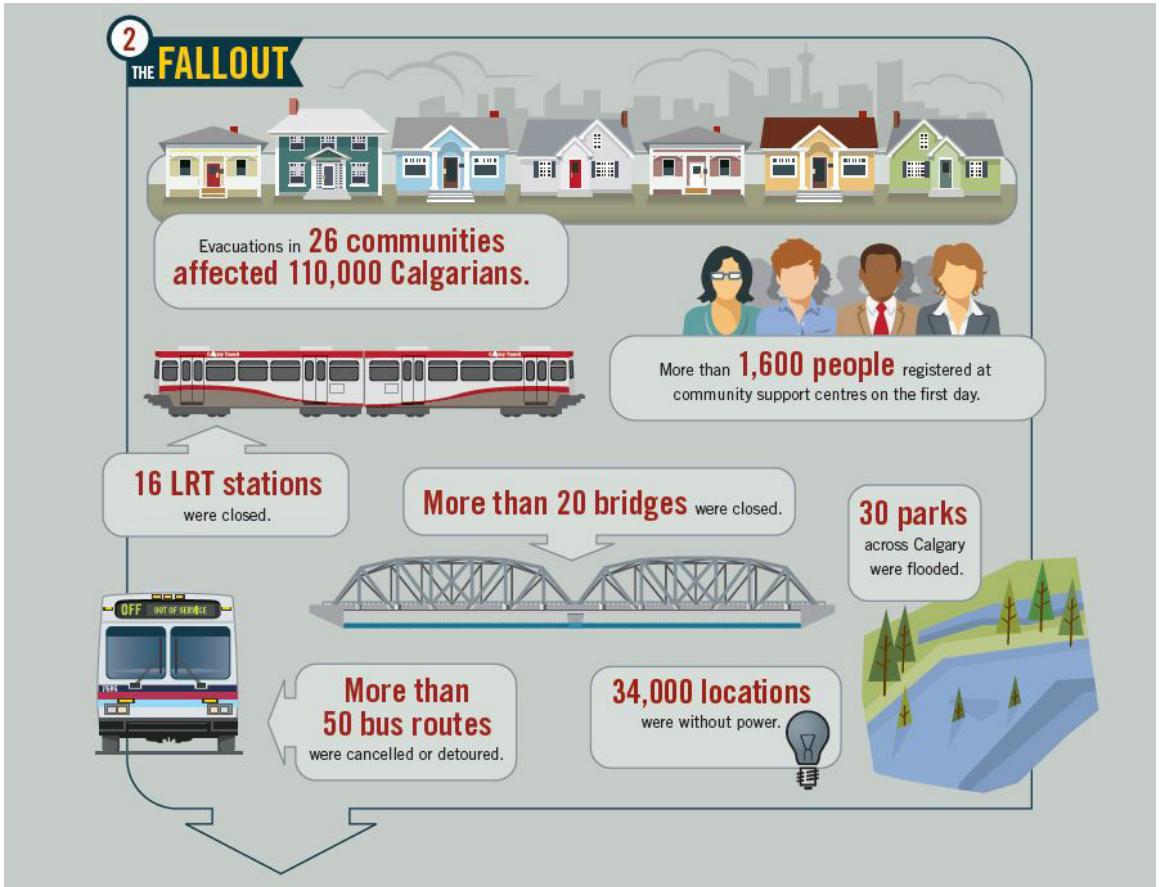


Figure.1.8. Impact of the 2013 Flood. City of Calgary.

On the afternoon of October 31, 1883, Calgary's only pedestrian bridge over the Elbow River was carried away by icy waters.



Popluation Just Over 500

1883

1884

Popluation Just Over 506



The flood destroyed all of Calgary's bridges inlcuding ten to twelve bridges and culverts along the CPR line to the west.The flood on the Elbow was made more dangerous as logs broke their booms.

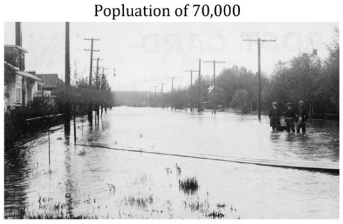
Both rivers and many of the surrounding creeks rose in the flood of 1897. Bridges were damaged or destroyed by the debris of other bridges being washed into the support structures.



1897

1923

Popluation of 70,000



Southern Alberta had faced several years of drought conditions. The rain heavy rain started on June 2 caused the flood. The flood casued considerable amount of damage before starting to recede on June 4th.

Bridges, including the 25th Avenue Bridge, were washed out in the heaviest rain the region had seen in decades.

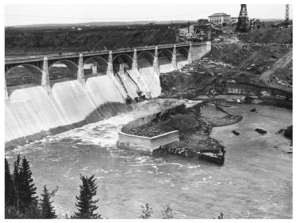


Popluation of 80,000

1929

1932

Popluation Over 80,000



Homes were threatened, and families had to evacuate both in the north and south sides of the city. Despite most of the city's infrastructure remaining intact, some roads along the Bow, most notably the government road which accessed the Keith Sanatorium, were washed out.

1902



On July 2, 1902, the Bow River overflowed its banks near the Langevin Bridge. Two families were evacuated and the police were on standby to evacuate the rest of the area.

Large amounts of rainfall were recorded in June 1915. The rivers rose rapidly and were soon threatening bridges, streets, homes and utilities. The rain was accompanied by winds and even a tornado at Red cliff



Popluation just under 68,000

1915

The flood was started by an ice jam in the vicinity of St. George's Island. Causing the ground water level to rise and creating overland flows which breached the dykes. The flood threat receded by Wednesday, December 6, when the Bow River created a channel through the south side of St. George's Island.

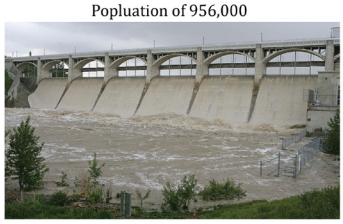


Popluation of 120,000

1950

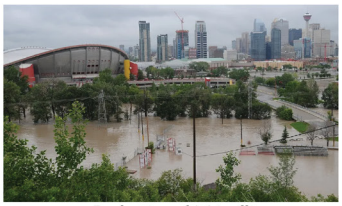
2005

Popluation of 956,000



A record 248 millimeters of rain – three times June's monthly average – fell on the city in three large rainstorms: June 6-8, June 18-19 and June 26-28, generating record high water levels. A state of emergency was declared, and the flood became one of the costliest natural disasters in Alberta's history.

A total of 32 local states of emergency were declared and 28 emergency operations centers were activated as water levels rose and numerous communities were placed under evacuation orders.



Popluation of 1.14million

2013

Figure.1.9. 1883-2013 Flood Events in Calgary. Collage by Author.

Calgary's current flood mitigation strategy is a defensive scheme to mitigate floods by building infrastructure to control water levels and resist water inundation. This management strategy has its strengths and weaknesses. As global warming and other factors in recent decades increase the risk of floods, it renders the current strategy ineffective and can cause serious risks to communities living along the riverbanks. After the 2013 floods, the City of Calgary started to invest in alternative solutions that looked beyond grey megastructures. Besides restoring riparian zones along riverbanks, the Dutch 'Room for the River' (RftR) program was introduced as the new urban strategy in their flood management approach. Room for the River is a preventative flood mitigation strategy that seeks to address the problem at its root by simply removing obstacles in the way of the water and creating more spaces to overflow.[23] The government of Alberta commissioned Netherland researchers to conduct RftR pilot projects in Calgary, however the project was suspended before completion.[24] There isn't a straight answer to exactly why the project failed and Chapter 2.3.1 of this thesis will reveal some of the challenges that the project encountered.

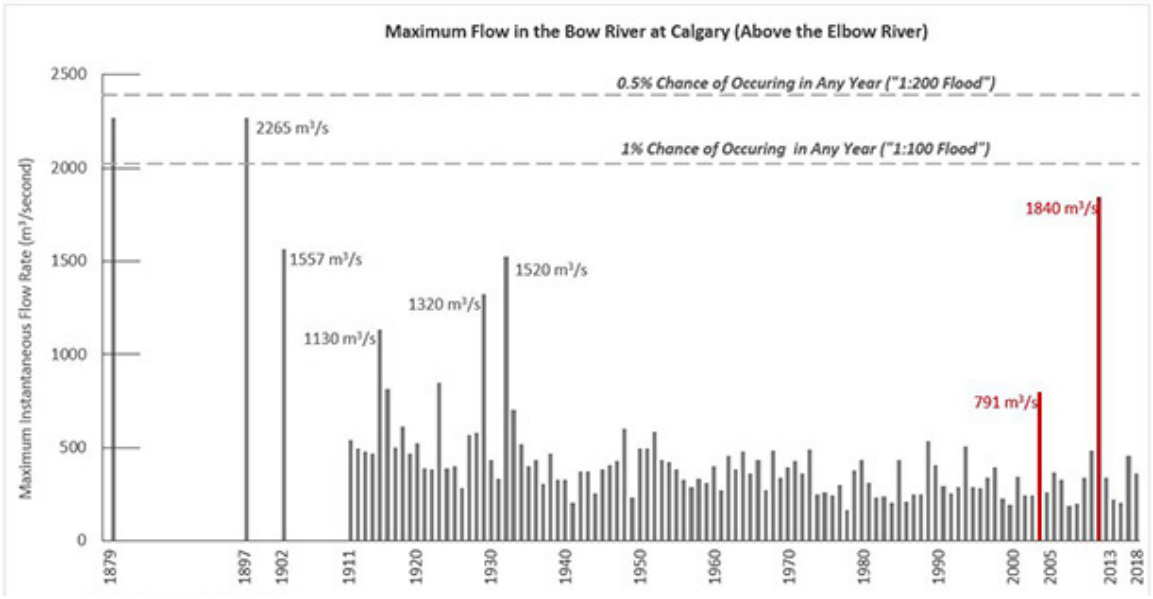


Figure.1.10. History of maximum flow in the Bow River. City of Calgary.

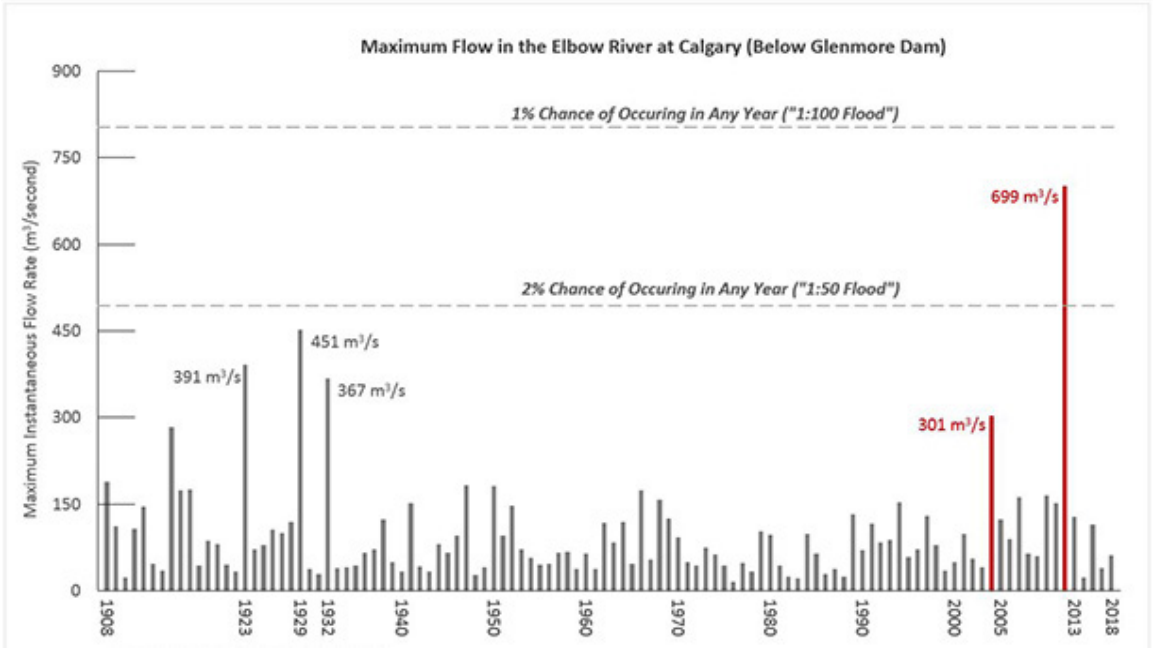


Figure.1.11. History of flows on Elbow River (below Glenmore Dam). City of Calgary.

A key to implementing the RftR strategy is relocation – relocating infrastructure and people from vulnerable floodplain areas. Relocation allows the rivers to reclaim their natural floodplains, reducing flood risk and enhancing the ecosystem.[25] Relocation was attempted by the Alberta Government in August of 2013 when the Premier drew on the rhetoric of risk and safety across the province.[26] Three main neighbourhoods, Elbow Park, Roxboro, and Rideau Park communities in Calgary were offered to relocate, but the result was unsuccessful. A total of 50 offers were presented to these three Elbow River communities, but only 17 homeowners accepted the offer.[27] In fact, most of the residents in the Roxboro neighbourhood refused to sell their heritage homes to the Province saying that they had little faith that the RftR program would actually future-proof floods in the area.[28] Overall, the buyout program offered by the provincial government was largely unsuccessful with only 37% uptake.[29] The program was highly contested and cost the government a significant amount despite being a failure.

Keeping development out of floodways is a constant battle as the desire to live close to the water continues. However, that does not and should not undermine the significant risks that come with living in the way of water - especially with the unforeseeable extreme weather challenges caused by climate change. What if the 100-year scale flood happens every couple of years in the future? Would the current urban planning approach and direction be sufficient to create flood resiliency? Room for the River strategies are essential for sustainable urban and environmental planning. It can offer long-term benefits that outweigh short-term gains from developing along waterways.

To replace the RftR program, the Alberta government announced the 3,700-acre dry reservoir located 15 km west of the city of Calgary. The hope is that this new mega structure, along with Glenmore Dam further downstream, will be able to prevent or reduce future severe inundation damages.[30] This Springbank Reservoir project, also known as SR1, will divert excess amounts of water into a temporary storage area when necessary and release them slowly over time. The dry reservoir is designed to hold 77.7 million cubic meters of water, which is 25 percent more water than the 2013 scale flood.[31]

It is thought the construction of SR1 will solve the flooding issues for a few decades, but it does not provide a permanent solution, and the negative ecological impacts of the dam will create further problems. The impact of over-human intervention in water cycles, overall disruption to the ecosystem, and sedimentation build-up due to damming could bring more harm than good, in the long run. Yet, engineered flood mitigation solutions such as dams and flood walls have

proven to fail over time, either due to lack of maintenance or reaching maximum capacity. It will be catastrophic if the Springbank Reservoir fails, pouring massive amounts of water out all at once, and the Glenmore Reservoir can only handle one-fourth the amount of water of the 100-year scale flood.[32] The existing lower Elbow riverbed condition won't be able to handle rapid discharge if there is a dam failure as proven during the 2013 flood. In this specific scenario, a natural-based solution that rehabilitates the capacity of the river's channel would provide an alternative approach that makes the overall flood mitigation strategy safe to fail while bringing long-term benefits to both the hydrosphere and communities along the Elbow River.

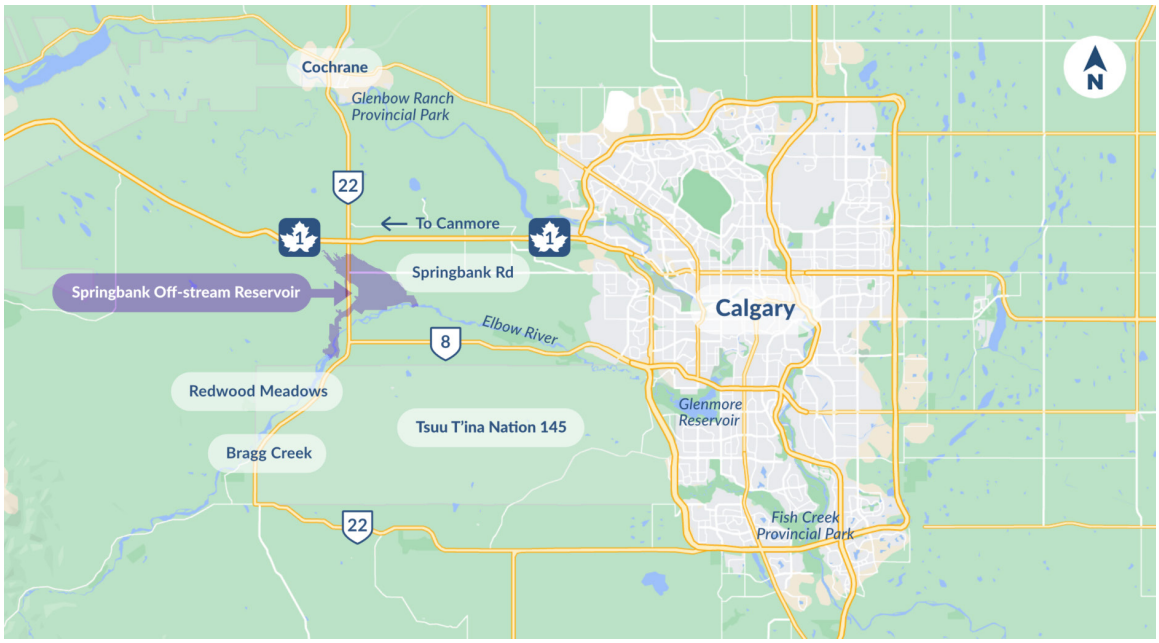


Figure.1.12. Location of the Springbank Off-stream Reservoir. Vinci Construction.

Despite the failure of the Room for the River project, the city of Calgary is still on board with the idea of applying nature-based solutions. Since then, the local government has implemented a series of landscape flood mitigation measures such as the Bend in the Bow project, the 101 riverbank and riparian projects, and the Bioengineering Demonstration and Education projects.[33] All these projects prioritize natural-based solutions and avoid using grey infrastructure if possible. However, one of the main challenges of landscape solutions is that it does not show immediate visible results and reassurance as mega engineering projects do. Regardless of the efforts by the city, the Bow River's flood mitigation solution is still being questioned by the public and citizens are requesting another reservoir be built.[34] However, as discussed earlier in this chapter, there are no silver bullets to all the river challenges and some of these problems, such as the phenomenon of flood itself, are unsolvable. Different from engineered solutions, the application of the natural-based method focuses on the cause of the problem rather than addressing the problem itself. One of the obvious and prominent causes is the over-development of the floodplain as the city grows. Returning the floodway to the river could be a long-term and more cost-effective solution which this thesis seeks to explore.

1.3 Human Over Intervention in the Rivers

The construction of SR1 is a typical approach that contemporary societies use to tackle flooding challenges. Such methods prioritize economic developments that separate human societies from nature and attempt to tame water. There are numerous cases of similar approaches across the globe. In the Netherlands, the coastline's position, level of dikes and river flow rates are constantly monitored by computers and defined by law.[35] In the U.S., over 76,000 dams were built in the past couple of decades to facilitate urban growth.[36] Human over-intervention in the water cycle is one of the main problems throughout urban development. Our actions in securing water supplies and encouraging developments have greatly impacted the overall environmental flows and recharge. [37] For instance, the construction of reservoirs to increase water supply and storage could potentially worsen water shortages as reservoirs will alternate the hydro climate, causing a change in the natural recharge rate due to large volumes of water being relocated.[38] Hence, despite efforts to conserve water, human actions have added to the consequences of disrupting the laws of nature.

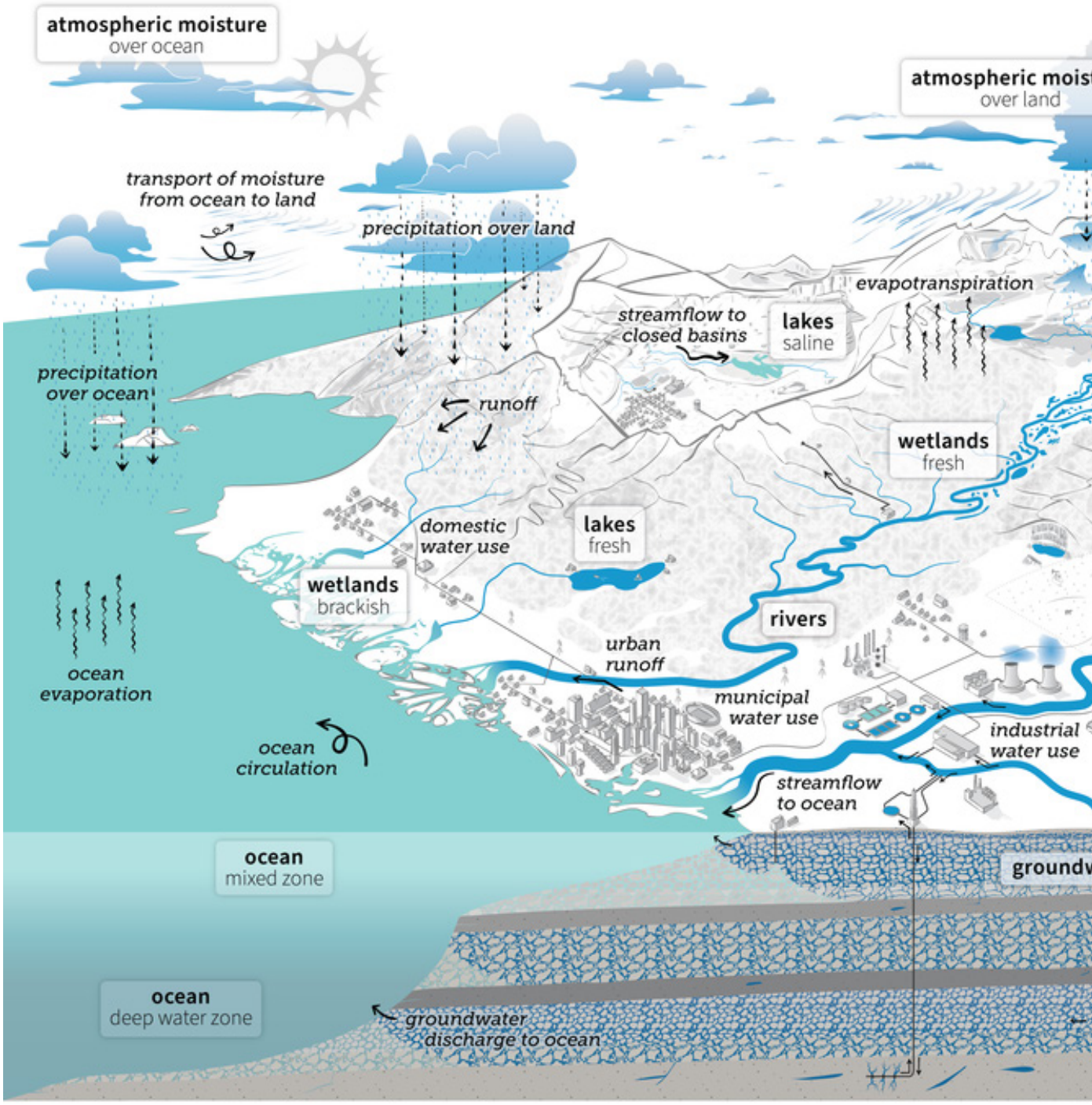
In 2022, a new water cycle diagram was released by the United States Geological Survey demonstrating the impact of human actions. Different from previous versions, this updated diagram includes social and environmental consequences of human activities such as farming, urbanization, deforestation, and damming impacts on the overall water cycle (Figure. 1.13).[39] These consequences were not included as part of the picture in the previous version. The updated information provides an important perspective on the socio-hydro

relationship between human societies and the overall ecosystem, offering a more comprehensive and accurate representation of hydrological systems. It is critical to realize the typical flood mitigation methods such as dams, reservoirs, and dykes, all assume that water is a tameable element.[40] This kind of assumption ignores that the landscape is constantly shifting and the action of stabilizing the landscape could seriously affect the overall ecosystem.[41] Climate change is the best example of the consequences created by our disruption to the environment. Besides the active strategy in the control of water, human disturbance over lands has also indirectly influenced the overall hydroclimate. About 75% of the ice-free land surfaces on Earth have been impacted by human activities.[42] In the process of exploitation, lands have been reformed, causing deforestation and wetland destruction.[43] All these actions have changed evapotranspiration, groundwater recharge, river discharge and precipitation on large scales.[44] Correspondingly, the hydrology system is also heavily impacted, which changes regional water flow and recharge rates.

Similar scenarios also apply to Calgary. Besides the massive Glenmore Reservoir that was constructed on the Elbow River, the Bow had been thoroughly redesigned, diverted, restrained, and flattened up by the 1960s to accommodate the needs and interests of stakeholders.[45] Concerns arise as this development pattern continues in today's Calgary despite the threat of climate change. How much water would the new SR1 dry reservoir, and the potential Bow River Reservoir relocate? What would the long-term consequences be? We are creating more issues by attempting to address one issue. Co-existing with the two rivers must become a number one priority for Calgary in order to prepare

for future unpredictable and extreme weather conditions. Understanding these dynamic principles will be the key to changing the approach to urban waterworks. Especially, climate change has been and will continue to be an additional factor in transforming the hydrosphere at the global level.

The question of how to better embrace atmospheric disturbance in urban planning will be the focus of our generation. One of the potential approaches to this complex question is to return critical lands, such as floodplains, to the ecosystem and give up attempts to control ever-changing dynamics of nature. Doing so will provide low-impact forward-looking solutions that create urban resiliency while the relationship between humanity and water are redefined. The next chapter will provide an in-depth explanation of the theory and the importance of the practice.


atmospheric moisture
over ocean
atmospheric mois
over land
transport of moisture
from ocean to land
precipitation over land
evapotranspiration
streamflow to
closed basins
lakes
saline
precipitation
over ocean
runoff
wetlands
fresh
domestic
water use
lakes
fresh
wetlands
brackish
rivers
urban
runoff
municipal
water use
industrial
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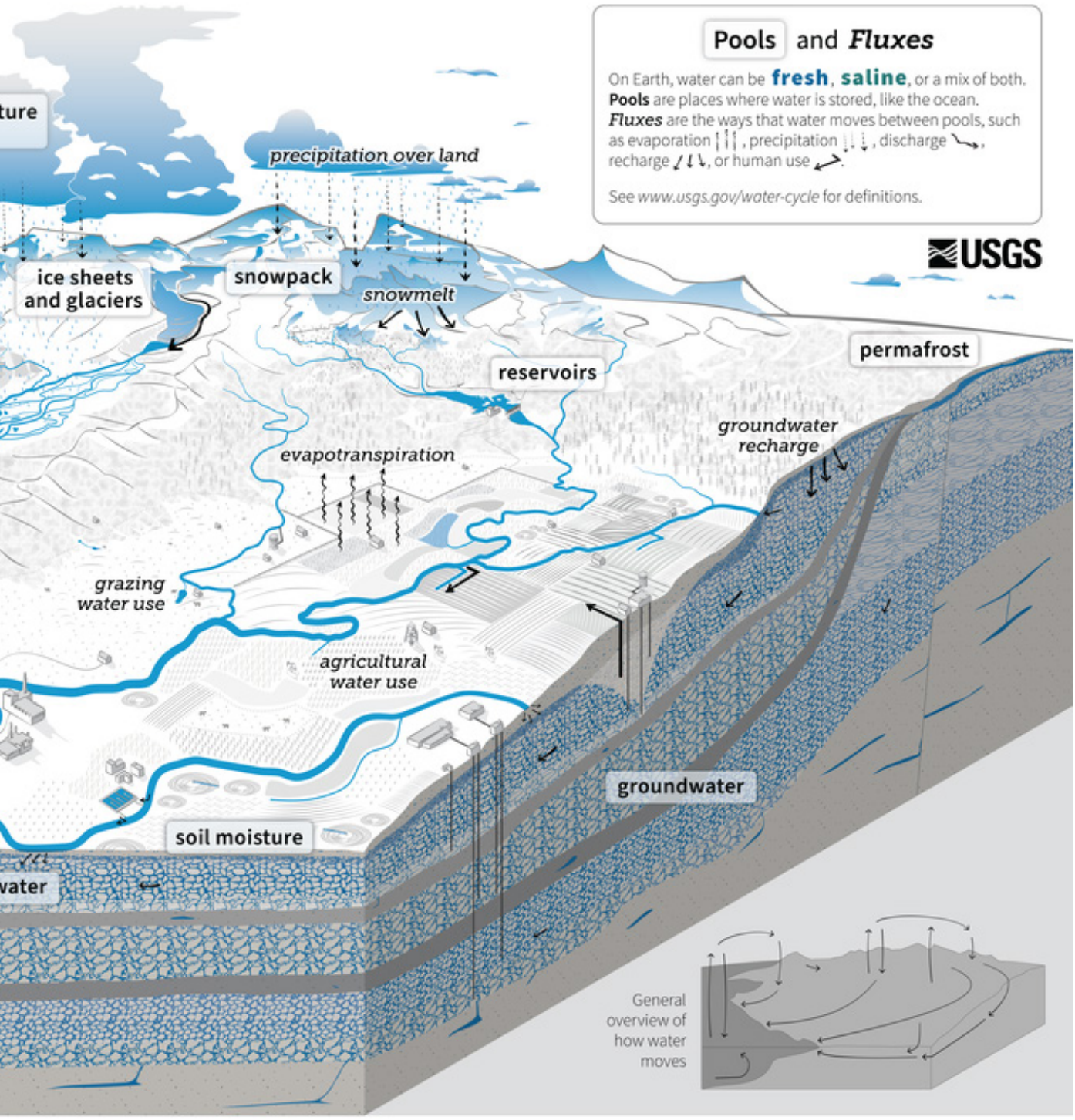


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2. LANDSCAPE OF RETREAT & STRATEGIES

2.1 Landscape of Retreat and PARA Framework

Flooding is one of the most common and destructive natural disasters in Canada.[1] A significant number of attempts to reduce the risks for residents and communities have been implemented in the past but have resulted in mixed outcomes.[2] As mentioned throughout Chapter 1, the traditional flood mitigation approach prioritizes engineering solutions to 'control' water, but this fails to acknowledge the complex social-ecological relationship between mankind and nature. This strategy fails to address the root causes of the problem and ignores other practices that could potentially reduce overall flood risk management, which trades long-term resiliency for short-term flood security.[3] Numerous historical Canadian flood events— such as the 2013 Calgary flood, the 2017 Ottawa and Montreal floods, and the 2018 New Brunswick flood—show vivid evidence that current Canadian flood reduction strategies have failed to mitigate those hazards.[4]

A new approach to flood mitigation is necessary—one that could provide solutions to the challenges that current rigid strategies are unable to resolve. This approach needs to emphasize accepting nature's unpredictability and acknowledging the destructive consequences of limitless development on our natural landscape. The concept of the "project, accommodate, retreat, or avoid" framework, also known as the PARA framework, was brought up by Professor Brent Doberstein to create adaptive flood resilience under climate disturbance in the Canadian urban context. As the name has already suggested, the PARA framework offers four main approaches:[5]

a) **Protect** falls under traditional flood mitigation practices, where engineered structures are put in place to control and limit water, thereby securing vulnerable communities from potential water disasters.
b) **Accommodate** is an adaptive approach that includes floodproofing and elevating structures from the ground to avoid inundation. This method is typically offered to floodplain communities that can't relocate due to numerous factors, offering them an alternative solution to cope with water.
c) **Retreat** creates flood resiliency by resettling communities, facilities and infrastructure designated in flood-prone areas to safe locations. Removing obstacles in the floodplain would allow rivers to flow along their natural courses again and avoid unnecessary damage.
d) **Avoid** is a preventive measure that addresses the problem at the root by restricting new developments happening in flood-prone areas. This can be achieved through means of bylaws and planning regulations.

In the specific context of Calgary, there are existing examples of the municipal government facilitating the retreat approach through strategies such as the Buyout Program and the Dutch Room for the River.[6] However, despite the initial intention, these were never fully implemented, and the complex sociopolitical dynamics shifted the outcome to the SR1 dry reservoir.[7] The reservoir would fall under the Protect category since it uses engineered structural approaches to achieve flood security rather than the Retreat framework. As discussed earlier, the implementation of grey infrastructure

lacks adaptability to the current climate trends. Therefore, this thesis seeks to continue to build upon the concept of Retreat through the use of nonstructural solutions to enhance flood resiliency in the city.

In Rosetta S. Elkin's book *Landscape of Retreat,* she states that "Retreat is not leaving in defeat, nor is it giving up hope." Elkin considers the idea of Retreat is not about abandoning land, but a change in perspective — instead of trying to bend the rules of nature with technology, the concept suggests achieving the end goal alongside nature.[8] This perspective shifts away from treating the natural environment as a force to be conquered or stabilized; and instead embraces it as a dynamic, ever-evolving entity that requires ongoing maintenance. By giving up on attempts to control nature, her book suggests shifting the focus of the flood mitigation framework from controlling water to adapting to the river, which redefines our relationship with the ecosystem and other species.[9] This change of perspective would open new possibilities, allowing other urban planning practices to look beyond engineering solutions. It is important to note that retreating differs from relocation. Retreat is an active and collective choice to leave certain lands behind to lower risks and vulnerability; while relocation is an involuntary process that happens after disasters.[10] Therefore, the act of retreat requires a recognition of the current deterioration of local environments, an awareness of the bonds with the past, and acknowledgment that cooperation between different government levels will be necessary to establish an effective approach for the benefit of society in the future.[11] By putting more emphasis on retreat practices, cities could achieve a more creative and resilient planning and building system that coexists with nature.

Floods pose considerable stress on communities throughout the lifecycle of an event, with both physical and mental health impacts.[12] At the same time, post-flood displacement can inflict profound trauma on those who are compelled to uproot.[13] They are forced to surrender properties rich with personal history and lands that are embedded with individual identities and memories. However, these physical and emotional damage scars could be avoided entirely should more emphasis be placed on the retreat practices.[14] Although the best solution is to retreat ahead of time, the relocation program could still act as a backup plan for communities that encountered difficulties in a pre-event retreat.

2.2 The Wicked Problem

Flooding is a wicked problem; it is a part of the natural hydrology cycle and a reflection of social interaction feedback on spatial and temporal scales. This means the challenge is constantly evolving due to social and climate factors, making it difficult to define and solve. Yet, the complex social values of different stakeholders, beliefs, and interests directly shape how these natural events are portrayed and hence impact the policies and outcome solutions.[15] Human societies tend to see rivers as lines that separate parcels of land and water, where the lands dominate over water.[16] Therefore, floods are usually portrayed as undesired events that need to be controlled within the drawn boundaries. As a result, the current flood management systems are set up as technical frameworks that attempt to separate human systems from external natural forces.[17] It is crucial to understand these underlying perspectives and values to reveal why certain methods are preferred over others and provide potential paths to unwind them.

Contemporary cities face a modern paradox: as societies increasingly rely on technology to shield themselves from natural threats, development in disaster-prone areas continues to expand.[18] The implementation of dykes, dams, and dry reservoirs provides false hope to the public — an illusion that potential floods are permanently managed.[19] During the absence of flood, developments will slowly expand to flood-prone lands as these "unclaimed" lands could bring investment values. At the same time, local memories associated with these hydraulic disasters will fade as well due to the lack of occurrence of deluge.[20] However, as history has proven multiple

times, these man-made hydrological solutions will eventually fail, either due to age, human errors, or reaching designed maximum capacities.[21] As a result, when the high water hits again, it will cause more damage than the previous event due to the new establishments adjacent to the water bodies. This phenomenon is usually described as the 'levee effect', where flood control structures often increase the vulnerability of communities and flood risks.[22]

Numerous examples throughout human history showcase the damages caused by dam failures. One of the memorable examples would be the Banqiao Dam failure in China. The dam was overtopped and disintegrated on August 9th, 1975, due to the excessive volume of water that was brought by Typhoon Nina, causing a flood wave approaching 500,000 acre-feet moving at a speed of more than 48 km per hour, causing 26,000 deaths.[23] Perhaps some of the casualties could have been avoided if the problem had not been overlooked. But the reputation of Banqiao Dam, renowned as the invincible "Iron Dam", overgrew government officials' confidence, which set the stage for tragedy.[24]

The loss of memories related to floods and the decrease in water-related disaster awareness is one of the main side effects of grey infrastructure. This could lead to tragedies when structures fail to shield the cities from external forces suddenly and citizens lack flood preparedness. Rather than interfering with the cycle of the water, natural-based solutions reduce risk by embracing flood. By doing so, memories associated with floods are constantly renewed due to the high occurrence of river overflows, maintaining the interaction and feedback loops between cities and water.[25] In this scenario, residents are highly alert to the potential of deluge and would likely avoid developments in the riparian zones.

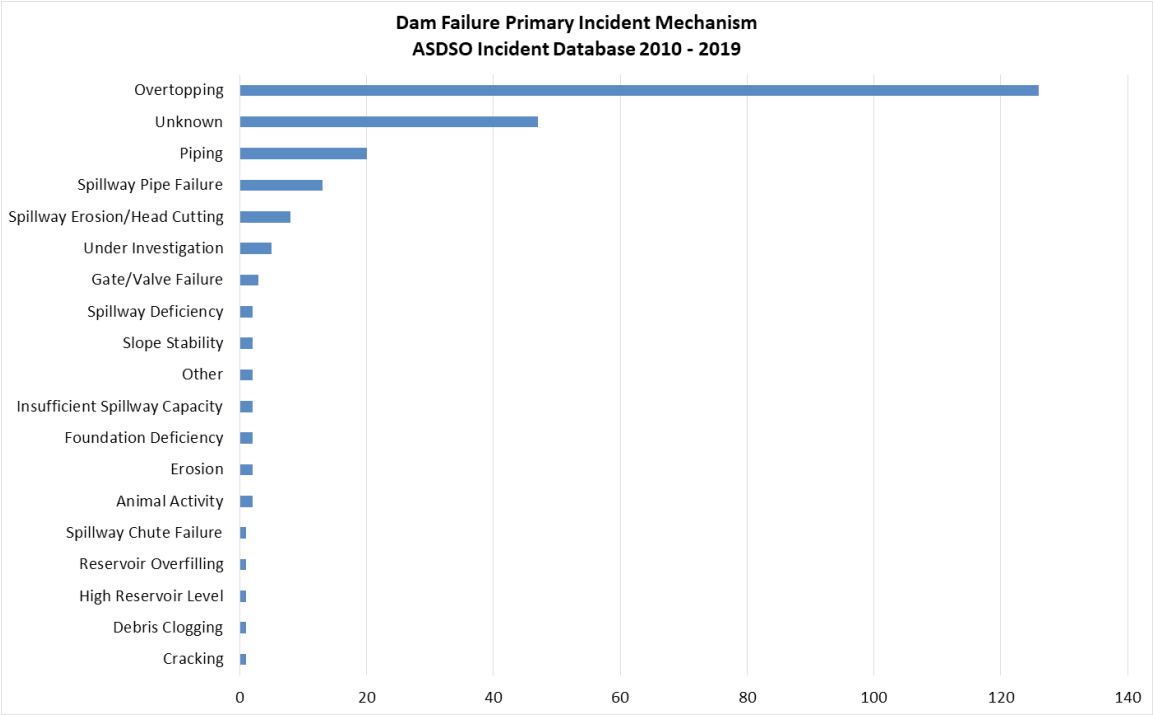


Figure.2.1. Causes of Dam Failures Incidents, 2010-2019. Association of State Dam Safety Officials.

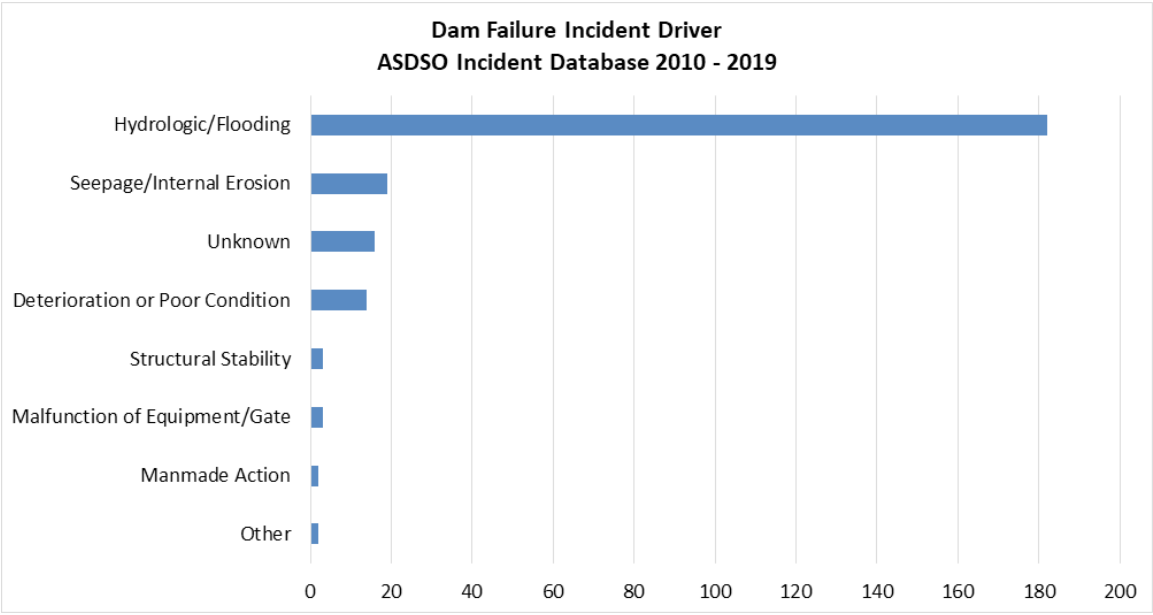


Figure.2.2. Dam Failure Incident Driver. ASDSO Incident Database 2010-2019. Association of State Dam Safety Officials.

The flood policy paradox continues in the insurance industry. Insurance and governmental reimbursements are stepping in to aid the recovery process after each catastrophic event. These policies are beneficial for the victims at first glance as they have relieved some of the financial pressure on restoration and appeased some anxieties. However, the risks remain unsolved when buildings are restored at the same location. The aiding initiatives have become a double-edged sword, turning people blind to the real problems with funding assurance, so they continue to rebuild in disaster-prone areas that are destined to ruin.[26]

As the frequency and intensity of floods increase over time, the cost of flood insurance coverage has drastically increased, becoming less affordable.[27] According to the Insurance Bureau of Canada, the financial loss averaged close to $800 million per year in the past decade.[28] To close the gap and avoid disaster insurance becoming a luxury that only the rich can afford, the Canadian Federal Government is considering introducing the National Flood Insurance Program to provide subsidized flood insurance for all homeowners.[29] However, it is questionable whether such a program would address the problem and the expense to insure and reimburse properties in high-risk areas has been and will continue to multiply. How much money will the government and insurance companies continue to pay when floods happen more often? In the case of the 2023 Florida hurricane event, there are cases where insurance companies refused to reimburse homeowners despite them holding hurricane and flood-specific policies.[30] On the other hand, the U.S. National Flood Insurance Program (NFIP) has a $250,000 limit per house for flood-related damages which is not enough to rebuild.[31] In this case, victims of the hurricane have to either pay the rest from their pocket or walk away from their homes.

The government-backed insurance program should be deemed a last resort rather than treated as the ultimate solution to the problem. Restoring homes within floodways is costly and puts people at risk. The recommended path moving forward is to strategically and slowly withdraw flood insurance from known flood-prone zones. Such action would provide long-term solutions and avoid unnecessary financial expenses while encouraging the practice of retreat by removing the barriers that sheltered residents from making better and well-informed decisions.

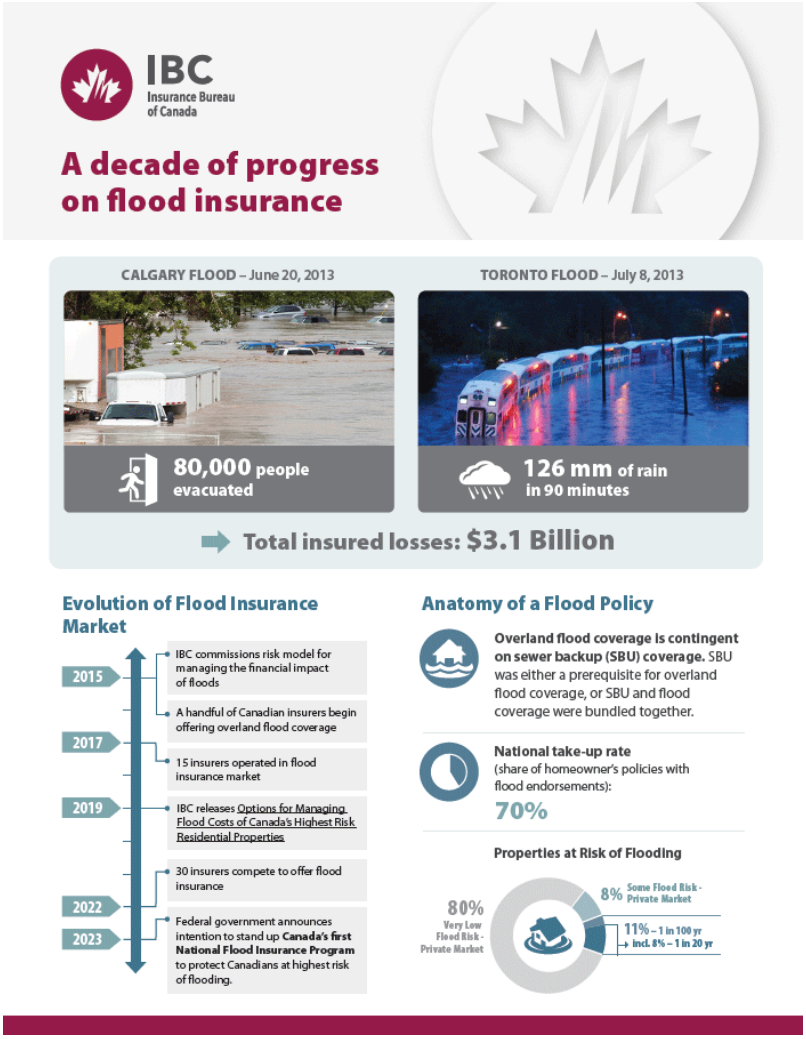


Figure.2.3. A decade of progress on flood insurance. IBC.

2.3 Design Strategies

After a successful retreat, a vast amount of land will be left vacant. Simply allowing nature to reclaim these areas will undoubtedly enhance the overall ecosystem within urban environments. However, returning land to nature isn't as straightforward as restoring it to its pre-exploration state. Land is more than just a physical surface; it embodies a complex web of relationships that are constantly evolving.[32] When these lands have been disturbed and modified by previous users, the intricate interconnections within the ecosystem are altered as well. As these homes are abandoned, parts of the materials and foundations will remain on site, becoming part of the land. Thus, fully restoring these relational values to their original state is impossible due to the ever-changing nature of these relationships.[33] Nevertheless, it is possible to rehabilitate these sites to a condition where they can sustain and support diverse forms of relationship-building. Given that these sites are located within human settlements and have been previously modified, it is crucial to recognize that human involvement is, and will continue to be, an integral part of this process.

The primary design focus is on floodplain ecology restoration. Unlike the typical urban park design that emphasizes more on a definitive outcome and spatial experience, this thesis aims to create an artificial landscape framework that prioritizes the ecological process while supporting the operation of the Retreat. An essential ecological theory guiding this process is the Mosaic Landscape Theory. This theory defines landscape as multiple habitat patches of various sizes, and the term 'mosaic' suggests that the boundary of these patches can gradually blur into one another as they

extend and interact.[34] As the theory explains, existing or newly created clusters of habitats—whether formed naturally or due to human activities—are essential to forming landscape mosaics.[35] This approach involves creating patchy distributions of habitats across the site that adapt to the evolving needs of the Retreat. Small rewild areas will generate diverse habitats, which will eventually expand and emerge with one another, forming larger and interconnected ecosystems. Categorizing the landscape ecology within a mosaic structure, the design would offer unlimited possibilities for adaptation and responsiveness to local environmental and social parameters. This approach aligns with the vision of the thesis, creating a dynamic and resilient urban environment. Utilizing movements and patterns of patches, referred to as Patch Dynamic in this thesis, will be a key focus in the later design phase.

As a result, the design proposal of this thesis will focus on creating an ecological park that is beneficial to both humans and the ecosystem. Two landscape strategies are studied to create a flood-resilient park. One is Room for the River, a great strategy to create space for the rivers to overflow, invented by the Dutch Government to manage flooding with minimum grey infrastructure. On the other hand, Sponge City is a strategy created by Chinese Landscape Architect Kongjian Yu, which uses nature-based solutions to create more permeable landscapes in the urban area that are designed to temporarily absorb the overflow water and release it slowly over time. Besides the two landscape strategies, the City of Calgary has commissioned O2 Planning and Design firm to create a series of landscape flood mitigation projects along the Bow River. Learning from these local precedents will enable this thesis to create a design that is complementary to the local context. Examining all the designs and strategies as case study

exemplars, the thesis will accumulate into an urban strategies' proposal implementing the combination of Room for the River and Sponge City to strengthen flood resiliency in Calgary.

2.3.1 Room for the River

The development history of the Netherlands is filled with battles against water. A saying perfectly describes the case: "God made the world, but the Dutch made the Netherlands." [36] About one-third of the country is below sea level and 55% percent of its territory is at risk of flooding.[37] Numerous waterworks infrastructures have been applied throughout history to make the land habitable. Among all the engineering infrastructures, the most prominent and the largest mega project in the world would be the Delta Works, a collective system that contains 13 different sections and spans 214 km.[38] Each section comes with individual sets of storm surge barriers, dikes, dams and sluice gates. This engineering masterpiece reflects how the Dutch dealt with water. In the country, most of the rivers are closely monitored and studied through models, metrics and chemical schemas, and these data are fed to the water engineers to test their designs and technological solutions.[39] This was the ordinary norm until a shift towards nature-based water management began to spread in the Netherlands in 1970.[40] The 1993 and 1995 severe storms in the country further accelerated the movement as existing grey infrastructures were unable to handle the challenges of growing climate risks, so new adaptive measures were needed to address more unpredictable weather.[41] This led to the invention of the Netherlands' national initiative Room for the River program, which aims to reduce flood risk to a reasonable level while enhancing the overall spatial and landscape quality to promote cultural, recreational, and aesthetic values.[42]

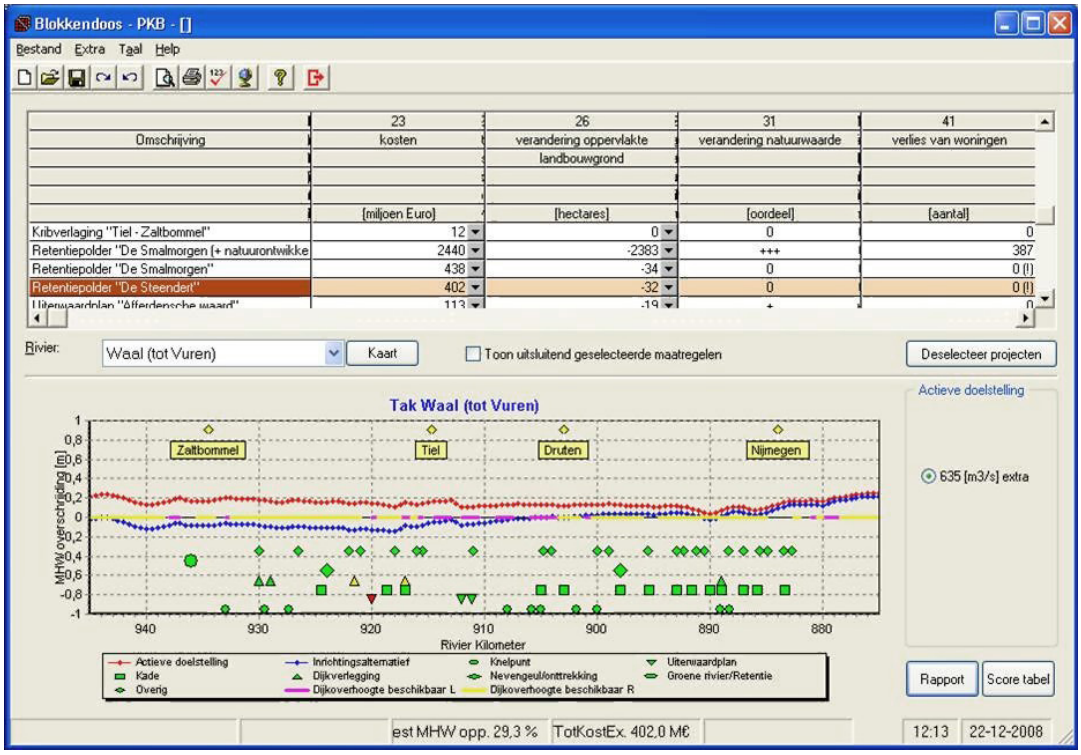


Figure.2.4. Blokkendoos software, used to visualize and compare the effects of different scenarios for Room for the River program. EduGIS.

Unlike the conventional Dutch approach, the new method Room for the River seeks to manage river systems through soft green infrastructure. The key principle of the approach is to rehabilitate a river's natural floodplain to create more spaces for the water to flow during high peaks rather than using grey infrastructure to withhold it.[43] Unlike the technological approach which treats water as set parameters, the new approach recognizes the behaviour of water is unpredictable. The shift began with environmental concerns of large-scale flood protection projects and with societal calls to rethink the water management approach between the 1950s to 1970s, which reshaped the Netherlands water management direction and measures.[44] In the following years, a government report called *Living with Water* positioned the "ecological main structure" at the center of the policy. [45] Furthermore, with the increasingly severe storms and the steadily rising sea levels, even the renowned Delta Works hydraulic structure has grown

vulnerable to the escalating risk of Climate Change.[46] All these events accelerated the creation of Room for the River and this soft structural measure focus represents a change of narrative from the Dutch standard flood migration approach. Rather than attempting to control water, the new concept thinks about how to 'live with water' — which aligns with the Retreat viewpoint. Yet, the RftR approach is still somewhat modelled and calculated through software called Blokkendoos to understand the effectiveness of removals, its impact on the water level, affected areas, and the number of buildings that need to be removed for the trade-off.[47] (Figure 2.4.) With the software, planners and stakeholders are now able to understand the results of different assemblages and test out options.

Returning the floodplains not only gives rivers more room to 'breathe' but also allows nature to form natural buffers to filter runoff and create habitats for wildlife. Despite the benefits the new program would bring, it is also a political project as creating space for water means certain communities and farmers need to surrender their land and current livelihoods. This means even if it is the best practice, policy and decision-makers will have to deal with local opposition which could impact the outcome of the project. Meanwhile, rewidening rivers is a softer approach and one that may appear politically risky when compared to the immediacy and impressive visual effect of mega structures.[48] It is easier for politicians to favour the latter option to gain more votes. This became evident in the case of Calgary when the Government of Alberta (GoA) initiated the Room for the River (RftR) pilot project.[49] The adoption of RftR approach in Alberta can be categorized into four main features: moving away from mega-infrastructure, creating space for rivers, relocating people, and regulating developments in floodplains.[50]

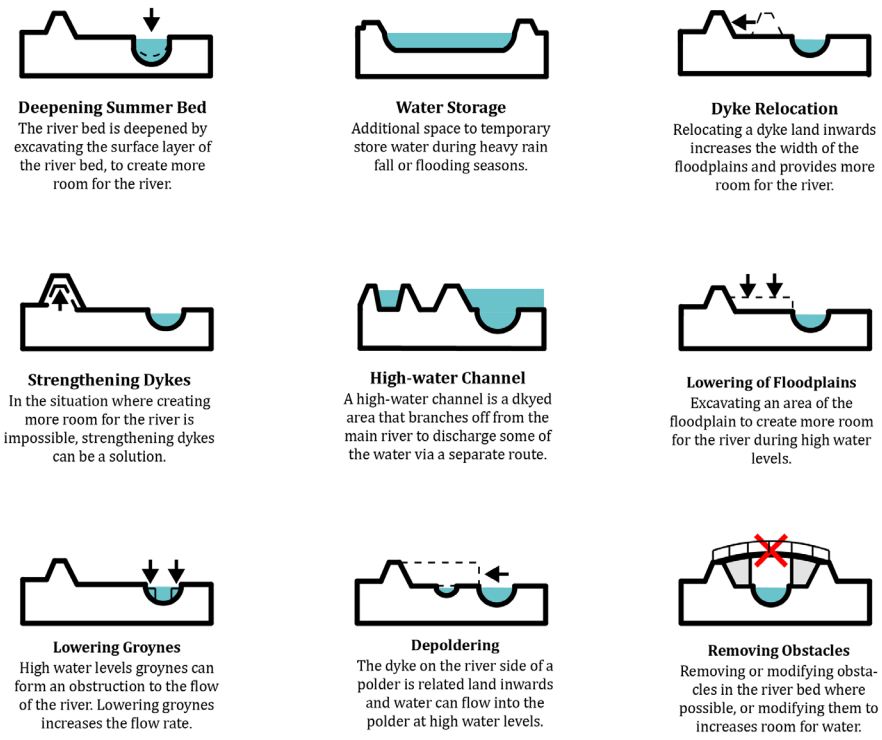


Figure.2.5. Room for the River Diagram. Re-illustrated by Author. Retrieved from: Busscher, T, M van den Brink, and S Verweij. "Strategies for Integrating Water Management and Spatial Planning: Organising for Spatial Quality in the Dutch 'Room for the River' Program." Journal of Flood Risk Management 12, no. 1 (2019). https://doi.org/10.1111/jfr3.12448.

The application of the RftR program began with GoA's announcement of the voluntary Floodway Relocation Program in August 2013, offering to purchase homes located in the floodway.[51] Out of a total of 254 offers across the province, 50 offers were presented in Calgary.[52] However, most of the homeowners in Calgary refused the offer, and only 17 of these offers were accepted. Although the relocation program was not initially labelled as part of the RftR project, it was acknowledged in a later report in 2015 by Deltares report.[53] In addition, Alberta WaterSmart Solution Ltd. conducted research in 2014 to test the feasibility of the program in Calgary's context. The report suggested a handful of sites contained great

potential along with fewer trade-offs and implementations of the program should bring overall benefits to the city and its biodiversity.[54] However, regardless of the existing actions already taken for the Room for the River program, and the potential benefits identified, there were a few back-and-forth shifts in politics and the large-scale mitigation project SR1 was announced as the final winner.[55] This political conflict is reflected in one of the Albert Government news articles, where Jim Prentice, the Provincial Premier back then, called the Springbank project 'an innovative "Room for the River" dry reservoir' despite the construction of SR1 dam being the complete opposite of RftR measures.[56] Yet, the Springbank Dry Dam was never associated with the Dutch Room for the River project before by any organizations or figures, so the mislabeling could have additional political intentions.[57] No official reason has ever been given as to why the project failed in Calgary. While exploring the political aspect is not the main scope of this thesis, it is important to note how they shape the eventual built environment.

As mentioned earlier, the values and interests of different stakeholders will directly influence how the flood is perceived and the result of the mitigation approaches. The government's decision regarding SR1 in Calgary is a clear representation of the priorities of those in power. However, in comparison, the Floodway Relocation project was also applied to High River, a town located 70km south of Calgary, and the result was successful. Two out of three communities who were offered relocation packages completely moved and returned lands to nature.[58] The other community didn't have to relocate because the flood was caused by water diversion from temporary berms in the town's core, the neighbourhood would have been fine without this external factor.[59] There are

numerous successful relocation projects across Canada and High River is one of these cases. It is also worth noting that High River town is much smaller in comparison to Calgary, and the political and societal factors involved would have been much lower. This thesis seeks to continue building upon the concepts of previous RftR projects in Calgary, focusing on the best flood mitigation practices without social and political influence.

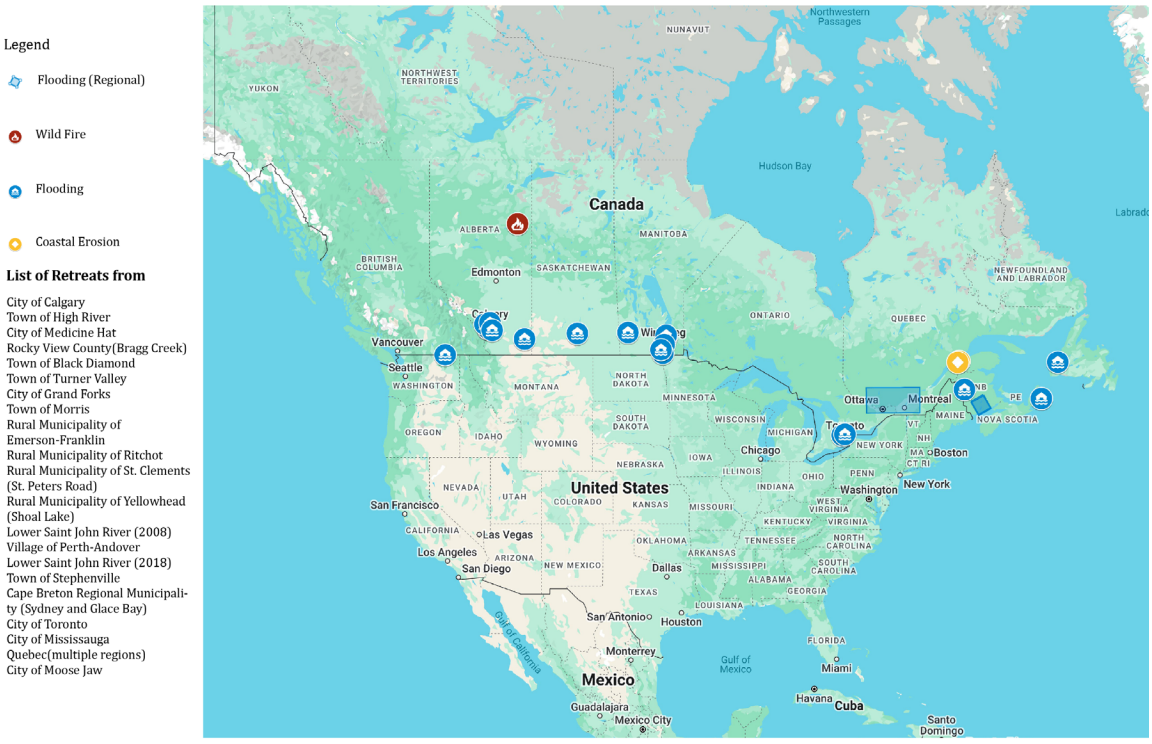


Figure.2.6. Map of property buyout initiatives across Canada throughout history. University of Waterloo.

2.3.2 Sponge City

Sponge City is an active landscape strategy invented by Landscape Architect and Professor Kongjian Yu that seeks to restore and artificially enhance land's absorption, infiltration and water purification capabilities.[60] The theory of Sponge City can be understood as an 'old wine in a new bottle'; it is a combination of traditional and contemporary landscape engineering knowledge, with some rainwater management methods dating back a couple of thousand years.[61] Sponge City was first officially mentioned by China's President Jinping Xi in 2012 and conceived in 2014 as the national urban water management strategy that is ecosystem-focused.[62] This concept was introduced in response to the increasing urban flood vulnerabilities in China, as 641 cities were identified at risk of flooding by the Office of State Flood Control and Drought Relief Headquarters in 2013.[63] The creator of the theory, Kongjian Yu and his firm Turenscape, have been working on the theory since 1997 and the first project was designed in 2000.[64] After the announcement as the national strategy, the theory has been widely implemented in China over the past couple of decades in the form of large-scale landscape projects that manage stormwater flooding and they have proven to be effective. However, with the increase in precipitation, numerous Sponge City projects have failed during the monsoon season.[65] It is debatable whether the concept has flaws or the failure was caused by other external factors. Some argue the perception data that were used to design these projects were outdated and not in line with current climate change estimates, while Kongjian Yu himself believes that these projects were not executed properly by the local authorities.[66]

The Zhengzhou Sponge City project is listed as an example of a "failed project" where the government has spent around C$10 billion to create a flood-resilient city which was overwhelmed by an extreme thunderstorm.[67] More research is required but questions and concerns about the concept have been raised as these non-structural projects are massive and highly expensive. The results of Sponge City projects show that relying on a single solution might not be enough to address the unpredictable weather and the complex urban water system. To increase the likelihood of success, a mixed approach appears to be the more cost-effective way ahead. The real challenge is to find interventions that are most beneficial with the least social, economic, and environmental costs. At the same time, acknowledging not all floods are preventable and creating design solutions that buy enough time for citizens to retreat, thereby making it an essential concept that, at worst, projects can be deemed as safe to fail.

Despite some failures, multiple Sponge Cities have been successfully operating as well. [68] Such as the Qunli Stormwater Park, Zhongshan Shipyard Park, and Ningbo Eastern New Town Ecological Corridor. The application of Sponge City could be implemented in three different scales: the macro scale focuses on general planning at the national and regional levels, the medium scale looks specifically at urban and city planning, and the micro-scale examines specific sites for opportunities to improve and create water management.[69] The concept shares similarities with other green infrastructure designs such as the Low Impact Development (LID) approach from the U.S.[70] It has adopted principles from LID and modified them to better address China's context, the improvement focuses on the effectiveness of urban runoff control, temporary water storage, recycling, reuse and purifying stormwater.[71] In addition, the

Sponge City theory also encourages the enhancement of the drainage infrastructure and protection standards, as well as the utilization of natural and artificial water bodies and greenspace for drainage designs.[72] As described, Sponge City is a complex theory that looks at the water crisis from multiple perspectives. The primary focus of this thesis only examines its landscape flood and runoff control methodology as the City of Calgary also has severe stormwater and drought issues. Combining both Rooms for the River and Sponge City strategies and applying them to Calgary's context could provide comprehensive flood protection to the city.

2.4 Precedent Discussion

Challenges arose during the search for well-documented design precedents that incorporate phased retreat strategies and practices. Therefore, the case studies section examines different landscape-based flood mitigation projects around the globe to understand the complexity of ecosystems in different contexts and styles of approaches to put together a design that works well for the Retreat theory. All the projects are carefully selected to ensure the approach aligns with the goal of this thesis.

2.4.1 O2 Precedents

West Eau Claire Park
Landscape Firm: O2 Planning + Design Inc.
Project Size: 16 acres.
Year: 2016-2018
Location: Downtown Calgary, Alberta, Canada

West Eau Claire Park is one of the popular linear parks along the Bow River. It sits next to the Calgary downtown and is close to the iconic Peace Bridge. It was commissioned by the City of Calgary to create additional flood protection for downtown Calgary while offering the citizens a public park. During the construction of the park, pre-existing pathways were raised and widened, riverbanks were restored and protected, and grading and landscaping were implemented to create resiliency against a 1:200-year flood event. This was one of the few major landscape flood mitigation projects built within the city of Calgary after the 2013 flood. This case study provides an excellent example of creating a linear park and natural-based strategies for flood management.

The author visited this project in Calgary at the end of May 2024 to gain a more comprehensive understanding of the project. Despite some landscape strategies being used for flood control, the usage of flood barriers is also prominent. About half of the park contains certain forms of flood wall. Some areas use either metal or concrete flood barriers, while in other areas, flood barriers are in the form of benches to provide additional amenities. The reason for the heavy usage of flood walls in this project is obvious — to protect mid and high-rise apartments behind the park. More active flood control

strategies are required as there isn't enough land to build a full nature-based flood solution between the apartments and the river. Furthermore, the cost of relocating these apartments would have been prohibitive. In this case, dykes would have been more effective and provided an important protective element of the overall landscape strategy.



Figure.2.7. Photo of the West Eau Caire Park Delta Garden. CANA Group.

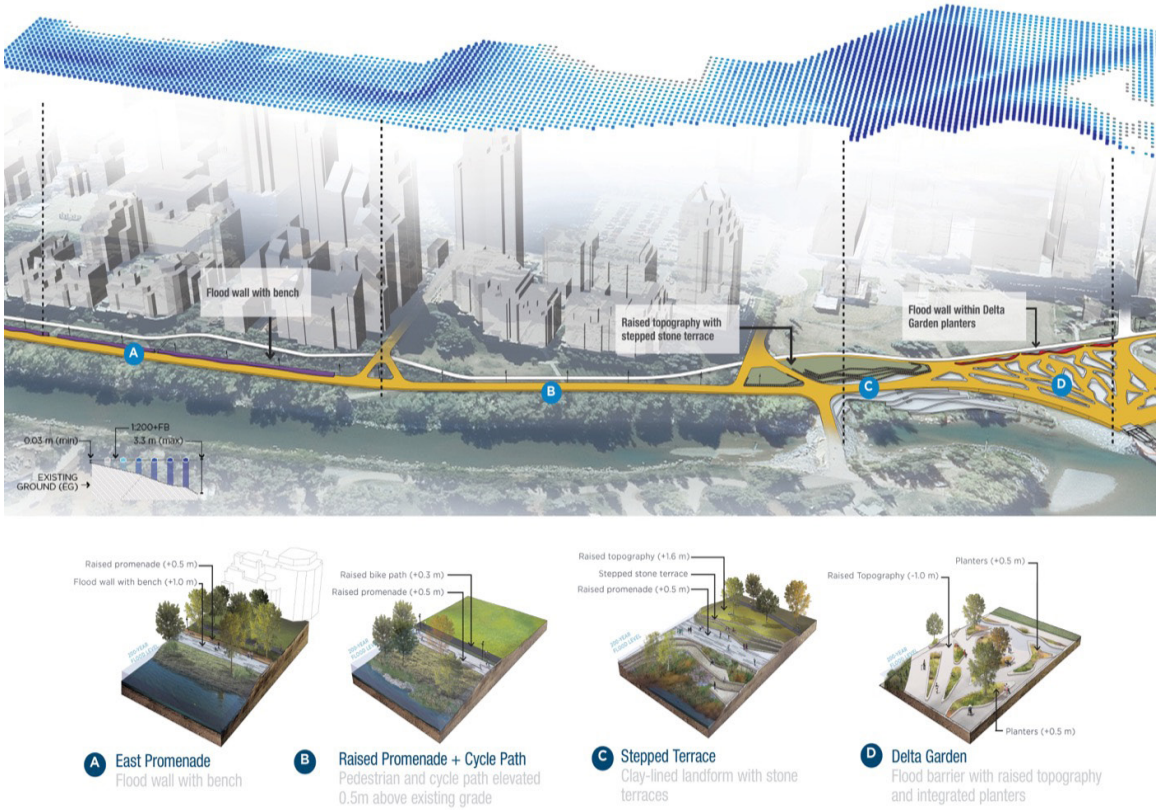


Figure.2.8. West Eau Claire Park. CSLA.



Figure.2.9. Metal Flood Barrier in the West Eau Claire Park. By Author.



Figure.2.10. West Eau Park Modified Riverbanks. By Author.

Bend in the Bow
Landscape Firm: O2 Planning + Design Inc.
Project Size: Over 100 hectares
Year:2015-2017
Location: Calgary, Alberta, Canada

Bend in the Bow is a connection project that connects three existing parks along the Bow River: the Inglewood Wildlands, Inglewood Bird Sanctuary, and Pearce Estate Park. This project seeks to maintain and enhance these sites' existing cultural and natural significance while creating additional educational opportunities. It also creates a linkage between the three parks and encourages complementary uses. The design vision of this project is to create a series of parks that tell stories of the local communities and the city, this includes Indigenous use, European settlement, rhythm of the river, and movement of the wildlife. The project is set to protect the important natural and cultural resources, finding a balance between nature and the city. Public engagement meetings were held to share visions and receive feedback. This case study would provide an excellent example of how to adjoin parks, create landscape elements that are beneficial to both social and ecological values, as well as increasing Calgary's flood resilience.



Figure.2.11. Pearce Estate Park Grand Vision Plan. City of Calgary.

While the Inglewood Bird Sanctuary and Inglewood Wildlands focus more on ecological preservation and education, a series of landscape strategies are used within the Pearce Estate Park. It uses wetlands, active water edge, flood protection landforms, bioretention, and weirs to separate and slow down flows. Harvie Passage is another landscape project within the park. This project has modified the Low Flow Channel between the park and the island into a recreational channel for surfing and kayaking. The island's river edges have been modified with moulded large river rocks to prevent soil erosion, but such action has significant ecological impacts.



Figure.2.12. Overview of the Harvie Passage at the Head of Lower Flow Channel. By Author.

Furthermore, there is an additional diversion happening besides the Higher Flow Channel, redirecting water to a subchannel with concrete riverbanks. (Figure 2.13.) This modification is not part of the Bend in the Bow River project, but it is worth noting that this diversion project is to protect the highways adjacent to the river.



Figure.2.13. Looking at the Diversion of Higher Flow Channel from Harvie Passage. By Author.

Dale Hodges Park
Landscape Firm: O2 Planning + Design Inc.
Project Size: 40 hectares
Year: Completed in 2019
Location: Calgary, Alberta, Canada

The Dale Hodges Park is located adjacent to the northern bank of the Bow River, it was known formerly as the Klippert Gravel Pit. The City of Calgary purchased and restored the land into a stormwater-treating landscape. This project can reduce the sediment in the stormwater by half before it enters the Bow River and the entire process is visible to viewers as a way to initiate curiosity and interaction with nature. This case study will provide an example of landscape strategies in rainwater management, and the approach shares similarities with Sponge City's terrace system, which also aims to filter water before it enters the river. Examining both approaches and combining them will form a solution that fits better for the local landscape.



Figure.2.14. Aerial Photo of Dale Hodges Park. O2 Planning + Design Inc.



Figure.2.15. Dale Hodges Park Rendered Landscape Plan. City of Calgary.

Summary

The most prominent approach implemented throughout O2 case studies is restoring the natural environment, where hard landscape solutions are only used when necessary. This is a more balanced and cohesive approach that involves less land modification in comparison to Sponge City and Room for the River case studies. However, all of these projects are located along the Bow River, which is wider and deeper than the Elbow River. More aggressive landscape flood mitigation solutions are necessary for the Elbow River to effectively reduce flood risks.

2.4.2 Sponge City Precedents

Ningbo Eastern New Town Ecological Corridor
Landscape Architect: Konjian Yu
Landscape Firm: Turenscape
Project Size: 37 Hectares
Year: 2010-2016
Location: Ningbo, Zhejiang, China

The Ningbo Ecological Corridor is built upon a post-industrial site that requires ecological reconstruction. The site is in the middle of Eastern New Town in Ningbo and now has been transformed from a contaminated brownfield to a linear "living water filter." This ecological corridor contains terraced wetland and islanding systems that will slow down rainwaters and filter them before they enter the river. This precedent provides an example of how these landscape engineering systems can be applied which will feed into the later design phase. On top of that, this project would be an excellent case study for creating an eco-corridor that connects all the scattered green spaces.



Figure.2.16. Photo of the Pedestrian Pathway and River's Edge. Turenscape.

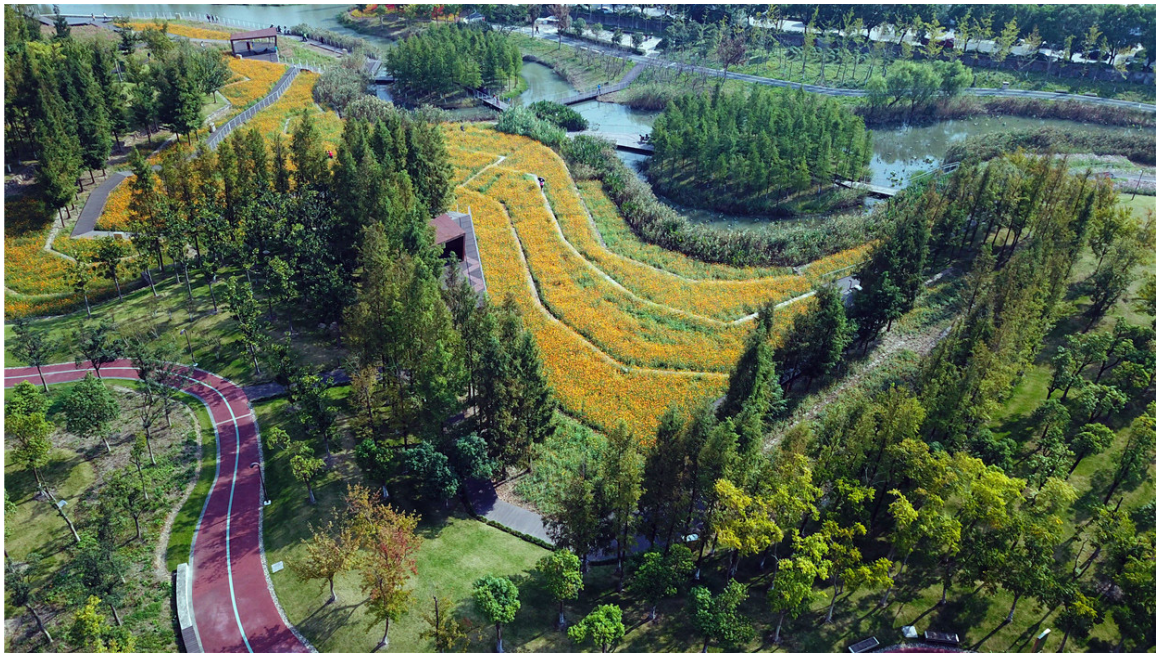


Figure.2.17. Aerial View of the Sponge City Terrace System. Turenscape.

Zhongshan Shipyard Park
Landscape Architect: Konjian Yu
Landscape Firm: Turenscape
Project Size: 27 acres
Year: 2002
Location: Zhongshan, Guangdong, China



Figure.2.18. Aerial Photo of the Zhongshan Shipyard Park. Turenscape.

Zhongshan Shipyard Park covers eleven hectares in Zhongshan, Guangdong, China. The original purpose of the site was an abandoned shipyard which is part of the city's development history. Much of the city revolves around the river and uses boats and ships as transportation throughout its history. The project utilizes recycled natural and man-made materials and uses these components to create architectural monuments. Existing vegetation and wildlife habitats were preserved. Machines, docks, and other industrial components were recycled to create spaces for educational, aesthetic, and functional purposes. The design addressed several site

challenges by accommodating variable water levels and balancing river-width regulations for flood control while protecting old riverbank banyan trees. This case study provides an example of how existing materials can be repurposed to create a landscape museum installation that reminds people of the history of water and human development. These landscape monuments also provide public spaces for people to gather and rest.

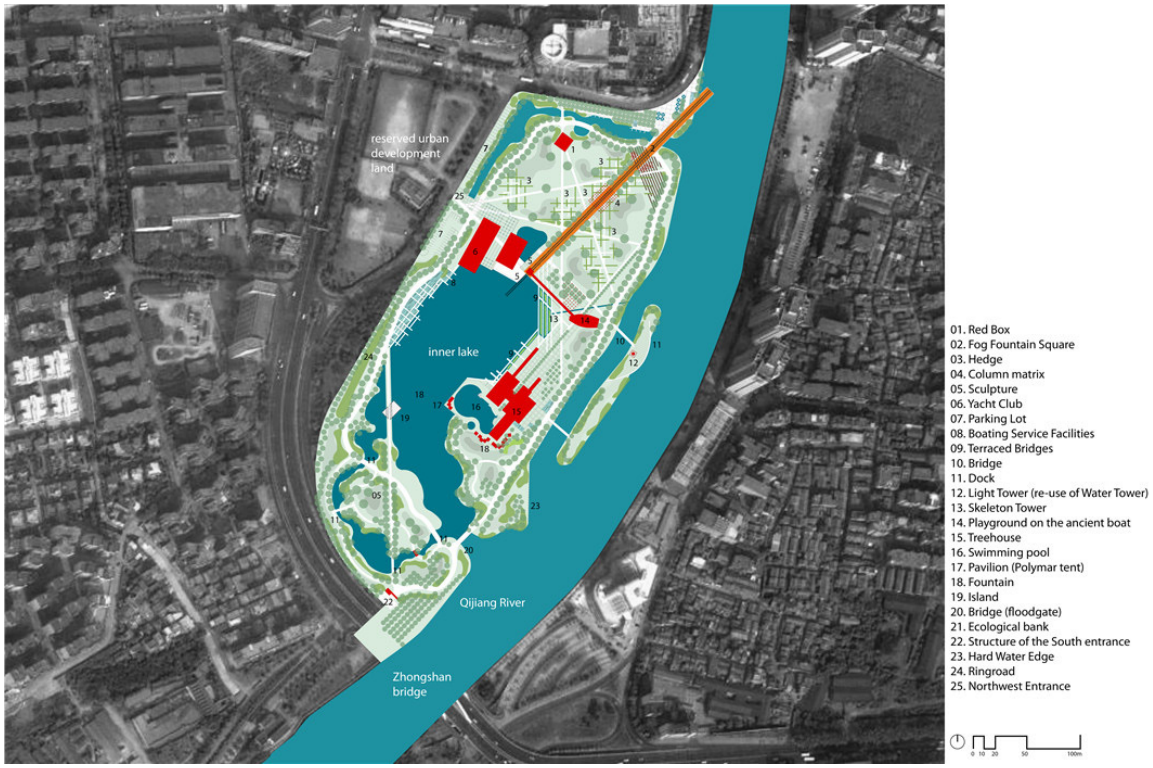


Figure.2.19. Zhongshan Shipyard Park Landscape Master Plan. Turenscape.

Summary

Most of the Sponge City strategies rely on heavy landscape engineering to enhance the land's ability to retain and filter water. These designs are great for densely developed urban areas that have runoff issues. This approach specifically targets rainwater management which applies to the Calgary context since the city also experiences overland floods from massive rainfall events. However, since Calgary also suffers from major river floodings, so another water management method is necessary to address their specific river-related challenges. Besides that, the example of reusing existing materials to create architectural monuments as in the Zhongshan Shipyard Park is a great way to retain memories. A similar approach can be applied to the chosen thesis site to retain flood memories, reminding people of the history of the site.

2.4.3 Room for the River Precedents

Room for the River Nijmegen
Landscape Firm: H+N+S Landscape Architects
Year: 2013-2015
Location: Nijmegen, Gelderland, Netherlands

Nijmegen is a Dutch city that is located adjacent to the Waal River, one of the largest rivers in the Netherlands. The Waal River narrows and makes a sharp bend as it approaches the city, forming a bottleneck.[73] Due to the river's geographical form, Nijmegen is constantly exposed to flood risk. This project created a bypass channel and moved inlets and dikes further inland, creating more room for the water to flow through. At the same time, an inhabited island is created in the center of the river, doing so, it offers better flood projection as water can be drained quickly during an extreme event.

The elongated island has been turned into a river park that offers a combination of water and nature, recreation and urban activities. The design enables the space to be multifunctional, including hosting events and exhibitions. New bridges were built to connect the island with the rest of the area while providing people access to the island.

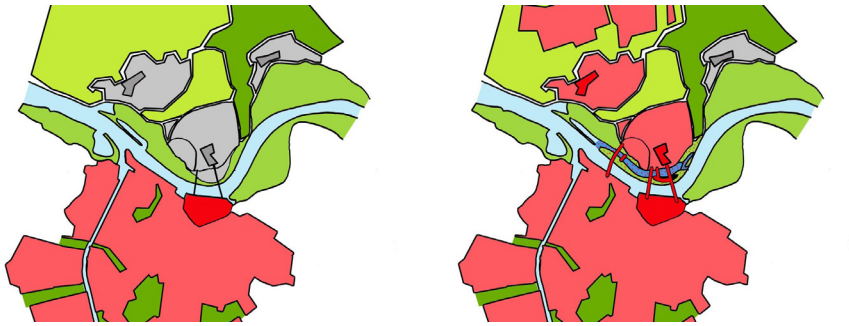


Figure.2.20. Before and After Diagram of the River Nijmegen Project. Left is before and right is after. H+N+S Landscape Architect.



Figure.2.21. Aerial Photo of the Room for the River Nijmegen Project. H+N+S Landscape Architect.

Room for the River Ijssel Delta
Landscape Firm: H+N+S Landscape Architects
Year: 2004-2017
Location: Kampen, Overijssel, Netherlands

In this project, a new river arm called Reevediep was constructed for the River Ijsseldelta near Kampen. It is the largest Room for River project, and Reevediep intends to channel and redirect excess water from Drontermeer and Vossemeer Rivers to the Ijsselmeer River.[74] Dikes will be built along the flood channel to control water damage during high water. On top of that, a dam was constructed between Flevoland and Overijessel to prevent water from flowing into Drontermeer in the event of a flood. This dam is expected to be opened most of the time and only closed down during extreme conditions.

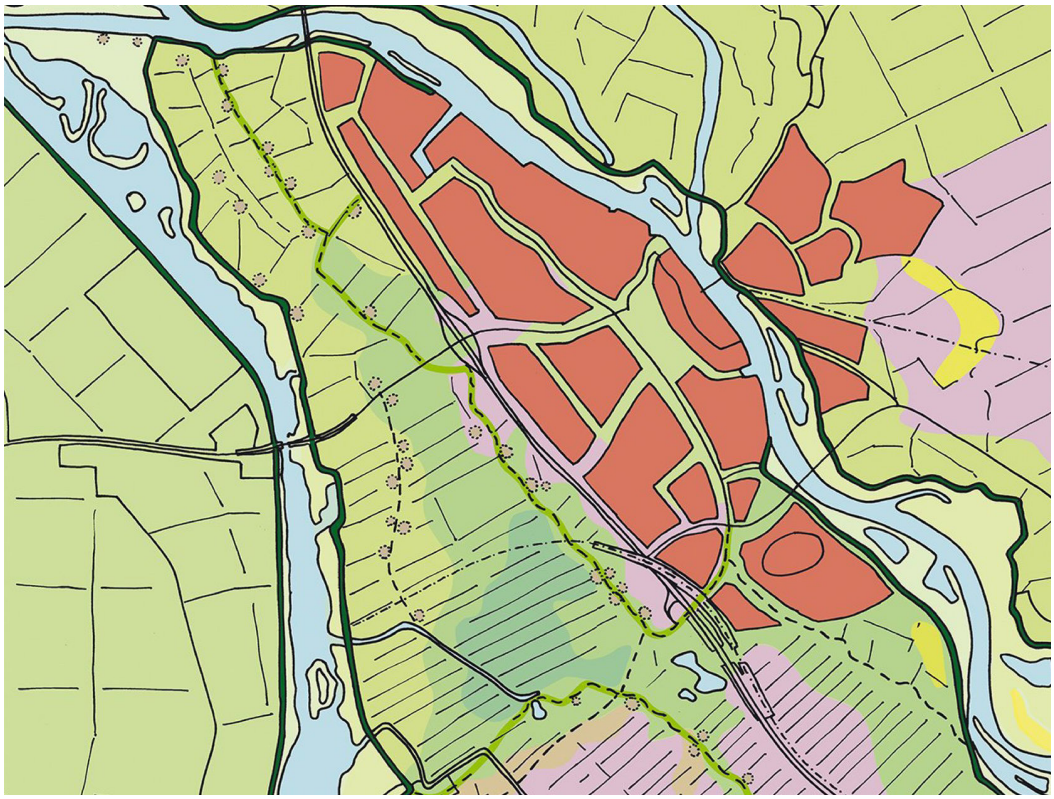


Figure.2.22. Existing Condition of the Ijssel Delta Project. H+N+S Landscape Architect.

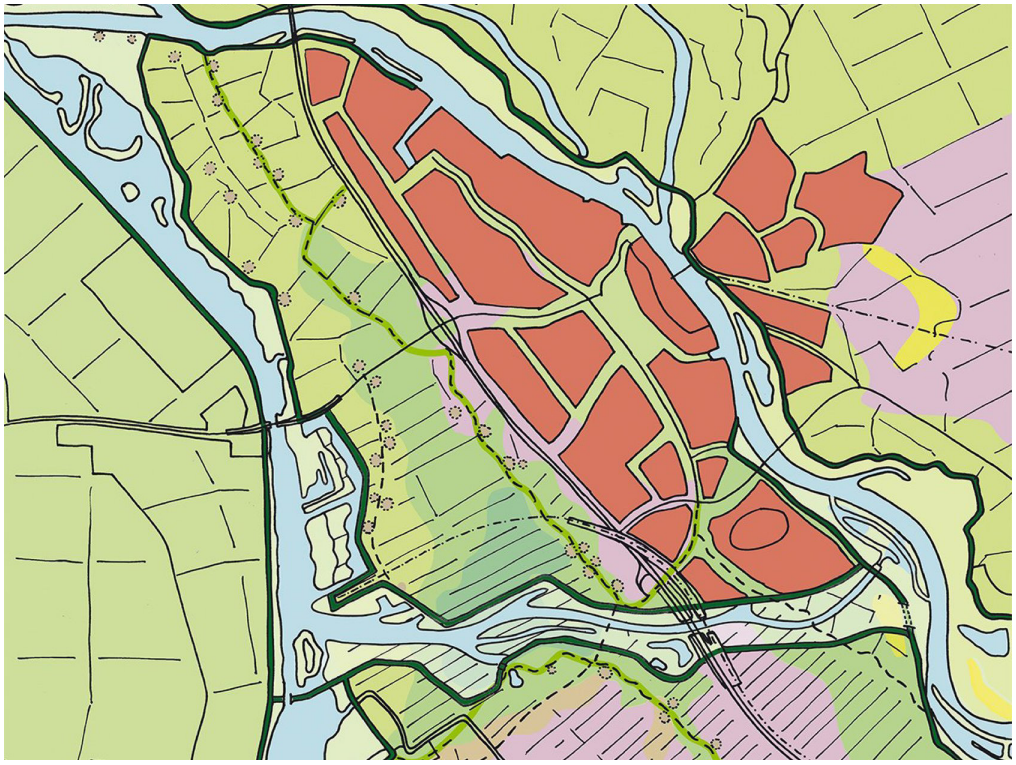


Figure.2.23. Stage 1 of the Ijssel Delta Project. H+N+S Landscape Architect.

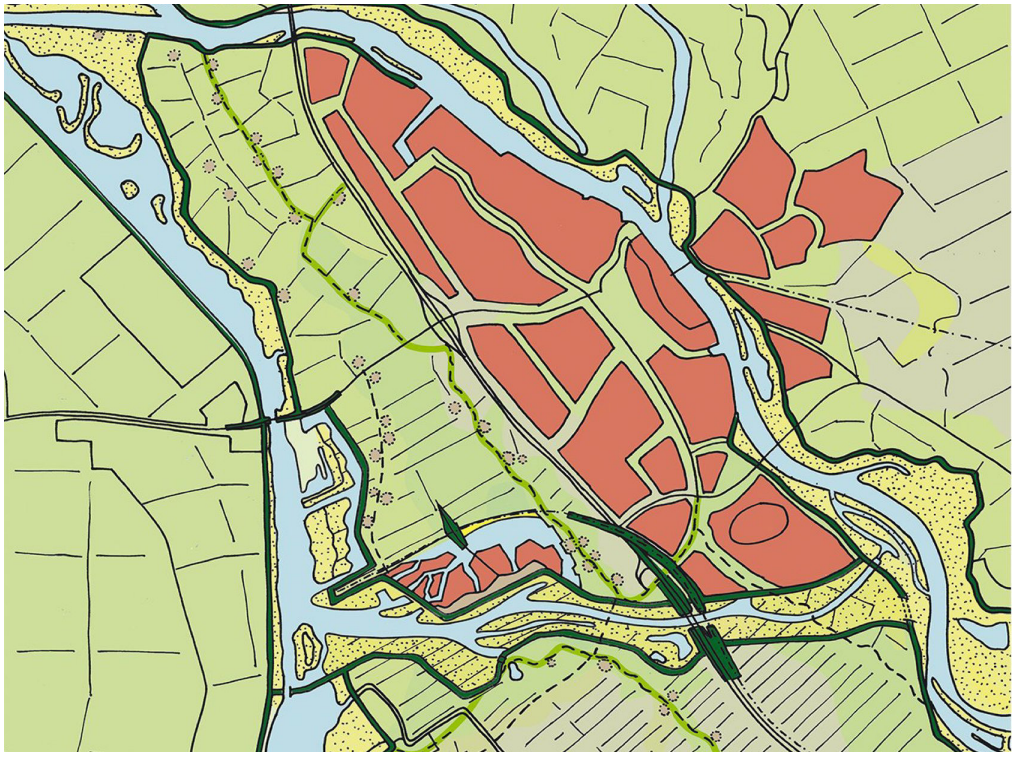


Figure.2.24. Stage 2 of the Ijssel Delta Project. H+N+S Landscape Architect.

Besides the technical water management strategies, part of the design also aims to transform the surroundings of the old and new rivers into more naturalized ares. These areas will form the dynamic landscape of Delta that is constantly shaped by water and wind, reflecting the character of the region.

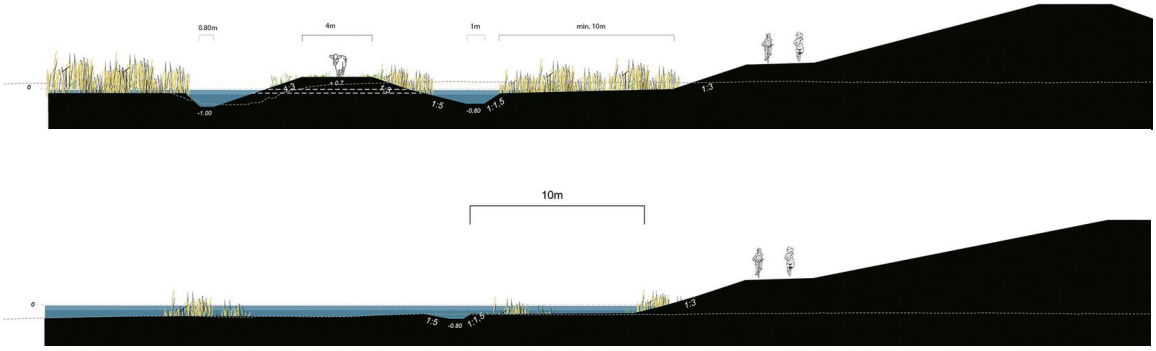


Figure.2.25. Landscape Sections. H+N+S Landscape Architect.

Summary

Both case studies listed involve heavy modifications of land. This kind of approach has much to do with the context of the Netherlands where most of the lands have already been highly modified. Canada, on the other hand, is a country full of wilderness, and heavy land modifications do not necessarily work for that environment. However, the principle of relocating obstacles and creating more space for water to overflow could still be adapted and applied. Yet, the idea of restoring developed lands back to dynamic landscapes, as demonstrated in the Room for the River Ijssel Delta project, is a great strategy that fits well for Calgary.

2.4.4 Other Important Case Studies

Parc De La Villette
Firm: Bernard Tschumi Architects
Architect: Benard Tschumi
Size: 125 acre
Year: 1982-1998
Location: Paris, France

Parce De la Villette is an award-winning project that creates a new urban planning strategy for its time. The project involved a complex programme that could accommodate the cultural, natural, and recreational needs of the city. Unlike the traditional park design that focuses on taming nature to form an artificial landscape, the design allows users to take control and define the meaning of these spaces through time.[75] The approach aimed to generate frameworks that would facilitate the definition of types of spaces instead of specifically programming them into the park. Depending on the point, movement, and time, every visitor could have a completely different experience. The follies in the park are artistically reassembled from various components that provide different functions and sensual experiences.[76] This thesis seeks to understand and apply a similar deconstructivism approach to the proposed design. However, rather than having humans as the major driver to define spaces, the vision is to also allow nature to adjust different spatial orientations within the artificial ecosystem framework.

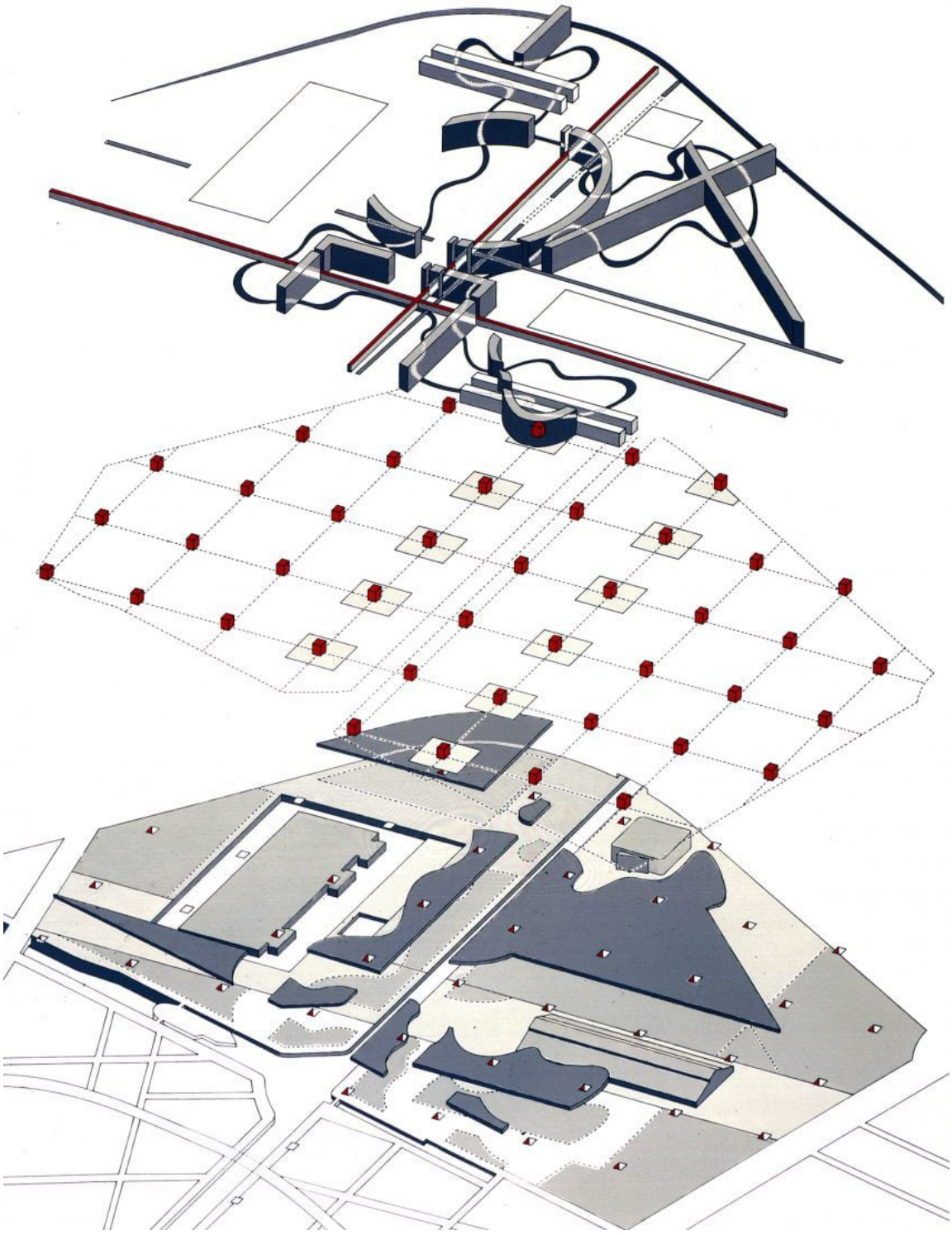


Figure.2.26. Exploded Diagram of Parc De La Villette. Bernard Tschumi Architects.



Figure.2.27. View of the Follies in the Park. Dezeen.

Fresh Kills Park
Landscape Architect: James Corner
Landscape Firm: Field Operation
Project Size: 2200 acres
Year: Expected Completion 2036
Location: New York City, New York, U.S.

The project is restoring one of the largest landfill complexes in the world and turning it into a massive ecological park. Restoration techniques are being implemented to slowly improve the quality of soils and water, as well as establish biodiversity. This thesis seeks to closely examine and learn from James Corner and Field Operation's design approach and methodology that are being used in this project. Specifically, how they diagramed and laid out the overall planning, as well as their mapping approach in representing complex landscape systems. Furthermore, this case study also considers habitat diversification over time, which is a critical component that this thesis would like to learn from.

- bosque parking lot
- non-vehicular entrance
- vehicular entrance to parking areas only
- vehicular entrance
- ferry landing
- DSNY + park service entrance
- proposed interchange
- existing interchange
- new park drive
- new park drive alternate A
- new park drive alternate B
- secondary park drive
- primary recreational path
- secondary paths + trails
- lighting and media screens
- low salt marsh
- high salt marsh
- mud flat
- low tide
- high tide
- wet woods
- swamp forest
- dry prairie
- moist prairie
- successional meadow
- turf
- program concentrations
- grove
- sycamore bosque
- proposed woodland
- existing woodland

NORTH PARK
1 tennis, handball or basketball
2 playground
3 hockey rink
4 restored stream and trail
5 softball field
6 Travis parade ground
7 nature center
8 picnic strip
9 birding dock
10 canoe dock
11 wildlife observation deck
12 fishing dock
13 floating dock for birders and kayaks
14 William T. Davis Wildlife Refuge
15 overlook picnic deck
16 hilltop open field for kites + games
17 flare station: art installation / performance area
18 wind energy farm
19 native plant center greenhouses

SOUTH PARK
20 horseback riding, cross-country skiing + hiking trails
21 restored wetland inlet
22 cross-country running and hiking trails
23 mountain biking course
24 hilltop meadow + overlook deck
25 berm overlook / art installation
26 Arden Heights neighborhood park, barbecue + play area
27 berm trail
28 pedestrian + bicycle bridge
29 equestrian center + stables
30 equestrian training ring
31 open lawn for steeplechase, carnivals, concerts
32 tennis center
33 multi-sport sports barn
34 restored wetlands
35 Owl Hollow soccer fields
36 Arden Heights Woods
37 early intervention entrance + information center

CONFLUENCE
The Point
38 restored wetland
39 pier overlook
40 ferry landing
41 market roof
42 fishing + family picnic piers
43 signature bridge
44 restaurant row
45 barge gardens
46 marina for small boats
47 light towers / media field posts + screen
48 banquet hall facilities
49 multi-use sports fields
50 arts exhibition space + cultural programming
51 discovery center
52 amphitheater
Creek Landing
53 visitor center
54 fishing pier
55 event lawn
56 esplanade + market shade roof
57 restaurants
58 canoe rentals, boat tie-up + boathouse
The Terrace
59 fishing piers and boat tie-up
60 wetland garden
61 flare station + screen
The Marsh
62 sunken forest exhibit + performance space

WEST PARK
63 hilltop field
64 habitat area for grassland + nesting birds
65 Department of Sanitation garage
66 methane gas recovery plant and screen
67 Isle of Meadows bird sanctuary
68 water entry to the park
69 Isle of Meadows bird-watching overlook
70 boat + fishing deck
71 September 11 earthwork monument to the recovery effort
72 September 11 materials area (TBD)
73 landfill leachate treatment plant
74 future rail lines to transfer station (outside park boundary)
75 organic compost manufacturing area (outside park boundary)
76 Staten Island waste transfer facility (outside park boundary)

EAST PARK
77 East Park drive (alt. A)
78 East Park drive (alt. B)
79 East Park drive south
80 waterfront bike path and running loop
81 event lawn and overlook
82 light installation, morphing timelines: energy
83 outdoor classroom
84 freshwater marsh interpretive center
85 wetland garden boardwalk
86 picnic area + paddling club
87 kayak and canoe tie-up
88 La Tourette Park
89 tidal marsh
90 flare station + screen
91 Department of Sanitation garage
92 berm overlook
93 potential golf course or recreation fields
94 pedestrian + bicycle bridge





Figure.2.28. The Fresh Kills Park Draft Master Plan. The Freshkills Park Alliance.

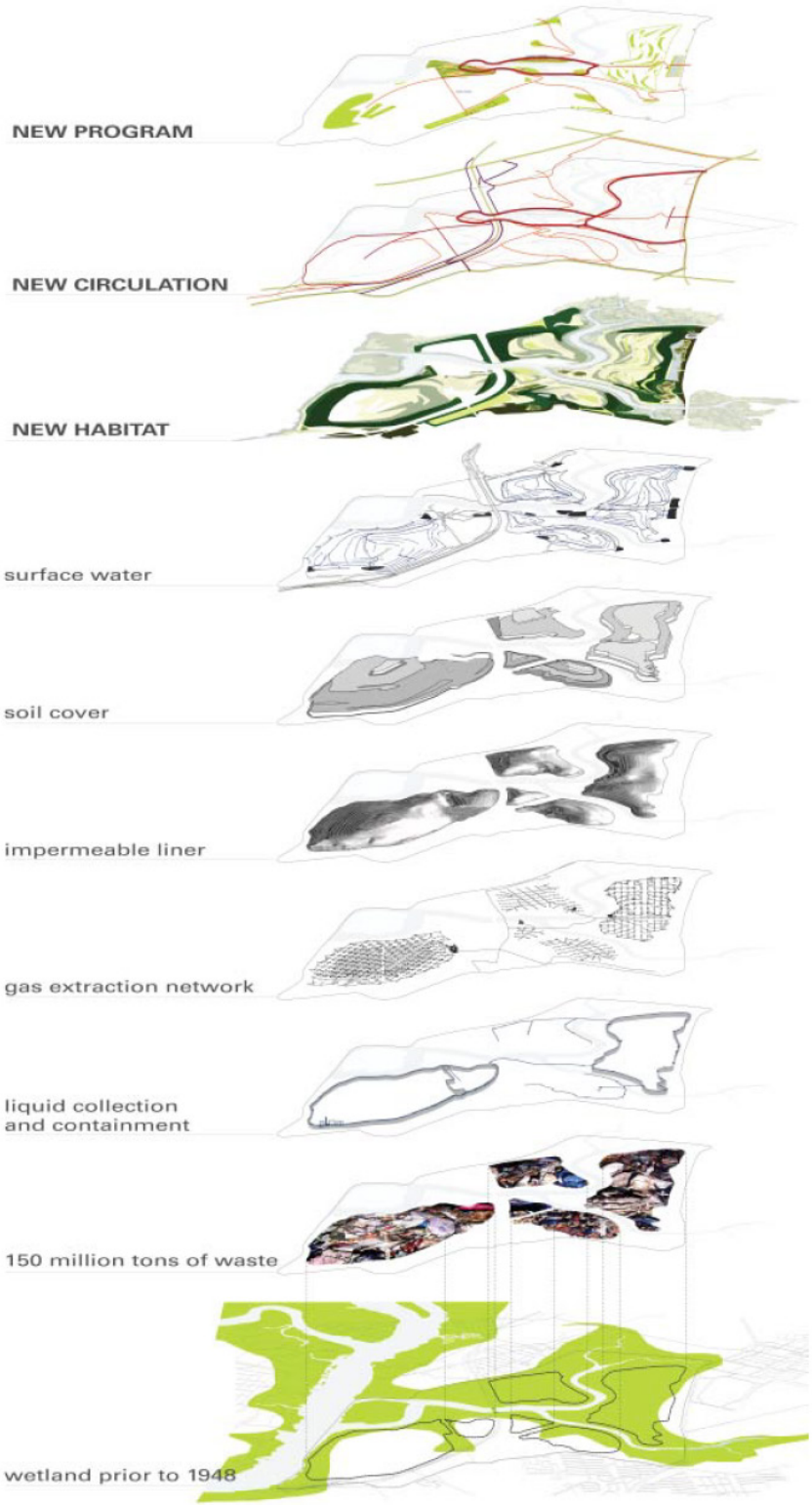


Figure.2.29. Fresh Kills Park Mapping. The Freshkills Park Alliance.

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3. THE SITE



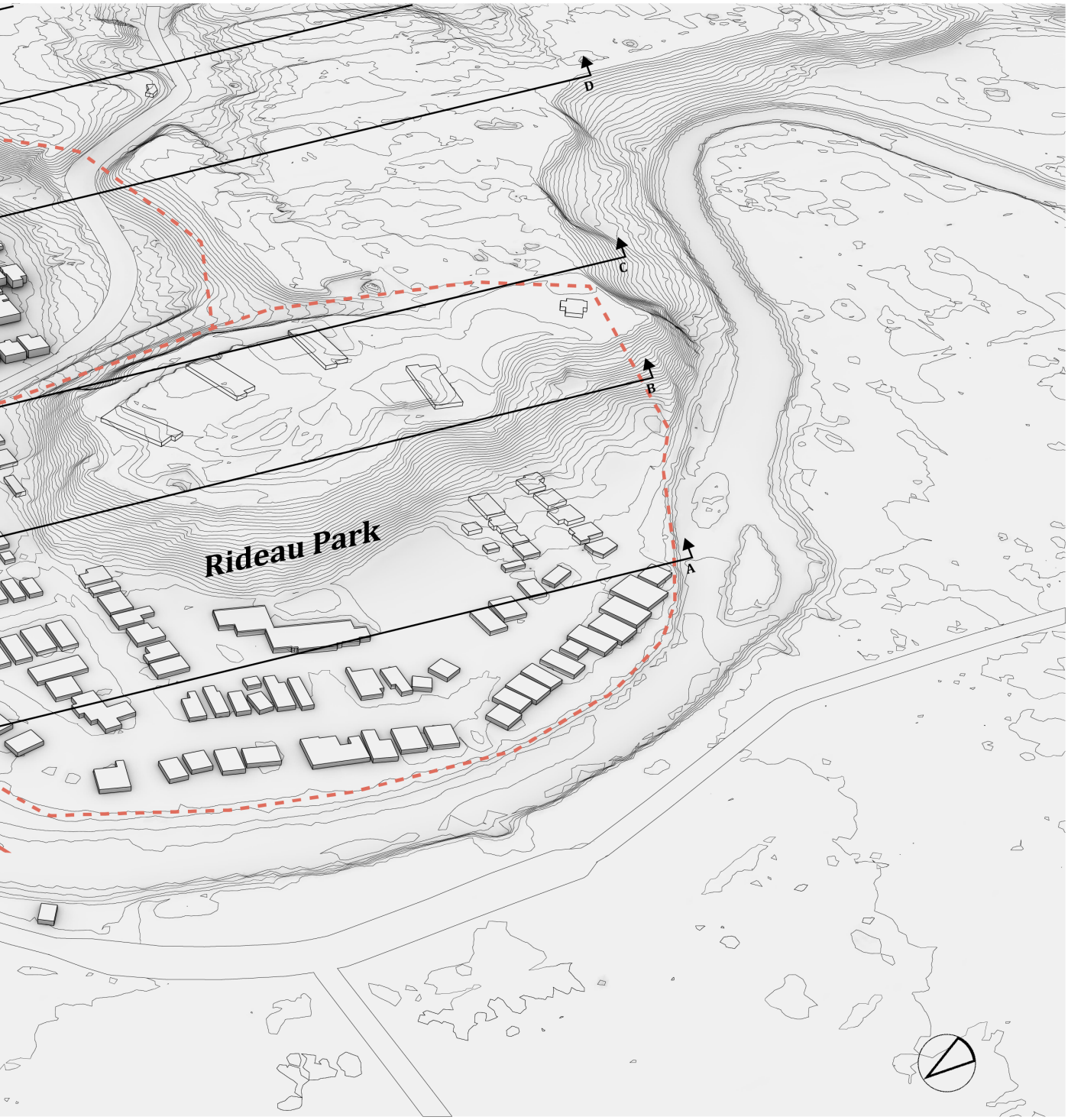
Figure.3.1. Front Page of The Calgary Herald on June 22, showing Elbow Park and Roxboro Communities near 4th street S.W. underwater. Calgary Herald.

Two neighbourhoods, Rideau Park and Roxboro, were chosen as the site for this thesis. Both neighbourhoods were part of the 2013 Alberta Relocation Program, providing a strong foundation for the thesis. These areas were severely impacted during the 2013 flood, an aerial photograph of the inundated site was chosen to be the cover page for the Calgary Herald's special flood edition. (Figure 3.1.) The image shows the chosen site was more devastated compared to the developed neighbourhoods across the river, primarily due to elevation differences. The unique geographic condition of the site turns it into a natural water storage area. The topography rises drastically at the south and west ends of the Roxboro and Rideau Park neighbourhoods, setting a natural boundary for the water.

Low-lying lands, including neighbourhoods across and adjacent to the site, are part of the floodplains and should ideally be retreated from to prevent further damage. However, the Mission and Cliff Bungalow communities across the way are already densely developed, making them costly and challenging to retreat. As a result, relocating properties on the more flood-prone site—where single-family homes dominate—would be a more practical solution. Once the site has been cleared, the site could serve as a natural flood water storage area, offering a more cost-effective way, offering a cost effective way to protect the other highly populated neighbourhoods from severe inundation.

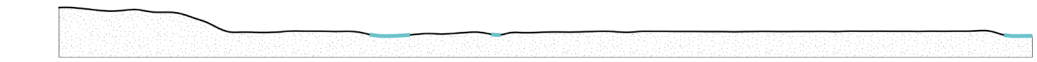


Figure.3.2. Topography Model: Digital Elevation Model -2M



Developed Neighbourhoods

M. Open Calgary. Modelled and re-illustrated by the Author.



Section A-A Cutting Through Elbow Park and Edge of Rideau Park Neighbourhoods.



Section B-B Cutting Through Cliff Bungalow and Rideau Park Neighbourhoods.



Section C-C Cutting Through Cliff Bungalow and Rideau Park Neighbourhoods.

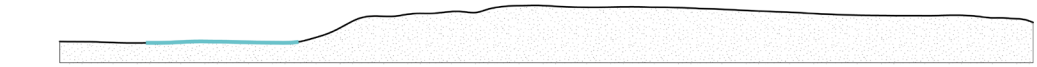
N **S**



Section D-D Cutting Through Mission and Roxboro Neighbourhoods.



Section E-E Cutting Through Mission and Roxboro Neighbourhoods.



Section F-F Cutting Through Edge of Mission and Roxboro Neighbourhoods.

Figure.3.3. Analytical Cross-Site Sections to Understand the Change in Topographies. By Author.

As mentioned in Chapter 1, besides the challenges of water overflow, drought is another environmental struggle for the city as Calgary is situated in the arid region of southern Alberta. Climate change has further increased the city's vulnerability to drought, with both the Bow and Elbow watersheds expericing historical lows in natural flows in recent years.[1] In response, a proposal to construct a new reservoir on the Bow River, replacing the existing Ghost Dam, has been put forward.[2] Although this project is still in the early phase, environmental concerns similar to the Springbank Dry Reservoir have arisen. The new project could cause a chain reaction, potentially worsening the existing hydroclimate condition.

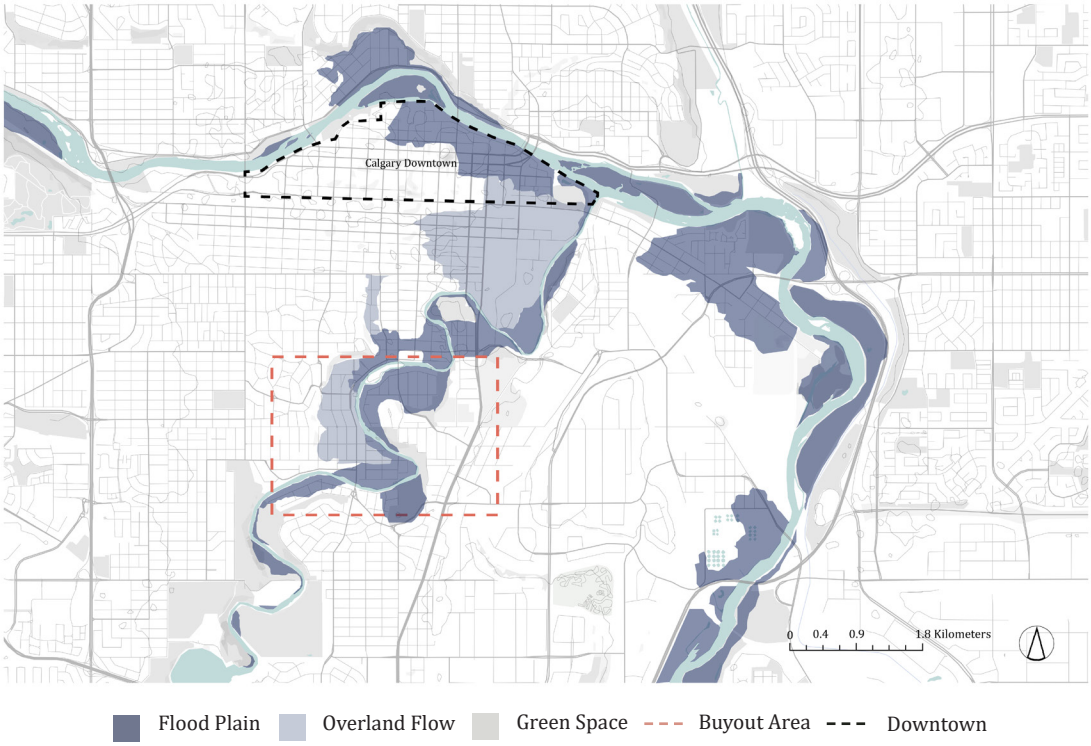


Figure.3.4. Flood Map. By Author.

The Alluvial Aquifer is an existing natural infrastructure within the city that could potentially address some of the drought issues. It can be seen as a natural sponge made out of sand and gravel that can release and store water based on the river's current water table and water level.[3] Much of the Elbow River's floodplain and riparian areas overlap on top of the aquifer, but a majority of these lands within the city have been developed.[4] The constructed roads and buildings could negatively impact the absorbance of the natural infrastructure underneath. Removing some of these hardscapes and restoring the Alluvial Aquifer could allow nature to perform its part in water management.

As discussed, the chosen site is part of the Elbow River's Alluvial Aquifer, which makes it the perfect Retreat Pilot Project. Yet, the ability of the Alluvial Aquifer aligns with the principles of the Sponge City Theory. Instead of artificially creating a new "sponge" through landscape engineering, it is better to restore the capacity of the Alluvial Aquifer in storing and releasing water as required.



Figure.3.5. Alluvial Aquifer Map. By Author.

The site is primarily zoned for low-rise residential use, while the opposite side of the river permits higher-density development. While it would be ideal to retreat from the Mission and Cliff Bungalow neighborhoods—also part of the Alluvial Aquifer—this is impractical due to the high cost of relocating apartments and commercial buildings. Therefore, the focus remains on Roxboro and Rideau Park, where retreat is more economically feasible.

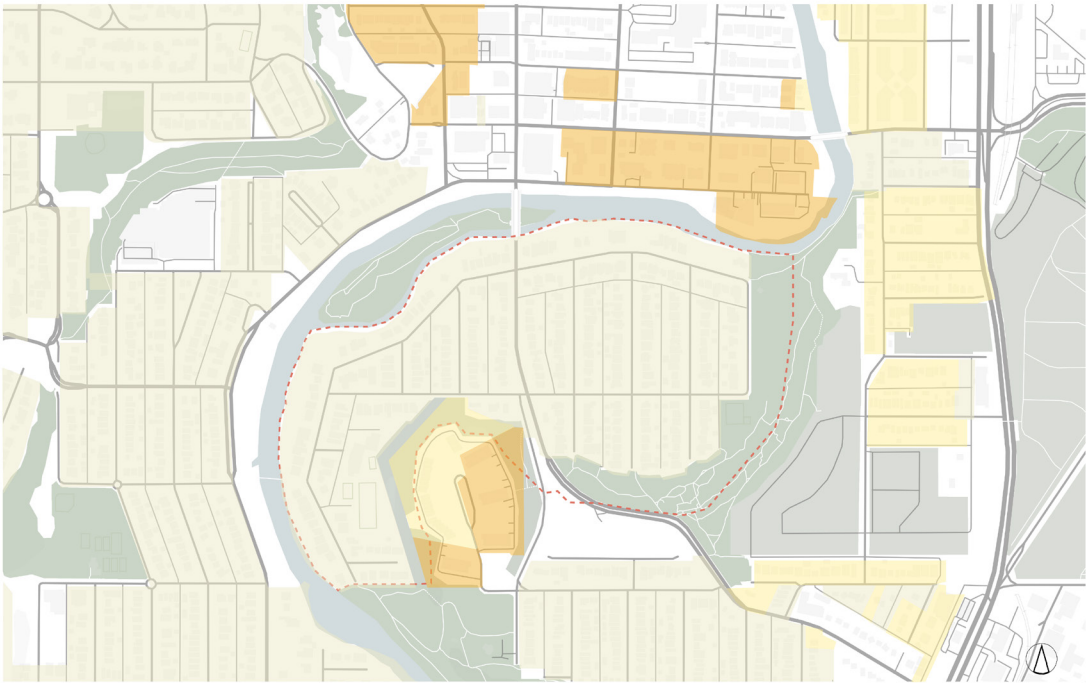


Figure.3.6. Residential Zoning Analysis. By Author.

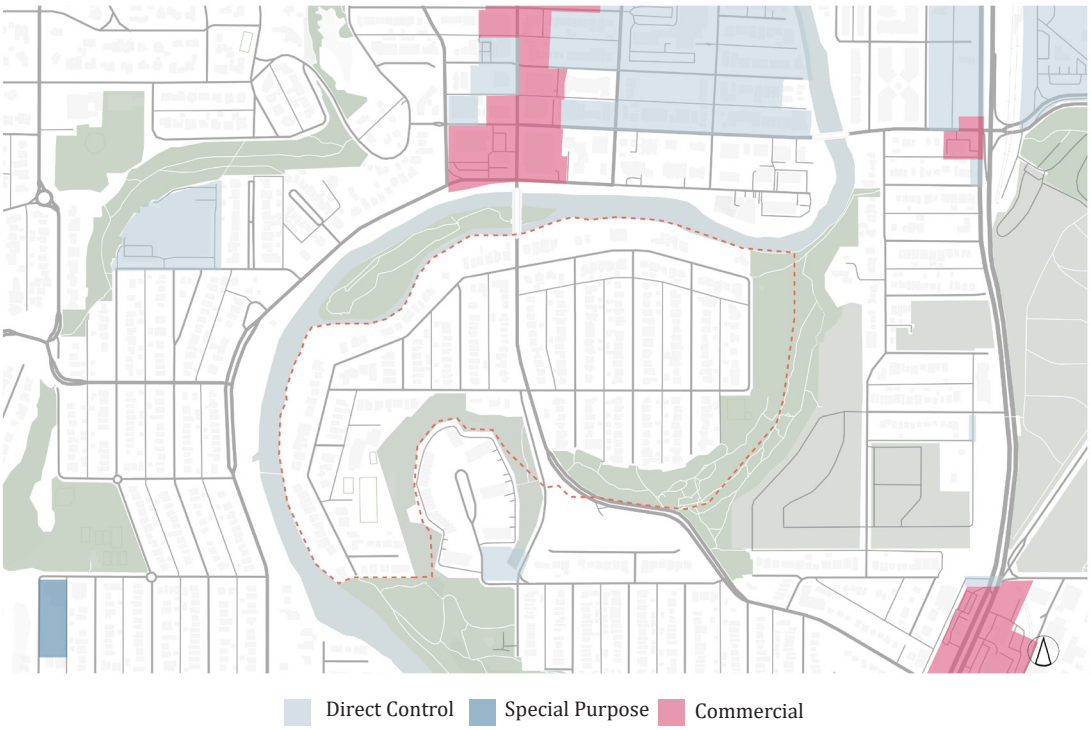


Figure.3.7. Zoning Analysis. By Author.

Seven out of seventeen relocated properties are located within these two neighbourhoods, and the rest are in the Elbow Park community. The author of this thesis visited the buyout lots on the site during the flooding season from May 25th to 28th, 2024. All the original homes had been demolished, and the acquired lands were left empty with signs warning citizens to stay off. (Figure 3.10.) These lands are visibly maintained and the local government has spent roughly $80,000 in maintenance during 2018-2019 according to CBC News.[5]

Maintaining monoculture lawns on these lots is costly and ecologically inefficient. These lawns require regular mowing and watering but provide little to no benefit to the ecosystem, offering neither habitat nor food for pollinators and beneficial insects. Alternative approaches, such as allowing natural rewilding or repurposing the land for recreational use, would be more sustainable.

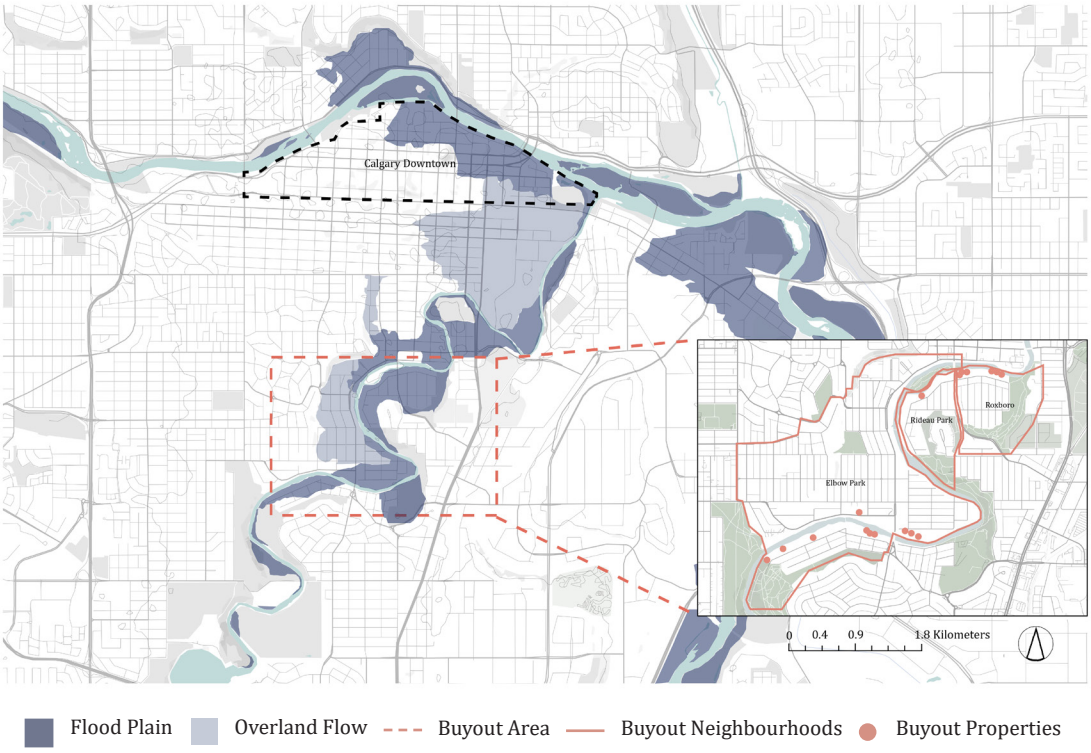


Figure.3.8. Location of the buy out neighbourhoods. Collage by Author.



Figure.3.9. Location of Buyout Properties. Collage by Author.



Figure.3.10. Warning Signs on the Empty Lots. By Author.



Figure.3.11. Existing condition of the 220 Roxboro Rd SW. By Author.



Figure.3.12. Three Empty Lots in Roxboro Neighborhood. By Author.

Elbow Island Park is a unique island sandwiched between the Mission and Rideau Park communities. In 2019, the city initiated a series of restorations of the island, including clearing and reconnecting the side channel that was damaged in the 2013 flood with the main channel again.[6] Besides the ecological restoration, another project called The Wandering Island was also carried out by the city. The project intended to create a series of art pieces within Elbow Island Park to encourage human interaction with nature.[7] An official entrance to the park was introduced with the project, allowing citizens to access the site safely.[8]



Figure.3.13. Photo of Elbow Island Park taken from the 4th Street Bridge (2017). Photo by Caitlind Brown.

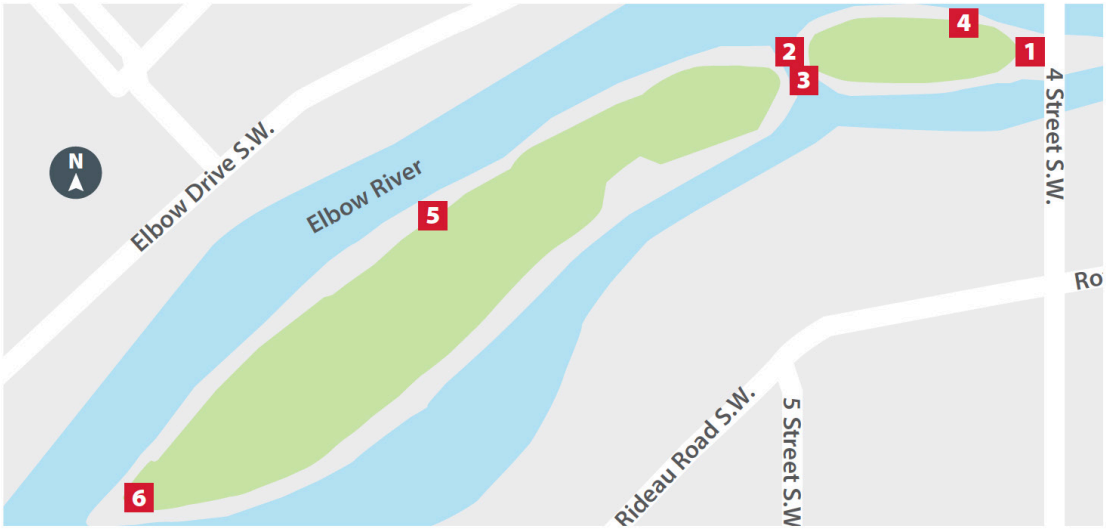


Figure.3.14. Artworks Location on Elbow Island. The Wandering Island.

Stairs

1 **Fish Ladder**
Caitlind r. c. Brown and Wayne Garrett (2020)
Steel, wood

Fish Ladder is the first of many artworks hidden on The Wandering Island. As described by the artists "the stairs reference fish skeletons, the ribs of a canoe, and ripples in water. As you move down the stairs onto Elbow Island Park, materials transition from steel to wood, indicating a change from urban to natural. Drooping stairs create a moiré pattern, rippling underfoot. You become the stone, skipping across water. Over time, foliage will grow up through the stairs, integrating them into the park."



Stepping stones

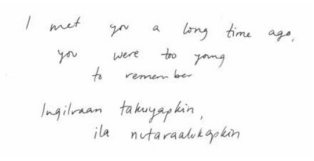
2 **Ephemeral Perch**
Lane Shordee (2020)
Stone, water

In the middle of Elbow Island Park is an ephemeral stream which can only be crossed using a rock ford. These stepping stones are flanked by large boulders, carved into seats providing a perch to rest above flowing waters. In the artist's words, "each seat faces a different direction, giving viewers two unique experiences. In one direction, the water flows away; in the other, water flows towards. The stones represent our species' relationship with the land as witnesses and stewards. When viewing the landscape in different ways, we consider its inevitable transformation. Over time these boulders will shift, making them more challenging to sit on."



3 **Things that both a relative you haven't seen in a long time and the river could say**
Kablusiak (2020)
Stone, engraved letters

Phrases are inscribed into the stepping stones and other large rocks hidden on Elbow Island Park. In the artist's words, "this project emerged from my time spent in Inuvik and Tuktoyaktuk during summer of 2018. I returned to those lands after a 20-year separation. The texts were translated into Inuvialuktun by my mother, Holly Carpenter. The phrases, though personal, offer space to include the collective experience of sometimes complex familial relations."

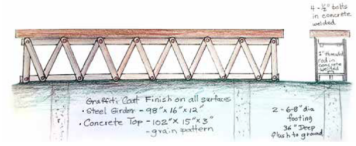


Benches

Each of the benches on Elbow Island Park was designed by artist duos with an intimate relationship: a father/daughter team, a long-time friendship, and a romantic partnership. Artists were asked to create a bench that is their ideal "together place" to sit, daydream, converse, escape, and watch the river flowing by.

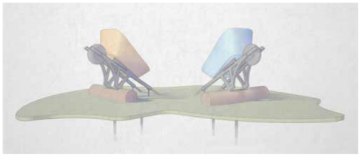
4 **Bridging Whirlds**
Laura and Michael Hosaluk (2020)
Steel, concrete

The first bench was created by a father/daughter duo and is located a short walk from the stairs on the north bank of Elbow Island Park. Built from a found bridge girder and concrete casting of a large wooden slab, the bench creates a literal bridge between nature and humankind. In the artists' words, "a bench acts as the vehicle for one or more to gather, an opening to belong in the interconnectedness of life, a place to sit in the experience of inner expressions combined with the outer world that surrounds. This installation represents imaginative environments that bridge the conditions to invent creative possibility found in viewing our Earth as truly ours rather than mine."



5 **Late Lunch**
Jeremy Pavka and Sean Procyk (2020)
Steel, concrete, found materials

The second bench was created by long-time friends and is located across the ephemeral stream. Referencing a relationship with nature based in the landscaping experience, this bench hearkens to an autobiographical experience shared by many who have worked outdoors. In the artists' words, "Late Lunch references a nostalgia related to labour and leisure. Two wheelbarrows tipped up create an impromptu seating arrangement to rest for a bit while the work stops. Late Lunch can be an agreement between the workers on an extended work day, or it can be an extended break as you relax and take in your surroundings."



6 **Sun Chairs**
Susan Clarahan and Joel Staples (2020)
Steel, wood

Located at the southwestern point of Elbow Island Park, the final bench was designed and built by romantic partners for the sunniest locale on the island. In the artists words, "Sun Chairs are meant to support a moment of gathered attention, vacation, rest and relaxation, recalling beach loungers next to swimming pools or the ocean. In these moments the focus can be soft: on the river, the sun, maybe the stars in motion. With the back of the chairs angled towards the sky our perspective can shift to what is above and beyond."



Figure.3.15. Artworks on the Wandering Island. The Wandering Island.

Unfortunately, due to pedestrian path closures on the 4th Street Bridge, which blocked the only access bridge to Elbow Island, the author was unable to access the island to document its condition. One main notable obervation is the soil erosion on the inner riverbank, along the side channel. Landscape strategies that could stabilize the riverbanks should be considered during the re-design process.



Figure.3.16. Photo of the Side Channel after the 2013 Flood. Photo by Mike Tan.



Figure.3.17. Photo Shown the Edge Condition of the Elbow Island. By Author.

The site is located within the designated floodplains, as identified by the City of Calgary. A critical part of the pre-design analysis is to identify the hotpots that are easily eroded by water and apply landscape strategies accordingly. Therefore, this thesis has created maps of the impacted areas and a section of the water levels under different scales of flood.

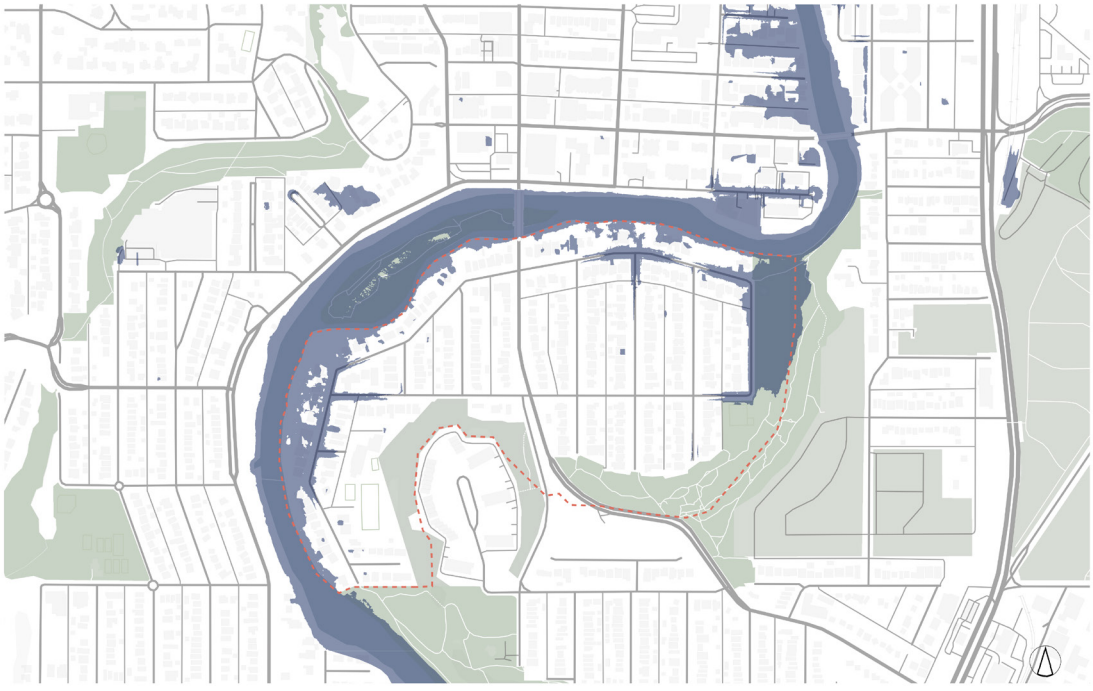


Figure.3.18. 20 Year Flood Map. By Author.



Figure.3.19. 50 Year Flood Map. By Author.

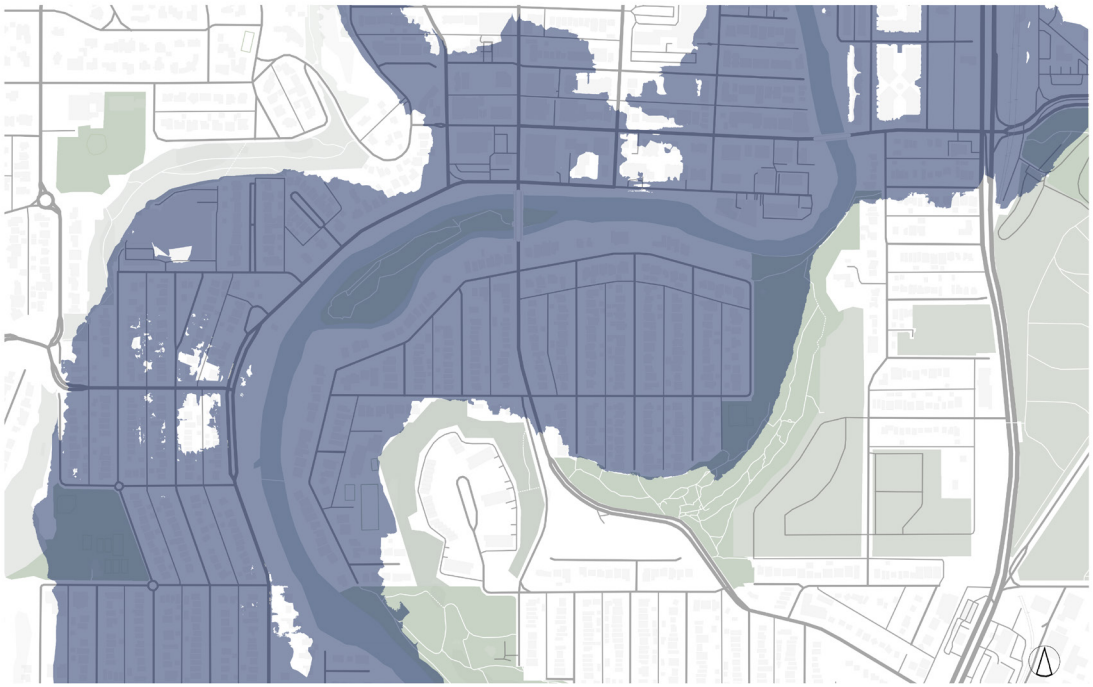


Figure.3.20. 100 Year Flood Map. By Author.

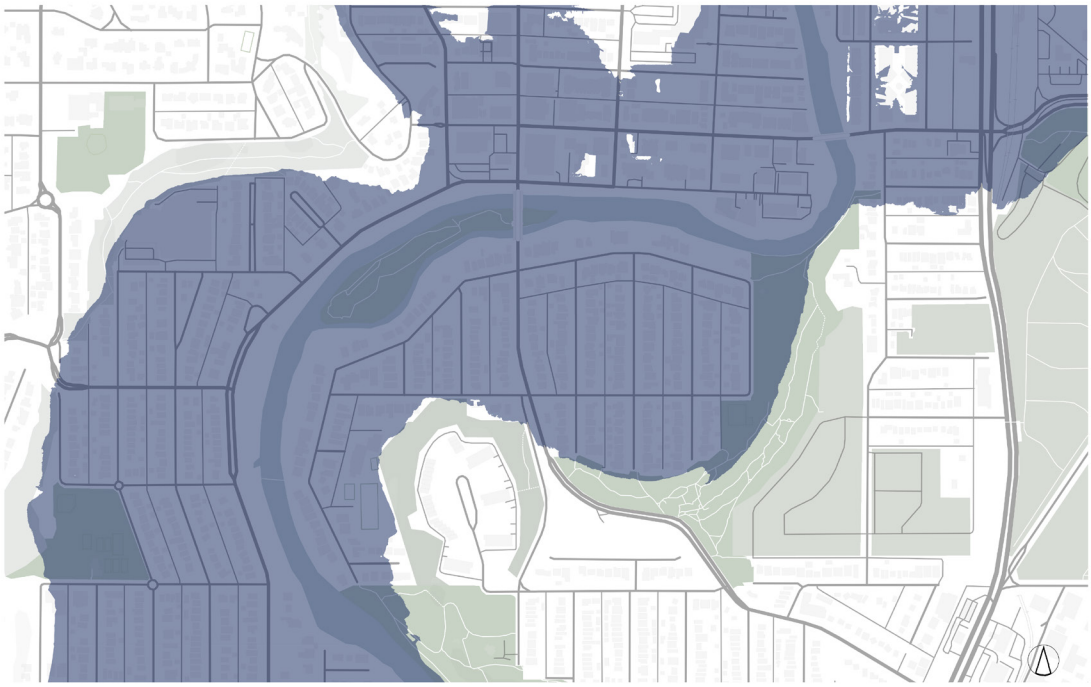


Figure.3.21. 200 Year Flood Map. By Author.

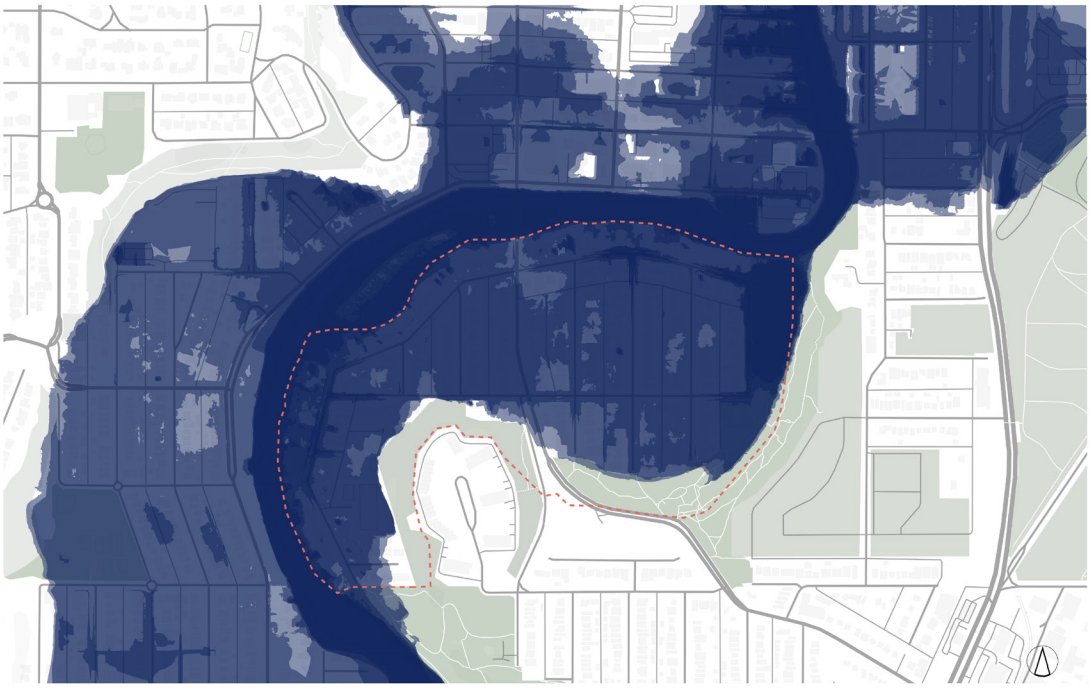


Figure.3.22. 10 to 200 Year Flood Map Collage. By Author.

The design vision integrates Landscape Mosaic theory to assist the recovery of nature. To ground this approach, the existing ecological conditions and tree species were also analyzed to assist design development.

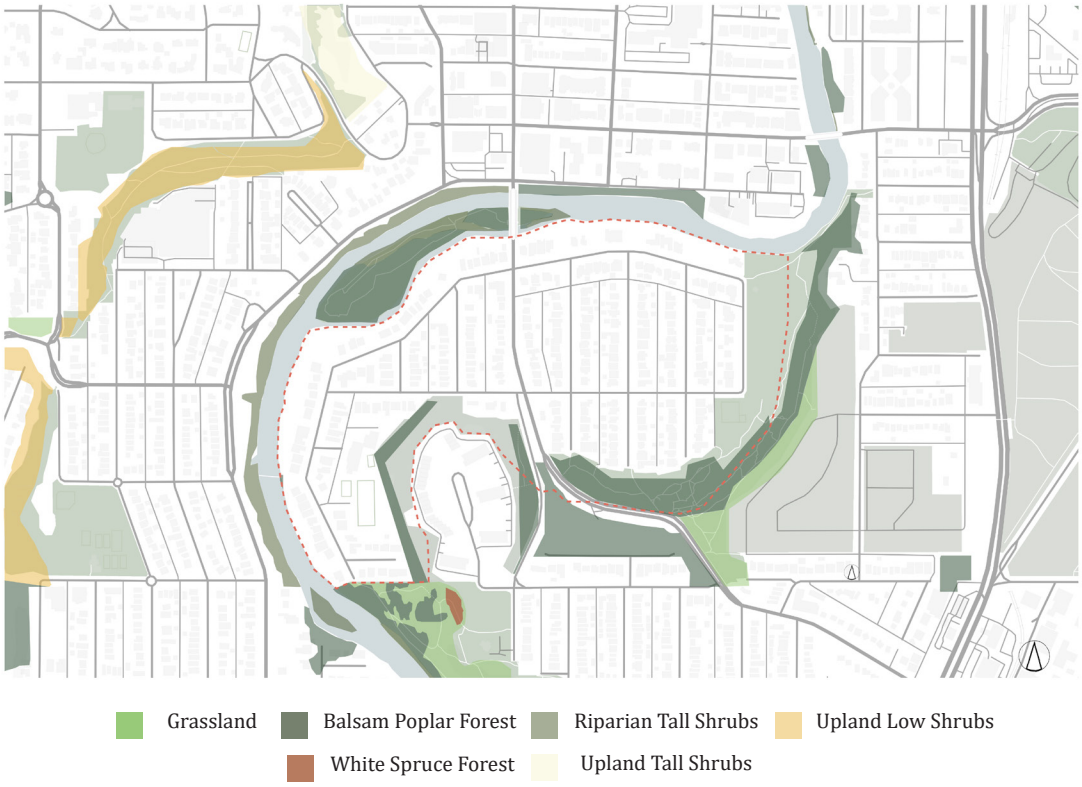


Figure.3.23. Existing Habitat Map. By Author.



Figure.3.24. Existing Tree Map. By Author.

This site analysis systematically examines the site condition in individual categories. The final phase is to synthesize these findings collectively to identify current challenges and opportunities. In doing so, the site analysis underscores the urgency of retreat strategies while highlighting the importance of ecological restoration as a pathway to flood resilience. All these insights will directly inform Chapter 4 Design Synthesis, ensuring the proposed interventions align with the local environment contexts.

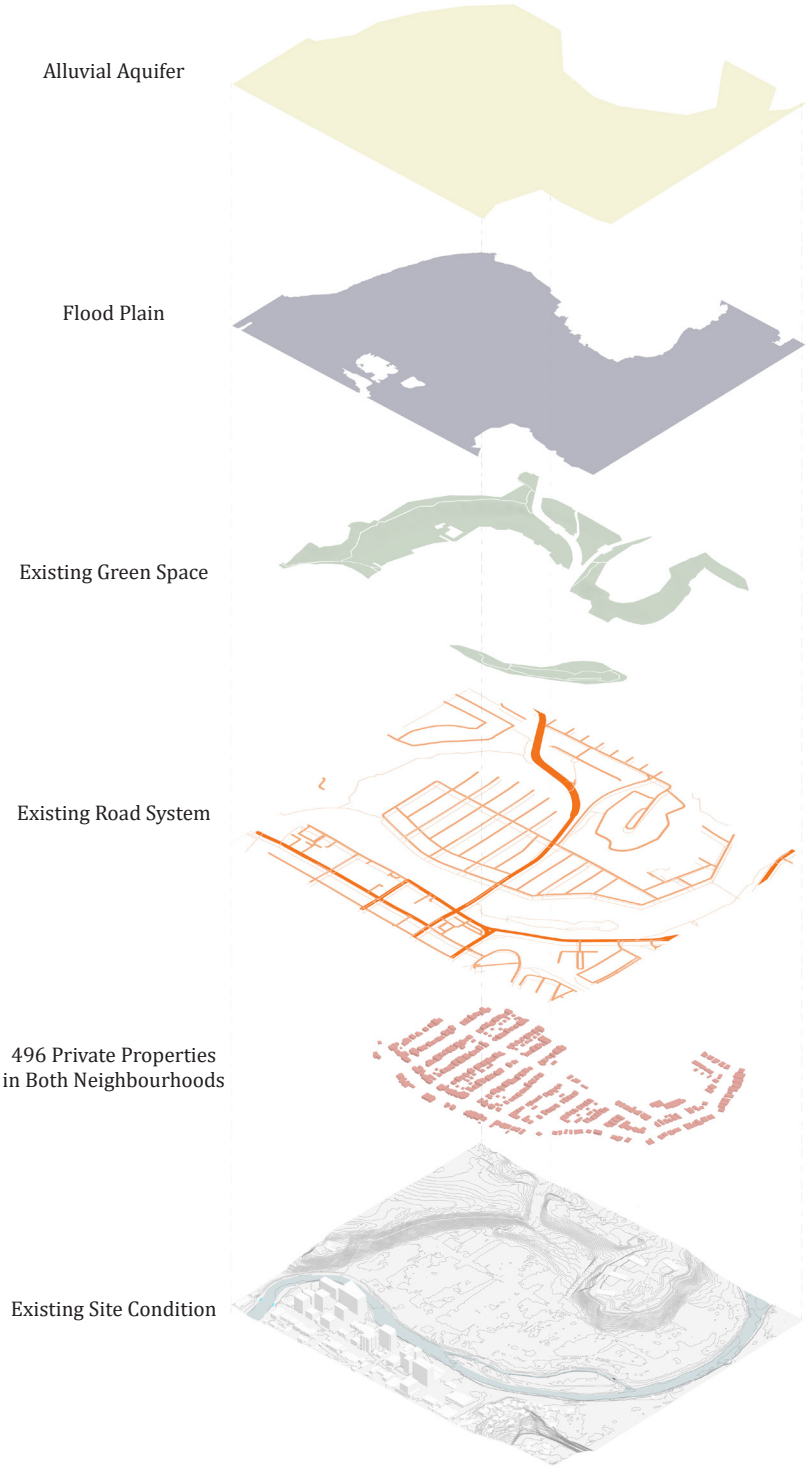


Figure.3.25. Layered Site Analysis. By Author.

Endnotes

1. Scott Strasser, "' Every drop counts': Water restrictions in Calgary could come earlier, last longer as drought continues." Calgary Herald. Feb. 2nd, 2024. https://calgaryherald.com/news/local-news/city-of-calgary-drought-resiliency-report-warns-water-restrictions-could-come-earlier-this-year

2. "Bow River Reservoir Options." Flood mitigation and recovery, Government of Alberta. Jan. 11th, 2024. https://www.alberta.ca/bow-river-reservoir-options

3. "Groundwater." Elbow River Watershed Partnership. Accessed Nov. 23rd, 2024. https://experience.arcgis.com/experience/6f36edb6d53241f9a85f653f0db1c3a8/page/Groundwater/?views=Vegetation-Biodiversity-copy#data_s=id%3AdataSource_12-Aquifer_1607%3A1

4. Elbow River Watershed Partnership, "Groundwater."

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6. "Elbow Island Park: The Wondering Island." City of Calgary. Accessed Sep 26th, 2024. https://www.calgary.ca/arts-culture/public-art/elbow-island-park.html

7. City of Calgary, "Elbow Island Park: The Wondering Island."

8. "Fish Ladder." The Wandering Island. March 3rd, 2021. https://wanderingisland.ca/2021/03/03/fish-ladder/

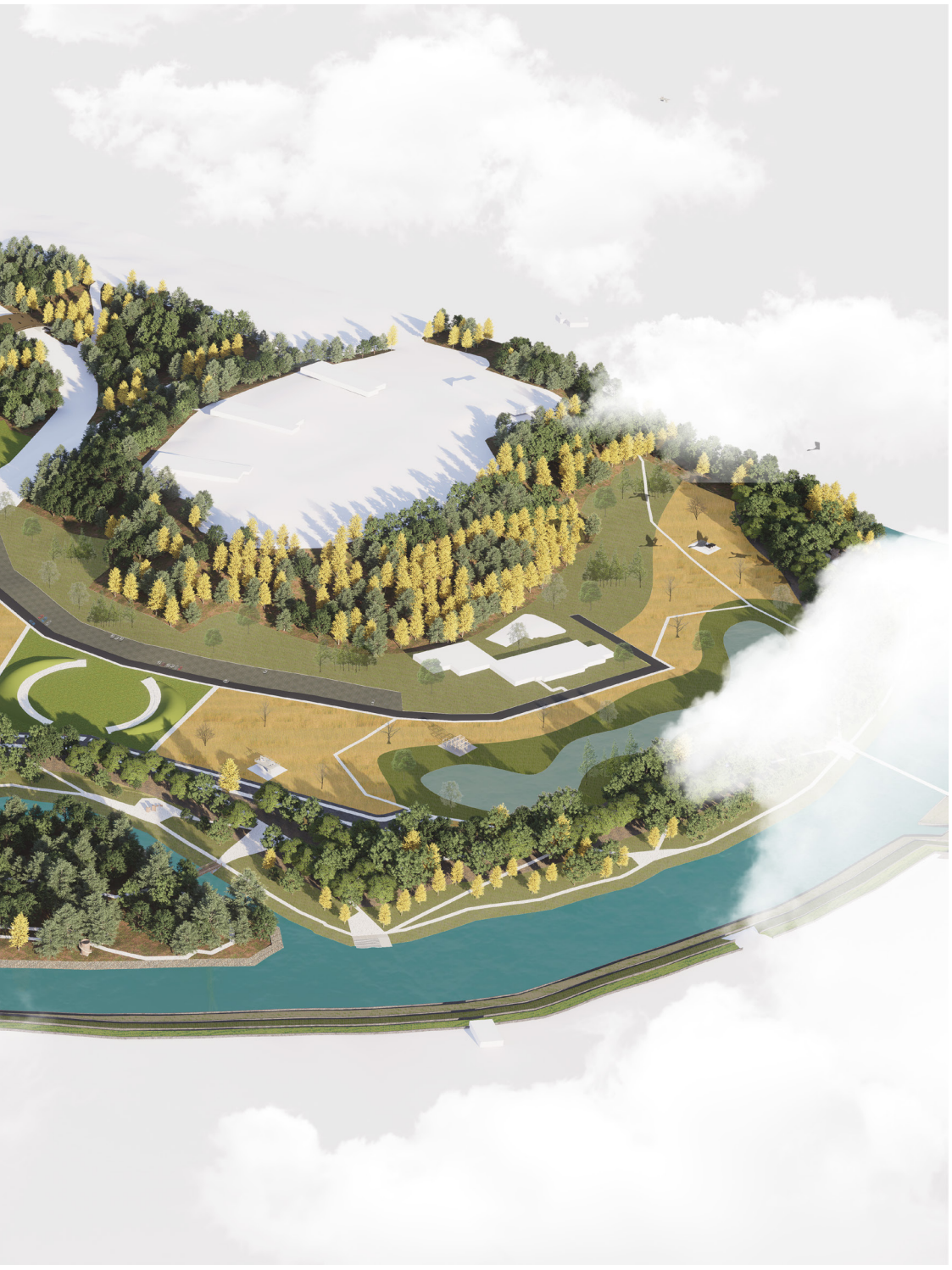
4. DESIGN SYNTHESIS

The following chapter proposes a landscape intervention that emphasizes retreat and rewilding. The design aspect is broken down into multiple phases to facilitate the implementation, acknowledging that the act of retreat will be a lengthy one for social reasons. This chapter will be divided into three distinct phases for an in-depth exploration of design. Phase 1 examines the recommended immediate actions that can be applied to the existing site, marking the initial stage of ecological restoration. These early interventions are set in place to address the urgent environmental needs and lay the foundation for recovery. Phase 2 focuses more on long-term measures, prioritizing sustainable rehabilitation and gradual transformation. Finally, Phase 3 will present the ultimate vision: a fully realized natural park returned to its natural habitat which will both memorialize past floods and encourage ongoing human interaction with the site, creating a space that honours history while fostering future engagement.

As discussed in Chapters 2 and 3, the Roxboro and Rideau Park Neighbourhoods are situated in an ideal geological position for the pilot project. The design proposes a different type of landscape solution that focuses more on edge conditions and dynamic landscapes. The entire design evolves around the relocation progress within the two neighbourhoods and applies artificial landscape infrastructure according to phases. With the implementation and guidance of landscape frameworks, the site will eventually transform into a natural park. By doing so, the approach does not provide a definitive outcome but an interactive proposition that will be constantly influenced by the users and environment. As a result, it positions the ecosystem, flood memory, and community at the center of the design.



Figure.4.1. Overview Render



ring of the Design. By Author

Phase 1 centers around the current conditions of the park, proposing immediate actions that can be taken to enhance the overall ecosystem while building the foundation for future transformation. Sponge City strategies, such as terrace wetlands and ecological island systems, are introduced to stabilize the edge conditions of Elbow Island and the adjacent densely developed neighborhoods. Both applications will stabilize the riverbanks, preventing soil erosion from happening. The wetland terrace system close to the densely developed area will filter the urban runoff while providing permeable flood walls to reduce potential damage during sudden major water events.



Existing Site.

Figure.4.2. Phase 1 Diagram #1. By Author.



Figure.4.3. Phase 1 Diagram #2. By Author.

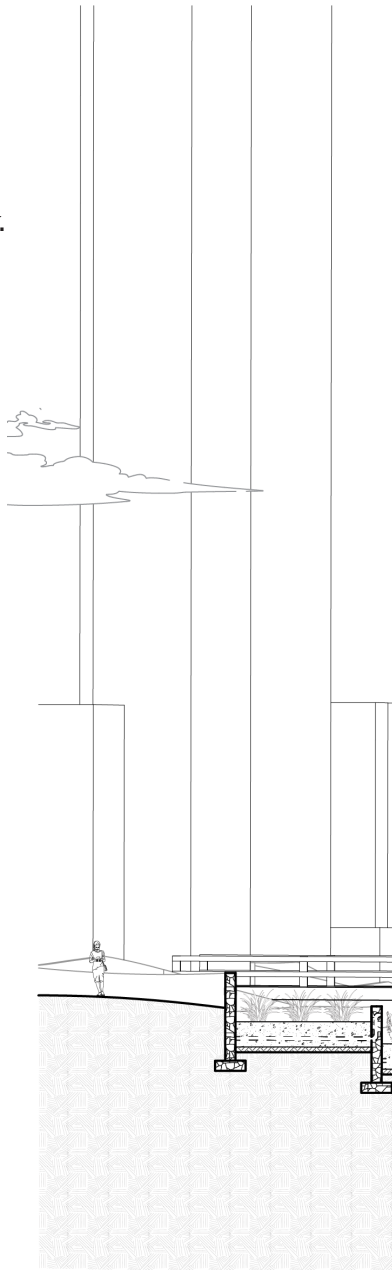


Empty Lots

Restore Ecological Conditions on the Empty Sites.

Figure.4.4. Phase 1 Diagram #3. By Author.

The distance between the edge of the river to the main road adjacent to the developed community varies, affecting the number of terraces that can be placed. Water drainage systems are installed within each level to ensure water will be discharged properly. Native plants with water-purifying ability will be planted in the raised beds to enhance water quality. In areas where space is too narrow for the terrace system, concrete flood walls will be installed to prevent water overflow.



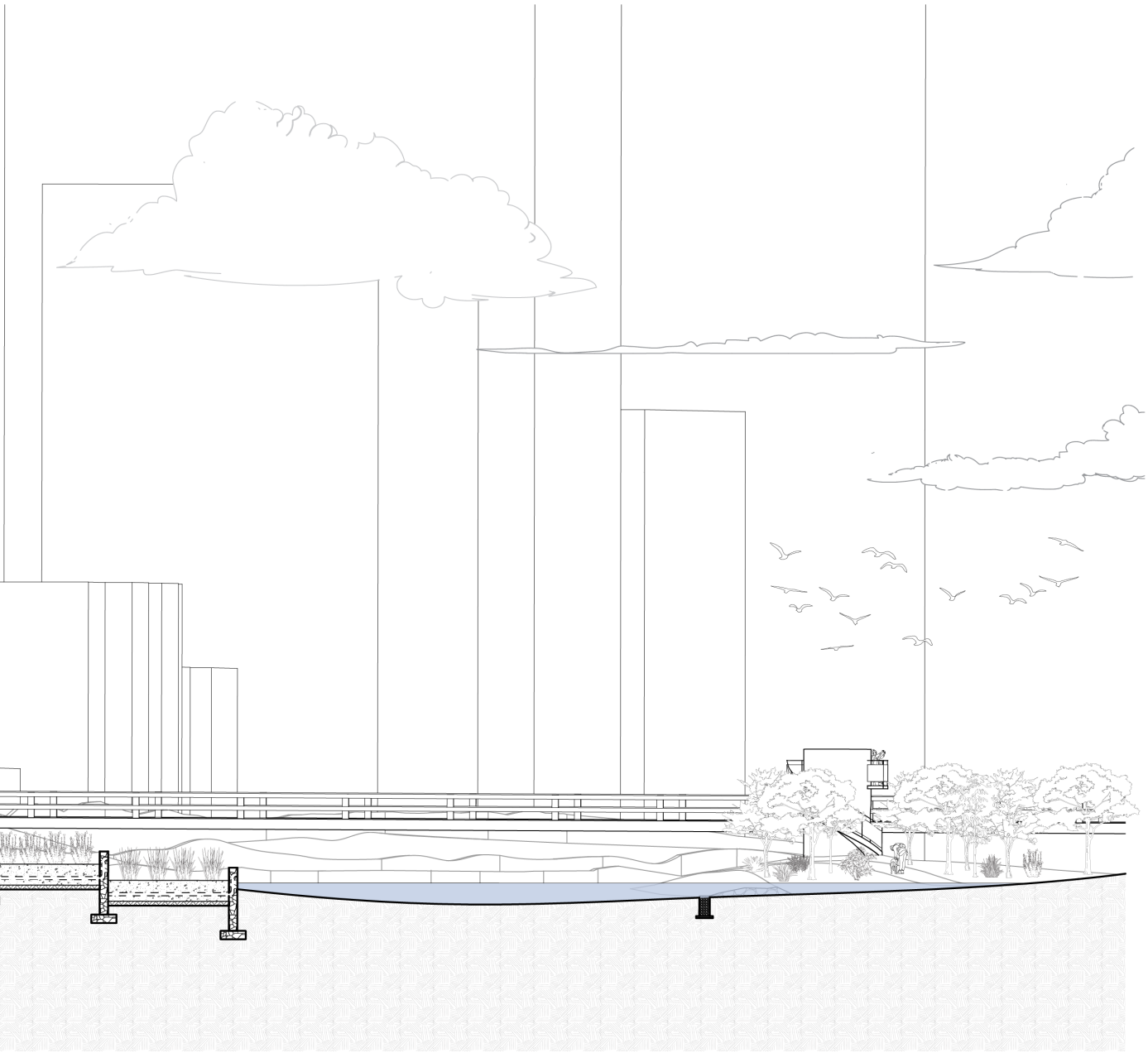


Figure.4.5. Detailed Section A-A Between Mission Neighbourhood and The Elbow Island. By Author.

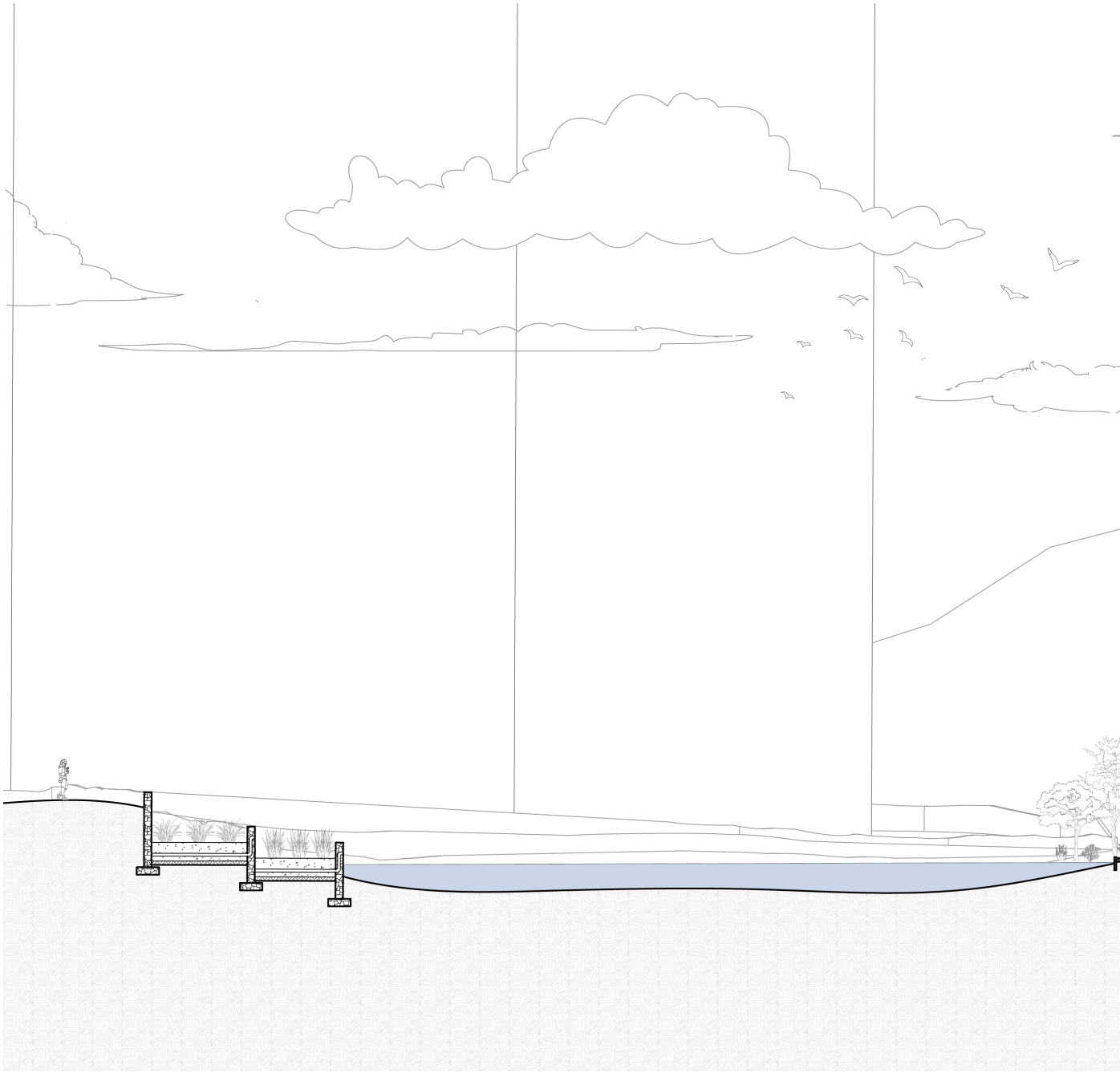
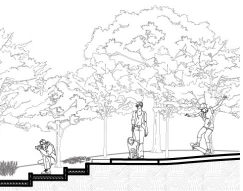


Figure.4.6. Detailed Section B-B Between Mission Neighbourhood and The Elbow Island. By Author.

On the other hand, since the intention is to rewild the two neighbourhoods to accommodate overflow, the approaches applied on-site involve less landscape engineering and more naturalizing. Therefore, the design encourages tree planting and riparian restoration on the empty lots that were bought out during the 2013 relocation program. Bridges are added to provide additional access points to the island.



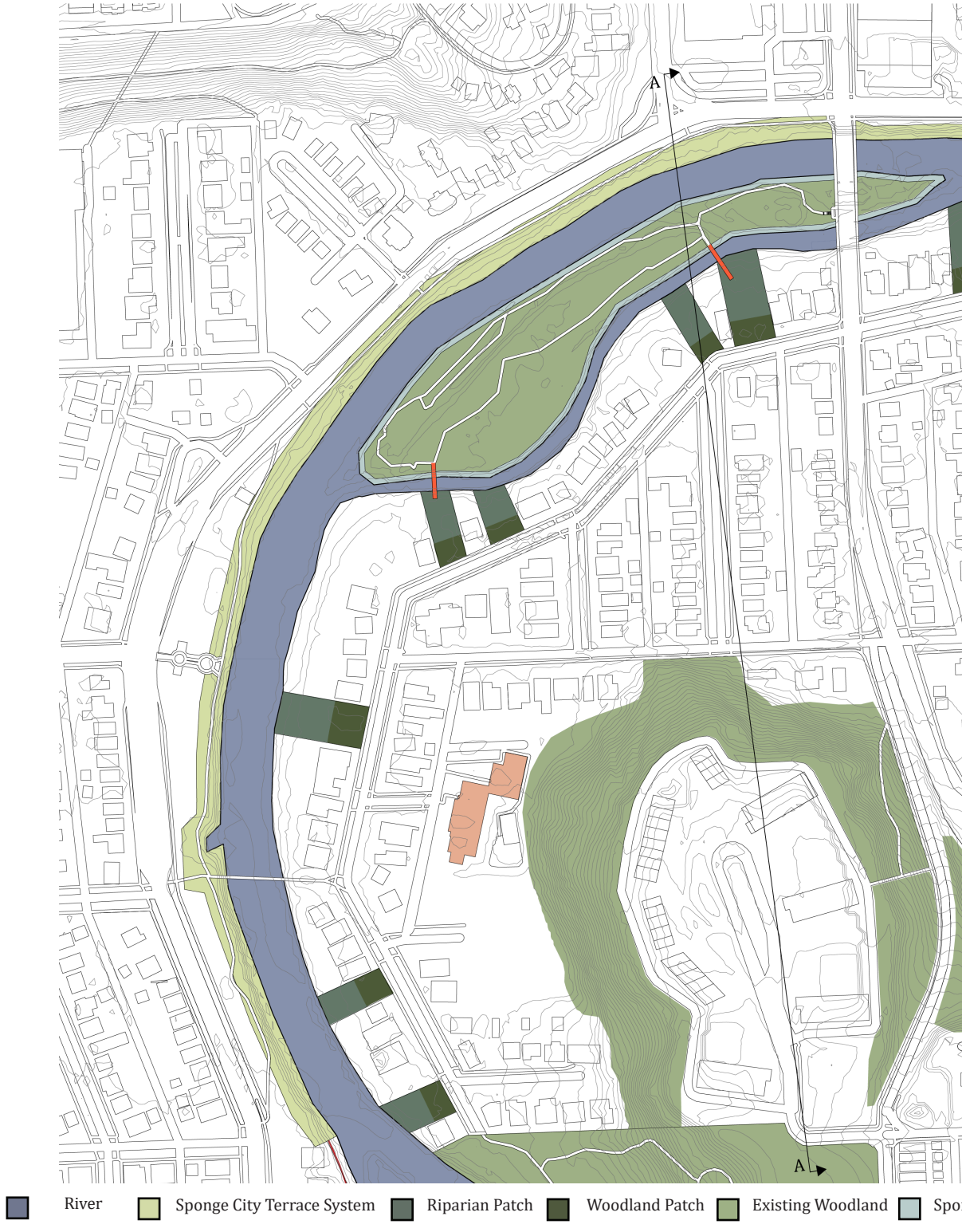


Figure.4.7. Phase



nge City Edge Restoration Public Building/Infrastructure Existing Recreational Facilities Bridge Flood Barriers

1 Plan. By Author.



Figure.4.8. View of the



Elbow River. By Author.

Phase 2 assumes the flood situation 25 years later has worsened enough that more people have moved out. In this stage, the design focuses more on using patch dynamic methods to encourage the recovery of nature on the abandoned lots. Different habitats will naturally form instead of being defined by designers. Yet, not all the properties will be fully demolished, some properties and materials will be repurposed to create landscape monuments to offer additional recreational opportunities. Some basements and existing roads will also remain. These remnants will preserve part of the flood memories, forming a different sense of aesthetics.



Riparian Zone

Restore Riparian Zone on the Site.

Figure.4.9. Phase 2 Diagram #1. By Author.



Riparian Zone

Create Pathways within the Riparian Zone.

Figure.4.10. Phase 2 Diagram #2. By Author.

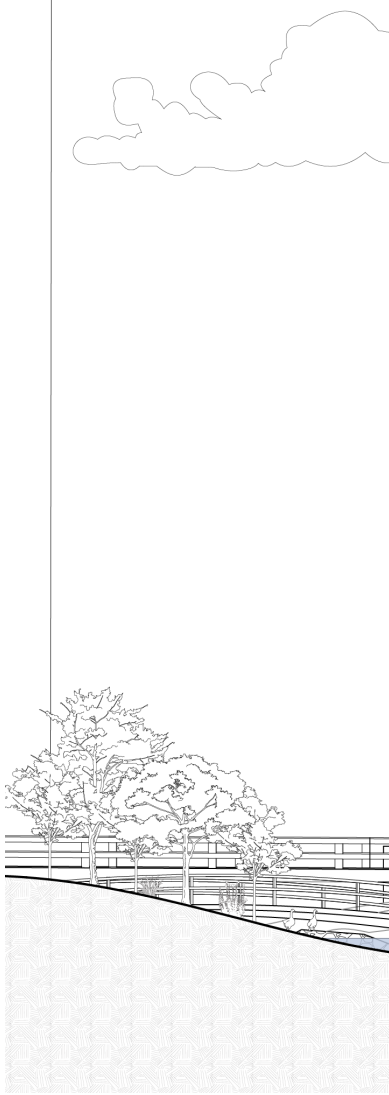


Landscape Monuments Empty Lots

Apply Patch Dynamic on the Newly Relocated Property Lots. Preserve and Reuse Some of the Building Componenets to Create Landscape Monuments.

Figure.4.11. Phase 2 Diagram #2. By Author.

At this stage, residents along the riverbank should have already moved out since they were the most vulnerable to water damage. Tree planting and riparian restoration will continue from Phase 1, eventually forming an ecological buffer zone that will serve as a natural defence to high waters. Pathways, platforms, and water access points are integrated into the ecological buffer to enhance its recreational value. These smaller monuments are built from recycled house materials to provide seating and gathering locations.



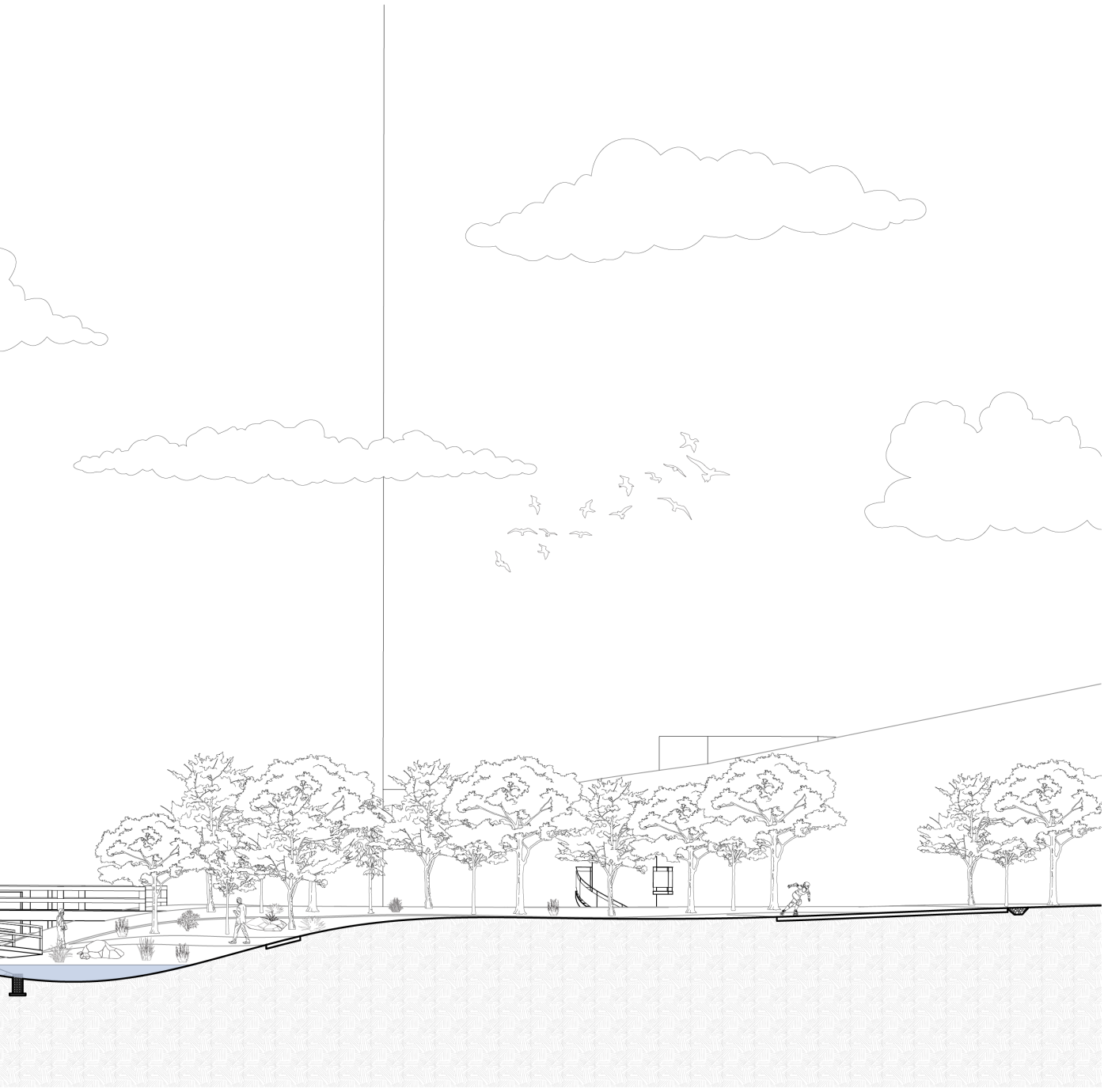


Figure.4.12. Detailed Section A-A Between Elbow Island and the Riparian Zone. By Author.



Figure.4.13. Phase



2 Plan. By Author.



Figure.4.14. Rendered Perspective o

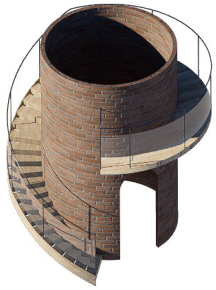


of the Riparian Trail. By Author.

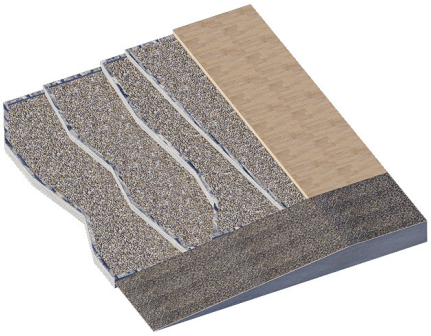
Building materials like bricks and stones will be crushed and used as pavement for the pedestrian pathways. Smallers monuments will be placed along thepathways while the larger ones will be placed on the abandoned lots to provide gathering spaces.



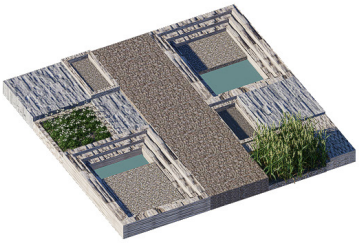
Market Area



Observation Tower



River Access Terrace



Terrace Platform

Figure.4.15. Landscape Mon



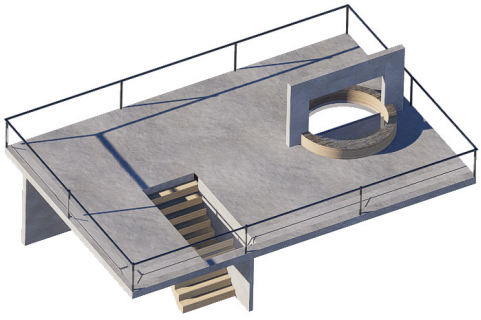
Seating Area



Multipurpose Platform



Gathering Space



Observation Platform

uments Diagram. By Author.

Phase 3 is the last stage, where all the homes will have been relocated over 50 years. In this stage, the entire site has been rewilded as guided by the landscape frameworks. Two artificial wetlands will be established in areas frequently exposed to water inundation. In addition to mitigating floods, these wetlands will serve as water reservoirs for wildlife during droughts. The excavated landfills from the wetlands will be used to create landforms in the dry prairie and a circular amphitheatre in one of the recreational areas. Wildlife crossing bridges are added on the main road to connect fragmented habitats and provide safe passage for animals.

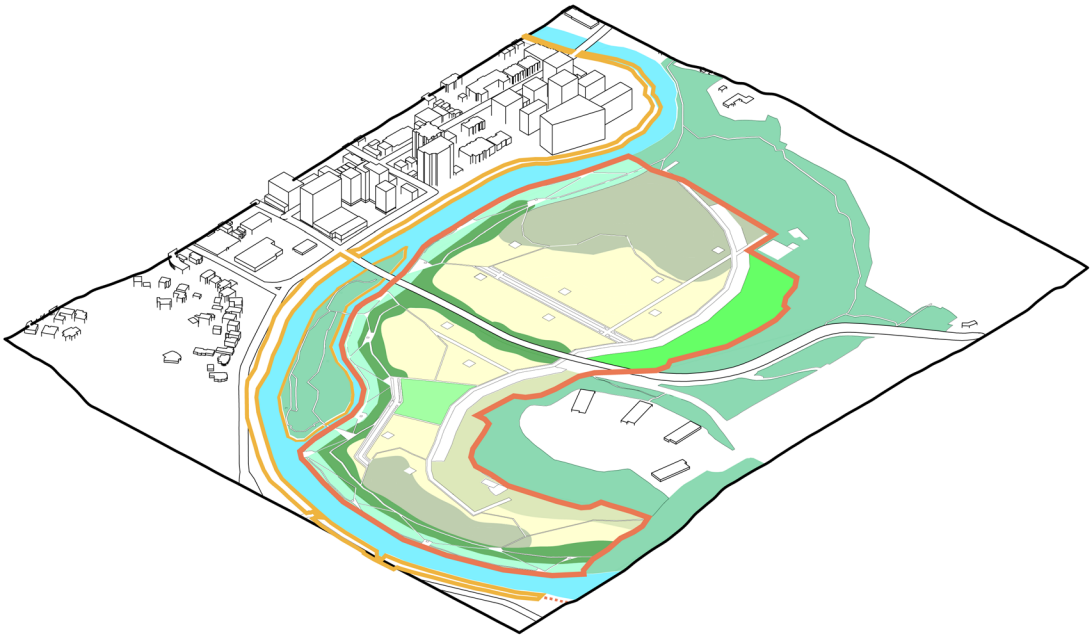


Figure.4.16. Phase 3 Diagram #1. By Author.



Figure.4.17. Phase 3 Diagram #2. By Author.



Parking Area Woodland Wildlife Bridge New Road System

Introducing New Road, Additional Entrance, and Parking Area. Added Wildlife Bridges to the Main Road to Reconnect Habitats.

Figure.4.18. Phase 3 Diagram #3. By Author.



Figure.4.19. Rendered Perspective From Top of t



the Hill Looking Towards 4th St SW Road. By Author.



Figure.4.20. Phase



ecreational Turf Upland Tall Shurbs Moist Prairie Wetland Wildlife Bridge Parking

e 3 Plan. By Author.

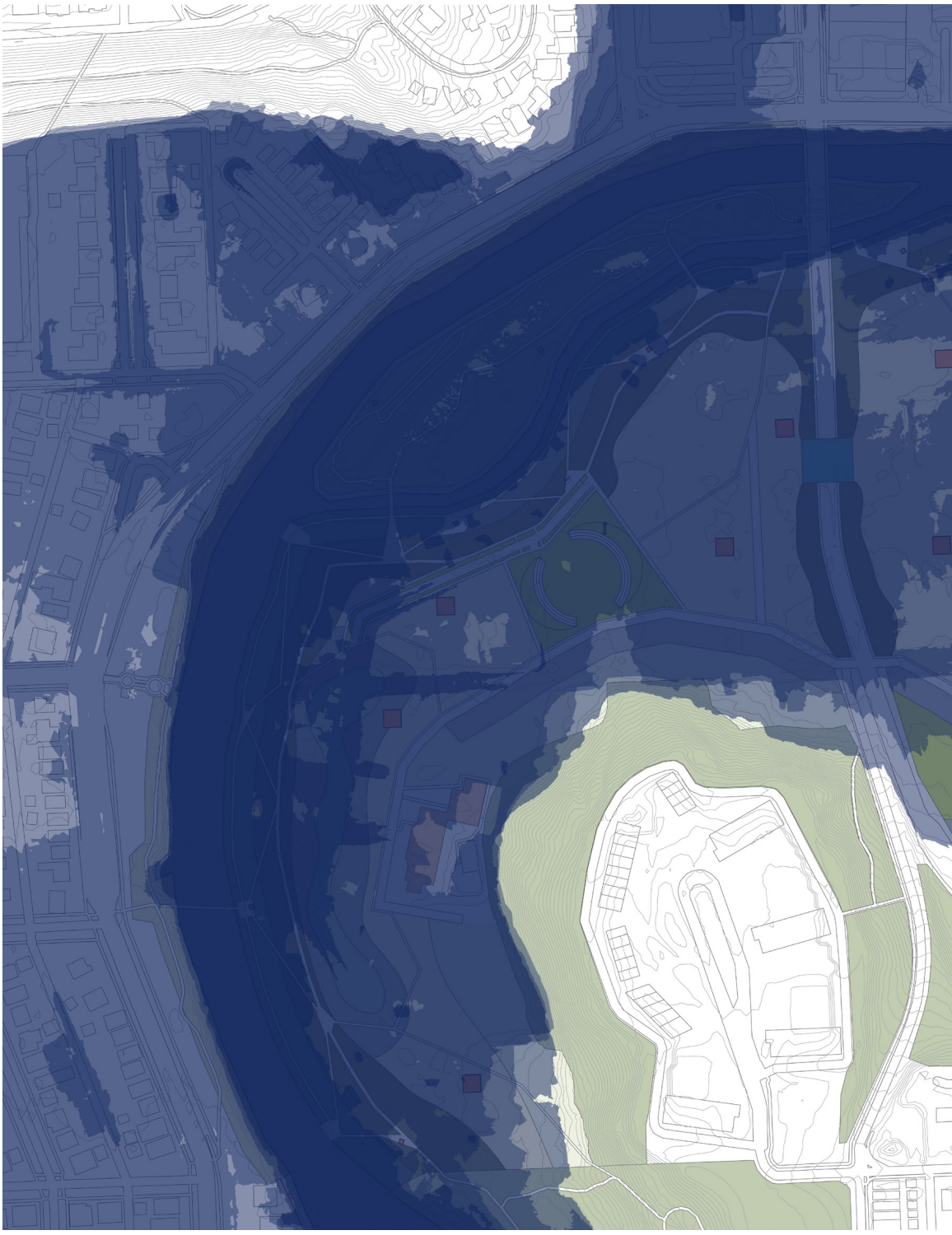
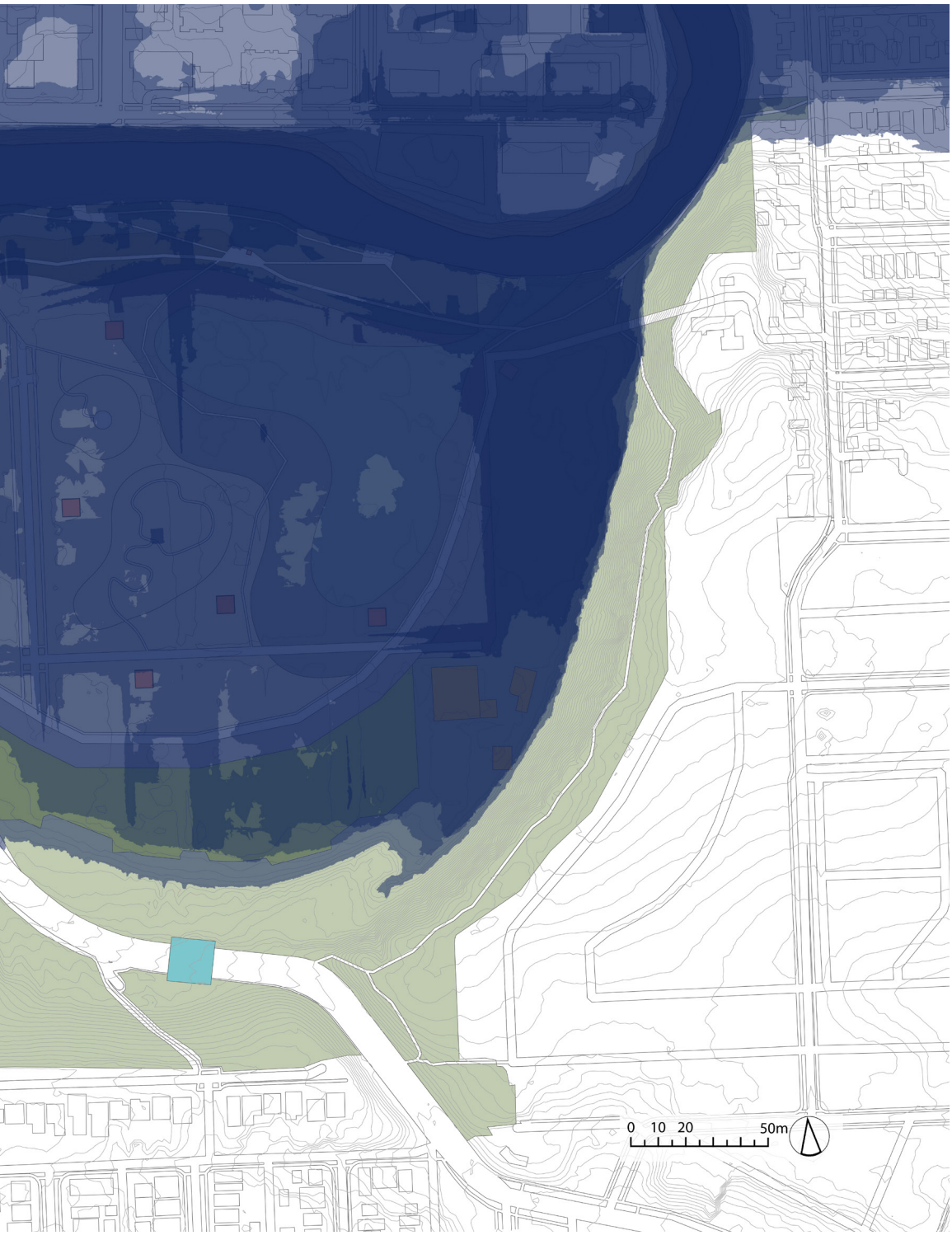
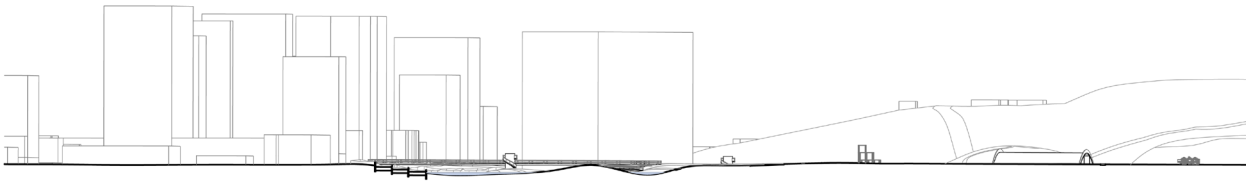


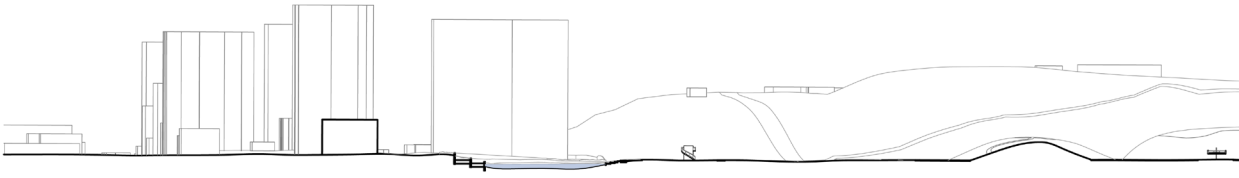
Figure.4.21. Phase 3 Design Plan with Current 20 to



o 500 Year Floods Impact Areas Overlaid. By Author.

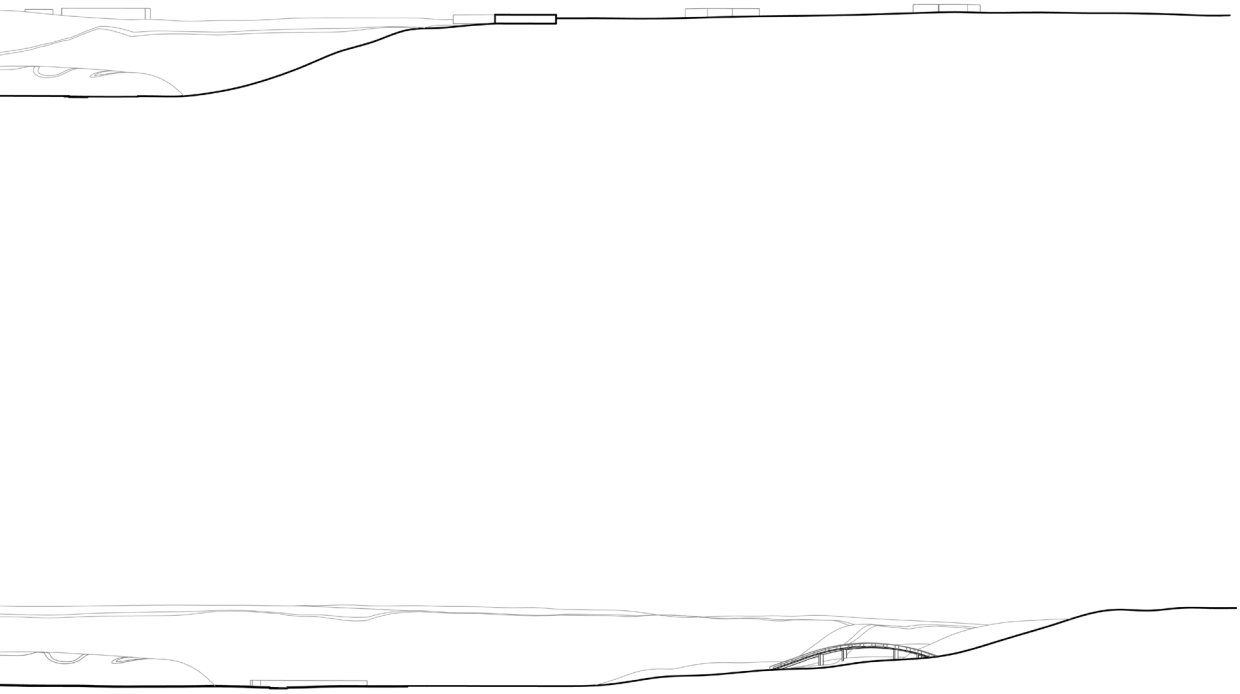


Cross Site Section A-A



Cross Site Section B-B

Figure.4.22. Cross S



Sections. By Author.

A newly built road and parking areas will serve as the last line of defense for remaining public service buildings, such as the school, recreational areas, and the sanitary lift station. In addition, a new entrance is introduced on the north end of the park to improve access and circulation.



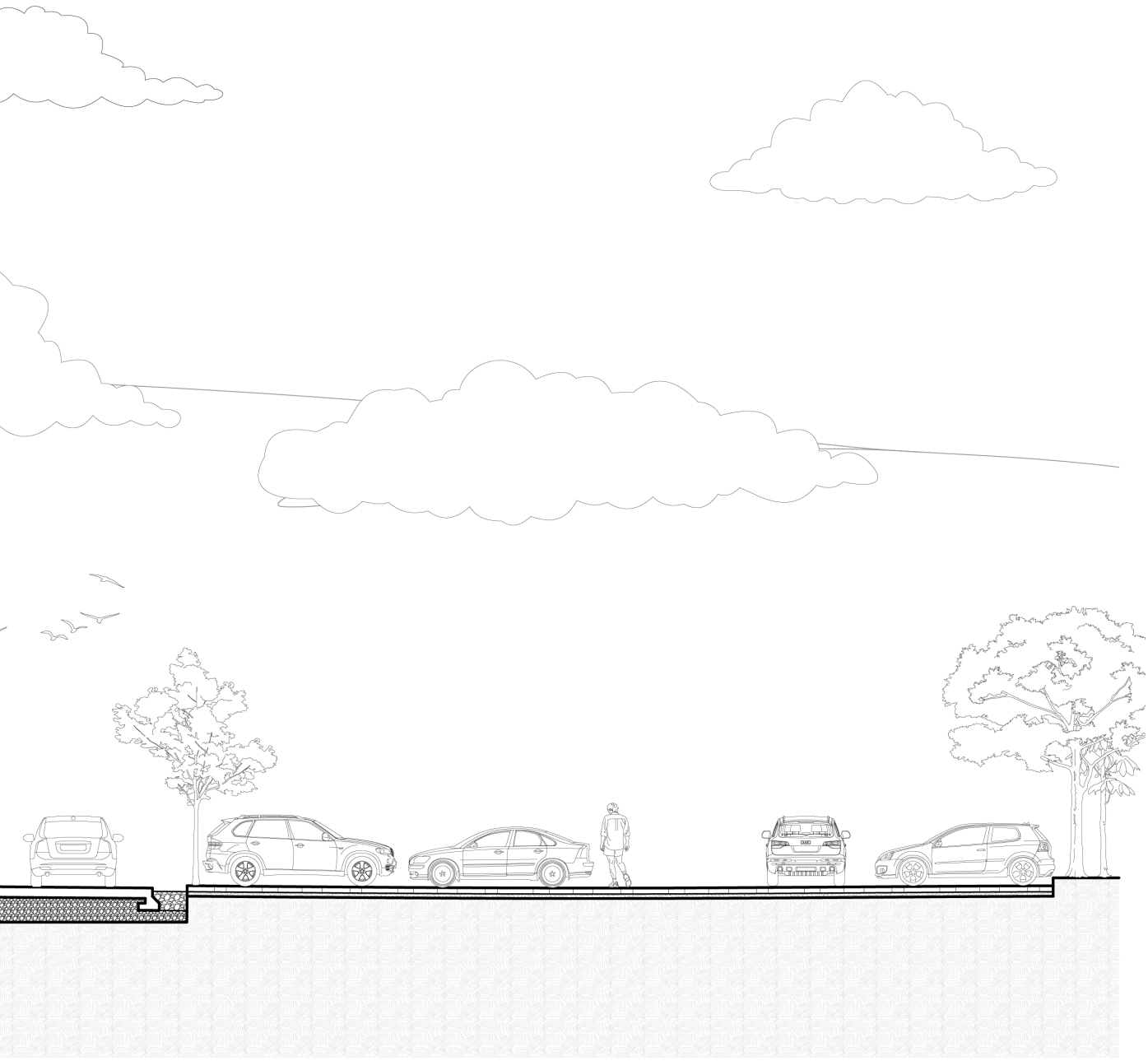


Figure.4.23. Detailed Section A-A Through New Road and Parking. By Author.

CONCLUSION

A Different Philosophy

This thesis provides a much softer flood mitigation approach in comparison to the grey infrastructural method. Differing from attempting to control the river, the approach seeks to accommodate the rhythm of the water, which challenges the existing urban planning philosophy. At the heart of this thesis lies the concept of Retreat—a term redefined by Rosetta S. Elkin as a deliberate and collective choice to step back from vulnerable landscapes. The practice of Retreat is framed as an active process of adaptation, rooted in a deep respect for natural systems, which differs from relocation that often is reactive and involuntary. Retreating from a floodplain is the first step in shifting the narrative from mastering nature to working alongside it, forming a mutual understanding between the man-made and natural world and acknowledging the inherent unpredictability of Climate Change caused by over-human intervention. By embracing Retreat, the thesis proposes a reimagination of the relationship between cities and local environments, one that prioritizes coexistence and long-term ecological resilience.

The design development of this thesis positions itself as an exploration of one of many ways identified in the Protect, Accommodate, Retreat or Avoid (PARA) model to enhance flood resiliency in the context of Calgary. It is not the ultimate solution that will solve all the complex water challenges created by urbanization and climate change but rather a challenge towards the the engineering-centric approach that is often favoured by local authorities. In the cases

where residents, such as indigenous communities, who have historically faced displacement and restricted access to their territories due to systemic injustice, the concept of Retreat may not be appropriate due to previous trauma. Technical solutions that can protect or accommodate to reduce flood damages will be more suitable for these communities.

Yet, the PARA framework remains somewhat economically driven and tends to prioritize engineered solutions. While more ecosystem focused frameworks are available, the PARA framework was chosen for this thesis due to its practicality in the current Canadian context—where the feasibility of the project is often determined by the cost-effectiveness considerations. Thus, analyses between financial and ecological trade-offs play an important role in this thesis. This reflects the broader dilemma of implementing ecologically centered designs in the capital-driven societies.

Furthermore, one of the primary discussions of this thesis revolves around the topic of removing and unbuilding flood-prone neighbourhoods. As indicated during the precedents discussion chapter, the author struggled to find well-documented design precedents that directly link with the concept of Retreat. To address this gap, this thesis provides a series of landscape and urban planning strategies and frameworks to assist the process of Retreat and rewilding. Showcasing a design outcome that is defined through time and the process of interaction. However, the work is yet perfect, given the scale and complexity of this topic. Further advancement would require a team with different expertise to refine and expand upon the ideas presented.

Challenges and the Path Forward

In the final stages of this thesis, new advancements have emerged where the government of Alberta has chosen the Ghost River location for its future Bow River Reservoir project.[1] Now the project has moved to phase 3, looking at the engineering and regulatory approval processes. The next phase would be constructing the dam if the government approves.[2] Issues arising from the project relate to potential water reallocation and environmental damage as discussed throughout the thesis. Most importantly, the concern of the provincial government reverting to the old flood mitigation scheme before 2013. As revealed in the thesis, the full technological approach is a fool's errand, attempting to sustain something that is unsustainable. It is worth noting that this thesis does not oppose the application of grey infrastructure, but advocates for a balanced and mixed approach. There are always trade-offs when it comes to human development and environmental challenges, but we shouldn't prioritize one over the other.

The thesis centers on adaptation and restoring the ecosystem, but it also acknowledges that politics will still play an important role in achieving some of the short to mid-term design goals. However, political issues are not something this thesis can address easily, as reflected in the history of Alberta. The important message is to absorb lessons from the past and avoid repeating the same mistake over again in the new era of climate uncertainty.

Time is of the essence in the challenge of Climate Change and humanity is short of time. The history of Calgary has always prioritized the implementation of engineering

solutions for waterworks, and nature-based solutions only began to surface in the past decade. An immediate commitment to incremental change, recognizing that retreat is a gradual process requiring cultural, social, and political shifts is recommended. The first step would be revisiting the Floodway Relocation program and identifying potential areas for improvements. Although this thesis never addressed or provided suggestions for potential improvement in the policy framework, there are numerous similar government initiatives of buying out floodplains that have been carried out in the U.S. and New Zealand.[3] These examples could provide case studies in creating a sustainable and equitable policy framework to assist homeowners living in the floodplain. On the other hand, the practice of Retreat will be an inevitable phenomenon if the current trend of climate disturbance continues. Government initiatives are more likely to be assisting programs to ease the relocation process, but do not dominate the outcome. For this reason, this thesis prioritizes filling the gaps by creating designs and landscape frameworks that adapt to different stages of Retreat.

Furthermore, in the case of the 2013 Alberta Floodway Relocation program, the expensive costs of properties could have contributed to the failure of the project. There are roughly 154 dwellings in the Roxboro neighbourhood and 342 dwellings in the Rideau Park neighbourhood.[4] According to the City of Calgary My Property website, these homes can be worth roughly between 1 to 6.5 million.[5] Indeed, it will be costly to relocate these homes in the current real estate market and potentially affect the implementation of Retreat. But these values are based on the livability and aesthetic of these two communities, it is questionable whether these properties will continue to retain such high values when flooding becomes

more frequent, and the area becomes uninhabitable. Despite the listed reasoning above, Retreat is not the ultimate answer to the hydrological challenges, there are many more aspects related to the water topic that await to be explored. However, the core principle of other solutions should align with Retreat, acknowledging the true measure of resilience never lies in our ability to resist nature's forces but in our courage to yield, learn, and reimagine our place within nature.

In conclusion, *Swampy Urbanism: Make a Little Room for the Elbow River* is more than a design proposal; it reflects our relationship with the natural world. By embracing Retreat as the philosophy and practice, this thesis pushes humanity to move beyond the illusion of control and instead forge a deeper understanding of our place in dynamic ecosystems. This work opens the ground for everyone to imagine a future where cities are not separated from nature but are integral parts of the cycle. In doing so, it offers hope for urban design in an era of uncertainty that prioritizes adaptation, collaboration, and respect for the forces shaping our world.

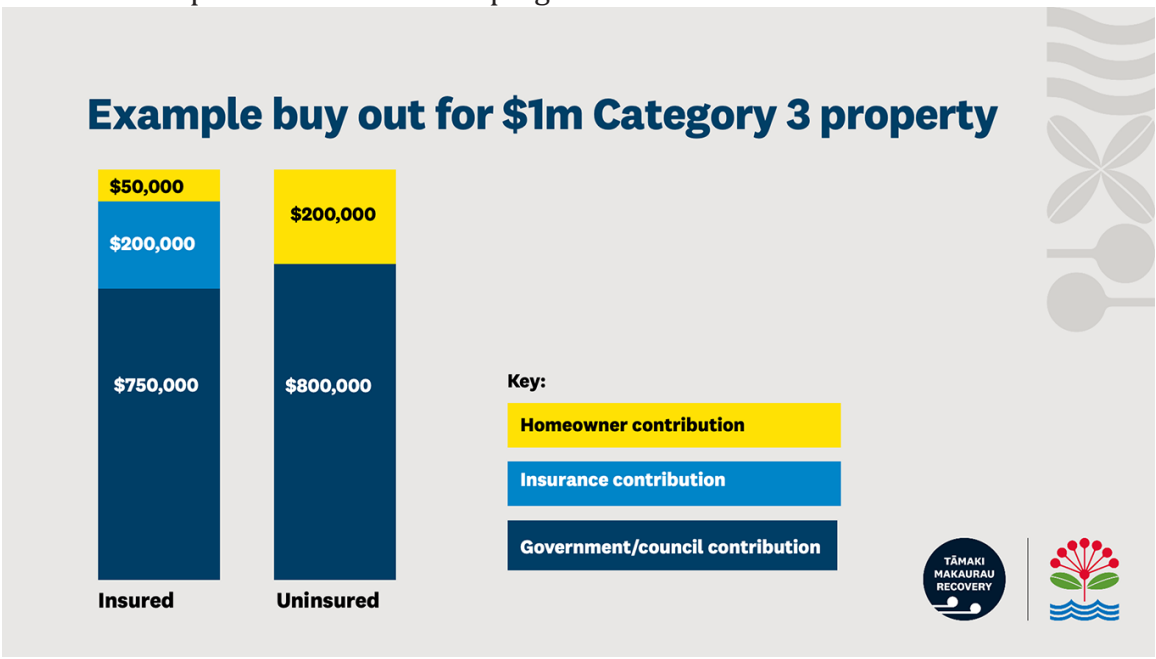


Figure.5.1. Example buy out for $1m Category 3 Property. Auckland Council.

END NOTES

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GLOSSARY

1. **0-Year Flood:** A flood event that has a 10% chance of occurring each year.
2. **20-Year Flood:** A flood event that has a 5% chance of occurring each year.
3. **50-Year Flood:** A flood event that has a 2% chance of occurring each year.
4. **100-Year Flood:** A flood event that has a 1% chance of occurring each year.
5. **200-Year Flood:** A flood event that has a 0.5% chance of occurring each year.
6. **500-Year Flood:** A flood event that has a 0.2 chance of occurring each year.
7. **Alluvial Aquifer:** The Elbow River alluvial aquifer refers to the shallow, unconfined aquifer made of gravel and sand. This aquifer was formed by alluvial deposition and is generally very permeable and highly hydraulically connected to the Elbow River.
8. **Climate Adaptation:** Adjustments in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects. It refers to changes in processes, practices, and structures to moderate potential damages or to benefit from opportunities associated with climate change. In simple terms, countries and communities need to develop adaptation solutions and implement actions to respond to current and future climate change impacts.
9. **Dry Prairies:** Dry prairies are large native grass- and shrub-lands occurring on very flat terrain interspersed with scattered cypress domes and strands, bayheads, isolated freshwater marshes, and hardwood hammocks.
10. **Environmental Flows:** Aquatic ecosystems such as rivers, streams, and lakes need certain levels of water flow throughout the year to remain healthy and sustainable. Environmental flows, also known as instream flows or instream flow needs, are a measure of that water quantity and quality over time.

11. **Flood Vulnerability:** Flood vulnerability measures the level of proneness of any area, infrastructure, or ecosystem to flooding. It considers geography, land use, infrastructural resilience, and community preparation.

12. **Grey Infrastructure:** Refers to human-engineered infrastructure for water resources, such as water and wastewater treatment plants, pipelines, and dams. Grey infrastructure typically refers to components of a centralized approach to water management.

13. **Hydrosphere:** A hydrosphere is the total amount of water on a planet. The hydrosphere includes water that is on the surface of the planet, underground, and in the air. A planet›s hydrosphere can be liquid, vapour, or ice.

14. **Landscape Mosaic Theory:** The ecology theory conceptualizes a landscape as a patchwork of diverse habitat types, resembling a mosaic. In this model, distinct ecosystems—such as forests, grasslands, and wetlands—form individual "patches" that are interconnected within a larger area. These patches are linked by corridors, facilitating movement and interaction between them. Rather than viewing the landscape as a uniform entity, this theory emphasizes its dynamic and heterogeneous nature, focusing on how the interplay of these diverse elements influences species distribution and movement across the landscape.

15. **Low Impact Development (LID):** An approach to land development that works with nature to manage stormwater runoff where it falls. LID preserves and recreates natural landscape features and minimizes hard surfaces to create functional and appealing site drainage. LID includes a variety of landscaping and design practices that slow water down, spread it out, and soak it in.

16. **Moist Prairies:** A native lowland grassland occurring on level, saturated, and/or seasonally inundated stream and river floodplains, lake margins, and isolated depressions in southern Lower Michigan.

17. **Nature-Based Solutions:** Nature-based solutions use tools such as restoration, conservation, and management of wetlands, grasslands, coastlines, and forests to mitigate and adapt to the effects of climate change while supporting biodiversity.

18. **Patch Dynamics:** Patch dynamics is a conceptual and modelling approach that recognizes the spatial patterning at a variety of scales and for various ecological criteria, including individuals, populations,

communities, ecosystems, and landscapes.

19. **Recharge Rate:** In the hydrogeological unit, the quantity of water that replenishes groundwater beneath the water table. Recharge is usually calculated using hydrology balance, integrating information from precipitation, hydrology data, drainage, soil properties, evapotranspiration, etc. The result is a raster dataset in which each cell has a given value for the recharge of the aquifer.

20. **Relocation:** The process of moving individuals, families, or entire communities from one location to another. In the context of flood mitigation, it is a post-flood approach where homes and communities are moved away from flood-prone areas to reduce future vulnerability.

21. **Retreat:** Habitation patterns that meaningfully engage processes of the landscape from climate dynamics to coastal erosion.

22. **Riparian Zone:** Riparian zones are transitional semiterrestrial areas regularly influenced by fresh water, normally extending from the edges of water bodies to the edges of upland communities.

23. **Savanna:** A mixed woodland-grassland biome and ecosystem characterized by the trees being sufficiently widely spaced so that the canopy does not close.

24. **Socio-Hydrology:** The impact of both natural and human interventions on hydrological systems, including inter-basin water transfers, droughts, and agricultural water usage.

25. **Solutionism:** «The capacity for producing a solution precedes and defines the problems. This results in a tendency to see the world in terms of solvable problems, ignoring aspects of the world that are not problems or not solvable.» — *Design with Nature Now*.

26. **Urban Resilience:** Refers to the ability of an urban system and all its constituent socio-ecological and socio-technical networks across temporal and spatial scales to maintain or rapidly return to desired functions in the face of a disturbance, to adapt to change, and to quickly transform systems that limit current or future adaptive capacity.

27. **Wetland:** Wetlands are submerged or permeated by water — either permanently or temporarily — and are characterized by plants adapted to saturated soil conditions. Wetlands include fresh and saltwater marshes, wooded swamps, bogs, seasonally flooded forests, sloughs — any land area that can keep water long enough to let wetland plants

and soils develop.

28. **Wildlife Bridge:** Wildlife bridges are human-built infrastructure designed to help wildlife safely crossroads. These bridges reconnect habitats that have been bisected and fragmented by roads, railways, and pipelines. Wildlife crossings reduce wildlife-vehicle collisions and wildlife mortality, increase human safety, and reduce the barrier effect that roads and infrastructure create.