Hybrid Thresholds

Redefining the Don River's Edge

by
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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

My proposal envisions the threshold between the built urban fabric and the natural environment at the water's edge. It focuses on the development of public space at the water's edge, and tries to transform that space into a new interface that can be experienced as a valued and essential part of urban life. Rather than subscribing to the conventional understanding of infrastructure as a service-based utility, this thesis intends to weave infrastructure and public works at this threshold. It addresses the question of how might urban groundwater filtration, normally considered a toxic function requiring separation from the public, be integrated within low-density public recreation areas involving full immersion and exposure to the environment.

Specifically looking at the Lower Don River, this thesis offers a new vision for this area and is compatible with the new generation of thinking about how landscape can not only restore natural area but also be visibly productive and socially accessible. The proposal's interest in doing so aligns with the ideas of architects and landscape architects such as Michael Hough, Mohsen Mostafavi, Elizabeth Mossop, Pierre Belanger, and Douglas Farr. The design proposal tackles existing environmental and ecological issues of the Don River by envisioning a series of three programs along the Don that offer dynamic community interactions, and foster the discourse on social and environmental responsibilities. These three programs are all defined by the same design strategy, which relies on a hierarchy of water systems with different volumes to develop a corresponding architectural program. The water is absorbed, retained, and purified through different basins, water remediation cells, and soft landforms during its journey to the river, while people have the opportunity to enjoy that process within the system of boardwalks, elevated decks, and seasonally accessible walkways. These habitable landforms provide room for different public recreational activities which could foster a unique character and renewed experience of a public work along the water's edge.

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Dedicated to my parents

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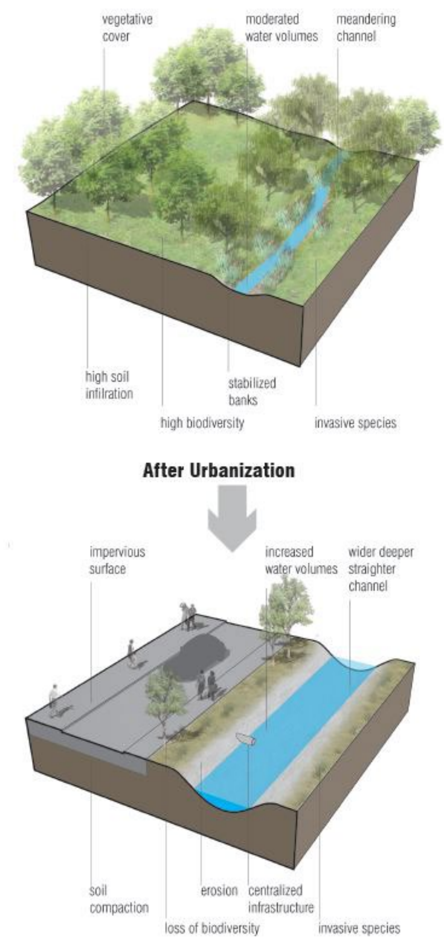
Introduction

1.1 Study Problem

Urban development can change the hydrology (water flow amounts and patterns) of an area to varying degrees. It can alter the natural way in which stormwater runoff finds its way back to the river. Whereas natural vegetation and soil structure once allowed the gradual absorption and slow throughput of rain and snowmelt, the expansion of impervious hard-paved surfaces throughout the watershed has sped up the delivery of both water and pollutants to our waterways. Now much of the stormwater runs off the surface, collecting dirt, oil, grease, and other pollutants before entering the river. This leads to degraded water quality and rapid peak flows during wet periods.

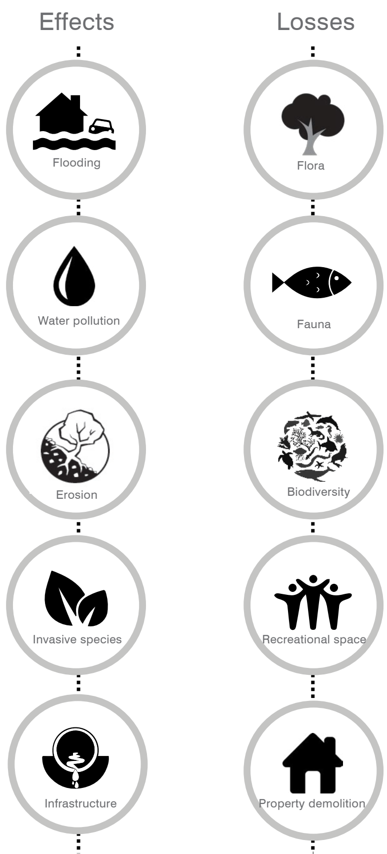
> *"The curb and catch basin that make rainwater disappear without trace below ground, cut the visible links between the natural water cycle, the storm sewers and dispose of it into streams, and the lakes and rivers that ultimately receive it"* [1]

Most north American urban areas have suffered severely compromised hydrological function and health, particularly in relation to stormwater and its storage, treatment and flow. Toronto's Don River is not an exception. The Don River is a seemingly natural space within an otherwise dense and noisy concrete jungle.[2] It has a history dominated by intense urbanization that has left it with a legacy of contamination that lingers to this day. Today almost the entire Don Watershed – about 80% of it [3] – has been urbanized, and the Don River has been identified as the most degraded river in the Greater Toronto bio-region, particularly in the river's lower region.[4]
With the high level of impervious cover in the Don River watershed, ranging from 19 per cent in the Upper East Don sub-watershed to 43 per cent in the Taylor/Massey Creek sub-watershed, based on 2002 land use, even small amounts of precipitation can have a large impact on surface flows.[5] The effects of urbanization on the water cycle become clear when we see that, on average, 72.6 centimetres of water per year leaves Ontario cities, of which 31.8 centimetres is from storm runoff.[6]



0.1 The effects of urbanization on the water bodies and the water cycle hydrology in cities. A comparison between condition of river and its surrounding environment before and after urbanization. Balderas-Guzman, Celina. Strategies for systemic urban constructed wetlands

Associated with an increase in impervious cover are an



0.2 Effects and losses of conventional, engineered stormwater management.

increase in runoff volume and velocity and a decline in infiltration potential.[7] In other words, urban stormwater runoff is a matter of both water quality and water quantity. Stormwater practices help to mitigate these effects by reducing peak flows, infiltrating runoff, and removing contaminants from urban runoff.

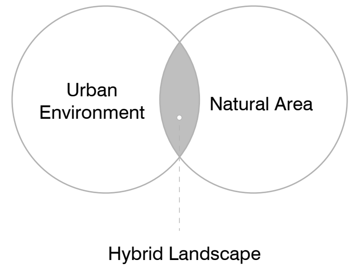
However, these practices are largely absent in approximately 80 per cent of the urban part of the Don watershed.[8] In addition, Toronto's conventional stormwater management is under stress. The current engineered stormwater management amplifies the flash flood condition with massive, dangerous contaminated flows, which arguably have a negative impact on the environment. In general, incidents such as bridge collapses, dike failures, levee breaks, coastal flooding, water shortages, road cave-ins, decaying sewers, and deferred maintenance, when considered together, provide evidence of the limited capacity of conventional infrastructure to deal with the complex challenges of mass urbanization.[9] Specifically in Toronto, there have been several records of combined sewer overflow (CSO) events in the Don River and central waterfront watershed, which are evidence of the limited capacity of Toronto's conventional infrastructure and stormwater management to handle peak-season torrential rainfall.[10]

> *"Ninety-five per cent of the Don's pollution was estimated to originate from discharges from storm and combined sewer within the Don's 36,000 hectare watershed. Estimates indicate that given an approximate removal efficiency of pollutants of 50 per cent through the elimination of combined sewer overflows and treatment of stormwater, the City of Toronto on its own could expect to achieve a 2.5 per cent reduction in annual loadings to the Don River."* [11]

As a result, what we experience within the Don Valley and the river environment is an unhealthy amount of polluted runoff water as well as sewer overflows, decades of contamination from industry, and a social detachment from the public space where activities such as fishing and swimming are discouraged.With the typical track of urbanization, the river has lost its natural resilience and rich ecology, particularly at its edg!

1.2 Morphology

My thesis is a proposition for a new way to design a river's edge in an urban environment. It envisions the threshold between urban area and natural environment as a new interface that can be treasured and experienced as a valued and essential part of an urban life. It critically questions the existing condition of the river's edge and the conventional infrastructure associated with that, and therefore proposes a new model of how this edge could be redefined for both the sake of the river and the benefit of the public. By reintegrating the river's edge as an accessible and experienced natural area in the city, this thesis intends to restore the natural environment and create spaces for people.

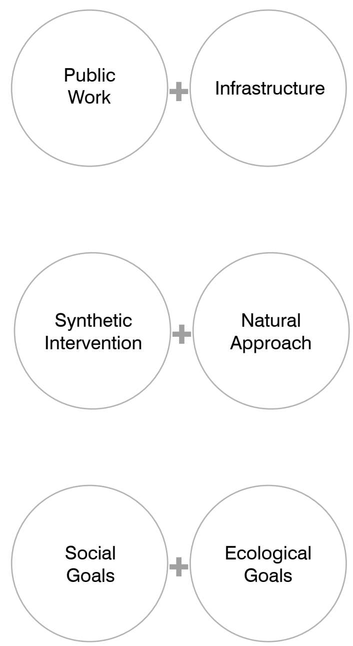


0.3 The basic idea of integrating urban environment and natural area to engage the edge of the river.

The proposal uses a hybrid approach in which certain city infrastructure such as stormwater retention and water filtration are combined together, and deliberately exposed for public spaces. Through this perspective, the urban river's edge becomes a new kind of public gathering space integrated into contemporary wetland restoration which engages technical performance of water filtration.

Specifically looking at the Lower Don River area, this thesis focuses on the threshold between the Don River and Toronto's urban fabric. My work offers a new vision for the Don River and is very compatible with the new generation of thinking about how landscape can not only restore natural area but also be visibly productive and socially accessible. Michael Hough's words in his book "Cities and Processes" describes this vision and emphasizes on the reintegration of nature and city:

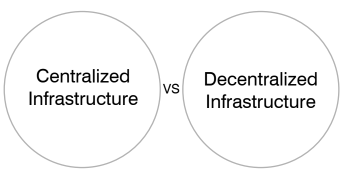
> *"It involves the creation of new landscape – a mix of the natural and the human that may not have existed before, but which recognizes the interdependence of people and nature in the ecological economic and social realities of the city."*[12]



0.4 The basic principle of the proposal.

Don River's issues of both water quality and water

0.5 Partial section of the proposed system.



0.6 Decentralized approach versus centralized approach

quantity are best served when they become part of an integrated design strategy that combines biology and technology, social and economic concerns.[13] The preservation and restoration of urban natural features inevitably depends on citizens' care and involvement in urban ecologies.With this in mind, the water's edge in this thesis is conceived as a public space which provides recreational activities as well as visual enhancement of the landscape. With potential for dynamic programming, the river's edge can transform into a new kind of urban public space which engages a more resilient infrastructure with a cultural identity that provides active waterfront experiences.

This thesis also tries to find an alternative solution to the current centralized system for stormwater management. As Pierre Belanger suggests:

> *this moment in history demands a reconsideration of the conventional centralized practice of infrastructure that has overshadowed the landscape of bio-physical systems as a decentralized infrastructure.*[14]

It argues that instead of having a conventional infrastructure with a centralized channel, which was the precondition of the river, we can break the stormwater system apart into distributed ones along the river.

0.7 The proposed scheme for the edge of the Don.

Douglas Farr, in his book Sustainable urbanism discusses that this alternative approach restores and stabilizes the historically groundwater-dominated hydrology pattern on a site-by-site basis and, as a result, decreases the chances of downstream flooding prevalent in traditional stormwater engineering practices.[15]

The thesis further proposes that this process of remediation be incorporated into the city itself, with the decentralization of the larger water treatment system in favour of a smaller, decentralized one that can serve multiple functions. Studies have proven, in fact, that the combination of water purification, nature development, and recreation is possible.[16]

The proposal appreciates a soft landscape and gentle transition toward our water's edge. In our current situation, the city is cut off from nature by a sharp edge, usually a designated flood line. As an alternative to this conventional and engineered way of treating the river's edge, this proposal seeks a more fluid geographical approach to land and water, which places an emphasis on continuous mutable ecologies which eventually creates a more sustainable future.[18]

This transition in my work employs natural approaches along with some synthetic interventions to remediate the water. Of course, bringing a natural system back to a state of ecological health and resilience is not necessarily a return to a purely natural state in the absence of human experience.[18] It involves the creation of a new "hybrid" landscape that will occupy a middle space between the highly urbanized inner city and the natural environment, in which the natural and human environments are integrated.

The 20th-century utility-based service water infrastructures that have supported cities for last decade are mostly constructed hidden from the public, and at the periphery of the inhabited urban realm.[19] We have seen the increasing standardization of infrastructural systems as they meet higher standards of technical efficiency. These ubiquitous urban environments have been considered and evaluated solely on technical criteria and somehow exempted from having to function socially, aesthetically, or ecologically.[20]

The traditional vision toward our infrastructure reserves water treatment plants as places for toxins and sewage that makes them unsuitable for public exposure. In addition, it considers the water treatment process as a pure, engineered work which prevents public access/interference in order to achieve its maximum efficiency and cost-effectiveness. However, this thesis explores a different approach toward our infrastructure which involves a recognition that all types of space, not just the privileged spaces of more traditional parks and squares, are valuable.[21]

The design strategy relies on a hierarchy of water systems with different volumes to develop corresponding stormwater management systems and architectural programs.[22] Instead of building flood walls to block out water, the ecological alternative creates a more resilient system that allows users to experience the change. Rather than treating water as a major threat to the city and avoiding it, the plan welcomes water as a design feature through creation of a new hybrid landscape with various "habitable terraced landforms" such as marshlands, swamplands, and wetlands. In doing so, it proposes disconnecting the combined sewers, and diverting surface and stormwater runoff into a cellular water management system which absorbs, retains, slows, purifies, and celebrates the water through different soft landforms and treatment plants during its journey to the river.

1.3 Design Objectives

Regenerating the Don river, and reintegrating its edge as usable, experienced and enjoyed space in the city is achieved through both "ecological" and "social" architecture in this thesis. The ecological and social goals of the design can be met by achieving the following objectives:

Ecological Objectives

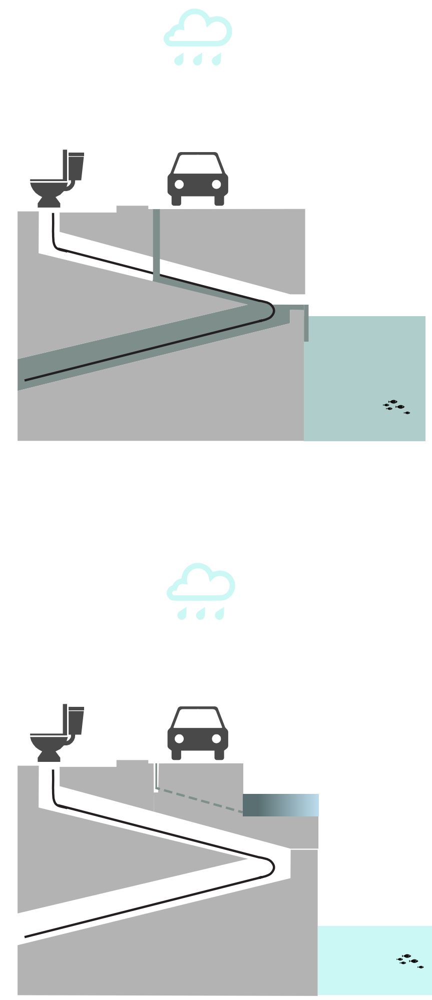
- Propose an ecological framework at the water's edge that adapts over time.
- Protect and restore the water quality.
- Control the peaks and lows of river flow.
- Preserve and improve the aquatic and terrestrial life of the Don River and at the water's edge.

Social Objectives

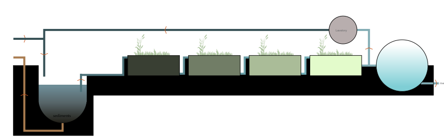
- Recreate the water's edge as an urban space and valuable public amenity.
- Attract people to the heritage of the city.
- Improve the viability of Don Valley lands as a place for recreational activities as well as one through which pedestrians and cyclists can walk/ride and commute.
- Increase public awareness by making the project visible.

1.4 Design Strategies

The design strategy chosen for this proposal is based on studying relevant design projects such as Kongjian Yu's Houtan Park at Shanghai's Huangpu riverfront and the Don Valley Brick Works in Toronto. The design solution for these projects is achieved through the creation of different occupiable public areas integrated with the 'soft' infrastructure. They all exist with the purpose of minimizing the harm of flooding, creating programs along the river, providing habitat for endangered species, and



0.8 The thesis design strategy in terms of its water remediation system. The top image illustrates the current system of water management; the bottom image, the proposed one.

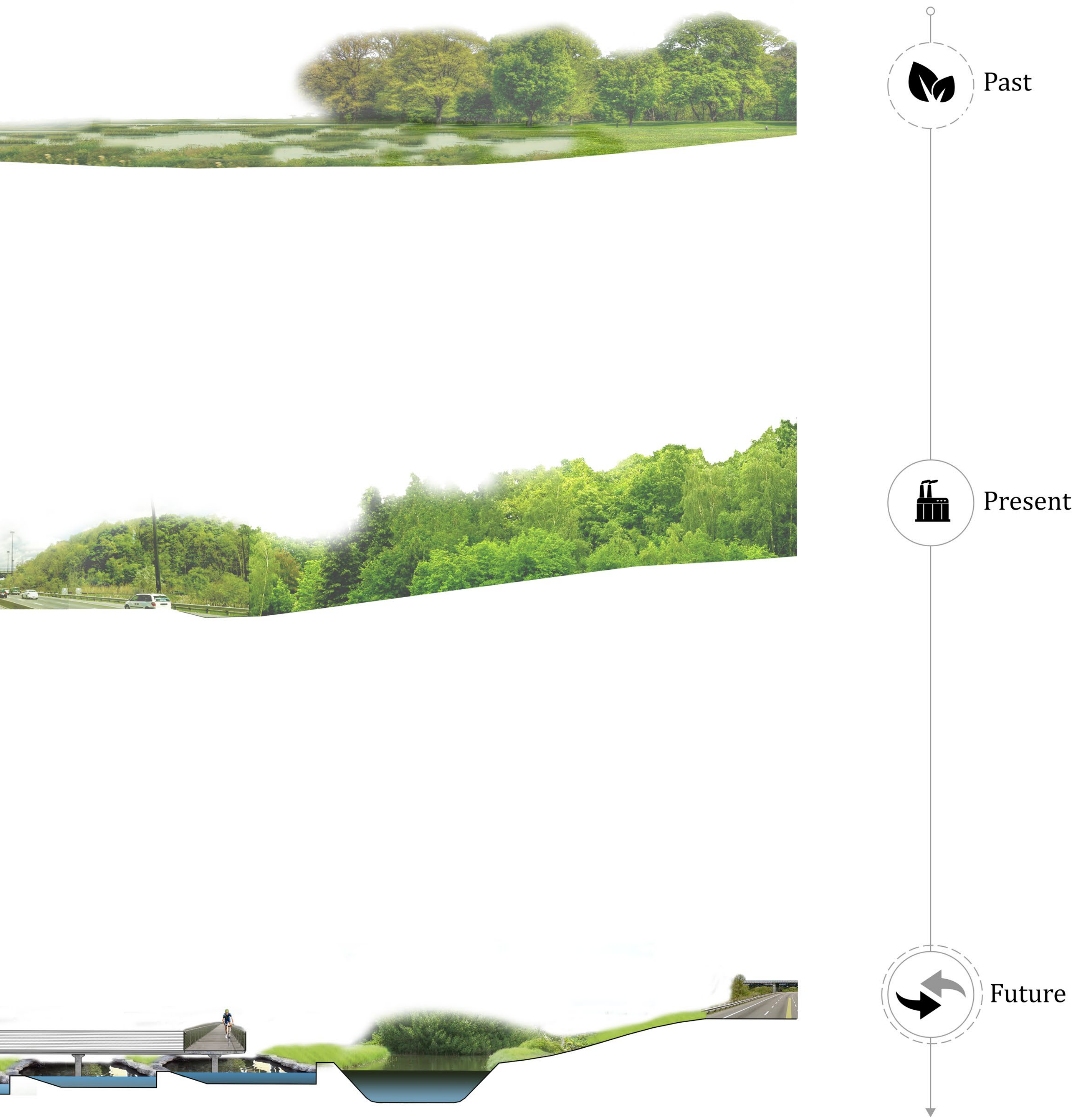


0.9 Process of water treatment: different basins used in the proposed cellular water remediation system.

Precondition of the river's edge: purely natural state with original resilience. This system has the capacity to adapt to changing conditions and to maintain or regain functionality and vitality in the face of stress or disturbance. It has the capacity to bounce back after a disturbance or interruption.

Existing condition of the river's edge in an urban environment: an engineered, highly channelled, hard-edge flood wall with an artificial ditch which separates city from nature. This system is based on the conventional static design approach which does not adapt itself over time.

Proposed condition of the river's edge in an urban area: a hybrid landscape employing natural approaches along with synthetic interventions. It aims to create a resilient framework rather than a fixed master plan, and to let the ecological strategy generate corresponding landscape along the water's edge.



0.10 River's edge: precondition, existing, and proposed condition.

making the water system visible to the public.[23]

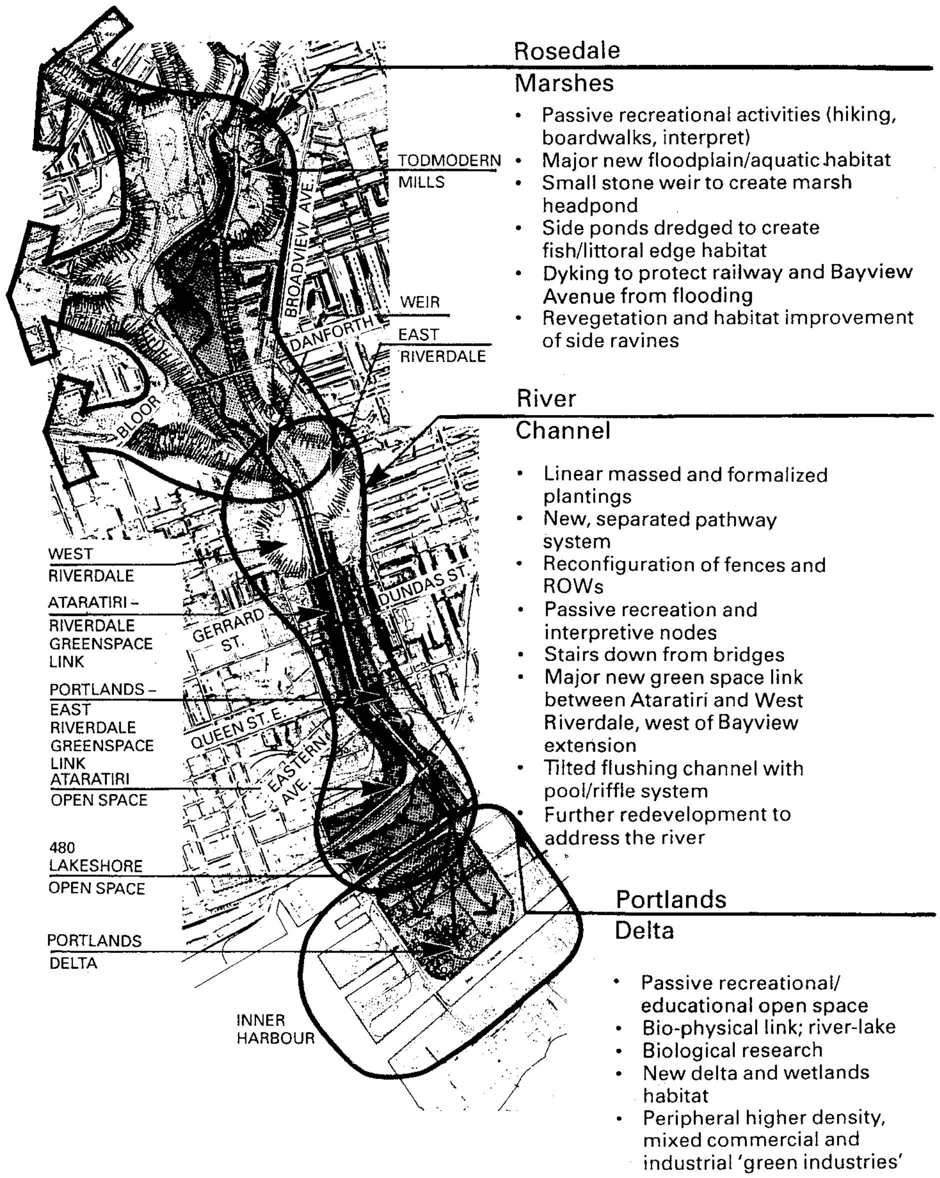
The basic principle of my design solution follows Michael Hough's design proposal for the restoration of the Don, which involves taking more dramatic environmental action to return the river to a state of health and diversity, and bring the valley back to the city.

> *" The overall strategy for restoring habitat, open space, and a delta/marsh in the lower valley depended on modifying the hydrology of the river using natural principles of river behavior"* [24]

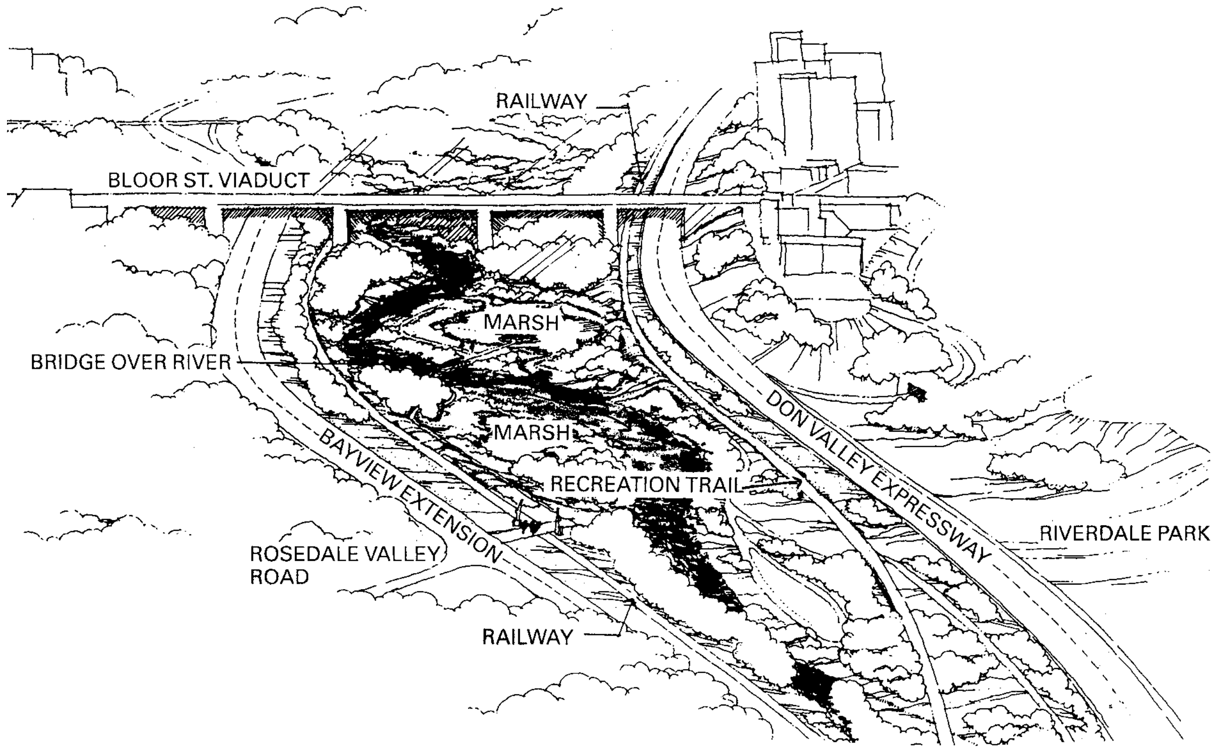
Michael Hough distinguishes three distinct kinds of landscape for the lower part of the Don River, each with a natural and cultural character of its own, and each intimately connected to the whole (figure 0.11): River mouth, linear part of the valley north of the delta, and the upper reaches of the Lower Don Valley.

He proposes an integrated three-part restoration strategy up the river. For the upper reaches of the Lower Don Valley, which is the focus of this thesis, he proposes the creation of upland marshes, ponds, and meadows, whose biological function would be to assist in improving water quality, and help balance highs and lows in water flows and flooding.[25] Figure 0.12 shows Michael Hough's conceptual sketch of the upper reaches of the Lower Don, illustrating the proposed marshes, meadows, walkways, and passive recreation.

Referring to Hough's proposal for the restoration of the Don, my proposal is characterized by creating marshes and meadows along the river's edge, and is then extended by providing exploration of certain qualities of cellular bioremediation system integrated with the public life. The plan provided in the Lower Don strategy proposed by Hough shows schematic orchestration but it only glosses the question of water quality itself by saying generically that creation of marsh lands would assist improvement of water quality. Therefore, this is a chance in this thesis to address the water quality in detail through creation of water cellular configuration. In addition, the architectural aspects of Hough's proposal for this area are relatively schematic through his



0.11 Michael Hough's proposal for restoration of the Don River. Lower Don strategy plan. Three distinct landscape units and the peculiar hydrology of the river valley depended on modifying the hydrology of the river using natural principles.



0.12 Hough's proposal for the upper reaches of Lower Don River area.

schemes and therefore it requires further development. In fact one of the areas where this thesis distinguishes itself is in its emphasis on the integration of more architectural programs and habitable land forms. In my proposal people will have the opportunity to celebrate water and culture within the system of boardwalks, elevated decks, and seasonally accessible walkways even during flooding. The areas where there is room for individual activities as well as public gathering could foster a unique character and renewed experience of the threshold between urban fabric and natural area.

The proposed program can be examined in its broader context while adapting to site-specific design interventions along the Don River. The site selections were made based on the critical condition of the site both ecologically and socially. The lower part of the Don has been degraded and has suffered the most from the urbanization process. The focus of this thesis is on the upper section, where the valley broadens out into a major floodplain.

A series of three architectural design interventions, each covering one of three test sites along the edge of the river in this zone, has been developed in this thesis. The interventions are located along the trail that attracts the public runners, cyclists, and pedestrians to the water's edge. Although the proposals are different for these sites, they are all defined by the same strategy, which gives the design a sense of wholeness. The essential ingredients of all three programs are a series of water remediation cells and landforms, along with public programs occupying some part of the landscape. A cafe, a contemplation area, and a stop area, combined with recreational boardwalks, have been assigned for the chosen locations. These are the public facilities which at regular intervals will connect the natural landscape with its context as a public space in a city.

For all three programs, there is a proposed network of elevated boardwalks along the river that are connected to the existing trail system, and above the landscape filtration cells, to form a complete pedestrian and cyclist system. Public open spaces are provided in the forms of non-flooded decks and seasonally accessible spaces integrated into constructed wetland and swamplands. The water system is made visible through the creation of all these habitable landforms, which form a healthy community centre. The recreational boardwalks permit access to water, and are kept unobstructed for activities such as fishing, jogging, swimming, or simply dipping one's feet in the water.

Among all three architectural interventions, the site plan of the cafe program will be developed in detail, with the other two remaining schematic. The main fabric of landscape cells (maintenance operation) and the basic geometrics of social activities (social operation) are addressed in detail through the plan of the cafe program. This site plans illustrates in detail the works of maintaining a civic scale water filtration facility as well as the public gathering areas of visiting, playing, recreation, etc. A series of three site sections from each location, accompanied by some detailed partial sections, describe the characteristics of these hybrid interventions both poetically/architecturally and technically.

0.13 Top: Map of the study area

0.14 Middle: Public life interwoven with cellular system, the elevated deck.

0.15 Bottom: Public life interwoven with cellular system, the seasonally accessible walkway.

1.5 Book Structure

The thesis is comprised of four chapters that provide the problem statement, the opportunities, and the strategic design proposal. The design investigation is generated from two primary bodies of research which will be explained in the first two chapters of the book.

The first chapter explains the problem statement of this thesis, and the theoretical background of the Don River. In addition, it addresses the challenges that the city of Toronto faces in keeping its watershed – particularly the Don watershed - clean and healthy. In other words, it tries to link the larger environmental and social issues of the Don River and its valley to specific flaws inherent within Toronto's urban water cycle specifically the design of the city's sewer management. Ultimately it determines that managing the stormwater runoff throughout the river necessitates an infrastructure that is not just a utility-based service. Indeed, it needs a more resilient infrastructure which is integrated with public activities, and able to attract people over a long period of time.

With this in mind, the second chapter, entitled "Infrastructure for People: Redefining an Urban River's Edge," proposes a new design language for urban environments and especially a new interface for the urban water's edge. It discusses different ways in which the form and performance of conventional infrastructure might be renegotiated to address challenges of rapid urbanization. Each strategy is outlined individually and accompanied by an analysis of exemplary waterworks that illustrate the particular theories discussed. These precedents not only demonstrate the potential for hydrologic infrastructure to be planned according to the proposed principles, but provide insight into specific strategies for my design proposal as well.

The third chapter, which is the design proposal, establishes a strategy based on the research of the two previous chapters. The design proposal is carried out to address the issues presented in the first chapter, and draws design inspirations through the vision of architects and landscape architects such as Michael Hough, Mohsen Mostavafi, Elizabeth Mossop, Pierre Belanger, and Douglas Farr. In addition, it employs some of the innovative and recent approaches of decentralized, less complex, multifunctional, and visible urban water management implemented in some American and European cities which are described in chapter 2.

Based on the research from the first two chapters, chapter three proposes a decentralized system comprised of smaller components integrated with public activities as a holistic approach for stormwater management. These networks would be integrated into the existing grid of Toronto's water infrastructure. This strategy has been used as a test examination for three sites along the Lower Don. However, the same methodology can be adopted all the way along the Don River's edge, and particularly in its lower region, which has been degraded the most due to intense urbanization over the past decades.

The scope of the proposal can also be extended into the rest of Toronto. We can imagine a vision of this spreading through the multiple ravines of the city and inhabiting parks and bridges, or simply wherever the city needs transitions between its land and water.

01
PROBLEM STATEMENT

THE RIVER
THE OPEN SEWER

Everything is connected to everything else.[1]

This principle has become, in the 21th century, the embodiment of the larger regional and global view as well as a local one. Therefore, it should be recognized that the Don River cannot be viewed as simply a narrow body of water in the city. It is linked by rivers and creeks to the watershed, and by water mains, storm and sanitary sewers, and roads to homes and businesses throughout the metropolitan area.[2]

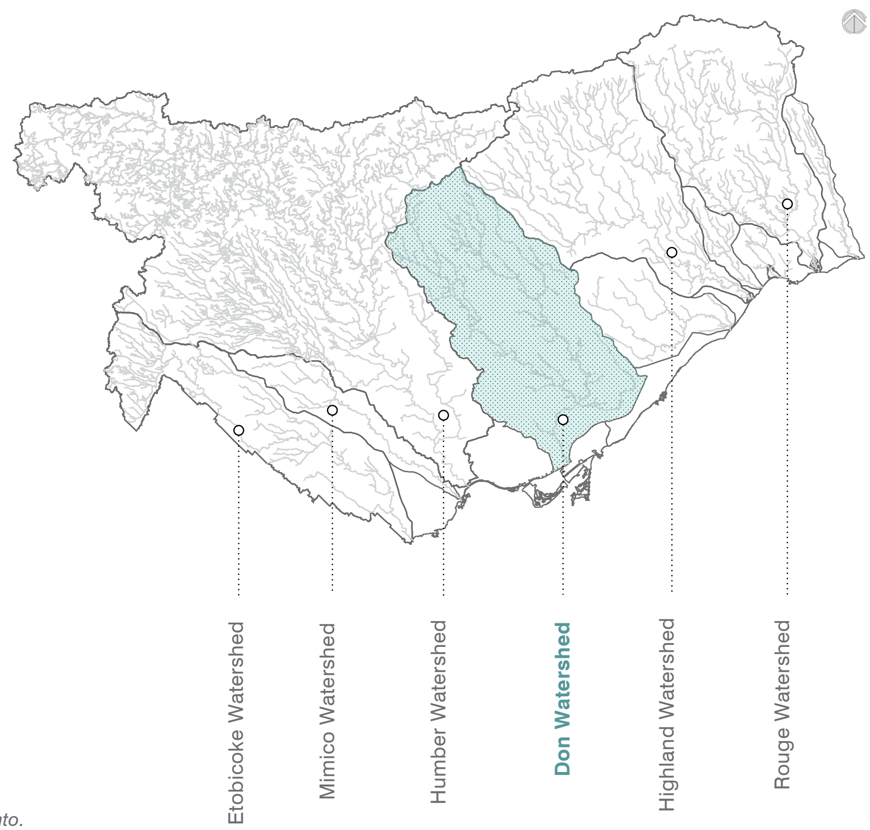
To properly understand a local place therefore requires an understanding of a larger context- the watershed and bio-region in which it lies. The following is a review of how the water system in Toronto has evolved and how it has influenced urban life.

2.1 Don watershed life

2.1.1 Toronto: City of Ravines

The Don River is one of the watershed systems in the Greater Toronto bio-region that extends from the southern slope of the Oak Ridges Moraine to Lake Ontario.[3]

Watershed	Watershed area (ha)	Areas of watershed in the city of Toronto (ha)	Percentage of city land in watershed	Watershed as percentage of city land area
Don River	**35,806.00**	**20,632.60**	**57.6**	**32.5**
Etobicoke Creek	21,164.80	1,478.60	7.0	2.3
Highland Creek	10,157.80	9,614.00	94.6	15.1
Humber River	91,077.80	13,731.90	15.1	21.6
Mimico Creek	7,709.10	2,900.50	37.6	4.6
Petticoat Creek	2,682.20	240.30	9.0	0.4
Rouge River	33,288.80	3,395.50	10.2	5.3
Total	213,474.40	63,581.30	29.8	100

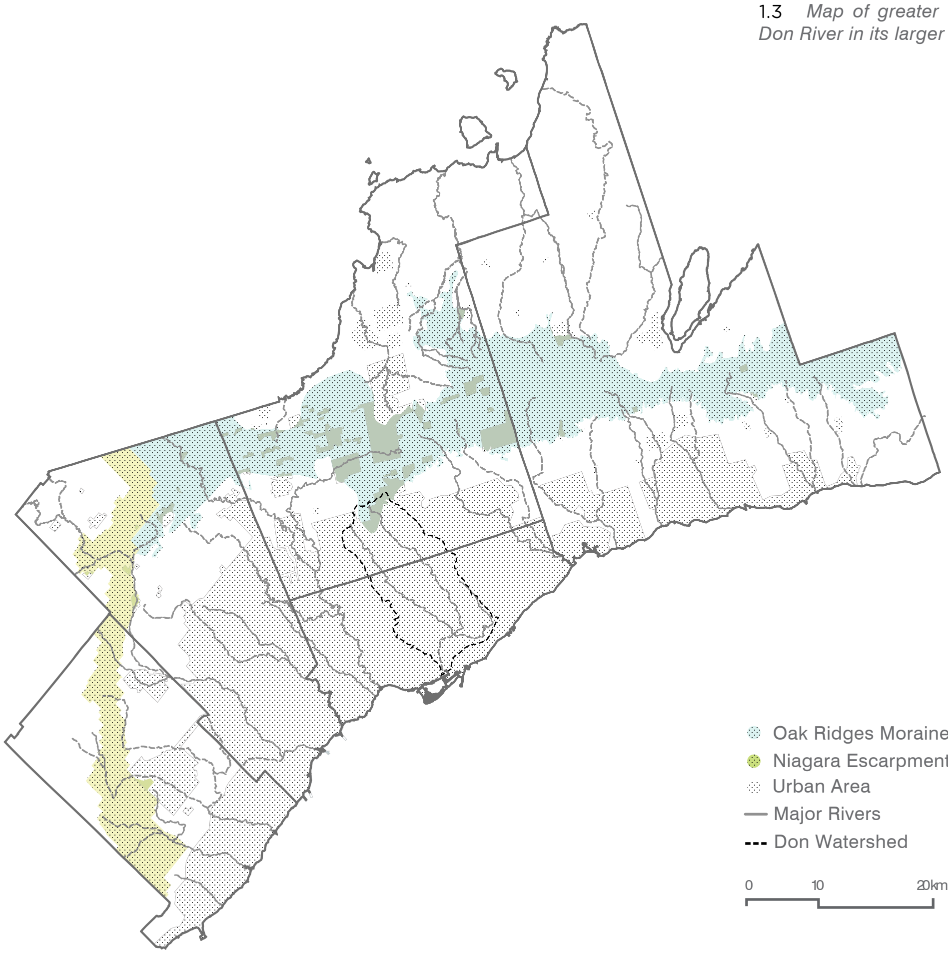


1.1 *Top: Areas of watershed in Toronto.*

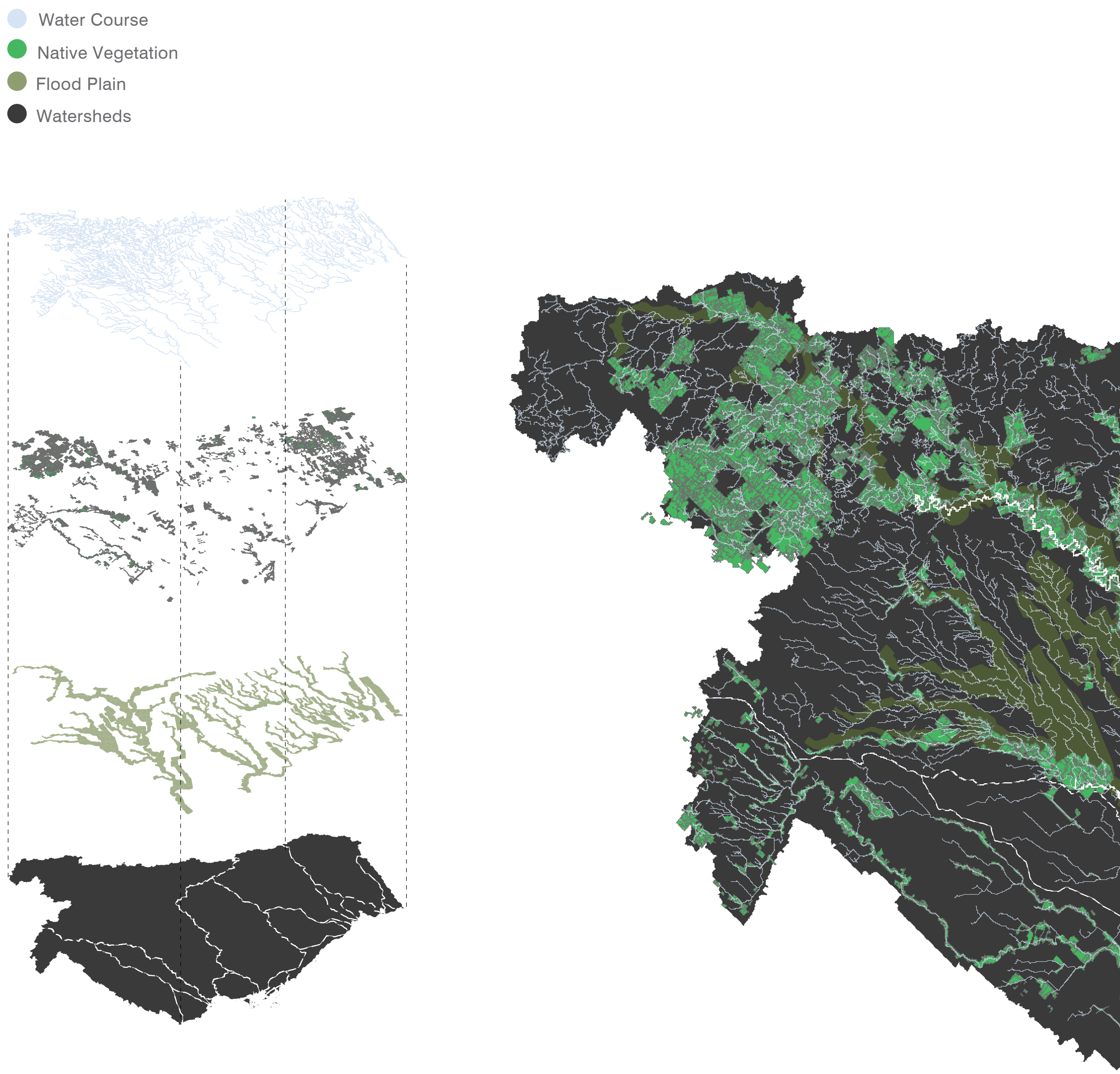
1.2 *Bottom: Map of watersheds in Toronto.*

"It's a city of ravines; remnants of wilderness have been left behind. Through these great sunken gardens you can traverse the city beneath the streets, look up to the floating neighbourhoods, houses built in the tree-tops."[4]

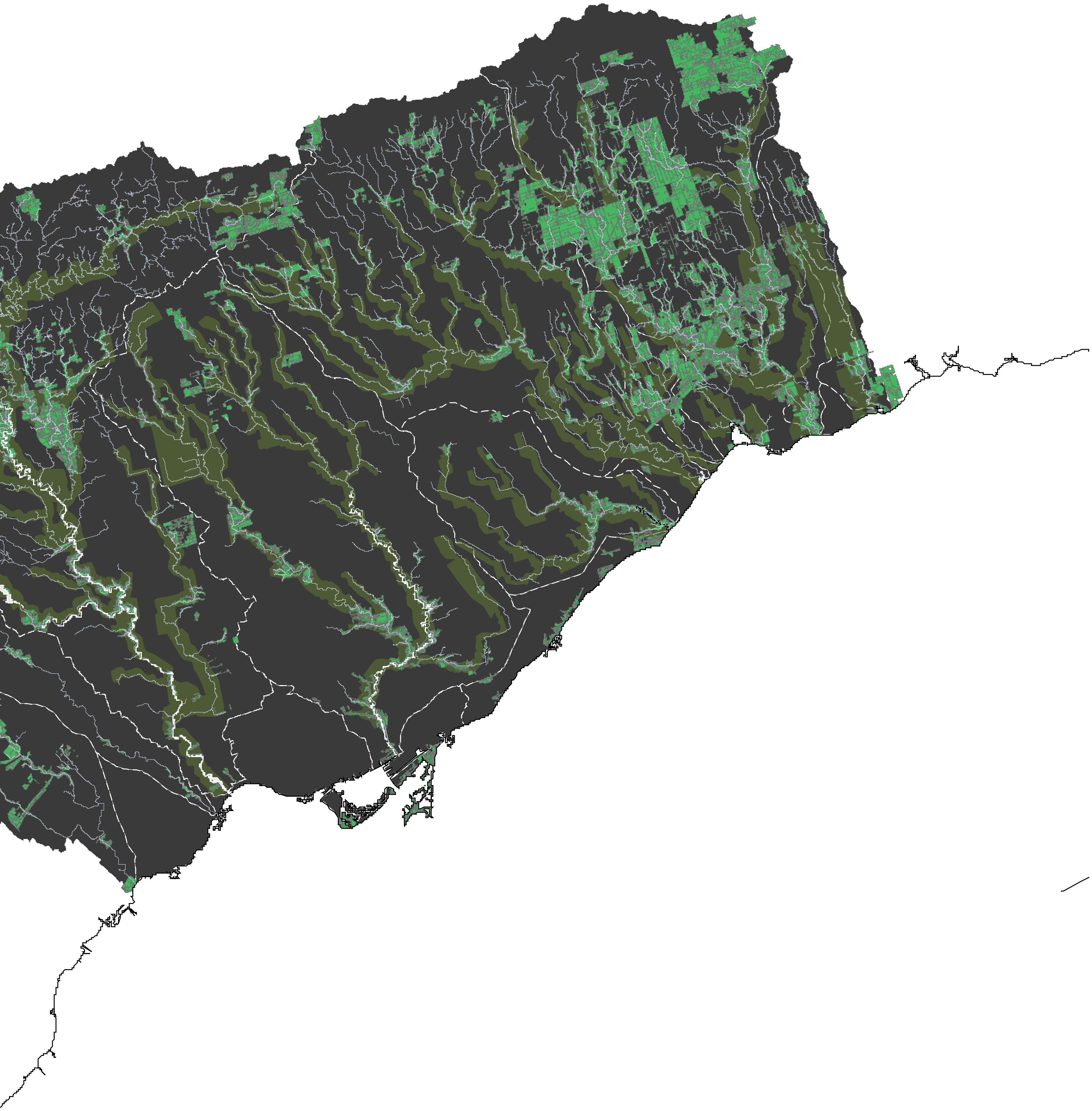
The Don River watershed drains an area of approximately 360 square kilometres. The watershed is comprised of two principal tributaries with an average stream density of 0.0031 metres per acre. The west branch, known as the West Don River, has its headwaters in the city of Vaughan, north of the village of Maple. The east branch, known as the East Don River or Little Don River, has its headwaters northeast of Maple in the northwest corner of the town of Richmond Hill.[5]

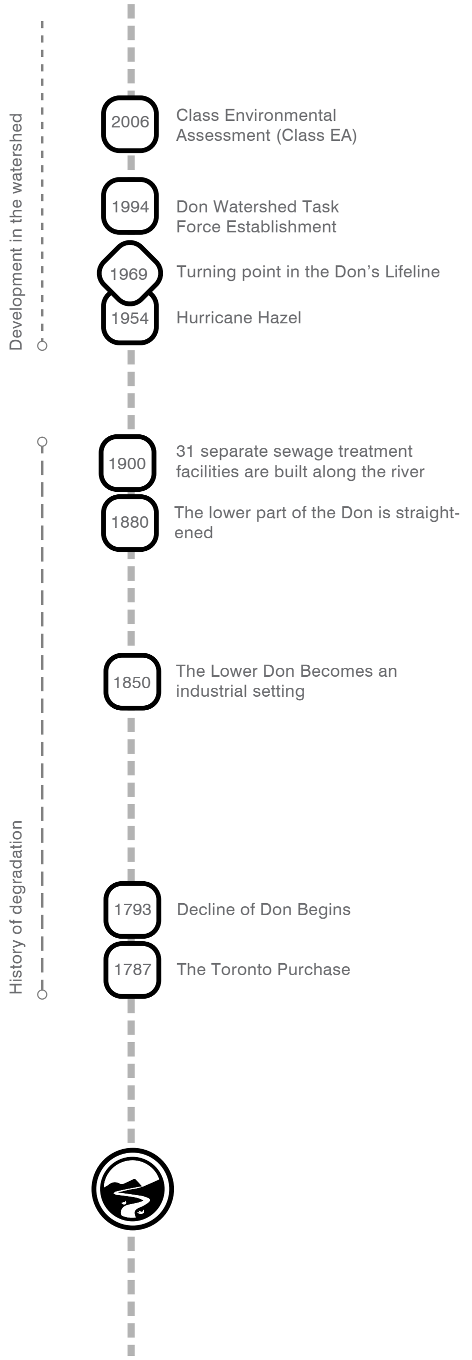


1.3 *Map of greater Toronto bio-region showing the Don River in its larger context.*



1.4 *Different layers of watersheds, watercourses, vegetation and floodplain in Toronto.*





1.5 *Timeline of the Don Watershed degradation and development.*

2.1.2 History of Degradation

The Don River is a seemingly natural space within an otherwise dense and noisy concrete jungle. What we see when we walk within this valley is the decades of soil and water contamination from industry and landfill, and the ongoing pollution from combined sewer overflows, highway runoff, and lawn care chemicals.[6] Looking at the satellite image of Toronto (Figure 1.7), it is difficult to tell where the Don River drains into Lake Ontario because the city's shoreline has been added to and reinforced with concrete walls, and most of the river is channeled not to follow its natural course.

For 200 years, the Don watershed has been subject to intense pressures from human settlement. The Don, like any other river in an urban environment, was not destined for what it is today. Decline of the Don began in 1793 with the establishment of York. What was a "working" river was transformed by local industry into a polluted vessel by which to dispose of waste. By 1850, the Lower Don was becoming an industrial setting. In that year significant infrastructure was created to fuel the needs of industrialization from gas works to petro-chemical plants.[7]

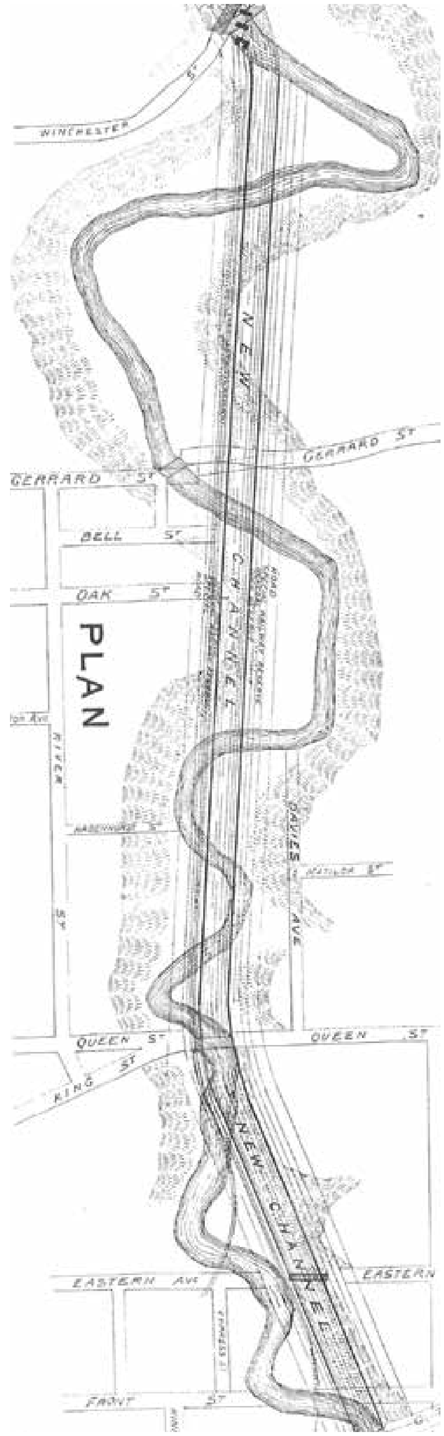
In the 1880s, the lower part of the Don south of the former Winchester St. Bridge was straightened. The Don improvement at the end of the 19th century is, to date, one of the pinnacle markings of industrialization which throttle the ecological growth of the Don watershed. The construction of a shipping channel and concrete shore-lines halted the threat of flooding and damage to local infrastructure.[8]

During the early part of the 20th century the river and the valley continued to be neglected. Thirty-one separate sewage treatment facilities were built along the river. In 1954, Hurricane Hazel struck Toronto with terrible force, and destroyed both homes and lives. Hurricane Hazel made it clear that the floodplain cannot really belong to anyone; it actually belongs to the river. Therefore, the City created the Metropolitan Toronto & Region Conservation Authority (TRCA), and future development on the floodplains was restricted, thereby preserving much of the natural space which now remains. The Don Valley and watershed are now preserved as a natural space under the jurisdiction of the TRCA for the Living City. [9]

2.1.3 Development in the Watershed

In 1969, Pollution Probe invigorated public interest in the betterment of the Don, which proved to be a turning point for the Don Valley. Task forces were created for environmental analysis, and city council appointed a committee to revive the Don Valley ecosystem. The report and the groundswell of public interest behind the Lower Don soon led to the formation of the Don Watershed Regeneration Task Force, later to become the Don Watershed Regeneration Council. Their report, "Forty Steps to a New Don" (Don Watershed Task Force, 1994) continued this call for naturalization of the Don mouth.[10]

In 2006, Toronto city council approved the start of the Don River and Central Waterfront Project – a Class Environmental Assessment (EA) study to look for solutions to improve water quality. The Class EA study is now complete. Carrying forward the recommendations laid out in the City's Wet Weather Flow Master Plan and based on extensive consultation with the public and other stakeholders, the study recommends solutions to address the problem of stormwater and combined sewer overflow discharges. New underground infrastructure will capture and treat polluted stormwater and combined sewer overflows before they enter Toronto's waterways. The improvements include upgrading the Don Sanitary Trunk Sewer system to help service future growth, and twinning of the Coxwell Sanitary Trunk Sewer to ensure the system's safe operation.[11]



1.6 *Plan for the straightening of the Don River, 1890, showing old and new routes.*

1.7 *A satellite image of the Greater Toronto Area. The Don River edge is hardly visible, especially in its lower region.*

1.8 *The urbanized channel of the Don.*

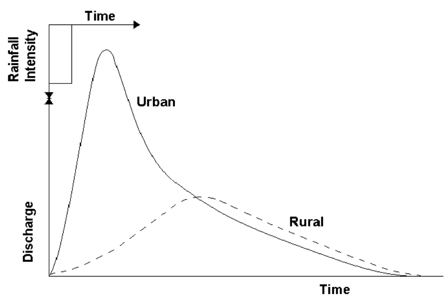
1.9 *Existing condition of the Don's edge showing the retaining flood wall.*

1.10 *Heavily forested upper reaches of the Don.*

1.11 *Birds eye view of the Don River and Don Valley Parkway.*

1.12 *Pedestrian and cyclist trail of the Don.*

1.13 *Staircase from the pedestrian bridg.*



1.14 *Top: flood hydrographs for Urbanized and Natural Drainage Basins. Ontario Ministry of environment.*

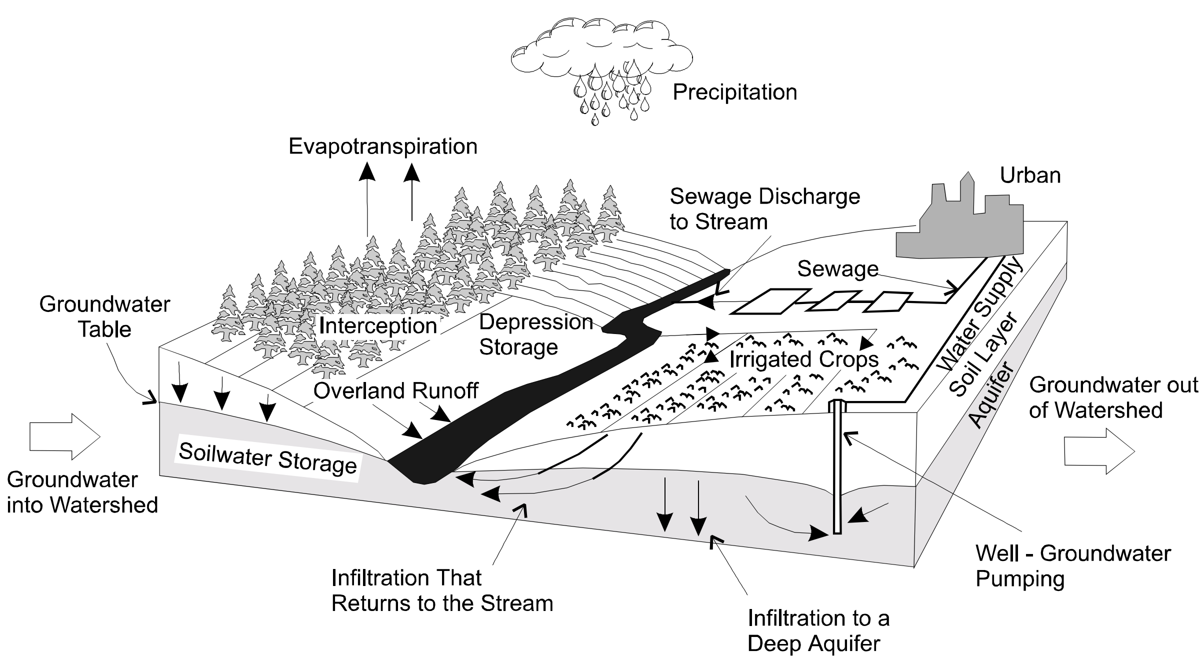
1.15 *Bottom: hydrological cycle. Ontario Ministry of environment.*

2.2 Surface water hydrology/urban water cycle

Urbanization creates a change in the landscape of a watershed. Urban land form and material changes have imposed a significant stress on the hydrologic system. Urbanization typically creates an increased area of impervious surfaces, such as paved roads, driveways, and rooftops that reduce infiltration and generate greater runoff. Many of the natural features, such as forests and wetlands, that helped regulate flows and filter contaminants during storm events have been lost as lands were converted first to agriculture and later to urban uses.[12]

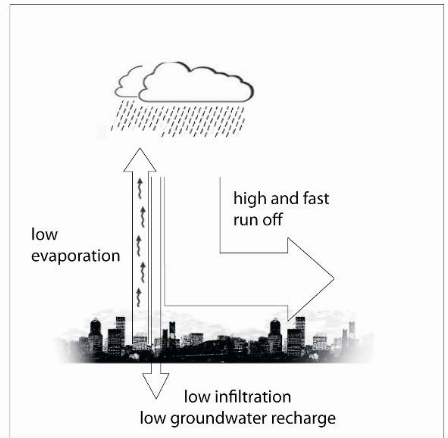
As a result of the urban impacts, seasonal variations in stream flow are less defined. Runoff response from a rainfall or snow melt event, regardless of the season, is more rapid compared to rural watercourses. The urban watercourse generally receives a greater total volume of flow in a shorter time frame, resulting in much higher flood flows. The more rapid hydrologic response rate and higher peak flows, combined with historical encroachment on the floodplain, result in a greater hazard from flooding in urban areas. [13]

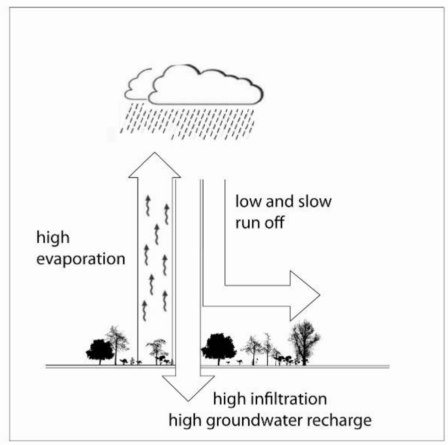
"The effect of urbanization on the water

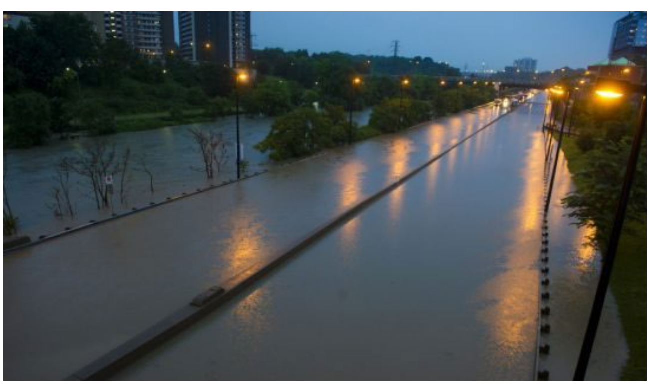


cycle becomes clear when we see that an average 72.6 centimetres of water per year leaves Toronto cities, of which 31.8 centimetres are from storm runoff. Annual stormwater volumes can exceed sewage flows in low-density urban areas. Calculations show that in an urbanized area that has 50 per cent impervious surfaces and is 50 per cent watershed, the number of stream flows that equal or exceed the capacity of its bank would, over a period of years, be increased nearly fourfold." [14]

Reduced infiltration can lower local groundwater levels, which can in turn reduce groundwater discharges to baseflow. Aquatic species dependent on natural patterns of flow are impacted by the increased amounts and frequency of runoff events as well by as decreased baseflows. Alterations in stream flow can aggravate degrading stream water quality and aquatic habitat.[15]





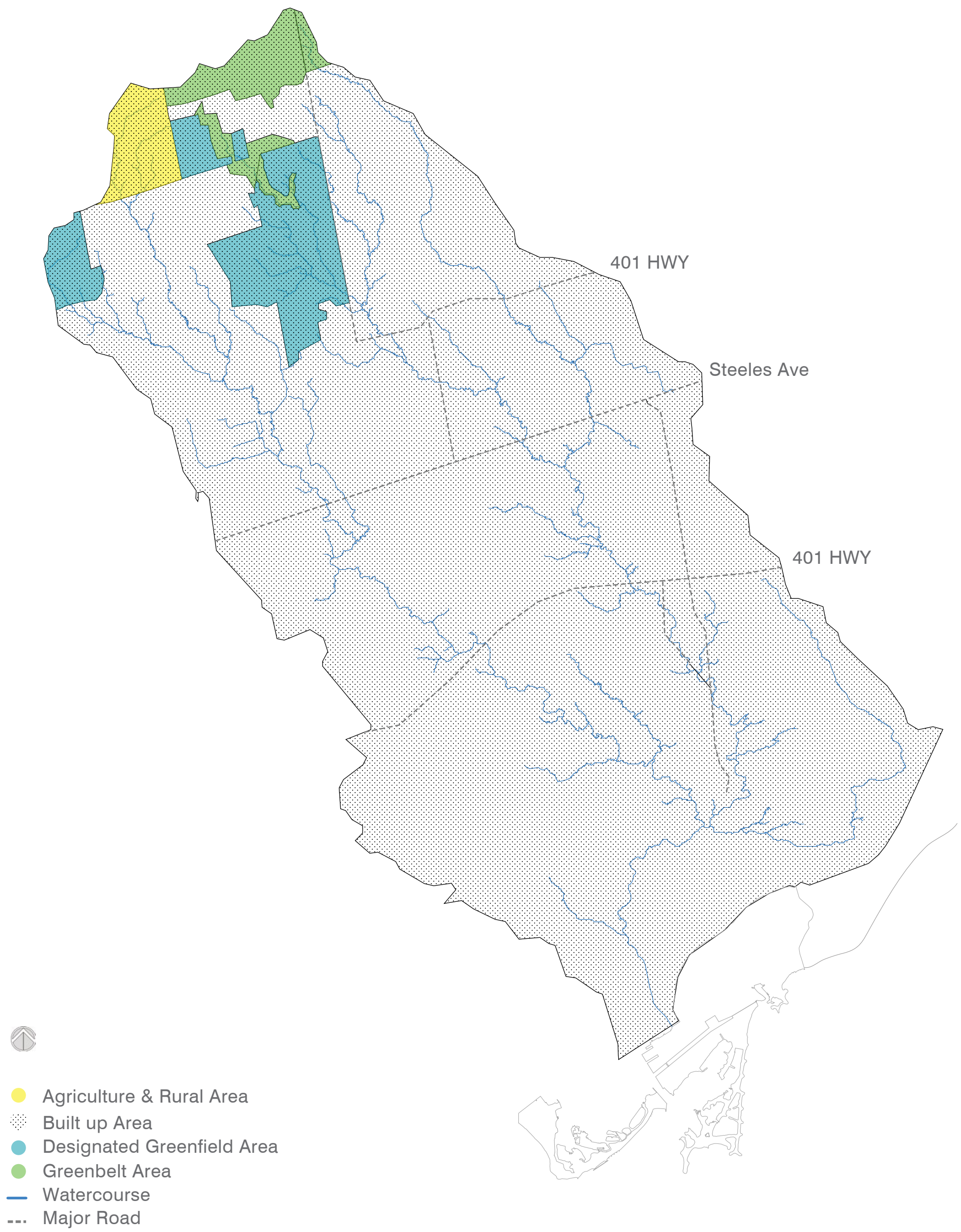


1.16 *Top right: natural water cycle.*

1.17 *Bottom right: urban water cycle.*

1.18 *Top left: Lower Don River condition when flood happens. Water Sensitive Urban Design report, 2011.*

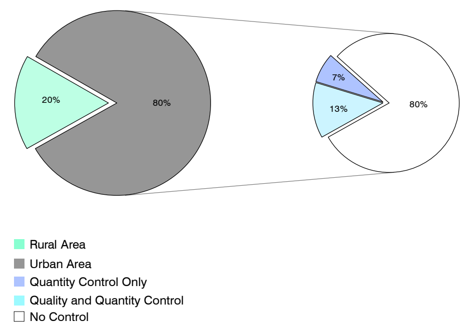
1.19 *Bottom left: Lower Don River condition when flood happens. Water Sensitive Urban Design report, 2011.*



1.20 *Natural versus urbanized areas in the Don Watershed. Courtesy of Toronto and Region Conservation Authority adapted by author.*

2.3 Stormwater management

Urban understanding of water management has evolved. Cities started with just a water supply providing the necessity of life. From that, the sophistication of the urban water system have grown and grown and now they have subsequent structural systems, sanitary systems, storm systems and then moving beyond that to waterways and water cycle focuses. So we recognize that if we want to have safe drinking water at the end of the pipes, we need to manage our source of water responsibly. In other words, we need to understand the big picture, and we can't take only one piece of the puzzle.[16]

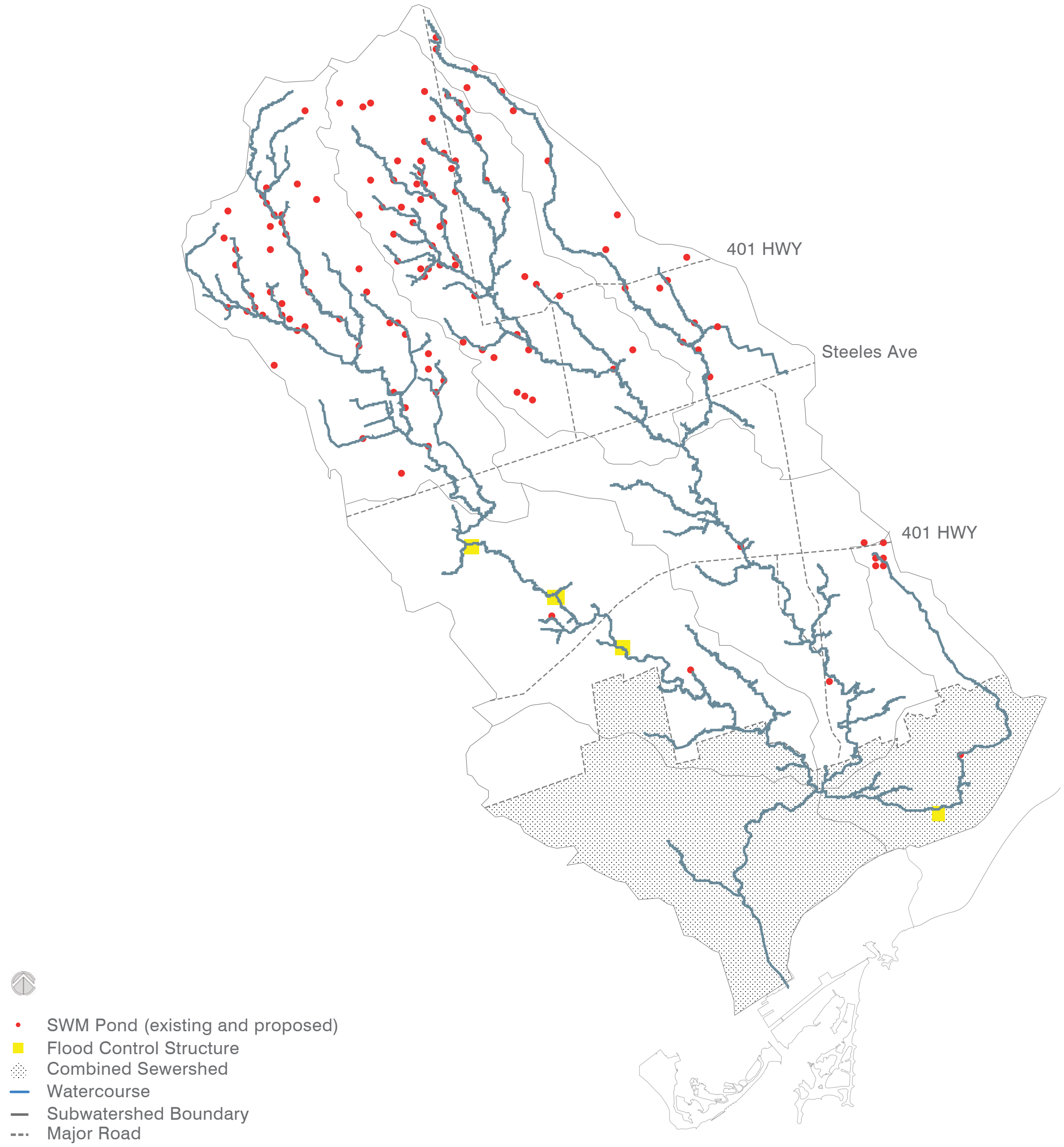


1.21 *Stormwater management controlled areas in Toronto. Courtesy of Toronto and region Conservation Authority*

Improved stormwater management practices can help to mitigate the effects of urbanization on the water cycle by reducing peak flows, infiltrating runoff and removing contaminants from urban runoff. However, within the Don watershed, stormwater practices are largely absent in approximately 80 per cent of the urban part of it [17] (figure 1.21). It was also found in the 1994 report "Forty Steps to a New Don" that as much as 70 per cent of the total flow in the Don River is comprised of stormwater, entering the system from 1,185 outfalls, and is the greatest source of pollution in the Don.[18] The 1991–1992 study's conclusions that form the Don River Watershed Plan show that stormwater management remains the single most important means of improving water quality in Toronto tributaries, as well as in the harbor and localized areas of Lake Ontario.[19]

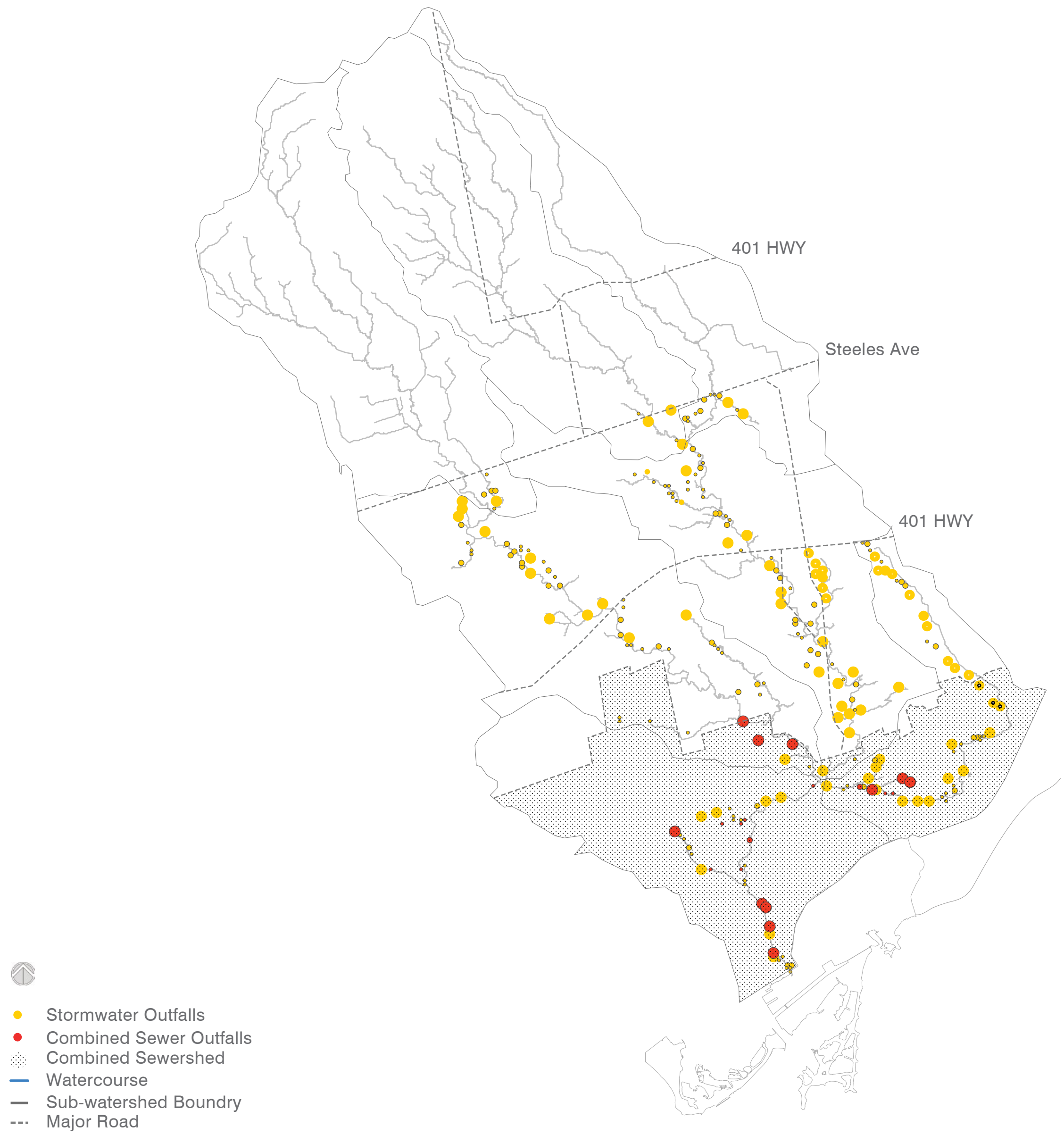
2.3.1 Today's reality

Currently, in the city of Toronto area of the Don River watershed, a little more than 6 per cent of the area has stormwater control facilities.[20] Its stormwater system is really under stress. There are 50,000 people moving to Toronto every year and that is anticipated to continue into the future, and that will continue to increase water demand. On top of that, Toronto has an infrastructure deficit. In Toronto, many areas that were built before the 1950s are serviced by combined sewer systems. During dry weather, combined sewers carry both stormwater and sanitary sewage to treatment plants. However, during wet weather, the volume of stormwater may



Don Watershed
Area: 385 Km²
2012 Population: 1,211,350
Surface Water Quality: F
Every milimetre of rainfall contributes 385,000,000 L of water to the watershed

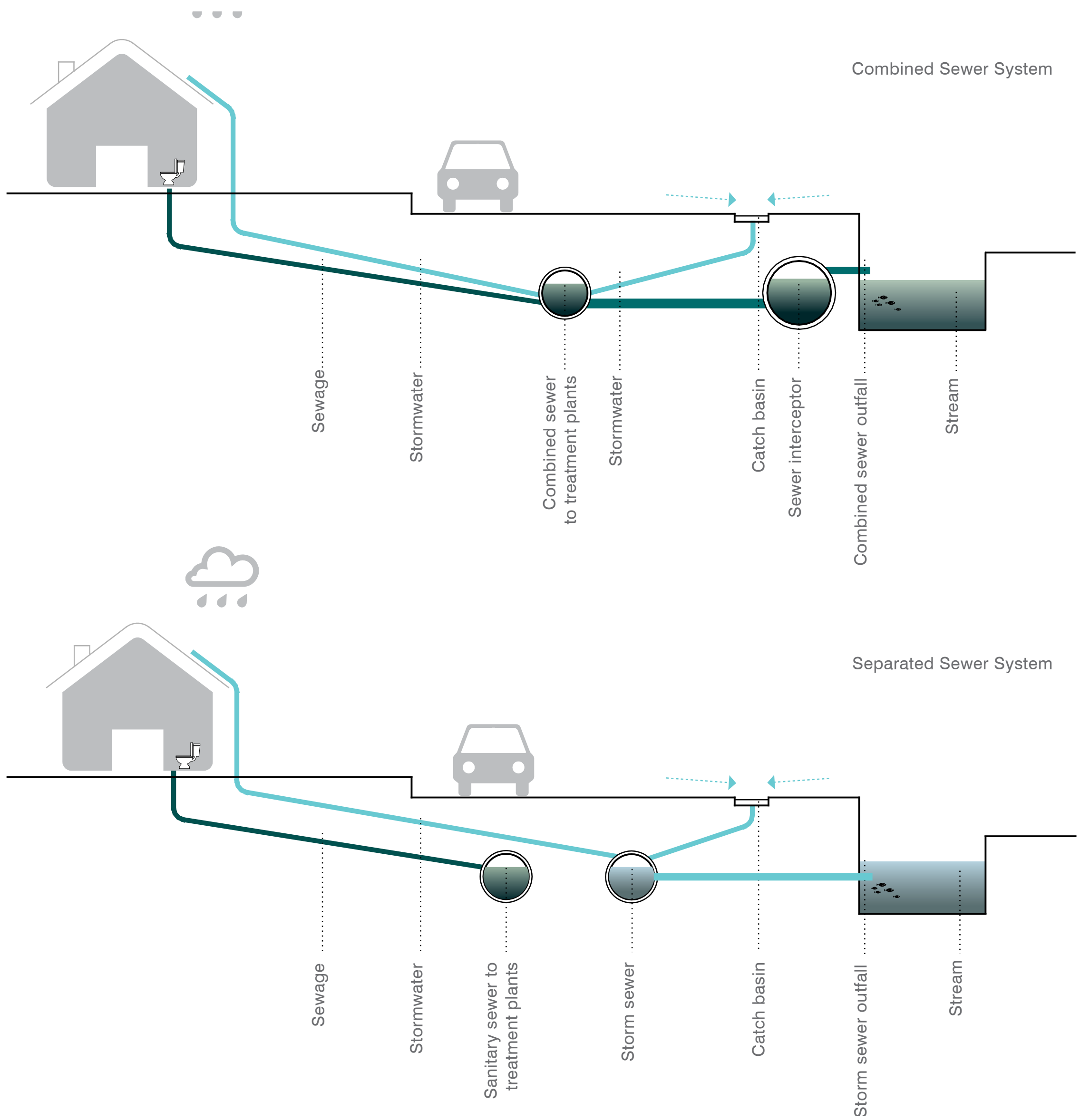
1.22 *Stormwater management in Toronto and the location of the ponds in the Don watershed. Courtesy of Toronto and Region Conservation Authority adapted by author.*



79 Combined Sewer Overflow Outfalls – 33 Directly to Lake Ontario
2,600 Storm Sewer Outfalls – 70 Directly to Lake Ontario
6 Watersheds and Waterfront
Sewer Infrastructure: 10,400 Km
Storm Sewers: 4,550 Km
Combined Sewers: 1,300 KM
Sanitary Sewers: 4,150 Km
Large Trunk: 400 Km
Watercourse: 370 Km
(WWFMInnovSWM-DANDREA-08050PDF P4)

1.23 *Stormwater management in Toronto and the location of the outfalls in the combined sewer watershed. Courtesy of Toronto and Region Conservation Authority adapted by author.*

exceed the treatment plant's capacity, releasing untreated sewage into our rivers and lake. This is called a combined sewer overflow (CSO). (refer to figure 1.24) Climate change is another issue, which in Ontario means increasing frequency of what we consider extreme events. Lastly, the expectation has increased; every day the population is demanding more of their water services for a variety of purposes. Water resources are expected to provide not only clean drinking water but also public recreational areas.[21]



1.24 *The configuration of a typical combined sewer system and a separated sewer system which are part of the existing water system of Toronto. Both diagrams show the various sources of wastewater that they collect. The combined sewer system shows how combined sewer overflows occur. However, the separated sewer system prevents the overflows by dividing the stormwater and sewage through separate pipes.*

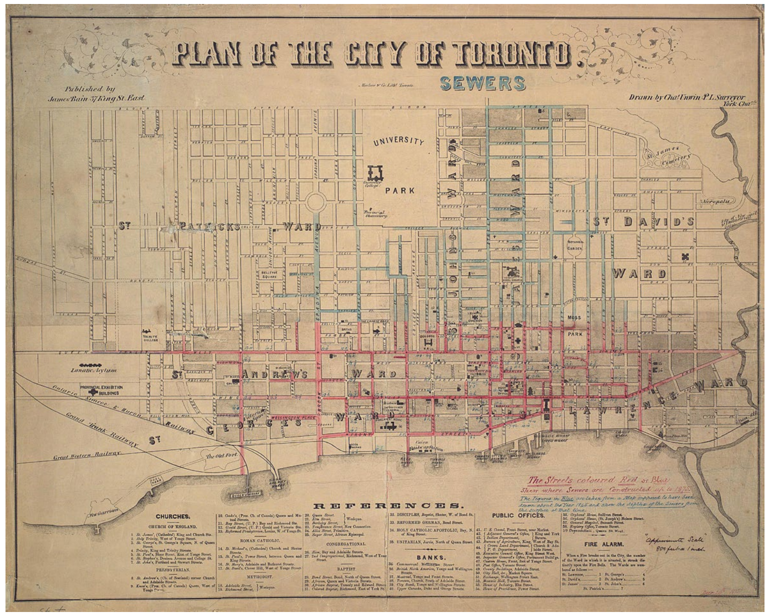
2.3.2 Evolution of Water Management in Toronto

In the beginning of the 19th century, households were still commonly using privies (holes in the ground to collect bodily waste) to dispose of human waste. The supply of drinking water was also primarily dependent on private wells. In the 1830s, due to the unsanitary disposal of organic waste, the city experienced several infectious-disease outbreaks. Consequently the city decided to build sewers to resolve the sanitation issues.[22]

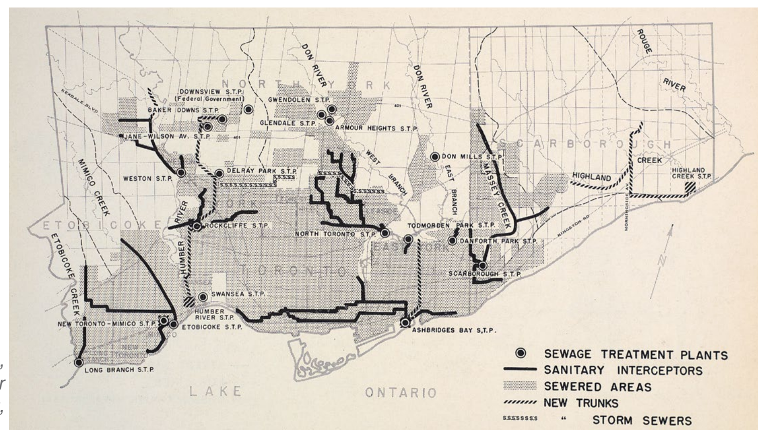
The first sewers in Toronto were built in 1835 as part of a series of strategies to combat health issues such as cholera and typhus.[23] By the late 1800s, in order to further improve sanitary conditions within the city, a sewage system idea was implemented by a group of engineers and medical professionals at the local board of health.[24] Sewers were laid in place to drain the city and carry waste away from the urban households; however, effluent from the sewers was eventually deposited into Lake Ontario with the belief that the size of the lake and its ecosystem could dilute the sewage.[25] In reality, sewage discharged into the lake not only emitted a dreadful odor along the lakeshore but also put the city's drinking water from the lake at risk. As a result, the city had to come up with another idea in order to resolve this issue.

The discussion of constructing interceptor sewers to carry all the urban waste to a filtration plant began in the 1850s, but it was only in 1910 that Toronto's first waste water treatment plant was built.[26] The interceptor sewers in Toronto function as final collection lines to transport waste water and surface runoff from all corners of the city to four centralized water treatment plants. As such, it seems that the interceptor sewers were an afterthought in Toronto's water infrastructure planning, as they were built with the capacity to handle only normal stormwater loads, and today the city still relies on combined overflow sewers to drain excess amounts of water directly into Lake Ontario during torrential rains.

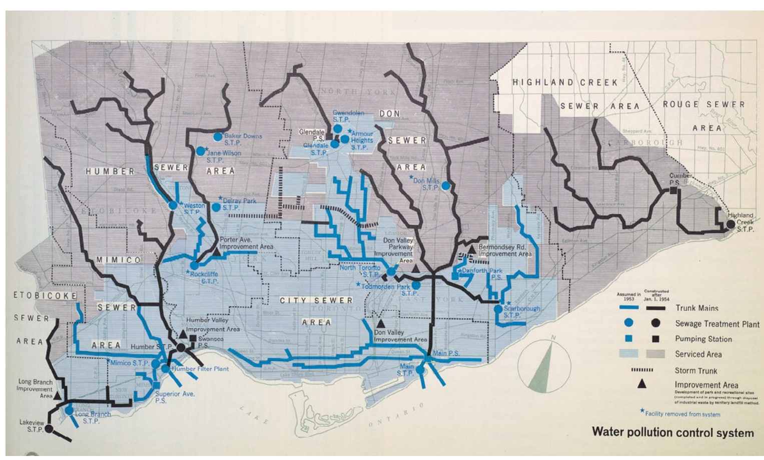
Starting in the 1980s, the City of Toronto began to realize that the combined storm and sanitary sewers used throughout the city, constructed in the late 1800s,



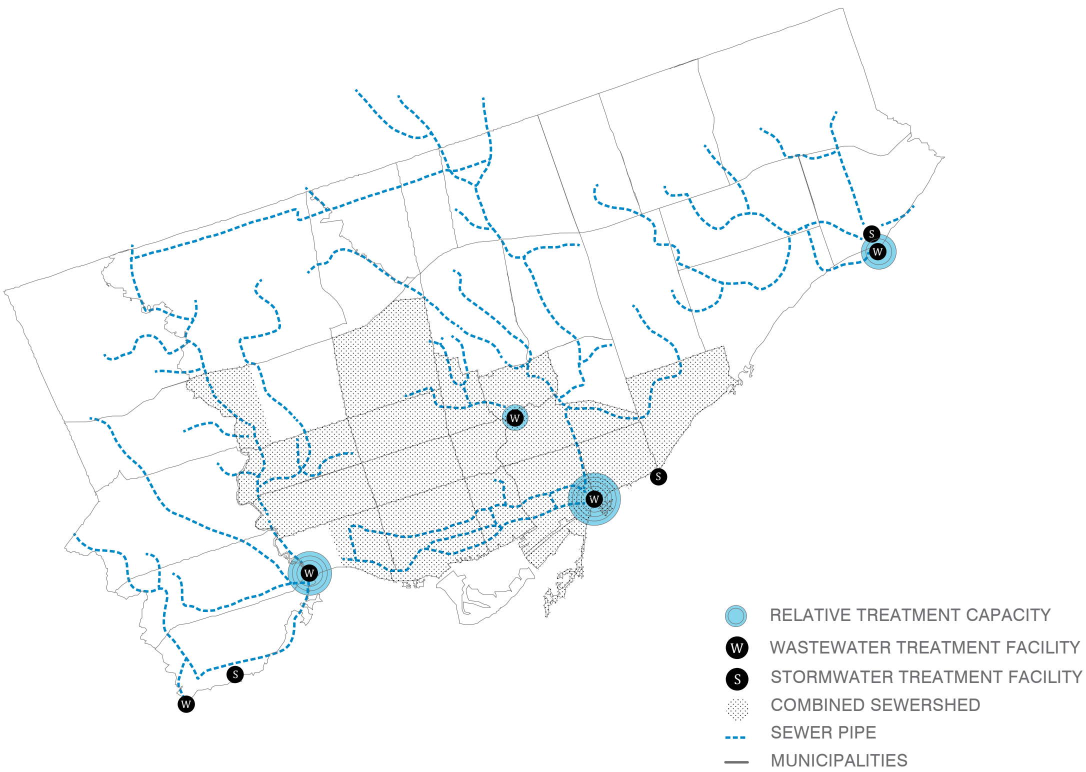
1.25 *Historic map of city of Toronto showing its sewer system. The red lines show sewers constructed up to 1875 while the blue lines are drawn about the year of 1845. City of Toronto.*



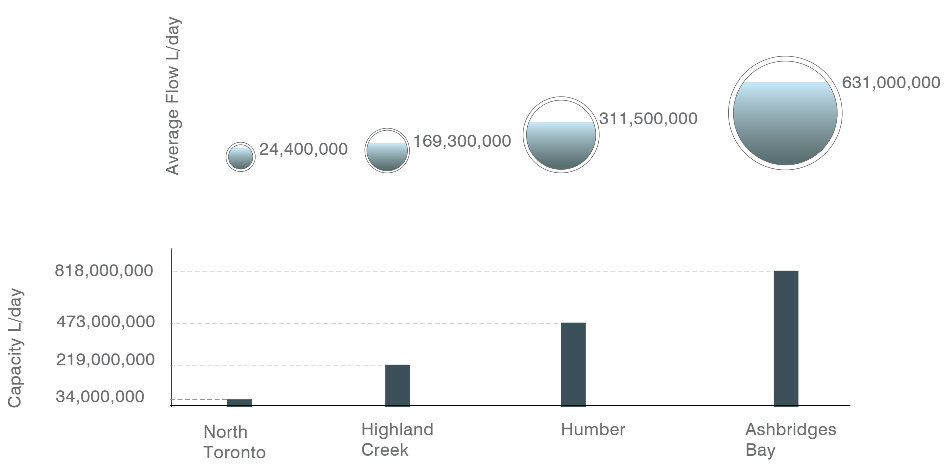
1.26 *Metropolitan Toronto Sewage System Plan, 1954, showing existing system and initial plans for expansion. Metropolitan Toronto Annual Report, 1954 (UAL).*



1.27 *Metropolitan Toronto Sewage System 1965. The Planned system is nearing completion after ten years of construction. The local treatment plants in North York remained in service until the West Don Trunk Sewer was completed in 1967. Metropolitan Toronto Annual Report, 1965 (UAL).*



1.28 *The existing system of water management in Toronto with its sewer pipes and treatment plants.*



1.29 *Water treatment facilities in Toronto and their capacities*

1.30 *Stormwater pond at Terraview Park, Toronto.*

were too small to serve the growing urban development surrounding them. During heavy rainstorms, the sewers and treatment plants were often overloaded with combined effluent, causing untreated sewage to overflow into Lake Ontario.[27]

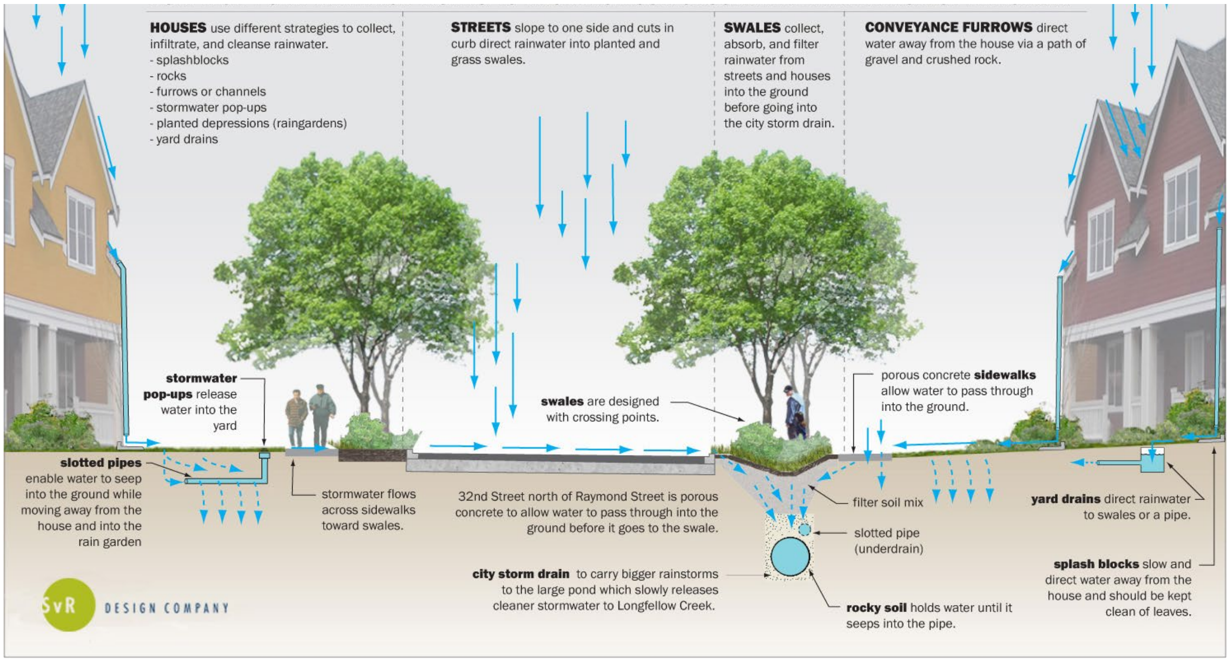
Hurricane Hazel showed that during periods of peak flow, there are significant water management problems in Toronto. Therefore, the city began urban development that includes designating areas to hold water during peak events. The default system that has been used since 1980 is a pond which allows some storage and also offers benefits in terms of water quality. Yet the problem the city is experiencing during flooding is an issue of rate. If water can be held for a specific amount of time, there won't be the issue of flooding downstream. Even in that case, if water is released later, it still contains energy which ultimately is going to lead to erosion, which is still going to cause some problems.

2.3.3 Stormwater Management in the New Millennium

The objectives of stormwater management have been broadened. There has been an emphasis on providing quality treatment as well as on managing erosion flows. New technologies and new ways of thinking started emerging in the field of water management around the 1990s.

Innovative management techniques were put in place. Porous pipes were installed in order to enhance infiltration into the ground, and swales were designated to collect, absorb and filter the water. Homeowner programs disconnected roof downspouts from sewers. Comprehensive programs combining lot level, conveyance, and end-of-pipe measures began to emerge.[28]

It has been discovered that by being dependent on one centralized infrastructure and a very efficient hydro engineered system, cities expose themselves to many risks. The infrastructure, including the stormwater management system, is only good as long as it is maintained, and municipalities may not always have the funds or systems in place to keep it operational. Therefore, over

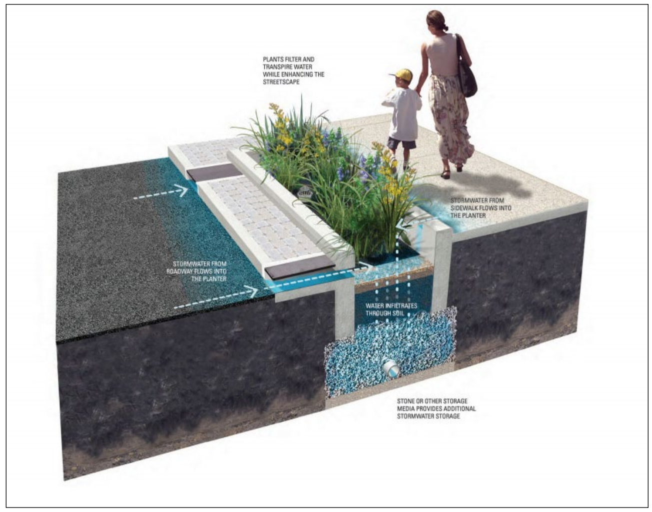


1.31 *Decentralized stormwater treatment strategies on a neighborhood scale. http://thegardeninspirations.biz/how-to-build-a-garden-drainage-system.*

the last decade, engineers, urban planners, and architects have incorporated the idea of a more decentralized stormwater management system that captures rain where it falls and uses natural hydrological cycle infiltration and evapotranspiration to reduce stormwater overflow.

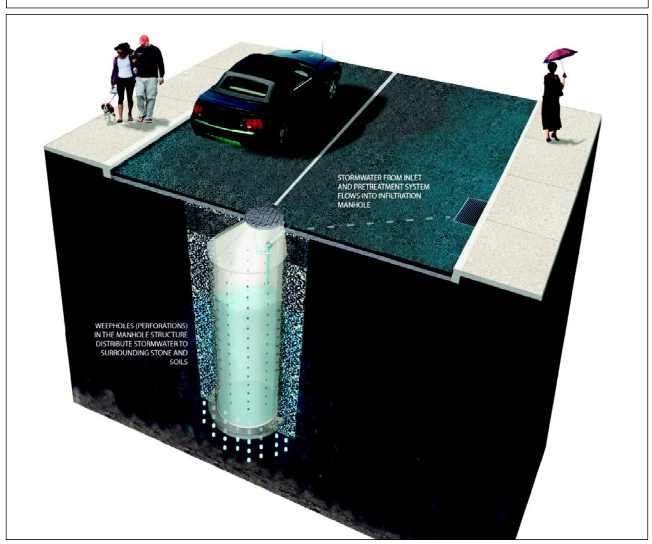
Conventional stormwater management amplifies the flash flood condition with massive, dangerous flows. Through a decentralized and much gentler transition, the total volume of the stormwater can be divided among a number of smaller treatment facilities which are more affordable, and ultimately more sustainable than the expensive, industrialized, engineered ones.

Over the last decades, many European countries and the United States have become more aware of such methods and have worked to develop system in this way.[29] These methods could be really small at local levels (figure 1.32-1.34). Sidewalk stormwater treatment system in Portland, USA is a good built example of a decentralized stormwater management system. Instead of using a conventional catchbasin, in this project the runoff water flows from the street and is collected into a wetland designed beside the sidewalk, which treats the water.



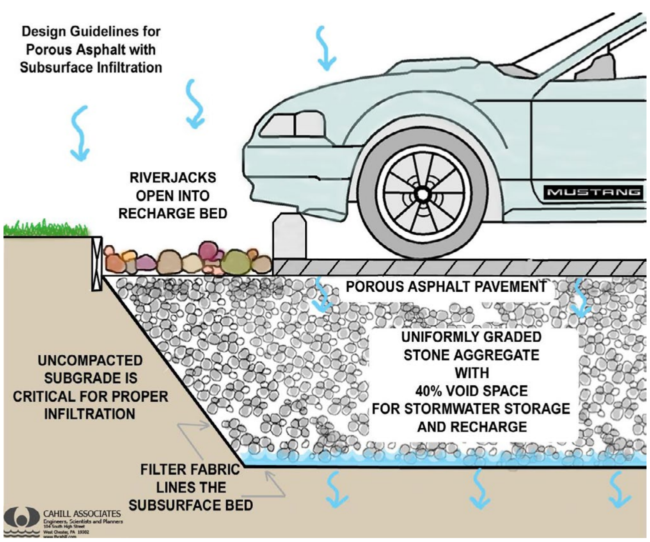
1.32 *Bioretention planters along sidewalks that collect stormwater and, using engineered soils and enhanced vegetation and filtration, remove pollution and reduce runoff.*

1.33 *A tree trench that collects and filters stormwater.*



1.34 *Drainage well with weepholes in its structure distributes the collected stormwater to surrounding stones and soil.*

Permeable paving is another method that allows rainwater to percolate through the paving and into the ground before it runs off. By using porous asphalt, previous concrete, paving stones, this approach absorbs the water into the ground, and slowly releases it later. In fact, it reduces stormwater runoff volumes and minimizes the pollutants introduced into stormwater runoff from parking areas.The methods explained in this chapter cover more small-scale techniques for decentralized stormwater management. A more comprehensive body of precedents on a neighborhood, or larger scale will be explained through the next chapter.



1.35 *Top: sidewalk stormwater treatment system in Portland, USA.*

1.36 *Bottom right: permeable paving.*

1.37 *Bottom left: permeable paving, which allows water to pass through into a gravel bed and retains it below the pavement for infiltration or evaporation.*

02
OPPORTUNITIES

INFRASTRUCTURE FOR PEOPLE: REDEFINING THE RIVER'S EDGE

"The city, in the presence of cheap energy supply, is becoming less the result of design and more the expression of technology whose goals are strictly economic rather than social and environmental. Human beings as agents of change have historically been concerned with modifying the land for survival, but are often unconscious about the effects of their activities on the original landscape. Traditional design values that have shaped the physical landscape of our cities have contributed little to their environmental health."[1]

2.1 *Top: Diagram of the subjects related to sustainable design.*

3.1 Redefining a new design language

> *"As environmental issues attract an increasing sense of urgency for the future of cities, it is becoming increasingly necessary to meet new goals in the way we shape the future landscape. There is a new attitude regarding how urban environments can be made environmentally and socially healthier; how they can become civilizing places in which to live."*[2]

The integration of urbanism and ecology achieved through design is a new paradigm that promoted sustainable and more resilient systems to underpin the next era of urban revitalization and city landscape.

Infrastructure is an inseparable part of a city. The new attitude toward the design of urban environments definitely requires a shift in the way we develop the infrastructure associated with that. Conventional infrastructures built more than a century ago are under now stress, and can no longer provide support for current concerns of cities. Water management is undoubtedly one of the main concerns of an urban infrastructure. The long-term decay of the sewage network is part of a widespread problem which North America cities are beginning to confront. As a result, a new generation of architects, landscape architects, engineers, urban planners, ecologists, and scientists have emerged, and begun to challenge 20th-century infrastructural models.

Specifically for the water infrastructure, the task today is to create a new design language that reflects the hydrological process of the city; an urban design language that re-establishes its identity with life processes.[3] This chapter intends to discuss some factors as strategies for water management in our cities, involving cultural, social, economical, political, infrastructural, and ecological concerns through design.

3.1.1 Ecological and Functional Basis for Form

In the process of urbanization, a natural landscape has usually replaced with totally designed and fabricated gardens and parks.[4] However, the new attitude regarding natural areas and landscape leans strongly toward preserving the natural processes and patterns instead of building, destroying, and rebuilding the surrounding environment. Planners are now required to understand the land as a living system and to identify an ecological infrastructure that will guide the urban environment.[5] A more fluid geographical approach to land and water, which places an emphasis on continuous mutable ecologies, is key to a more sustainable future.[6]

The Yongning Park Project, located in Taizhou City in China, assumes an alternative approach to conventional urban water management and flood control engineering through its use of floating gardens. The proposal takes an ecological approach to flood control and stormwater management, and has been remarkably successful in addressing the flood problems and revealing the natural landscape, making people in the park able to view the flooding as a positive thing.[7]

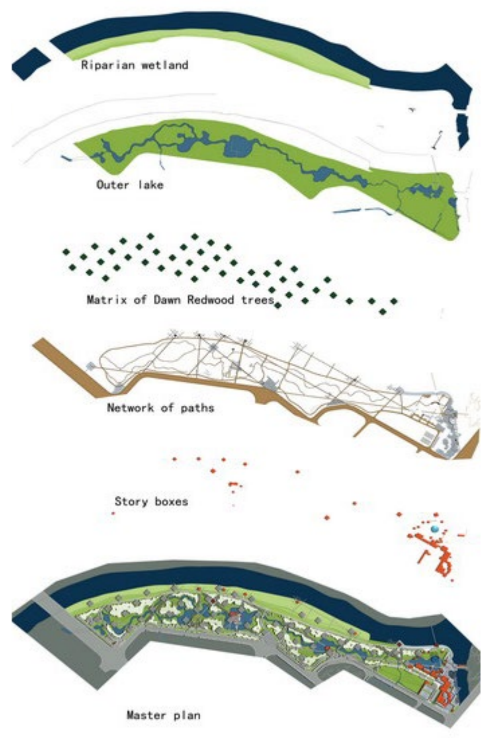
As an alternative approach to conventional urban water management and flood control engineering that uses concrete and pipes, this project demonstrates how we can live with natural water. It takes an ecological approach to flood control and stormwater management, revealing the beauty of native vegetation and the ordinary landscape. The results have been remarkably successful: flood problems were successfully addressed, and native grass has been appreciated by local people as well as tourists.[8] My proposal uses the same methodology as Yongning Park Project in a way that it proposes an ecological approach for stormwater management as an alternative to the commonly used concrete embankment and channelization.

3.1.2 Multifunctional

The preservation and restoration of natural environment inevitably depends on citizens involvement in urban ecologies. It has been perceived that the inclusion of natural landscape improves the livability of cities, like what has been experienced in the Royal Parks in London, and the Boston Common.[9] On the other hand, economy should be perceived as an integrated part

2.2 *Top: The Yongning Park: the Yongning Park Project: the objective is to design a functioning park, which unlike a natural bird sanctuary which can flood and serve wildlife, must also be accessible and serve tourists and locals.*

2.3 *Bottom: The Yongning Park Project and layers of its landscape elements: it is composed of two layers: the natural matrix which is composed of wetland and natural vegetation designed for the natural processes of flooding and native habitats, and human matrix which is composed of a designed tree matrix, a path network, and a matrix of story boxes.*

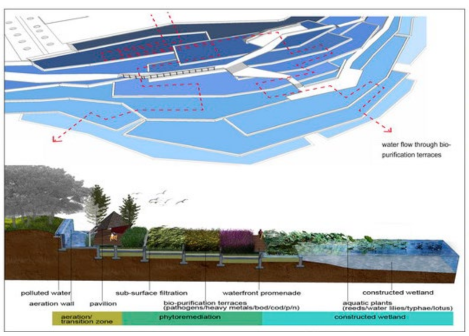


2.4 *Boston Park, Boston, USA*

of design in urban environments. Infrastructure is an untapped resource that could be productive as well as service-oriented.[10]

In designing stormwater management facilities, we should consider the great potential of parks, recreational areas, and open spaces as places in which to integrate these amenities within the landscape. These areas provide opportunities to construct infiltration or filtration facilities, water feature amenities, picnic areas, playgrounds, trails, and walkways. In addition, when the flood happens, reacreational areas will avoid most damage. In fact, little can be built in the flood plain, and from a landscape design perspective, these types of areas will provide more interesting potential than a park without a natural water feature.[11]

Houtan Park is a good example of a multifunctional,

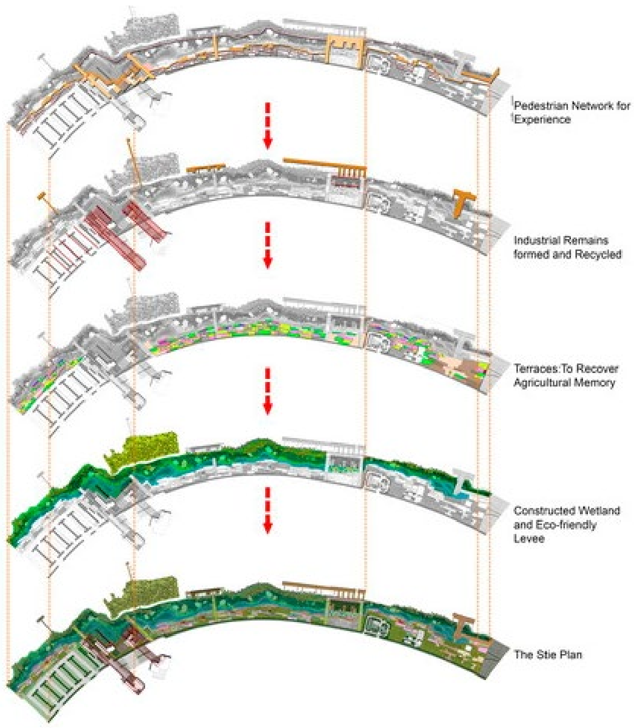


2.5 *The plants used in terraced wetlands absorb elements from the nutrient-rich river water.*

2.6, 2.7 *Constructed wetlands at Houtan Park: A regenerative living landscape on the riverfront that integrates water management with recreational facilities.*

integrated water infrastructure built on a brownfield of a former industrial site. The Park is a regenerative living landscape on Shanghai's Huangpu riverfront. Its constructed wetland, ecological flood control, reclaimed industrial structures and materials, and urban agriculture are integral components of an overall restorative design strategy to treat polluted river water and recover the degraded waterfront in an aesthetically pleasing way.[12]

The site is a narrow, linear 14 hectare band located along the Huangpu River waterfront in Shanghai, China. This brownfield, previously owned by a steel factory and a shipyard, had few industrial structures remaining and



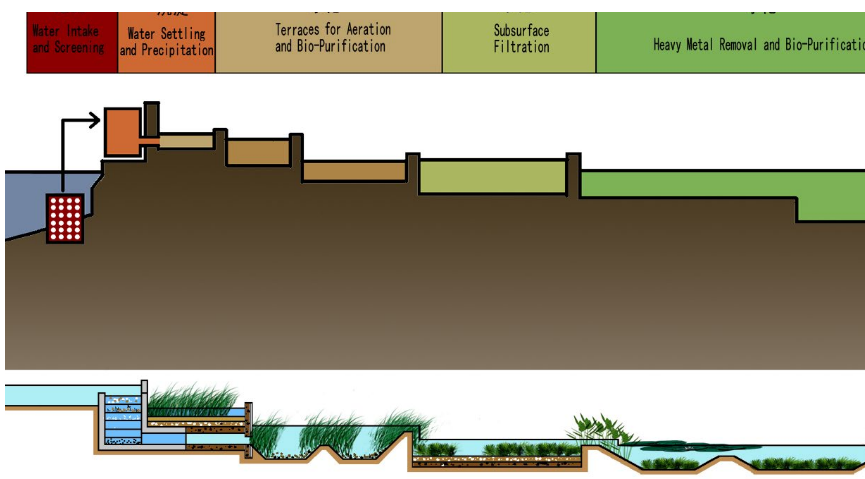
2.8 *Top: Layered approach was used to organize the space, to integrate multiple functions and ecosystem services of the park.*

2.9 *Bottom: Bird's-eye view of the Houtan Park project.*

the site was largely used as a landfill and lay-down yard for industrial materials.

The objective of the park design was to create a green Expo, accommodate a large influx of visitors during the exposition from May to October, demonstrate green technologies, transform a unique space in order to make the Expo an unforgettable event, and transition into a permanent public waterfront park after the Expo. The 2.1 meter daily tidal fluctuation creates a muddy and littered shoreline and was inaccessible to the public. A conventional retaining wall continued to limit accessibility and preclude habitat creation along the water's edge, so an alternative flood control design proposal was necessary.[13]

Although this project is different from my design proposal in terms of the size of the project, the idea of building a decentralized infrastructure and creating a regenerative living landscape using different types of constructed landforms to treat the water gradually in the site is common to both. Using different cells of bioremediation and designing habitable marshland and swampland for public activities at the edge of the water make this project a good precedent for this thesis.

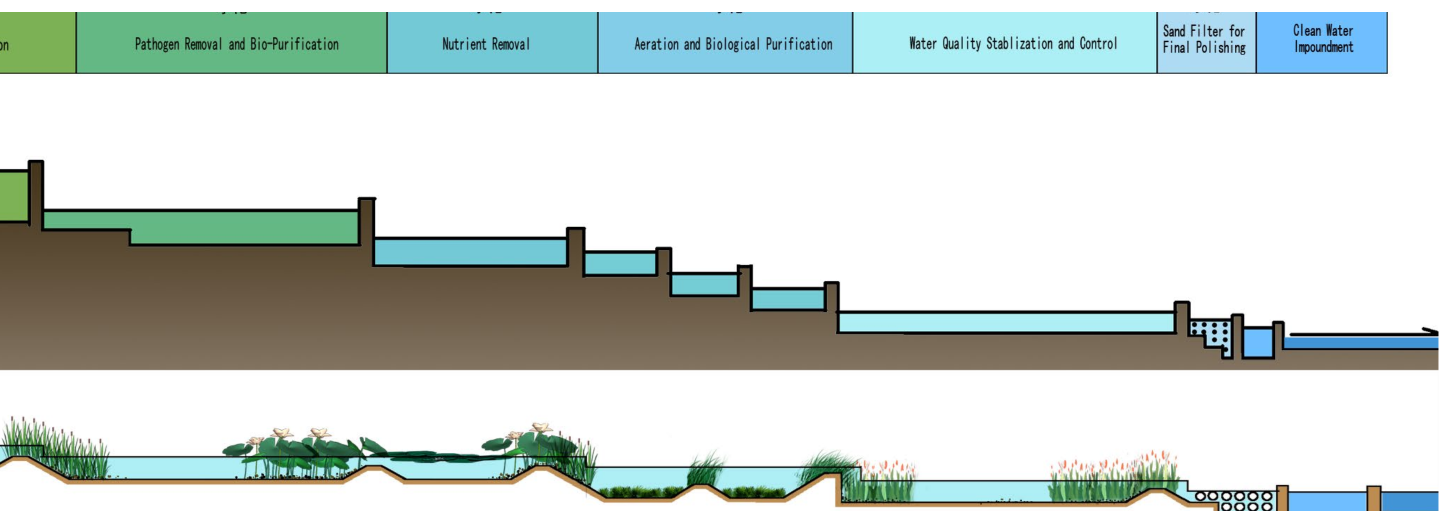


2.10 *The Houtan Park's constructed wetland functions as water cleaning facility. Reclaimed industrial structures and material, and urban agriculture are integral components of an overall sustainable design strategy.*

2.11 *Water treatment pools in Houtan Park.*

2.12 *Water treatment pools in Houtan Park.*

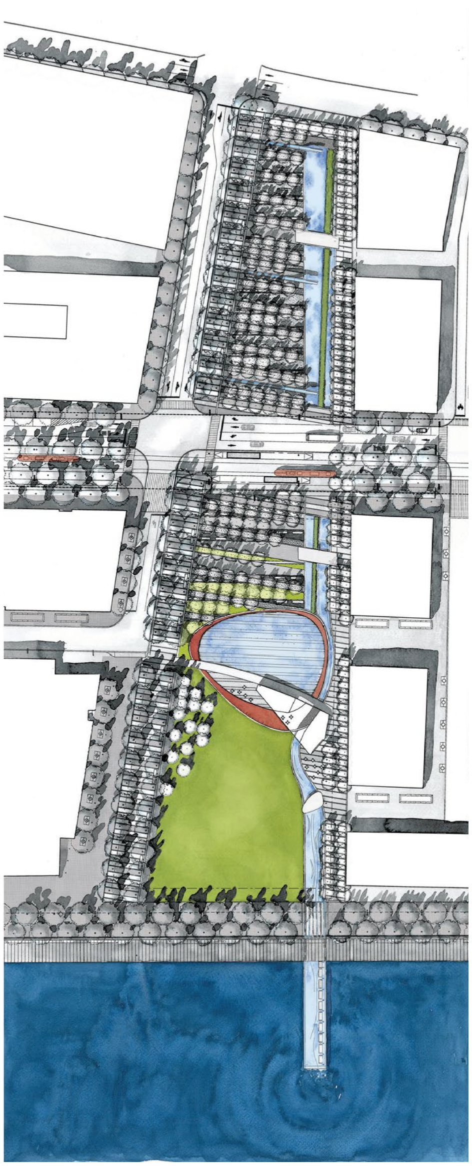
2.13 *The stormwater management system for Houtan Park, illustrating different sets of wetlands for water purification and how they work together to treat the water during its journey through the park.*



2.14 *Left: the stormwater management system for Sherbourne Park, illustrating the movement of water through the site.*

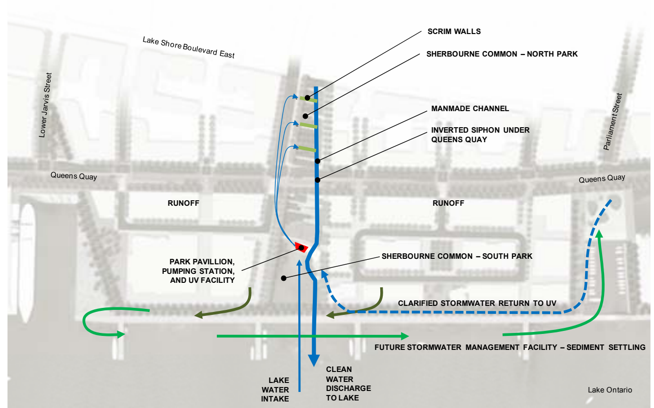
2.15 *Top right: aerial view of Sherbourne Park.*

2.16 *Bottom right: proposed stormwater management for Sherbourne, illustrating how the water is collected from the neighborhood into the site.*



Sherbourne Commons, as part of the Waterfront Revitalization Process initiated by the City of Toronto, demonstrates an innovative approach to park design in an urban context. It is the first public park in Canada to interweave stormwater infrastructure with landscape, architecture, engineering, and public art. The park provides interactive and engaging spaces for public use while treating the runoff water.[14]

The stormwater runoff is gradually purified through the park and ultimately discharged into Lake Ontario. The stormwater management is a composition of a UV purification facility, which is located in the basement of the pavilion, and a bio-filtration mechanism using aquatic grasses. Once UV treated, the water cascades down a tall art sculpture and then passes through a channel with different types of aquatic grasses for extra filtration.



Although the process of water filtration is mainly through a hidden UV purification facility, this project beautifully integrates the process of collecting the water, cleansing it through some biological treatment basins,

2.17 *Top: Sherbourne Park, showing the water treatment process, which uses a bio-filtration strategy along the way.*

2.18 *Middle: the water treatment process in Sherbourne Park integrated with recreational facilities and artwork.*

2.19 *Bottom: the stormwater management is interwoven with landscape, architecture, engineering, and public art at Sherbourne Park.*

2.20 *UV facility of the project located underground to filter the water.*

and reusing it for public activities. This project binds all these parts together from north to south, and therefore provides interactive and engaging spaces for public use.

2.21 *Top: integrating the process of water remediation with public works.*

2.22 *Middle: treated water to be used as a water feature and kid's splash park.*

2.23 *Bottom: social activities integrated to the landscape.*

A A new proposal for Toronto's waterfront stormwater management doubles as an interceptor sewer for combined sewer overflow. This idea can also be employed in open landscapes as planted bike lanes; or running paths could double as stormwater distribution networks.[15]

2.24 *A new proposal for Toronto's waterfront stormwater management.*

3.1.4 Making the Process Visible

The conventional infrastructure that has supported cities for the last decades is mostly buried underground, hidden behind screens or constructed at the periphery of the inhabited urban realm. Keeping the urban infrastructure invisible and hidden from citizens' eye significantly increases the cost of renovating or repairing it. In addition, visibility is essential in economic and political terms.[16] Policies should capitalize on the visibility of the environmental consequences of human actions in the process of daily living. Therefore, the next generation of infrastructure must be made visible to citizens and taxpayers so that they will be aware of how these systems are operating to serve them.

> *"Designers have most often been charged with hiding, screening and cosmetically mitigating infrastructure.... They are rarely asked to consider infrastructure as an opportunity, as a fundamental component of urban and regional form."*[17]

2.25 *Top: waste water management in Sweden that uses visible algae ponds to treat water.*

2.26 *Bottom: catch basins with a fish design are a visible reminder of the water treatment process.*

The notion of visibility in a city's infrastructure and specifically in water management has already been implemented in some European and American cities in a way that facilitates a greater public understanding of the systems at work. In Jarne, Sweden, the engineering functionalism of a sewage treatment plant is brought into harmony with form.[18] The sewage water cascades down some flow-form sculptures serving as basins. In Canada fish shapes are built on city catch basins to remind people of where the water goes. Furthermore, cut-outs of birds and animals are currently placed on the chain-link fences on the Don River which separate pedestrians and cyclists from the valley's railway corridor.[19] In addition, with the emergence of new landscape-based water treatment (LID) systems in both the united states and

2.27 *Top: bird's eye view of Naturbad Park.*

2.28 *Middle: view to the natural swimming pool and the social activities around it.*

2.29 *Bottom: diagrammatic plan showing the cycle of water, where green arrows indicate the flow of the contaminated water from the pool and street runoff and blue arrows show the flow of the treated water that runs from the natural filtration system on the slope of the hill.*

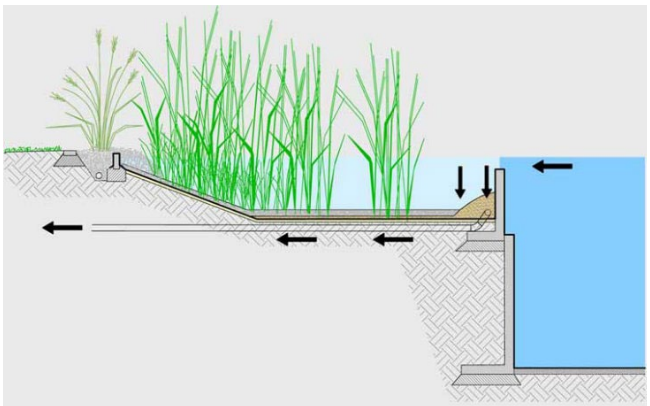
Canada, the idea of making the process visible – both in storage and treatment phases – can be easily achieved.

Naturbad Riehen, located in Riehen, Switzerland, includes a lap pool, a diving area, a recreational swimming area, and a kids' pool. The surrounding park-like area provides places for families to play and have picnics. The scheme substitutes a more natural pond using biological filtration processes for the conventional swimming pool, treated using mechanical and chemical water systems.[20]

This innovative swimming pool has an irregular, green boundary, and offers various ways for guests to enter the water. These include a gently sloping gravel beach, staircases, and wood docks that allow for a jump into the small lake.

Functionally, the pool utilizes a series of filters to process and clean the water. First, particles, grease, and hair are strained out. Then the water goes across the street, outside the facility boundary, to the regeneration area, where the water basins are embedded in a sloping landscape. In this area plants like water lilies and irises work with aquatic sediment to filter and absorb bacteria and other compounds. With respect to the system's ecological cleaning capacity, the baths are able to accommodate 2,000 guests per day.[21]

This process of collecting the stormwater, naturally treating it instead of using chemical processes, and filling a recreational pool with it, is similar to that proposed in my design. Given the fact that Toronto and Riehen are similar in temperature, these systems could work in extreme climates like that of Canada,

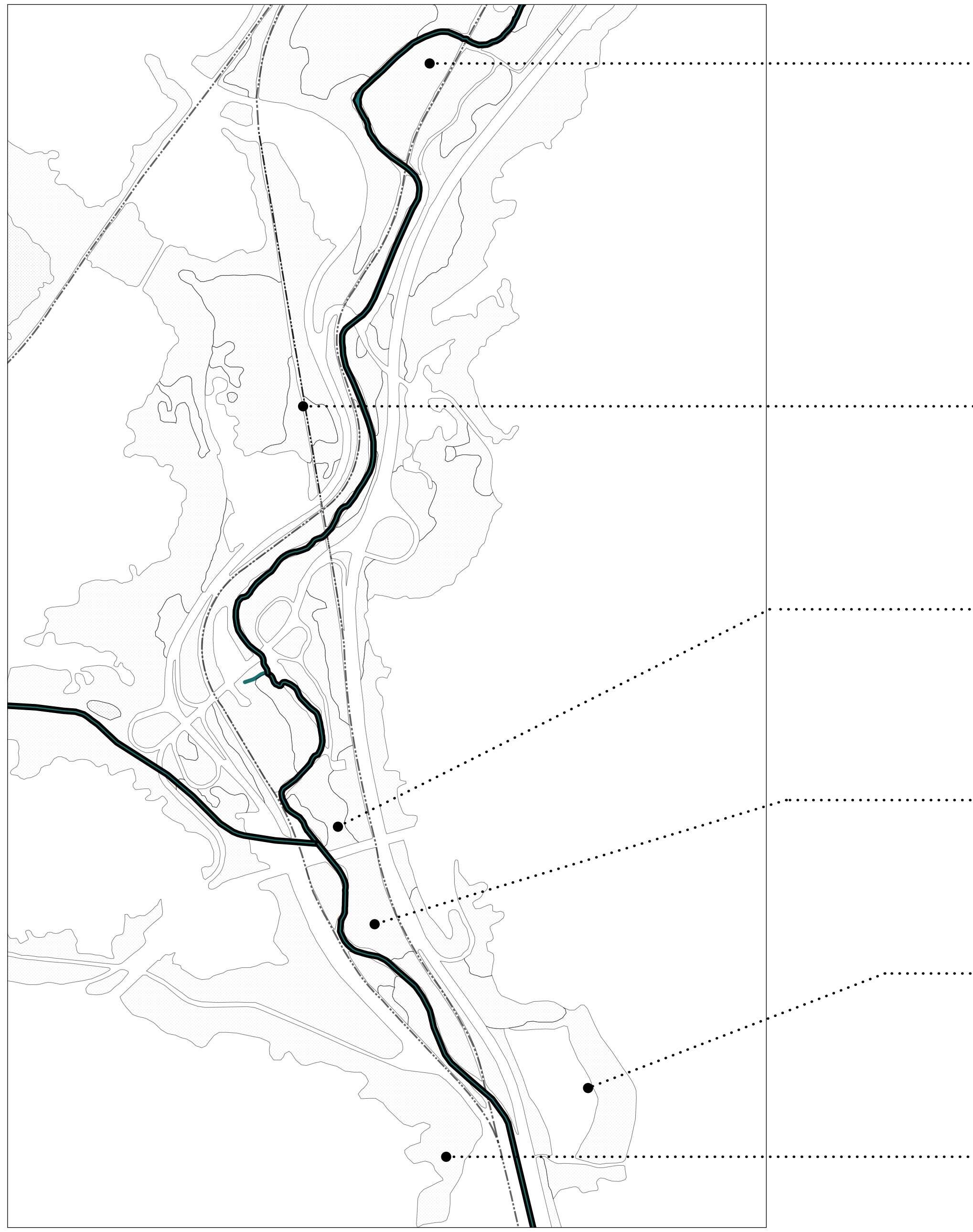


2.30 *Top: a diagrammatic section from the edge of the swimming pool showing different plants treating the water.*

2.31 *Middle: a terraced edge of the swimming pool.*

2.32 *Bottom: plants used to the treat the water at the edge of the swimming pool.*

3.2 Rebirth of the valley



2.33 *Restoration works and demonstration wetlands on Don River and its Ravines since the establishment of "task force to bring back the Don" based on Michael Hough' proposal for restoration of the Lower Don.*[22]

The Don River and its valley have been degraded over the last decades of their life. However, much restoration work was implemented in the Don Valley in the final decade of the 20th century. Demonstration wetlands were created in the river floodplain and smaller ones in

Beechwood Wetland: One of the newest wetlands, this place is just north of Pottery Road. An old swale was cleared of weeds, expanded and restored with native trees and shrubs. The swale retains water year-round but does shrink in size by late summer. The portion depicted in the picture was mostly dry by August last summer.

Don Valley Brick Works: The Brick Works ponds (there are two more in addition to the one pictured) are an outstanding example of a quarry restoration. The former quarry pit was 40m deep in this location. It was all filled in and the ponds were added on top. Today, diverted water from nearby Mud Creek provides a constant flow of water for the ponds and provides a wide array of habitat for a host of wetland plants and creatures.

Helliwell's Hill: This site just north of the viaduct captures runoff from the DVP. Three small embayments were excavated and they are all full in the spring. However the one pictured usually dries up by mid-June. There may be a small spring that still trickles water into the site because one of the embayments always has a little bit of water in it. However it is totally surrounded by Cattails so it is hard to see. The surrounding trees and bushes have done well - some of them are in excess of 10m high.

Chester Springs Marsh: Chester Springs Marsh was the first major wetland restoration project of the Task Force to Bring Back the Don in 1996. Entirely dependent on the river for its water, it does dry up during the summer unless there is a big flood. The initial excavation inadvertently exposed an old landfill site beneath which revealed flotsam from a previous generation. The prospect of finding bits of old pottery has attracted people who dig holres here and there looking for items for sale in flea markets. These holes have altered the drainage of the marsh so that water no longer stays around as long as it did when the marsh was first created.

Riverdale Park East:This marsh was created about five years ago to capture runoff from the hill and adjacent sports field. It functions fairly well but tends to dry up by mid-July. The city was forced to fence it off because off-leash dogs kept mucking up the marsh and making a mess of the planted bushes and flowers.

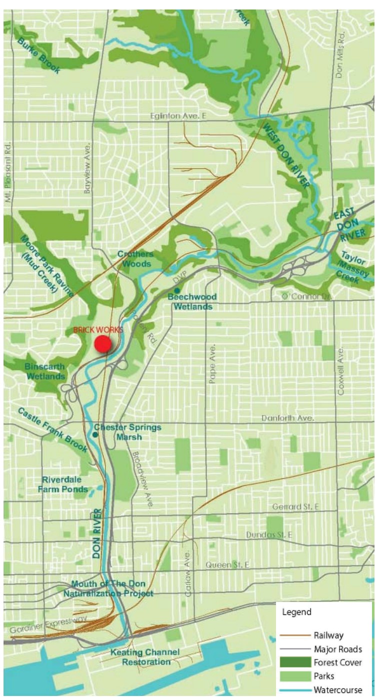
Riverdale Farm Ponds: The granddaddy of the lower Don wetlands, this has been around since the Riverdale Zoo was created in the 19th century. The pond shown here used to have a water fed fountain in the middle of the pond. Ducks and geese swam here fed on a steady diet of bread crumbs fed by zoo visitors. The fountain and the zoo are long since gone but the pond remains. With no steady water input the pond becomes very stagnant in the summer and poor oxygen conditions mean that not much can survive in it. Last year an aerator was installed to pump air into the water. Ongoing studies are monitoring the pond to see if this is improving the pond's living conditions.

2.34 *Top: Brick Works, Children's Playground.*

2.35 *Bottom: Brick Works, Community Garden.*

the ravines (figure 2.33). In the mid-1990s the regional conservation authority (TRCA) started a project to restore the Don Valley Brick Works, and design it as an important link in a chain of natural, cultural, industrial, and historic places and events taking place in the Don River Watershed. Evergreen Brick Works has been built on the former site of a brickyard, and is now contributing to the health of the city by addressing environmental and social issues along the valley. It is a public place for passive recreation and environmental learning, including a farmer market, a plant nursery, and a playground, which engages the industrial heritage with social life.[23]

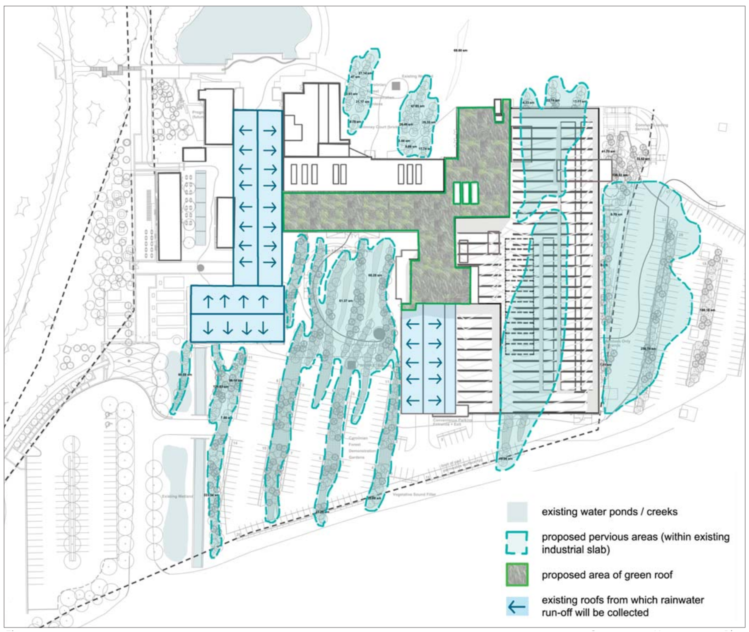
The former quarry site associated with the brickworks has been transformed to become a scenic park where wetlands and water detention ponds provide a resilient ecology. The wetland gardens were created to provide habitat for different insects, fish, and birds, and to



2.36 *Brick Works, Natural Context.*

2.37 *Bird's Eye View of Brick Works Project.*

restore water quality to a diverted stream that flows into the Don River, thus contributing to the renewal of the Don River. Evergreen Brick Works is a good example of an area's heritage as a continual, dynamic process of renewal, as something that once contributed to the degradation of the valley, but has now become part of its restoration.



2.38 *Top: plan showing the project's stormwater Management.*

2.39 *Middle: wetlands and water ponds designed for Brick Works Project.*

2.40 *Bottom: a water pond integrated with a walkway designed for Brick Works Project.*

2.41 *The site condition before the construction of Earl Bales Pond.*

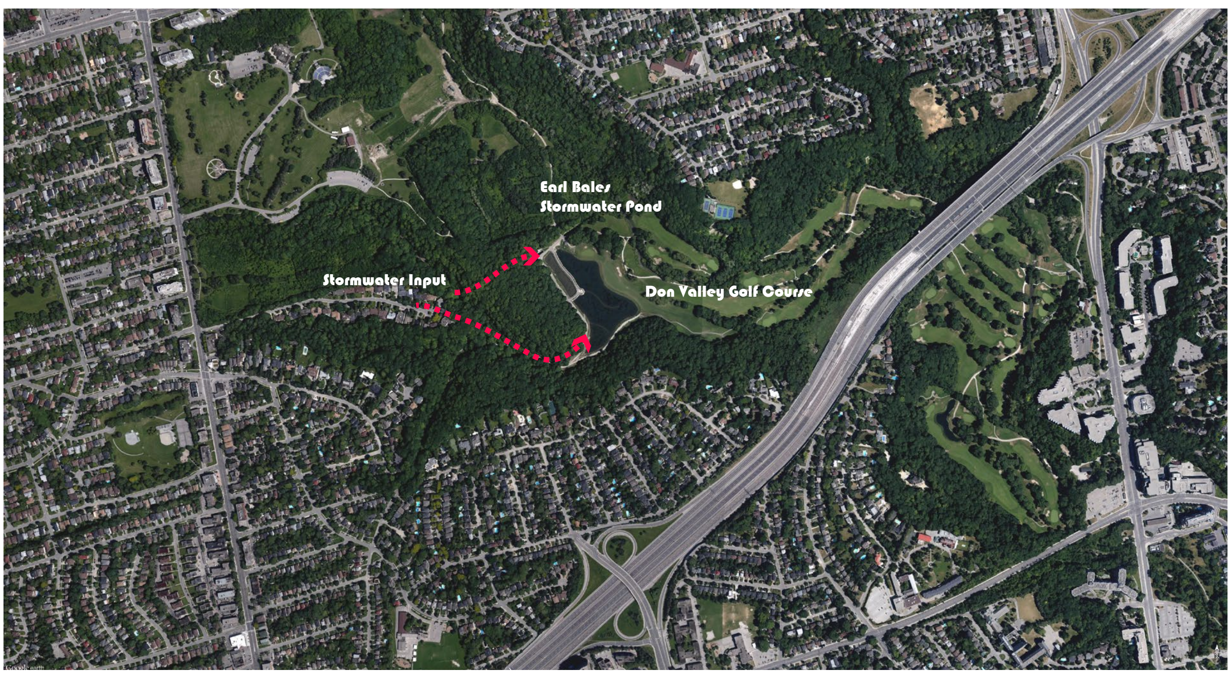
2.42 *The site condition after the construction of Earl Bales Pond.*

2.43 *The Earl Bales Stormwater Management Pond.*

The Earl Bales Stormwater Management Pond is one of the largest facilities of its kind in Canada. Built in 2011, the pond covers an area of 3.2 hectares and is approximately three metres in depth. The pond has the capacity to manage and treat stormwater runoff from a catchment area that encompasses 550 hectares of residential and industrial development.[24]

The project deals with stormwater that discharges into the West Don River and traditionally has adverse effects on water quality and fish habitats. Stormwater flows have also caused erosion of area ravines, resulting in the loss of trees and other vegetation in the valley, as well as the exposure of underground sewer infrastructure. and putting it at risk.

The pond location is at the base of two creeks, Earl Bales Creek and Dehavilland Creek, which used to be mostly buried in storm sewers. The remnants of their ravines are now confined to the park east of Bathurst Ave.



Adjacent to the Don Valley Golf Course in the valley lands of the West Don River, the pond was designed to blend in to the natural environment. A pathway through the site connects with a pre-existing trail system.

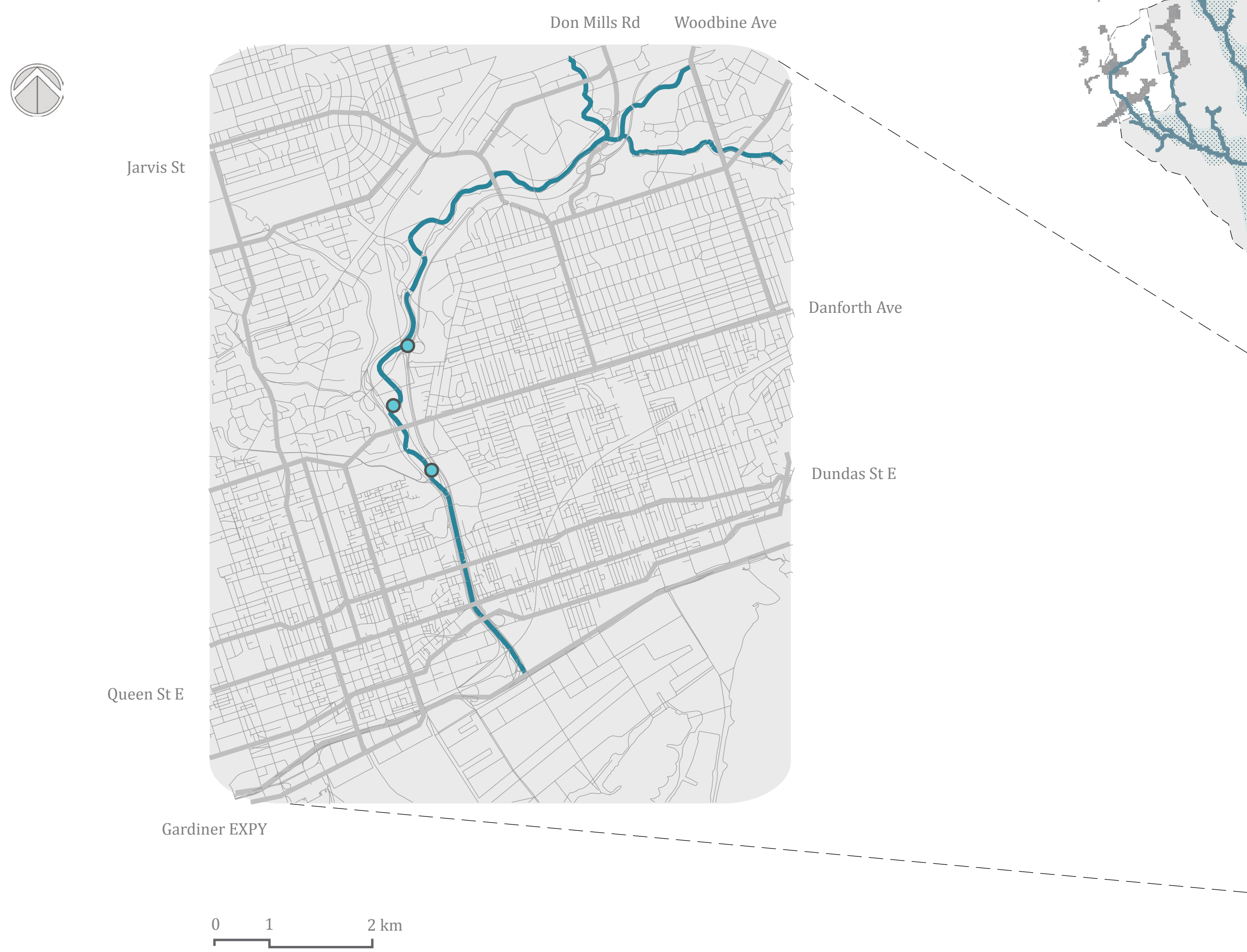
Key innovations of the project include using the pond water for golf course irrigation in the summer and for snow-making on the Earl Bales ski hill in the winter. In the past, water was withdrawn from the Don River for these activities, which adversely affected fish habitats and aquatic vegetation.[25]

2.44 *Top: site plan and the pathway through the pond connecting with the existing trail system. The project demonstrates the responsible use of public land to achieve collective benefits by applying creative stewardship principles, integrating common and well-understood processes with innovative ideas.*

2.45 *Bottom: community benefits extending from the project include an accessible, open-water-based park amenity in an underutilized corner of Earl Bales Park, a golf-course-based water feature and reliable alternative water supplies for non-potable public uses.*

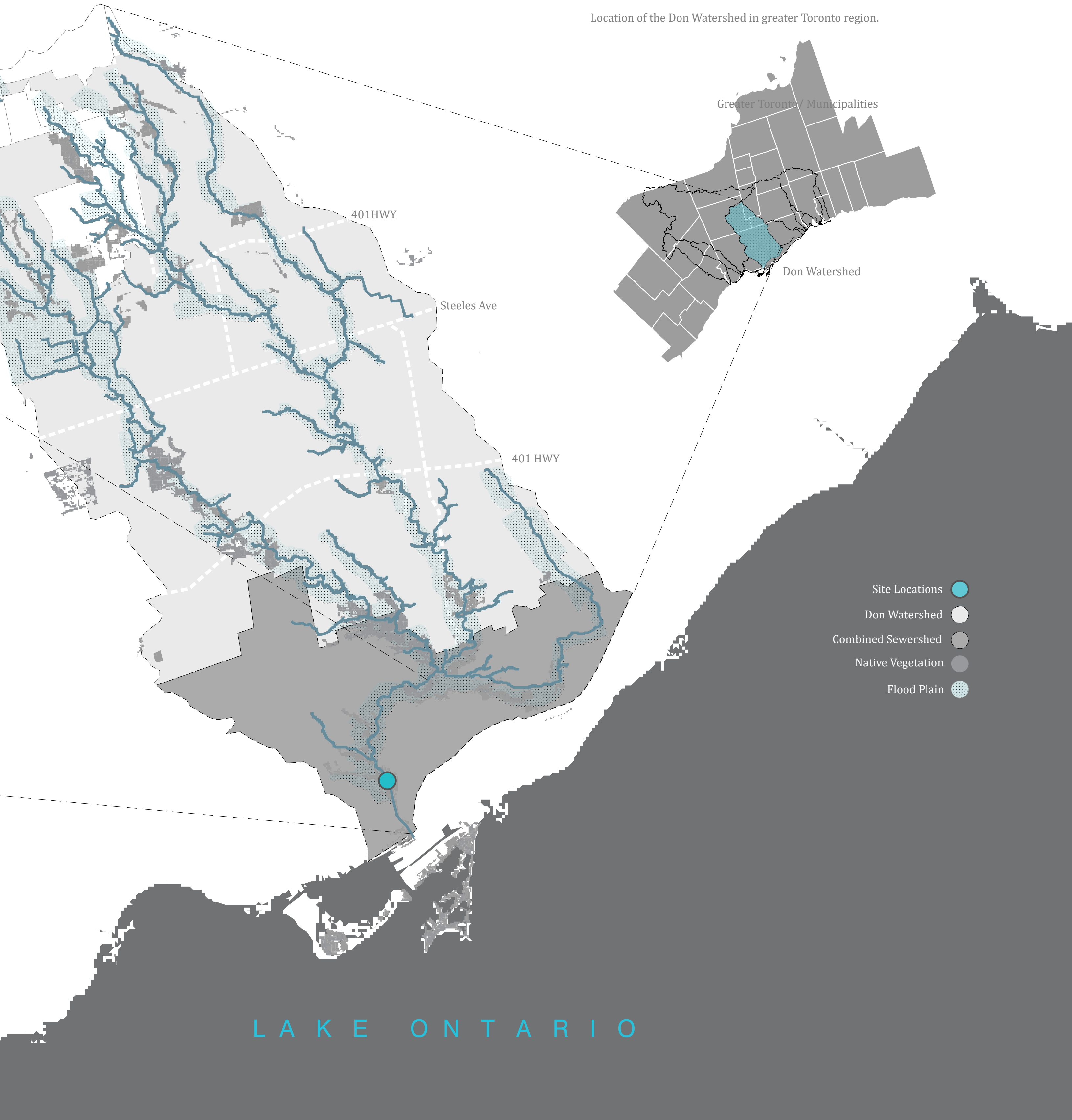
03
EXAMINATION

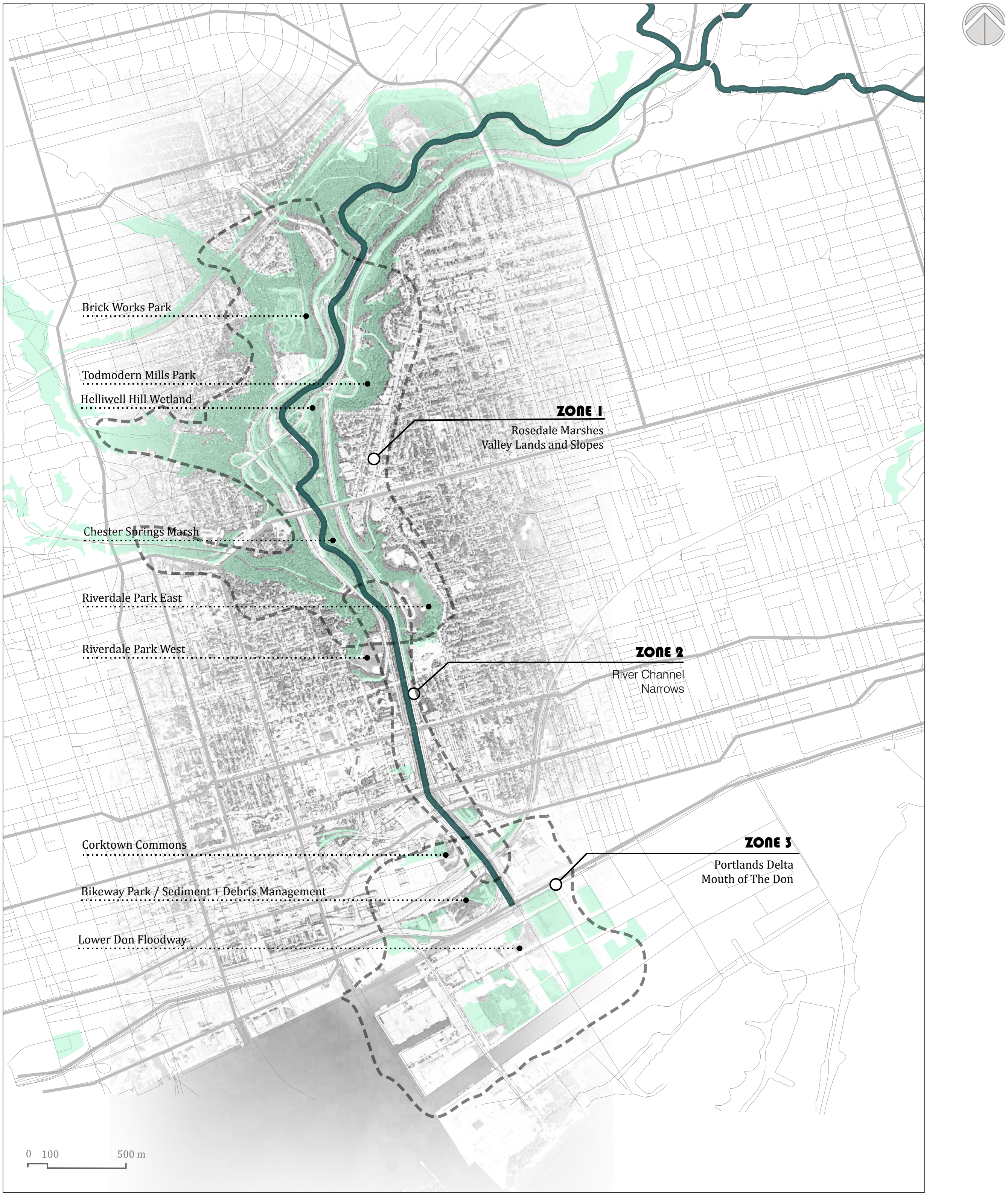
Study Area: Lower Don River
This part of the Don has three clearly defined landscape types, each intimately connected to the whole, yet each with a distinctive natural and cultural character of its own. The focus of this thesis is on the upper section, where the valley broadens out into a major floodplain, and where there is more room for social activities.



3.1 *Study area in its greater context.*

Location of study area in the Don Watershsed
The site selections were made based on the critical condition of the site both ecologically and socially. The lower part of the Don has been degraded and suffered the most from the urbanization process.



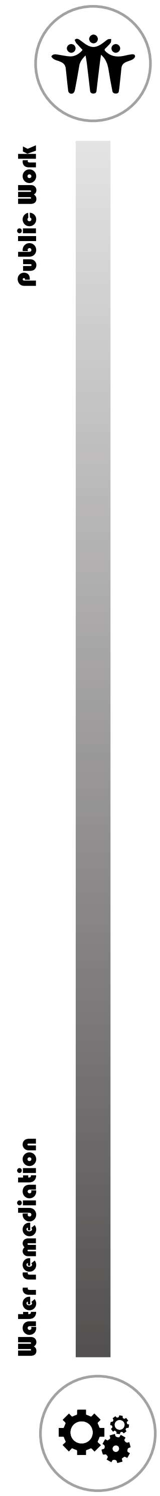


3.2 *Map of Study Area: The Lower Don with three clearly distinct landscape types. According to the Hough's proposal each zone suggests a different strategy of remediation.*

4.1 Scenario

A series of three design interventions, each covering a certain area along the edge of the river, has been developed in this thesis. These sites are chosen as test sites and the same strategy could be further developed all the way along the edge of the Lower Don River. The interventions are located along the trails that attracts the public runners, cyclists and pedestrians - to the water's edge.

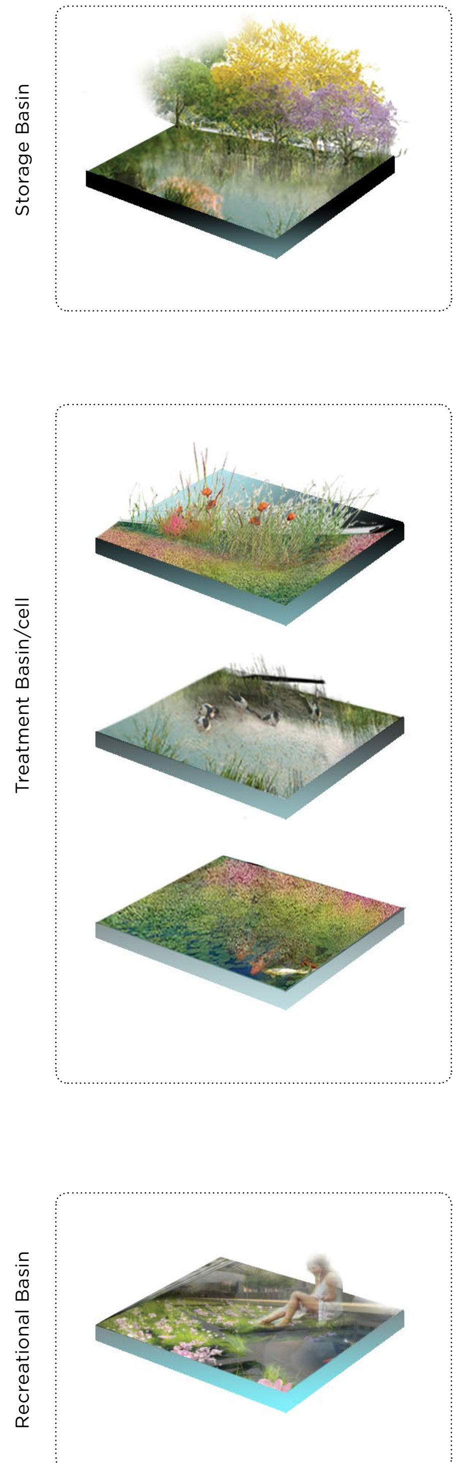
As we go from north to south in the study area, the water remediation aspect of the design proposal becomes increasingly more significant than its recreational qualities. The first site located at the north part of the study area is mostly focused on creating a social life. It pays more attention to enriching the public sense of the place with less area of water treatment. On the other hand, the third site located at the south of the study area requires a gentler strategy since it is in the river channel zone, and is located in a more industrial area than the other two ones. Therefore, the design solution for this one is really serious about the water treatment, and is very minimal and simple in terms of public amenity and recreational areas.



3.3 *The project spectrum between ecological and social qualities of the site.*

3.4 *Site plan: the existing condition of the study area.*

3.5 *Locations of the three design interventions highlighted on the study area.*



3.6 *Three different basins of water management process.*

4.2 Bioremediation landscape program

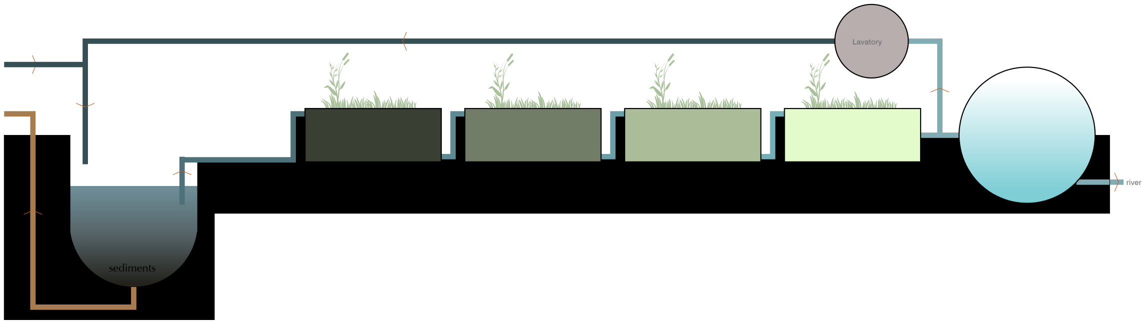
The whole system of water treatment includes three basins: a storage basin, a series of graduated treatment basins/cells, and then a recreational basin.

Step 1: Storage basin: Studies have shown that the first 2.5 centimetres of rainfall carries 90 per cent of the pollution load in a rainstorm.[1] Furthermore, most pollutants in stormwater are attached to sediment particles. Therefore, my design includes a pretreatment stage to collect and settle out sediments and heavy stuff to the bottom of a storage basin over a period of days, rather than spreading them out through the whole system of remediation. In addition, by storing the water in this stage and releasing it slowly to streams, we can smooth out peak loads and lessen the danger of downstream flooding. A bypass is needed for this part so that, in the event of a serious storm, the polluted water won't go through.

Step 2: Treatment basins/cells: Stormwater carries the collected pollution from rain, road, paved surfaces, and rooftops, which includes a range of organic and chemical compounds as well as heat from paved surfaces. Aquatic plants and vegetation can contribute to the remediation process by filtering the water and cooling it through shading. Proposed remediation wetlands incorporate a mixture of plants and aquatic organisms, which absorb or break down heavy metals, biological toxins, and bacteria out of contaminated water.

In this step the water gradually flows into different stages of treatment as it flows to the stream. Firstly, it enhances the quality of stormwater by providing a biological treatment. Secondly, it plays a significant role in controlling changes in the water levels and stream flows as well as peak flows. Lastly, it provides habitats for aquatic and terrestrial species.

Step 3: Recreational Basin: Located close to the edge of the river, and at the very end of the water treatment process. The water in this stage is clean enough for people to put their feet into this shallow pool, experience the treated water and enjoy watching the river.



3.7 *Process of water treatment: different basins used in the proposed cellular water remediation system.*

Functional Bioremediation Landscape Program / Relative Capacity[2]

Constructed wetlands are typically sized by a couple of methods. Below is a method calculating a resulting wetland size and hydraulic loading rate (HLR). HLR describes the desired flow in a wetland as equivalent to the rainfall. It is a function of the wetland size and water flow rate, where q is the hydraulic loading rate (m/day), A is the wetland area (m2), and Q is the water flow rate (m3/ day).

$$q=Q/A$$

The following steps are used to size a wetland based on an approach which starts with specific storm or desired treatment volume.

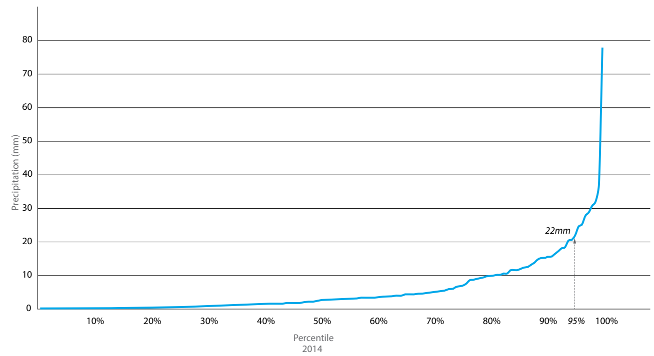
1. Identify the desired design storm. For example for Toronto in 2014, the 95th percentile storm is 22mm, with total annual rainfall of 733.8mm per year. (Figure 3.9)

2. Calculate the watershed area or the drainage area for each site. Calculate the watershed's runoff coefficient and total runoff volume. The runoff coefficient is the fraction of rainfall that becomes runoff. Runoff is very site specific, as it is dependent on soil conditions, slopes and other factors. However, the following equation is frequently used by urban hydrologists to estimate the runoff coefficient.

runoff coefficient= 0.05 + (0.009 x percentage imperviousness)

Month	Total (mm)
Jan-14	46.6
Feb-14	54.4
Mar-14	27
Apr-14	91.6
May-14	56.2
Jun-14	97
Jul-14	86
Aug-14	38.8
Sep-14	102.8
Oct-14	55.6
Nov-14	43.6
Dec-14	34.2
Annual	**733.8**
Per day	2.010410959

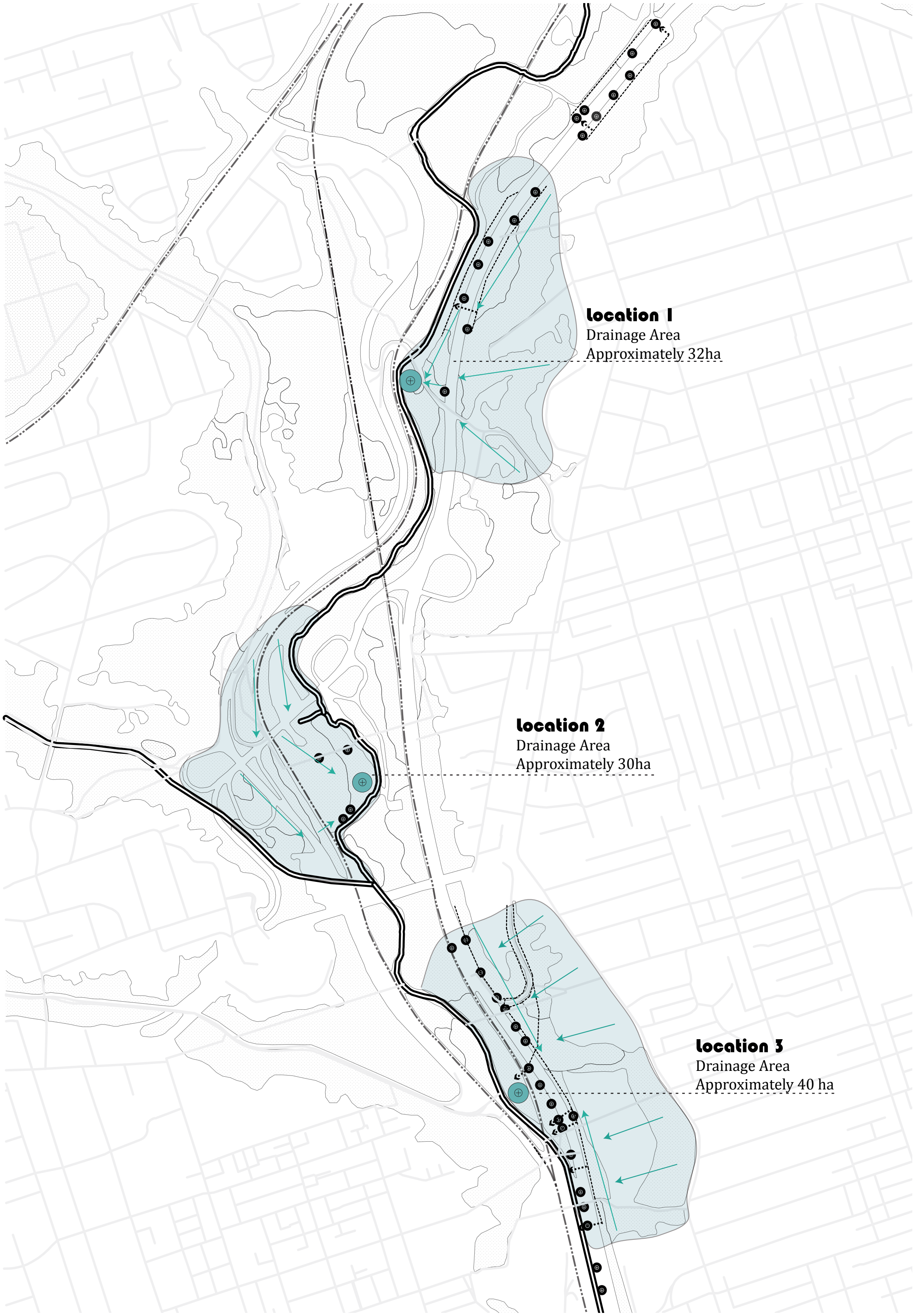
3.8 *Annual rainwater of Toronto. http://toronto.weatherstats.ca/metrics/rain.html*



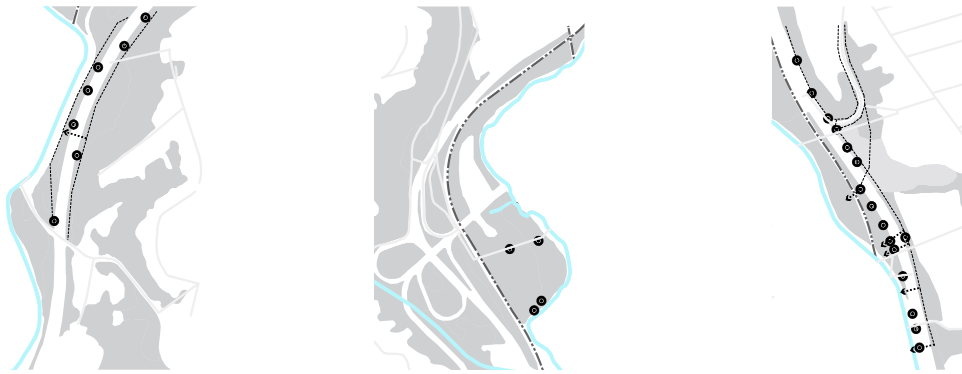
3.9 *Degree of precipitation in Toronto in 2014. http://climate.weather.gc.ca*

The total runoff volume will be watershed area - for each site the drainage area- multiplied by desired design storm and runoff coefficient.

3. Allocate the total runoff volume to wetland components to obtain a wetland size. In each of my wetlands, 60% of the total volume is allocated to 0.3 metre deep marsh zone, and 40% is allocate to 1.2 metres deep zone.



3.10 *Outfalls and the main drainage areas.*
The stormwater is conveyed first through the natural topography of the site, and then through the outfalls shown on the map. The direction where the water flows is also indictaed on the map.



	Location 1	Location 2	Location 3
Area	32ha	30ha	40ha
Imperviousness	32%	35%	51%
Runoff Coefficient	0.05 + (0.009 x 32)=0.33	0.05 + (0.009 x 35)=0.36	0.05 + (0.009 x 51)=0.50
Runoff Volume	2323m3	2376 m3	4400 m3
Runoff Volume size	0.3 m, 40%, 3097m2	0.3 m, 40%, 3168 m2	0.3 m, 40%, 5867 m2
	1.2 m, 60%, 1161 m2	1.2 m, 60%, 1088 m2	1.2 m, 60%, 2200 m2

3.11 *Water treatment cells calculation methodology.*

4.3 Architectural program

In order to demonstrate the appropriateness of the programs for the test sites and the logic behind their location selection, I studied the documents and master plans that already exist for that area.

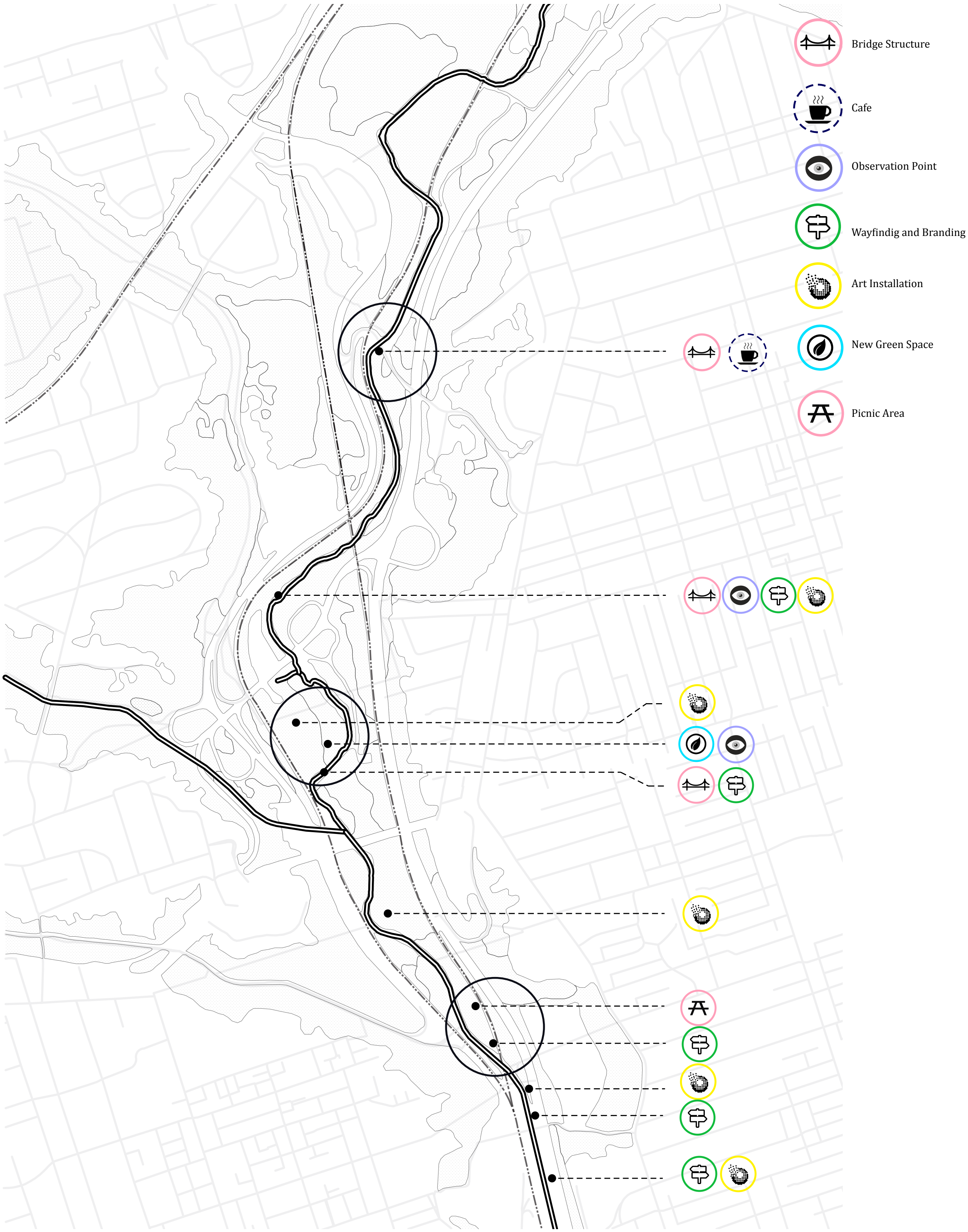
The trail master plan proposal for lower part of Don Valley presents a high-level vision for the future of the portion of the Don River trail south of Pottery Road. It shows the Lower Don Valley as it might be after the completion of an array of projects and restoration efforts. The programs included in the master plan have tried to design a continuous path to connect different parts of the valley and create an enjoyable trail along the valley and its river. However, in my opinion that master plan does not really take into account the relationship between nature and culture. In fact it is completely preoccupied with pedestrians, whereas my proposal provides the opportunity to go back and forth between the substantial emergence of the natural environment and social encounters.

Provided that the suggested path system is accepted I intend to include the master plan's suggested programs in my design but to create a more social environment for those enjoying the trail and also to engage them more with the natural area.

A Cafe, a contemplation area, and a stop area combined with recreational boardwalks have been assigned for the chosen locations. These are the public facilities, which will connect the natural landscape with its context as a public space in a city.

The recreational boardwalks used in all three programs permits access to water, and is kept unobstructed for activities such as fishing, jogging, or simply dipping one's feet in the water. It is used sometimes as a maintenance path as well.

3.12 *Lower Don Trail Master Plan: access strategy.*



3.13 *Lower Don Trail Master Plan: suggested programs on the study area.*

	Smaller Bridges
A3.4	Existing Bridge Crossing Realignment
A4	**Belleville Underpass Improvements**
A5	**Picnic Areas / Observation Points**
	One-Sided On Street Trails
A6.1	Bayview Multi-Use Path (Phase 1)
A6.2	Bayview Multi-Use Path (Phase 2)
	Stairways
A7.1	Gerrard Stairs
	Streetscape Improvements
A9.1	Broadview Streetscape Improvements
A9.2	River Streetscape Improvements
A10	**Rosedale Valley Intersection Improvements**
A11	**Narrows Trail Widening, Surface Improvements and Art Fence**

3.14 *Site 3: Lower Don Trail master plan: site-specific project guidelines.*

A1	**New Green Space on Former Snow Dump**
A2	**Lower Don Trail to Beltline Trail Bridge (West)**
	Smaller Bridges
A3.1	Pottery Road Bridge
A3.2	Lower Don Trail - Beltline Trail Bridge (East)
A3.3	Lower Don Trail to New Green Space Bridge
A5	**Stops / Observation Points**
	One-Sided On-Street Trails
A6.1	Bayview Multi-Use Path (Phase 1)
A8	**Bayview On-Ramp Walkways**
	Streetscape Improvements
A9.1	Broadview Streetscape Improvements

3.15 *Site 2: Lower Don Trail master plan: site-specific project guidelines.*

4.4 A TESTING GROUNG

3.16 *Site location 1.*

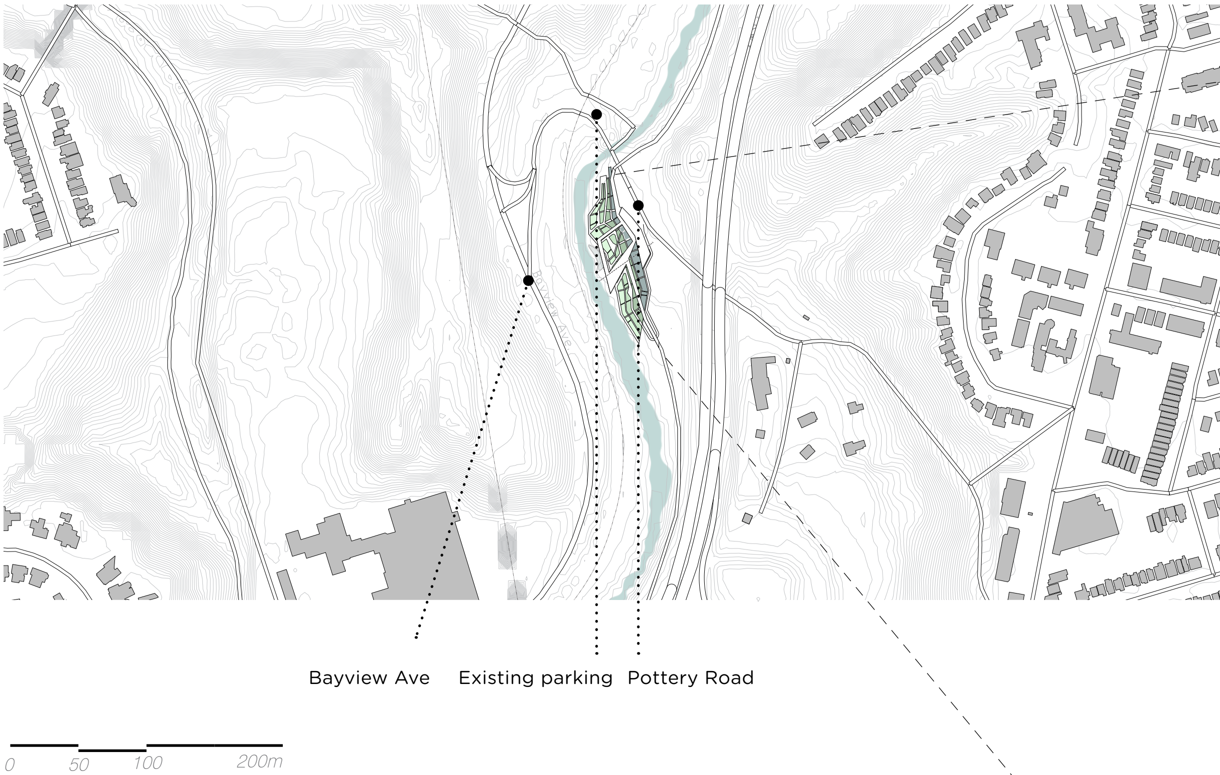
3.17 *Panoramic view at location 1 showing the parking space, vehicular and pedestrian accesses.*

3.18 *Recreational trail at the Trailhead.*

3.19 *Recreational trail at the Trailhead.*

3.20 *Existing parking area at the Trailhead.*

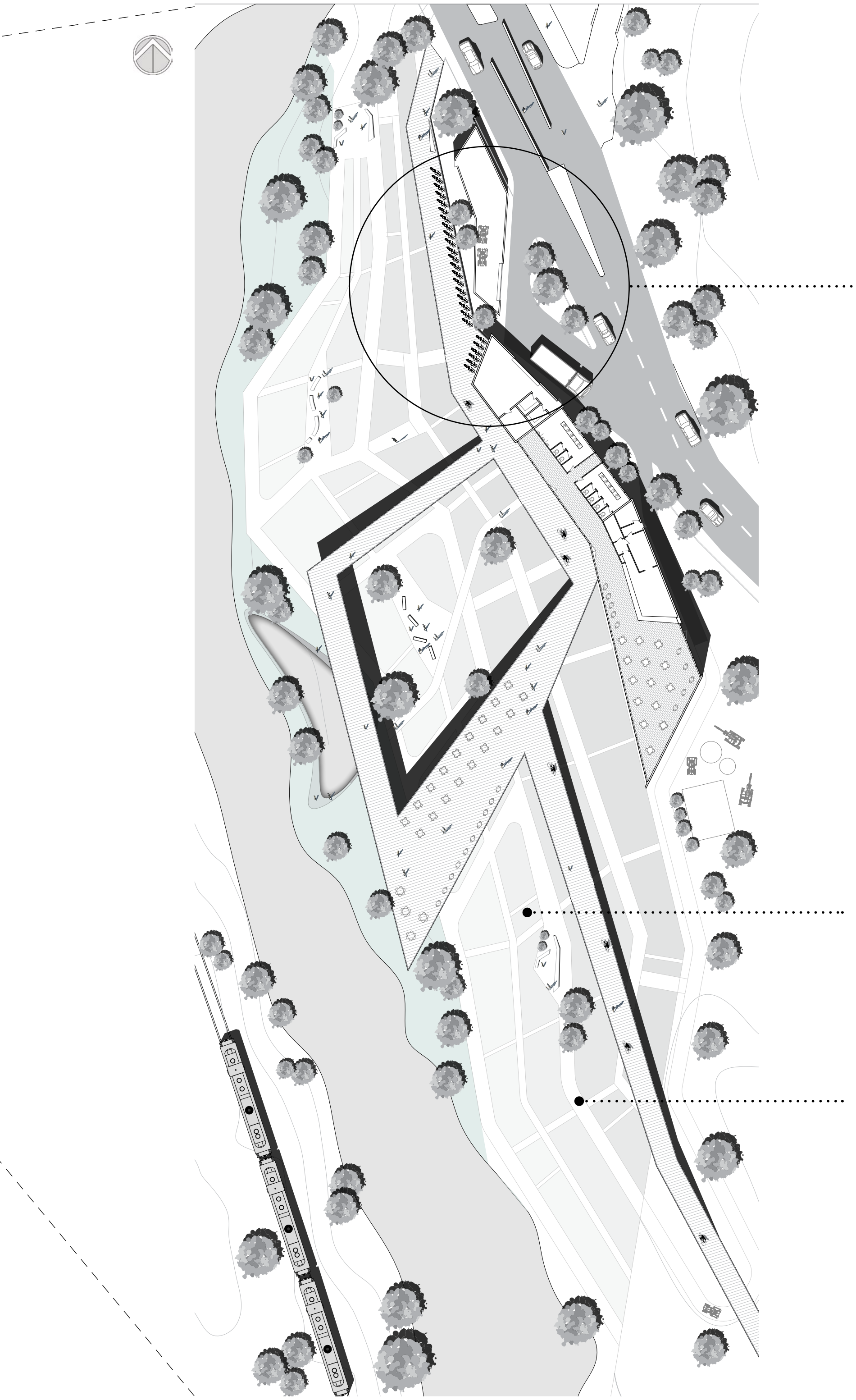
3.21 *Pottery Road: sidewalk connects the parking to the Trailhead.*



3.22 *Site Plan drawing: location 1.*

This site is located at the Trailhead and is a convenient place to start the route as a parking area is provided beside it. A lot of people would drive here, bringing their bikes on the backs of their cars, and park in the existing parking, while others would either bike here or walk on the pedestrian bridge to get to this location.

A café is provided for location. The other architectural programs are public washrooms, a bike storage area, a boardwalk, and an outdoor sitting/dinning terrace in front of the cafe and above the treatment cells. This site is the most developed facility within the thesis. The plan shows the heavy work of maintaining a civic-scale water filtration facility and the spaces required for that including an area for dredging equipment , storage of materials and consumables, fallow pools, staging area, and work area.



Maintenance space, developed with additional rooms and with a turnaround space for trucks serving it from the road side facing away from the river.

This space requires separation from the public activities, since toxic sludge extracted from city groundwater, and the quasi-agricultural functions of bioremediation natural plant management can't easily be placed beside people relaxing.

This is achieved through a large boardwalk filled with bicycle parking. This design approach makes a boundary between the maintenance area and the pools interwoven with public.

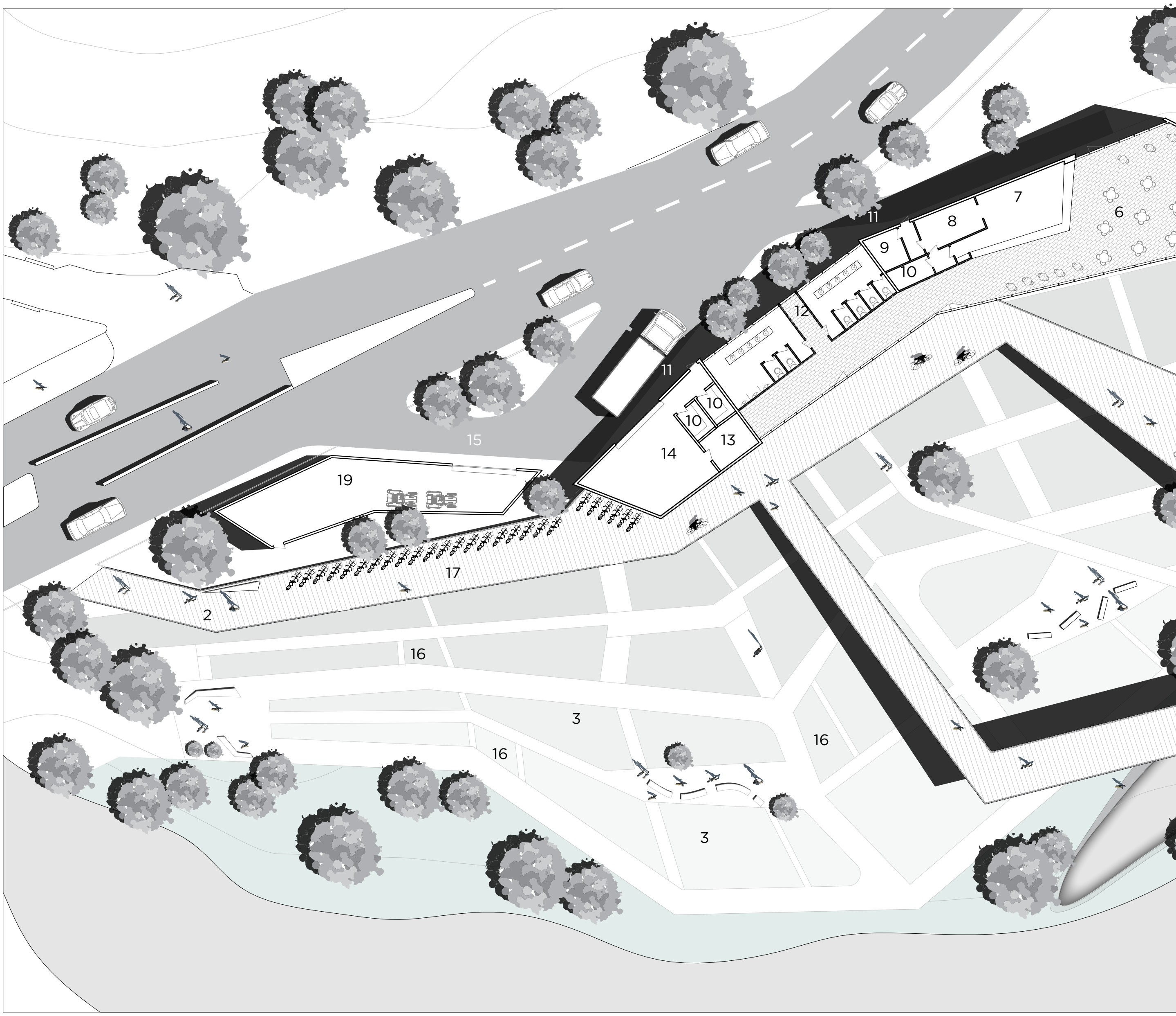
Natural areas in recovery and fallow pools required for the biotic process.

Maintenance path designed to accommodate tractor and dredging equipment movement within the treatment cells.

3.23 *Site plan location 3 showing the designed pedestrian boardwalk as well as the rest area for pedestrians and cyclists.*

1. Maintenance space, material Storage
2. Public boardwalk connected to the existing trail
3. Water treatment landscape cell/pool interwoven with public access
4. Recreational Pool
5. Sitting/dinning Terrace
6. Cafe indoor sitting area
7. Preparation area
8. Commercial range
9. Storage
10. Staff's closet
11. Loading area
12. Washroom
13. Electrical Room
14. Maintenance space, equipment storage
15. Staging area
16. Fallow pool
17. Bike parking area
18. Maintenance access
19. Equipment storage

Refer to Page 133 for the functional space program.



3.24 *Site plan location 1 showing the main fabric of cellular pools and the basic geometrics of social activities. (for the functional space program refer to appendix on page 135)*

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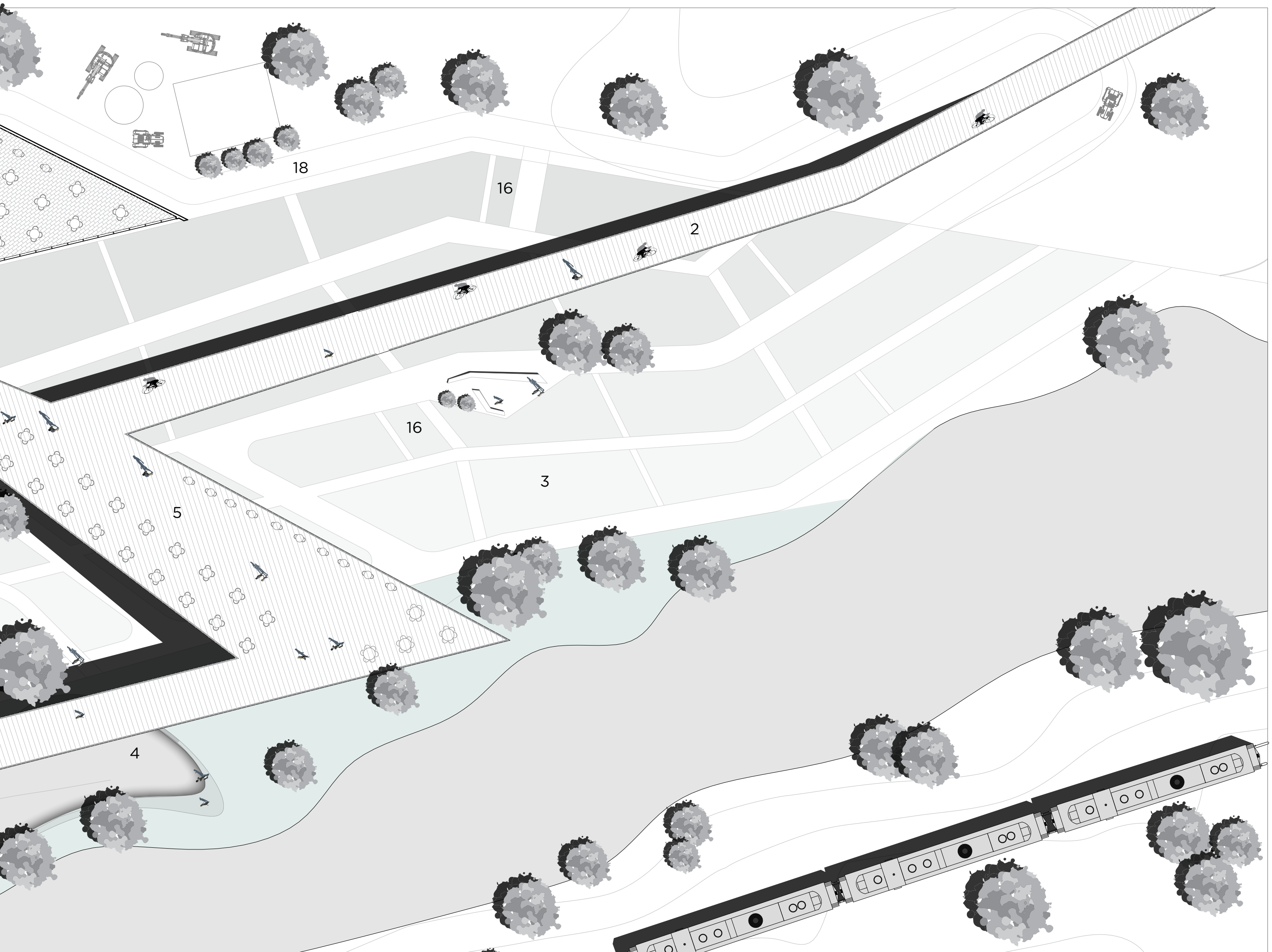
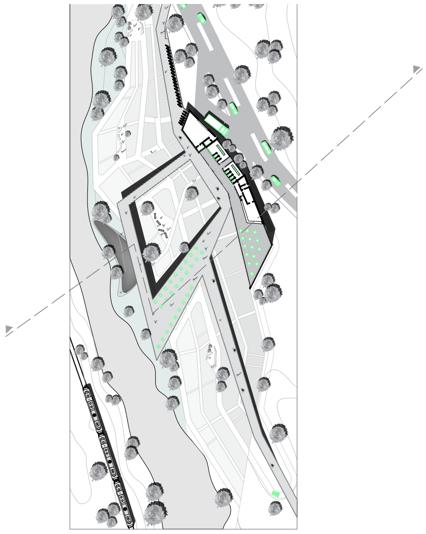
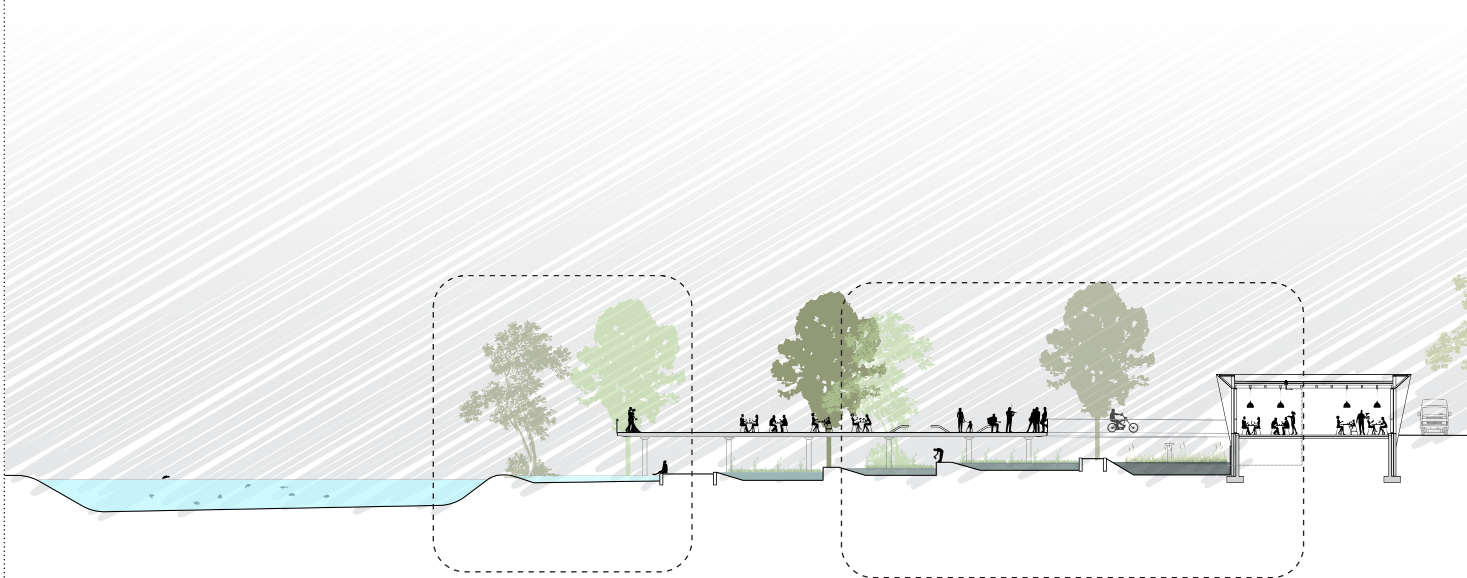


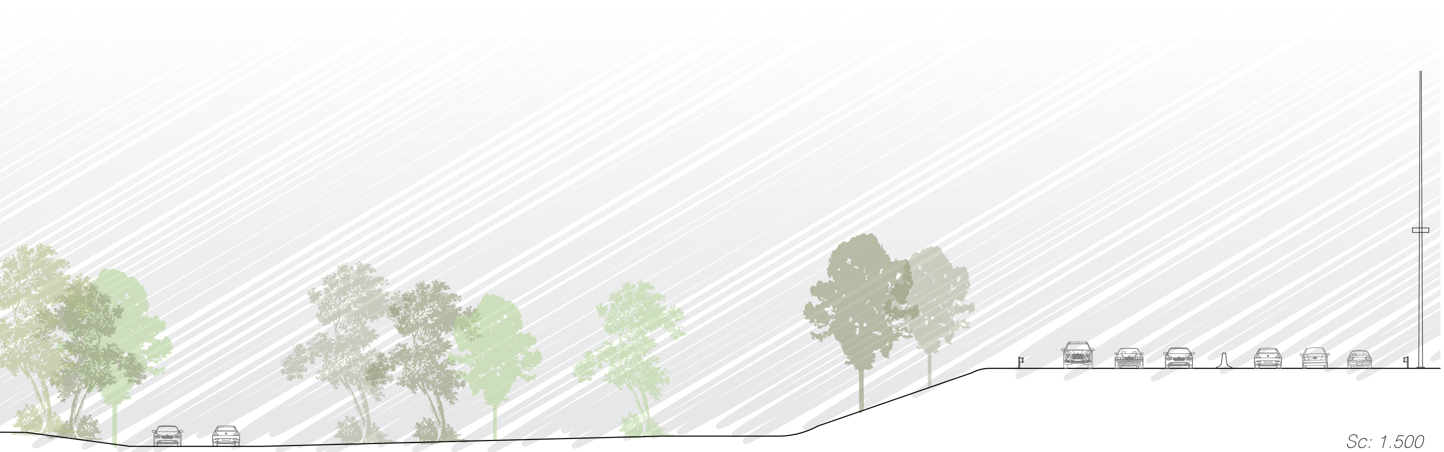




Plan detail 1.2

Section detail 1.1

3.25 *Site section location 1 showing the proposed landforms and the architectural spaces at the water's edge; cutting through the cafe indoor area as well as outdoor sitting and dinning areas, and the water filtration landscape cells.*



3.26 *Site location 2.*

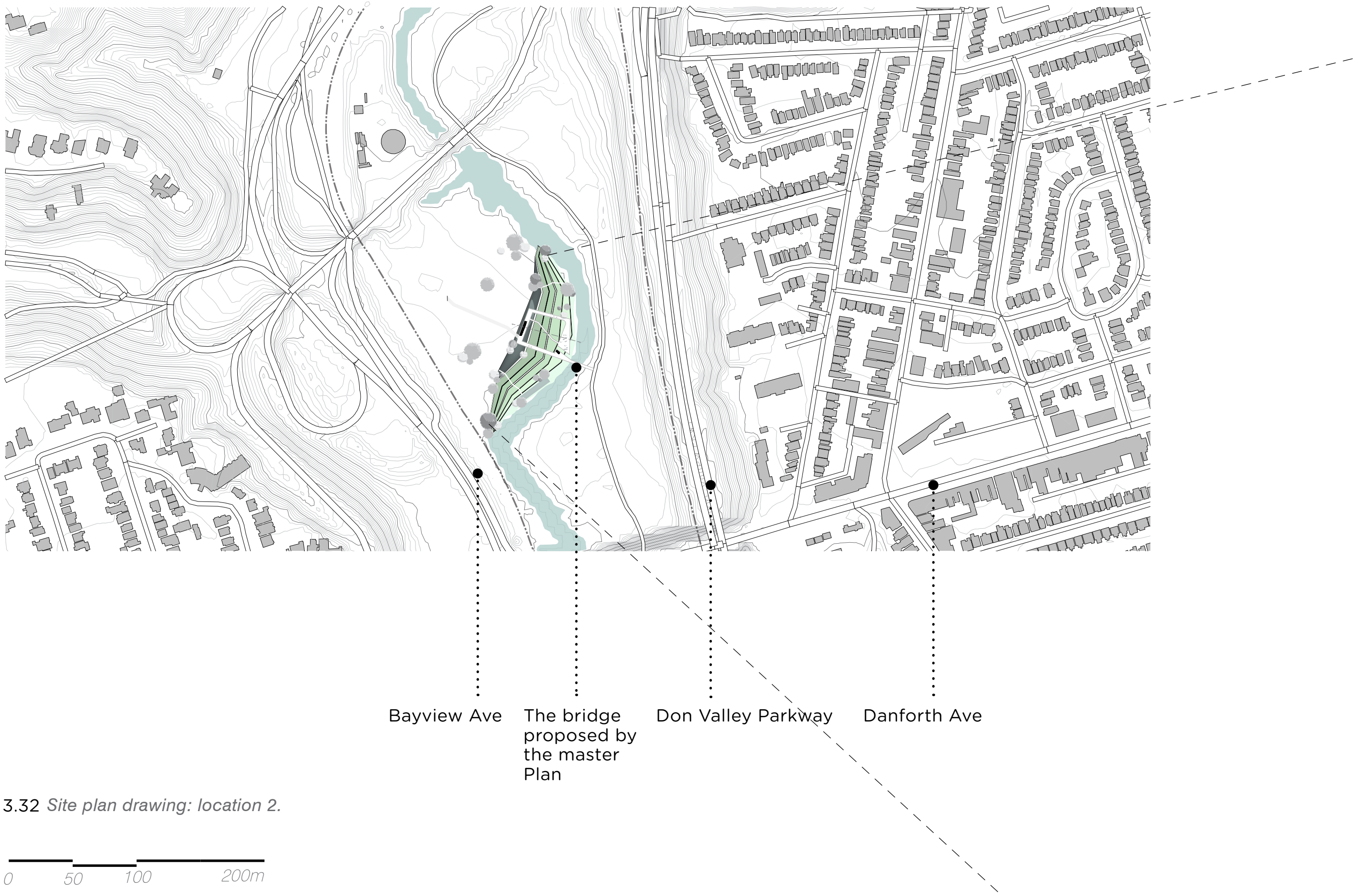
3.27 *Panoramic view at location 2 showing the existing river's edge condition, outfalls, and the untreated water dumping into the Don River.*

3.28 *View from Bloor Ramp to location 2.*

3.29 *Existing condition of the river at location 2.*

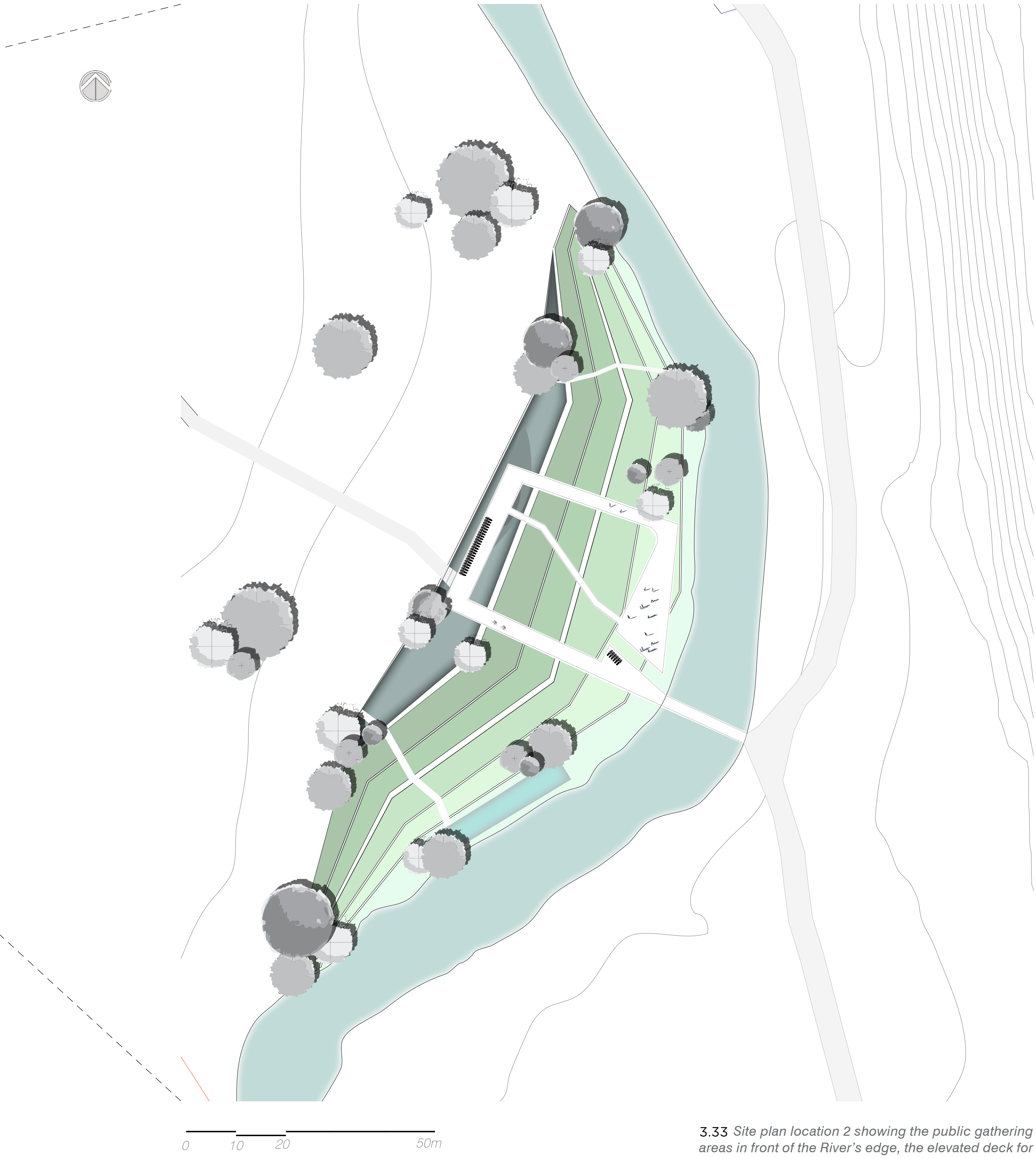
3.30 *Existing outfalls at site location 2.*

3.31 *Existing green area at location 2.*

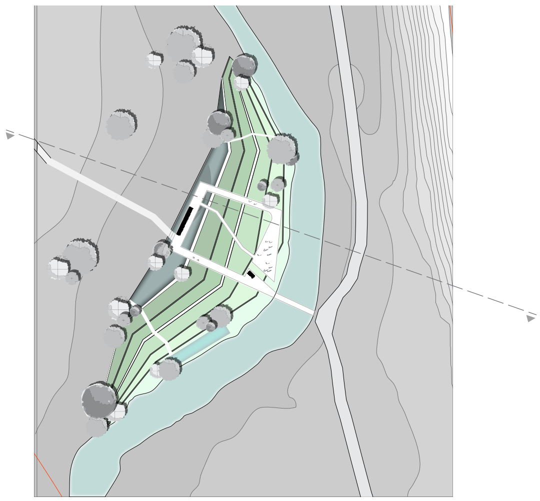


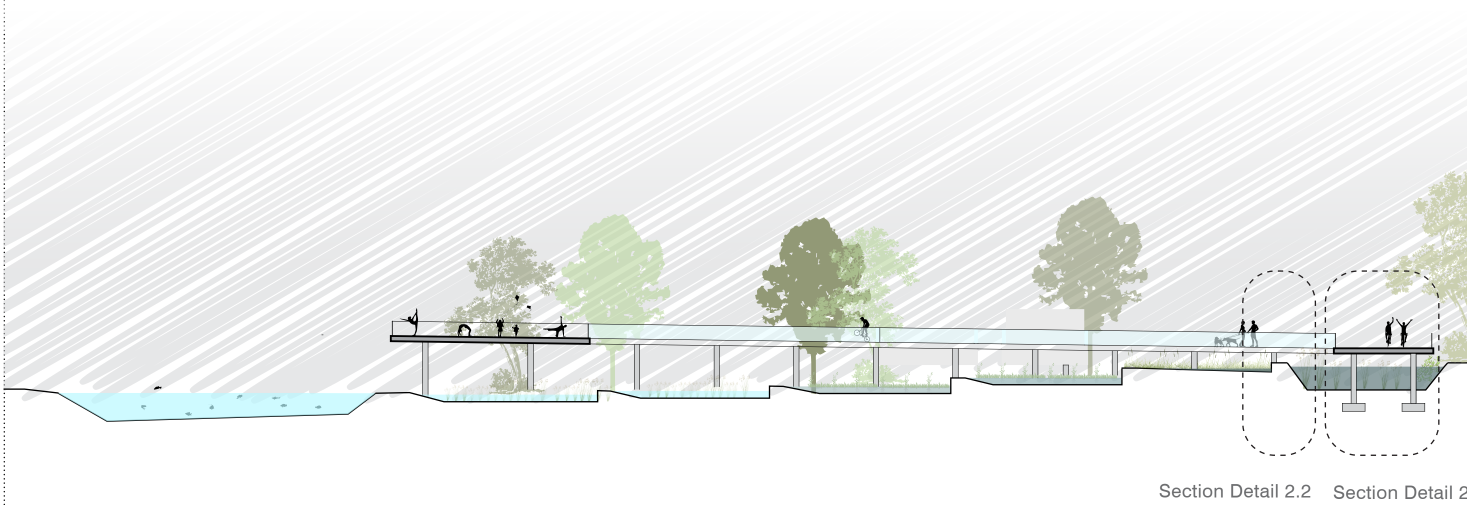
3.32 *Site plan drawing: location 2.*

This site is a quiet place. A platform for yoga/contemplation activities is assigned for this location (refer to Lower Don Trail Master Plan). The yoga area is an elevated platform on the treatment cells which is connected to the bridge on the river. A bike storage area is provided at this location, too.

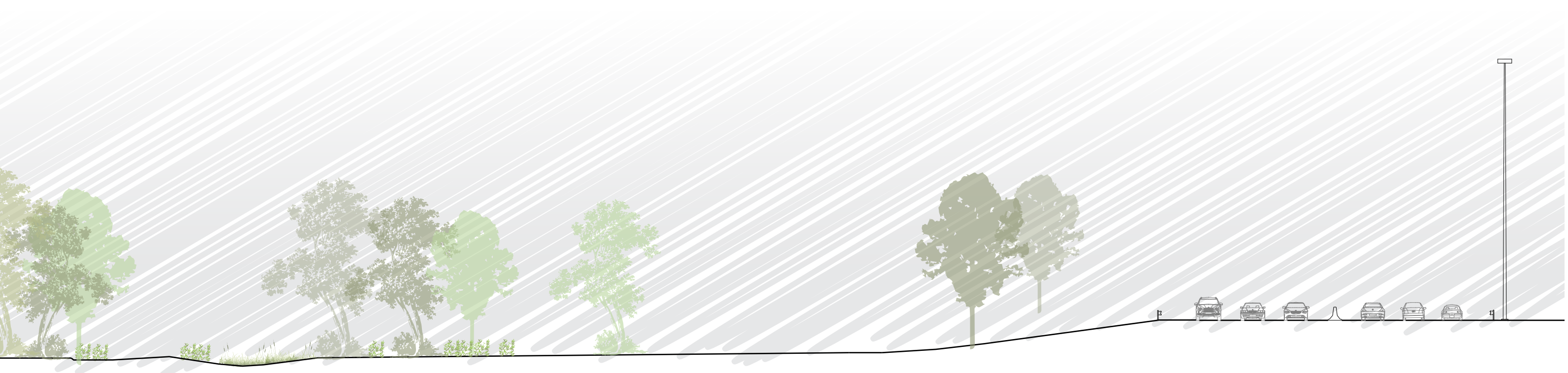


3.33 *Site plan location 2 showing the public gathering areas in front of the River's edge, the elevated deck for yoga activities, and the bridge connecting the program to the existing trail.*




Section Detail 2.2
Section Detail 2

3.34 *Site section location 2 showing the proposed landforms, water remediation landscape cells, and the architectural spaces at the Rivers's edge; cutting through the elevated deck connected to the bridge.*



.1

Sc: 1.500

3.35 *Site location 3.*

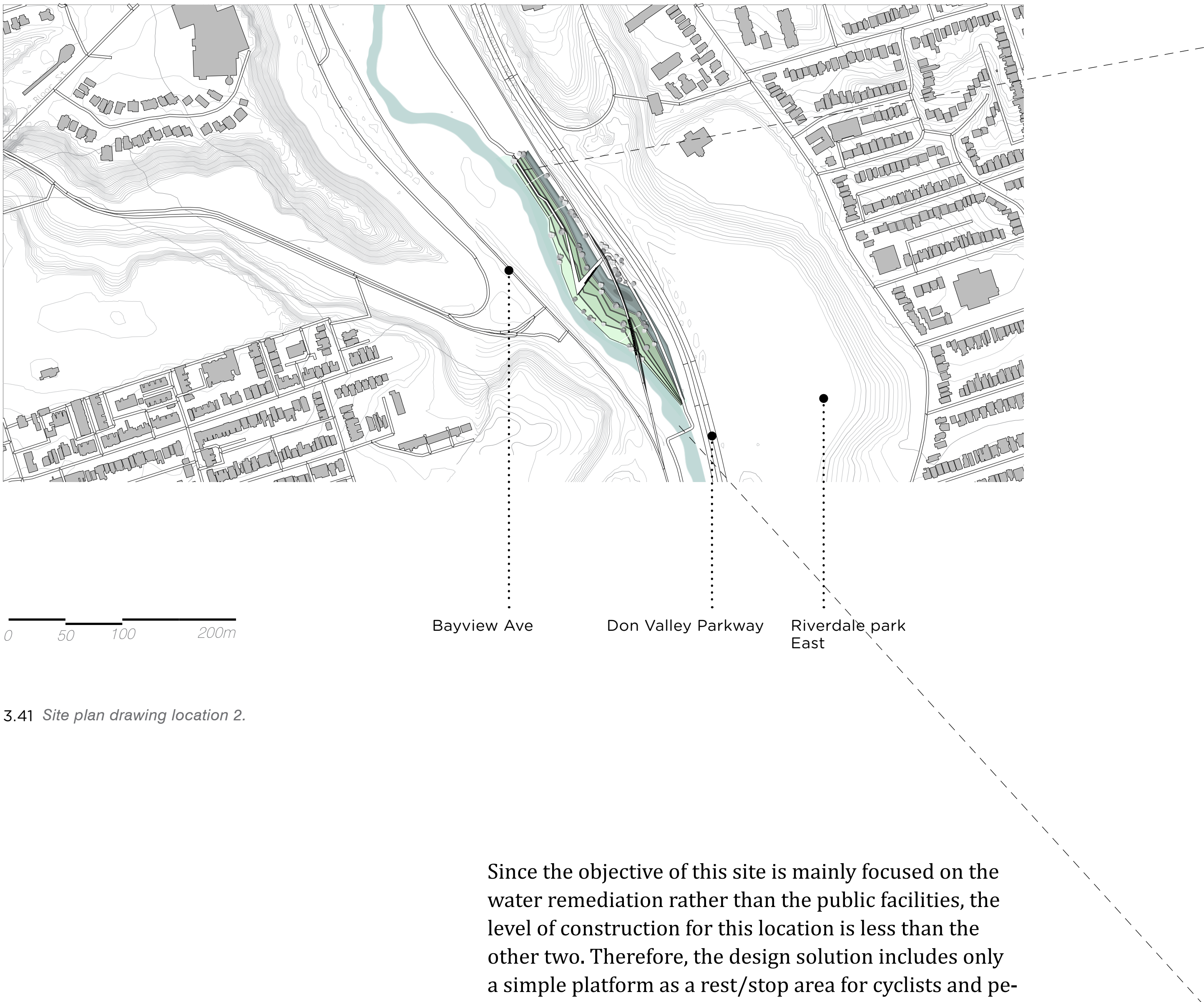
3.36 *Panoramic view at location 3 showing the existing River's edge condition and the surrounding environment.*

3.37 *Existing condition at location 3.*

3.38 *Existing condition at location 3.*

3.39 *Existing recreational trail going through the site.*

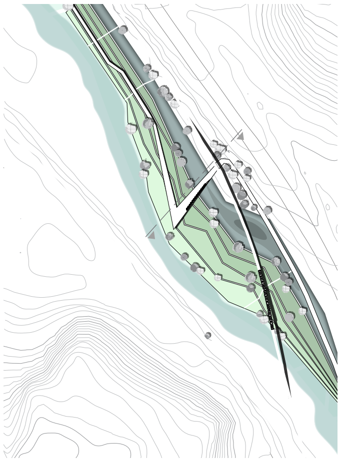
3.40 *View to the Prince Edward Viaduct from location 3.*



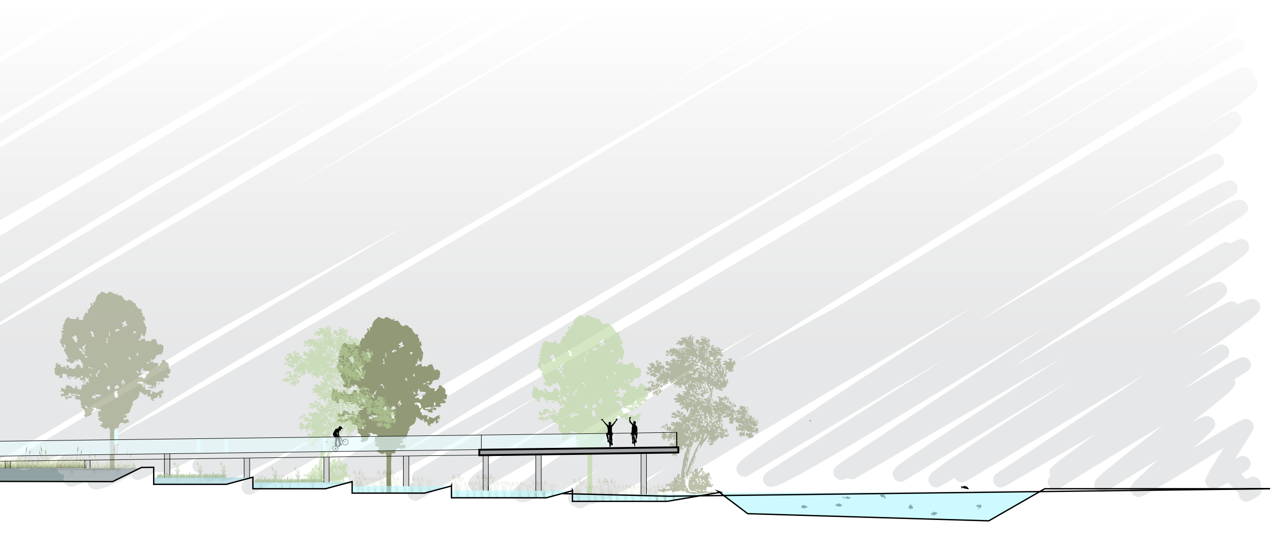
3.41 *Site plan drawing location 2.*

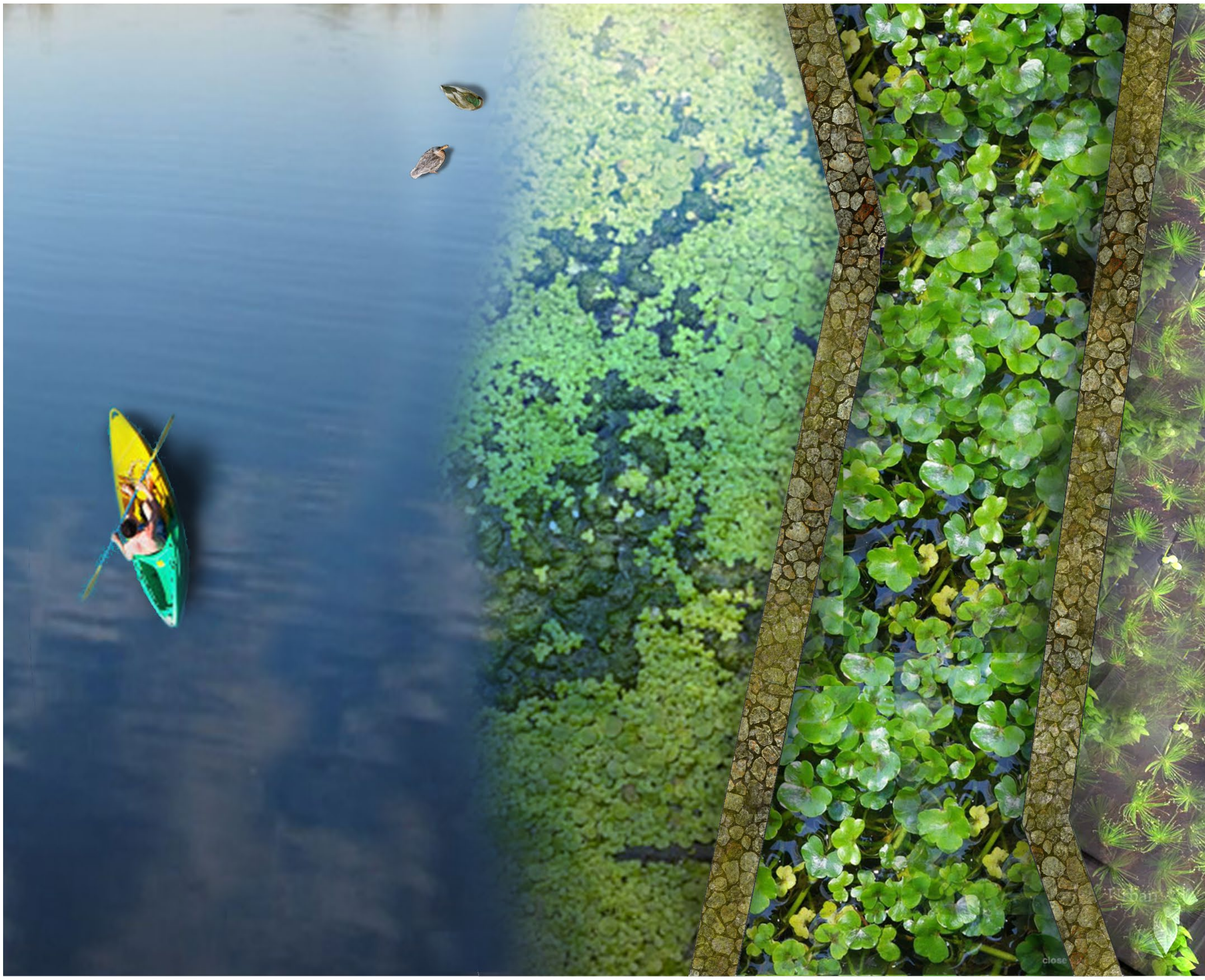
Since the objective of this site is mainly focused on the water remediation rather than the public facilities, the level of construction for this location is less than the other two. Therefore, the design solution includes only a simple platform as a rest/stop area for cyclists and pedestrians which is connected to the existing recreational trail.

3.42 *Site plan location 3 showing the designed pedestrian boardwalk as well as the rest area for pedestrians and cyclists.*



3.43 *Site section location 3 showing the proposed landforms, water remediation landscape cells, and the architectural spaces at the Rivers's edge; cutting through the elevated deck connected to the bridge.*





Wet Meadow

Shallow Marsh

Deep Marsh

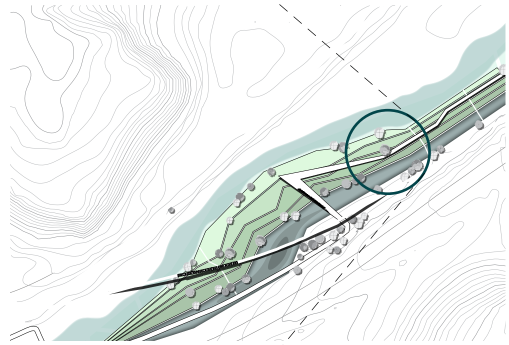
carex pendula groping sedge

American elodea or Canadian pondweed

water Milfoil

Landform types

3.44 *Configuration of the proposed constructed wetlands/bioremediation cells. Each type of plants processes a certain type water pollution. For more information on the plant types and water pollution refer to appendix on page 136.*



Plants process heavy metal

Plants process Metalloids/ non-metals

Plants process Nutrients

Plants process Organic Contaminants

Plants process Bacteria

Shallow Marsh

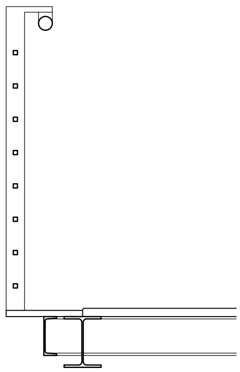
Wet Meadow

Step 1: Treatment basins

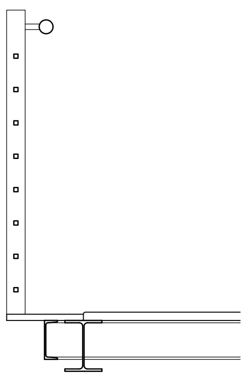
3.45 *Section detail 1.1 cutting through the cafe and its outdoor sitting area integrated with the water remediation landscape cells.*
The calculation for determining the height of each cell is provided on section 4.2.
Refer to figure 3.40 for the types of plants used in each cell.
The width of the paths adjacent to the pools varies based on their functions. Some are wider and appropriate for public gathering, while the others are narrower, which encourage walking as opposed to staying.

3.46 *Typical section detail cutting through the water remediation landscape cells showing the suspended walkway above the wetland as well as the maintenance path. The walkway is accessible throughout the year and is connected to the existing recreational trail.*

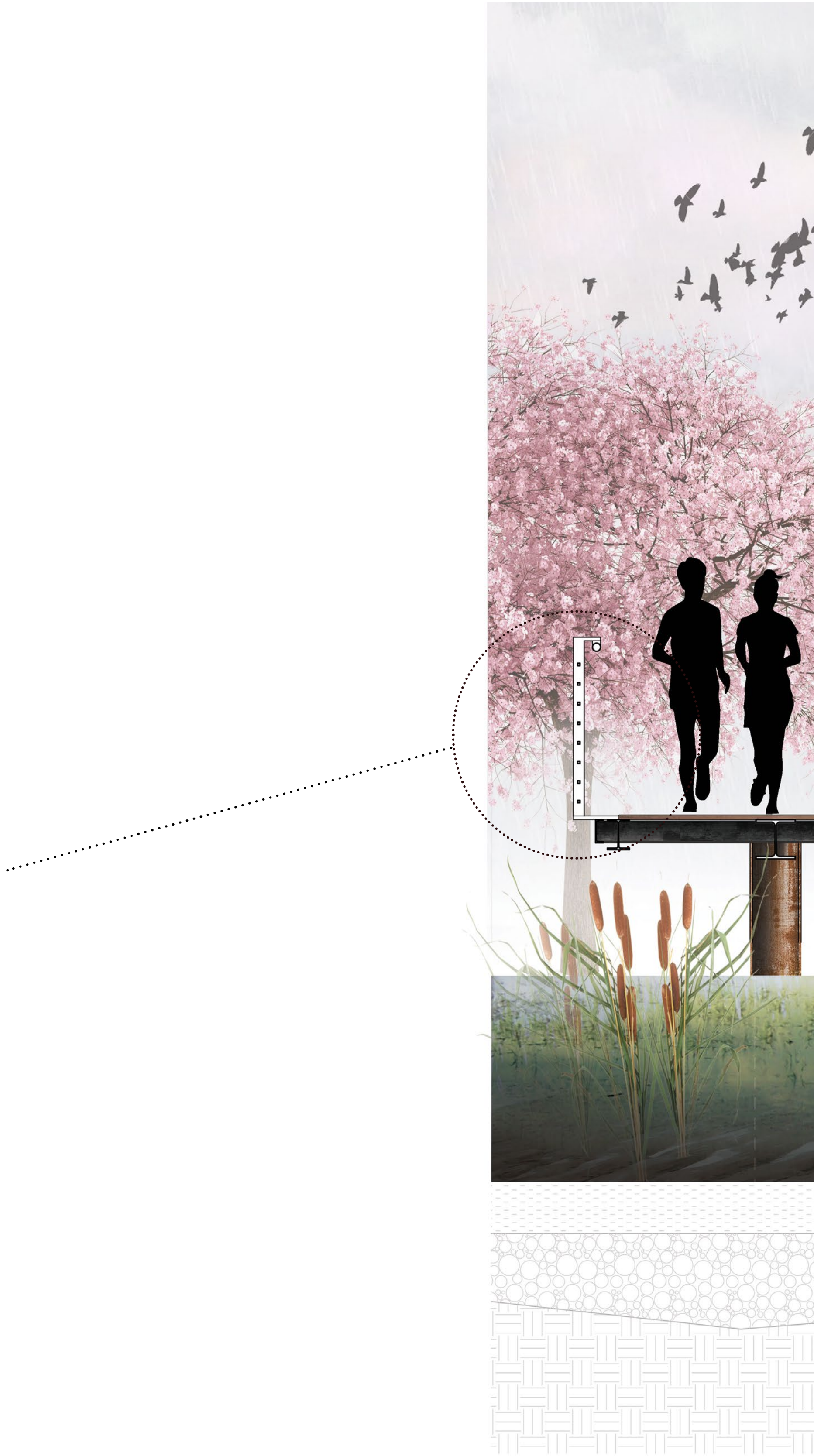
Wet Meadow



3.47 *Handrail detail 01: this type of segmented handrail is provided in areas such as the dinning deck or the yoga platform where it invites people to stop, rest, and enjoy the view.*



3.48 *Handrail detail 02: this type of continuous handrail is provided for this long straight walkway where the intention is to facilitate walking (for those who require this such as the elderly),*

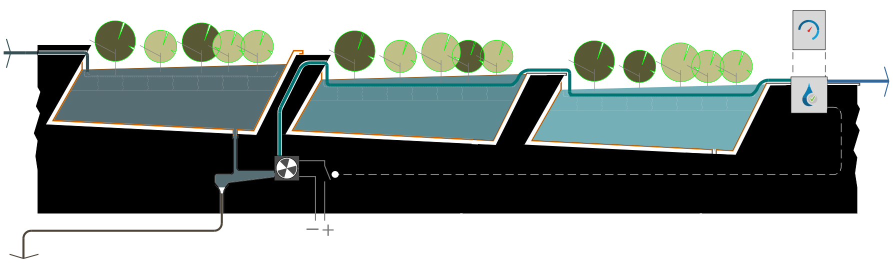


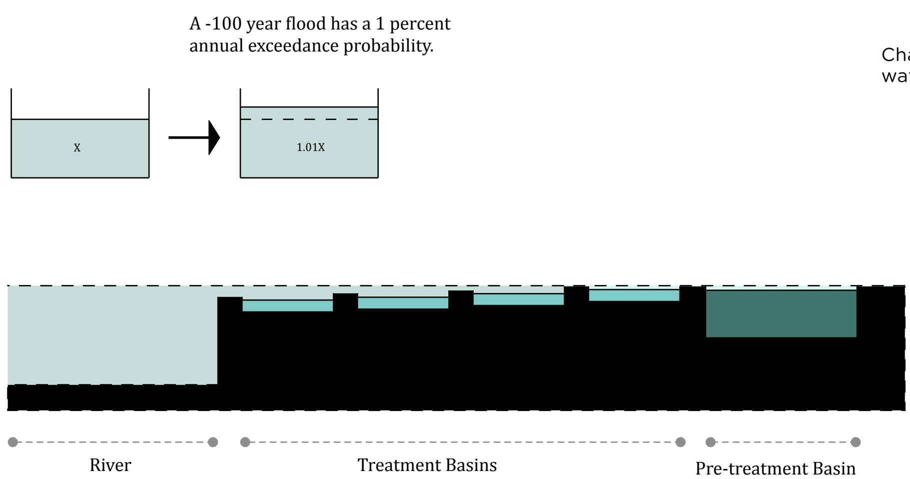
3.49 *Section detail 2.1 cutting through the water storage area, first step of water treatment, illustrating the pedestrian walkway connecting to the existing trail.*

3.50 *Right: section detail 2.2 illustrating the maintenance path as a vehicular access to clean the water treatment cells. This path is used as a seasonally accesible walkway too.*

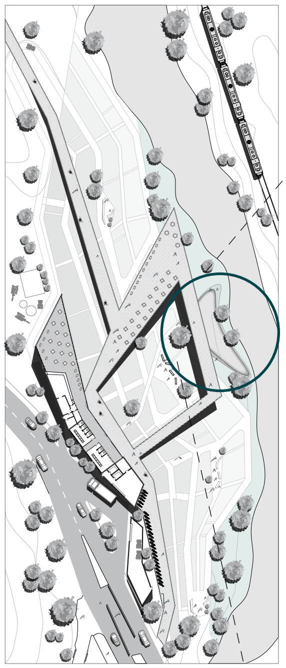
3.51 *Top left: water flow diagram.*

3.52 *Bottom left: water level change based on a 100-year flood.*



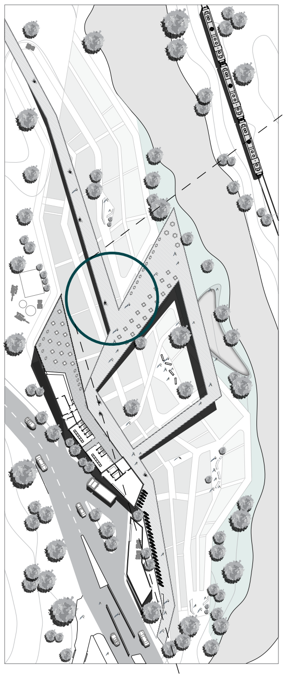


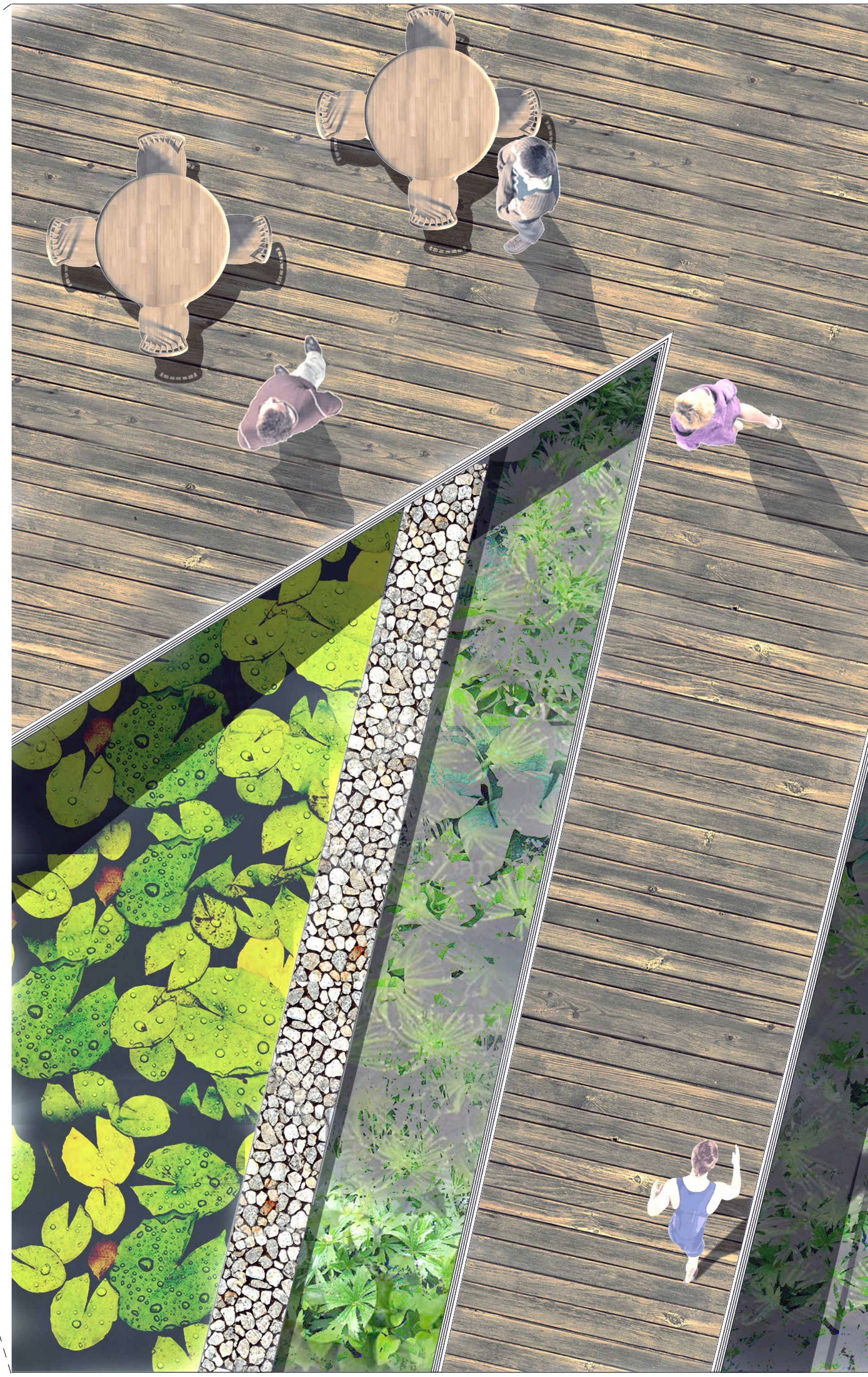

Water pump from pretreatment stage to water treatment basins
Maintanance acess hatch
Permeable paving
Collection pipe



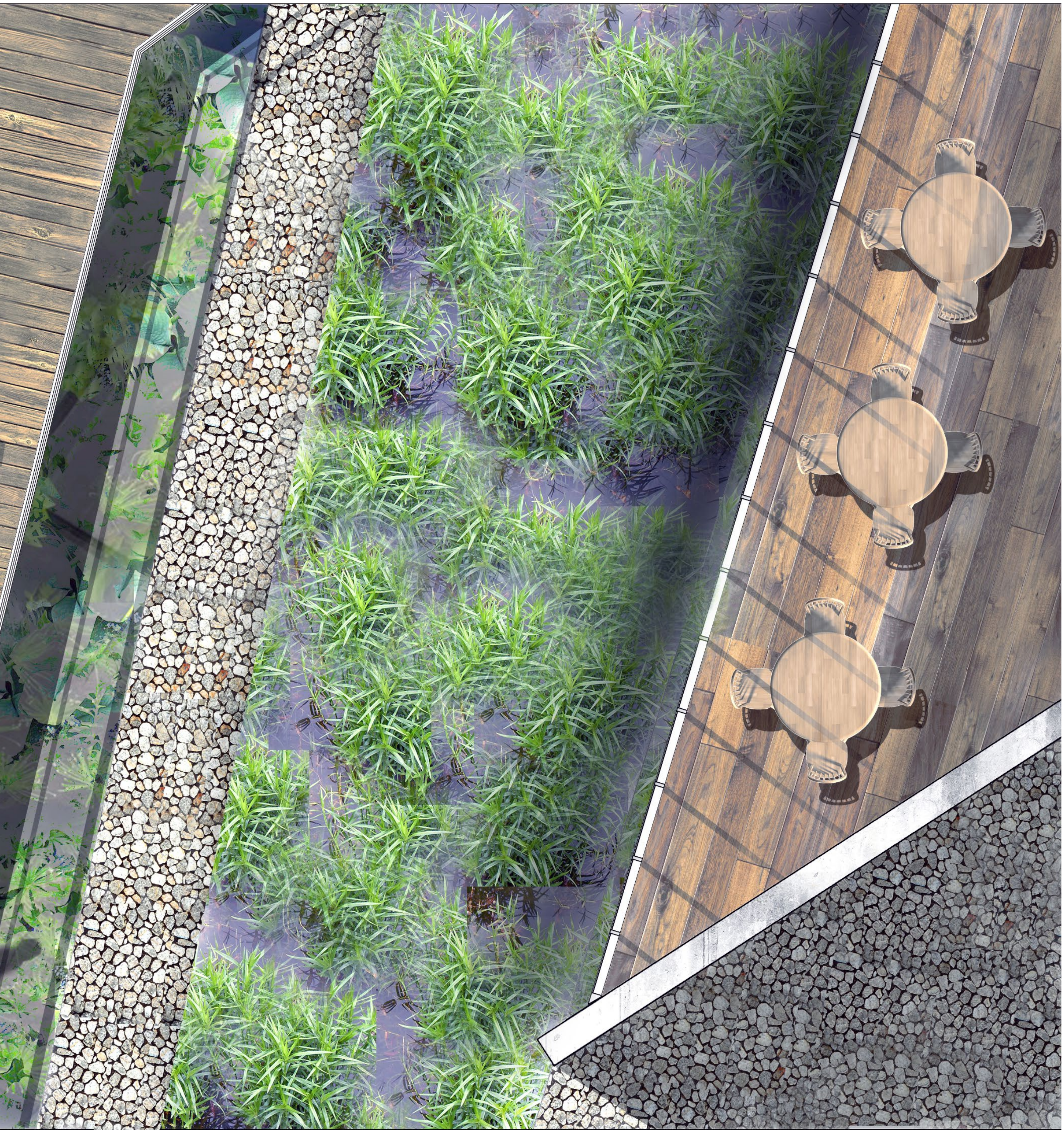
0 1 2 4m

3.53 *Plan detail showing the recreational pool.* Located close to the edge of the river, and at the very end of the water treatment process. The water in this stage is clean enough for people to put their feet into this shallow pool, experience the treated water and enjoy watching the river.





3.54 *Plan detail showing the elevated deck and the treatment cells.*



04

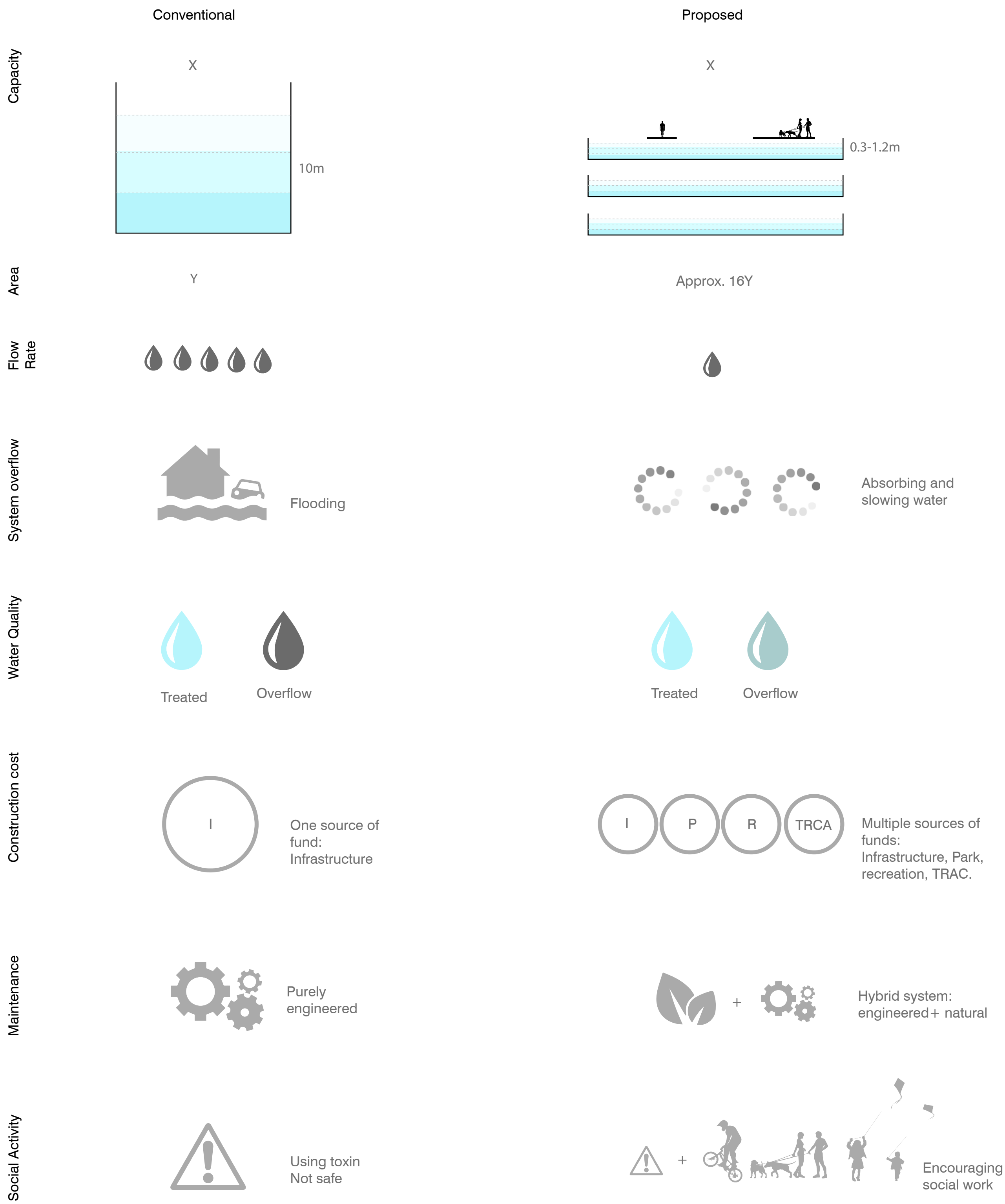
Conclusion

This thesis focuses on the development of public space at the water's edge, and tries to transform that space into a new interface that can be experienced as a valued and essential part of urban life. It integrates stormwater management with the cultural context of important historic sites, recreation areas, and the Don Valley facilities in a way that creates programmable urban open space while improving the environment. Through this vision, the Don River will be productive again as what it used to be around 200 years ago. This vision provides accessibility to natural water ways while introducing new public walkways, and integrates these areas and associated infrastructure into the existing urban cultural landscape.

Through this perspective, consideration of the environment becomes an integral part of the way the system functions. The design proposes realistic strategies of how bioremediation process might be employed within parkland areas, helping to heal urban riverfront areas that have suffered rapid urbanization and concentrations of toxins.

It is important to recognize the significance of this proposal's vision to the future of urban infrastructure. Water management within the design strategy is based on reconfiguration of cities' stormwater systems to reduce reliance on expensive engineered solutions that do not include generative biological structure. This thesis has challenged the engineered conventional approaches to infrastructures that have limited them only to solving utilitarian problems, and explores the need to weave infrastructure into public spaces in cities.

Figure 4.1 illustrates a comparison in which strengths and weaknesses of the proposed and conventional method of treating the water's edge and the infrastructure associated with that is compared in broad. The conventional technology might be considered to have some significant advantages. For example, with the same capacity of water in both systems, the proposed method will have a surface area which is 16 times more than the conventional solution since it uses a decentralized system which is spread out on the ground surface. However, in the case of a system overflow, the conventional method will be more dramatic in the case of a flash flood



4.1 A comparison between a centralized/conventional and decentralized/proposed stormwater infrastructure illustrating the pros and cons.

condition. However, the proposed method will be much gentler due to its ability to absorb the water through the development of the cellular system. Instead of having a maximum flow through the entire channel, the proposed method controls peak and flows of river through localized infrastructure which absorbs and slows water.[1]

Rather than simply elevating buildings or dramatically increasing the stability and quantity of urban ground, this project does the inverse by incorporating calculated runoff volume into its design parameters to encourage a gentle and more fluid relationship between architecture's artificial containment and the flux of natural environment.[1]

In terms of water quality, in a normal situation the water can be treated by either going through the conventional chemical system or the proposed cellular bioremediation system. However, in the case of overflow this thesis claims that the quality of water through the proposed system will be better since the conventional system will cause the sewage overflow while the water through the proposed system will be still partly treated through the landscape cells.

Although the construction cost of the proposed system will be higher, there exist funds available which could be divided into different agencies which might alleviate the cost. While the conventional system gets its fund only from infrastructure, the proposed system has access to multiple sources of funds, and draws that from different agencies such as infrastructure, park, recreational as well as Toronto and Region Conservation Authority (TRCA). Furthermore, in terms of using a decentralized network of infrastructure, the proposed system can be upgraded on an as-needed basis, which avoids the large costs of renovating a conventional municipal sewage network.[2]

The traditional vision toward infrastructures reserves water treatment plants as places for toxins and sewage that makes them unsuitable for public exposure. Moreover, it considers the water treatment process as a pure, engineered work which prevents public access in order to achieve its maximum efficiency and cost-effectiveness. However, this thesis explores a different approach. It tries to integrate the urban groundwater filtration, normally considered a toxic function, with low-density public recreation areas involving exposure to the environment. There will be still some areas within the proposed system which cannot easily be placed beside people relaxing, but in general the idea of making a balance between public realm and technical support for the water filtration is core to this thesis.

Challenges

With all of the benefits and opportunities that have emerged from this approach, there are of course a number of challenges that accompany projects like the one proposed in this thesis.

The first challenge would be to address the increase in cost compared to the existing solutions. In addition, the implementation of this project through the city could be a substantial challenge. Such a multi-functional and integrated project requires close collaboration among agencies such as Toronto Conservation Authority, different planners, city councilors, engineers, and public work officials.

There is a potential danger using the paths adjacent to the bioremediation pools. The walkways interwoven with the pools might not be safe enough for toddlers and cyclist due the depth of treatment cells. However, the kids are always accompanied by their parents who are aware of this potential risk to protect them. On the other hand, the elevated boardwalks and decks are equipped with handrails all the way along their edges making them safe for kids to play.

There is also a question of health issues and by-law requirements in reusing the stormwater management for public recreational water use in Toronto. For instance, the design includes different sets of treatment pools, which involve significant maintenance areas that include spaces for dredging equipment, moving different grades of fill and plant matter around to suit constantly evolving conditions between the different cells. In addition, toxic sludge extracted from city groundwater, and the

4.2 Potential locations throughout the city of Toronto for the proposed system.

quasi-agricultural functions of bioremediation natural plant management are not compatible with public access. The proposed design strategy intends to reconcile the maintenance/technical realm to the public realm. However, in a typical park design in the city these two realms are totally separated from each other. Therefore, the proposed public areas may not pass the same safety standard as the typical existing public areas and parks in the city. However, case study examples such as Naturbad Riehen project using a natural swimming pond could be used to show how other developed countries have integrated the naturally treated water into public activities.

Visions for the Future

The design strategy in this thesis has been used as a test examination for three sites along the Lower Don. It is important to note that the same methodology can be adopted all the way along the Don River's edge, and particularly in its lower region, which has been degraded the most due to intense urbanization over the past decades. If this soft and decentralized approach can be adopted by Toronto's city planners in this area, this threshold.

will be transformed into a network of connected hybrid landscapes with various habitable terraced landforms which will be the destination of pedestrians and cyclists. It will be a new definition of public space at the water's edge, filled with momentary pauses to celebrate water and culture within the system of seasonally accessible boardwalks, decks, and walkways.

The scope of the proposal can also be extended into the rest of Toronto. In fact, this design solution could be quite transformative and this vision could be taken as a model for large-scale development of a new generation of the public space integrated with the infrastructure. We can imagine a vision of this spreading through the multiple ravines of the city and parks and bridges, or simply wherever the city needs transitions between its land and water.

This thesis proposes a model of hybrid landscape that will occupy a middle space between the urbanized inner city and the natural environment. In this way, this proposals aspires to a level of resiliency with regard to long-term environmental, social, political, and economic shifts in that this landscape can be considered truly sustainable, responsive, and adaptable over the long term.[3]

APPENDIX

Functional space program

Cafe program

SPACE	Unit	Quantity	Area Per Unit SqF	Toral SqF
Indoor Space				
Sitting Area	Four sit table	10	36	360
	Two sit table	14	20	280
Kitchen	Counter	1	45	45
	Preparation Area	1	180	180
	Storage	1	100	100
	Commercial Range	2	86	172
Loading Area		1	430	430
Staffs' Closet		5	64	320
Furnace Room		1	161	161
Electrical Room		1	45	45
Washroom-Women	WC	4	90	360
Washroom-Men	WC	2	90	180
	Urinal	3	60	180
Outdoor Space				
Dinning Terrace	Six sit table	3	54	162
	Four sit table	18	36	648
	Two sit table	10	20	200
Bike storage	bicycles	26	20	520
River Boardwalk		1	11000	11000
Water filteration facility				
Equipment Storage		1	700	700
Storage of consumables and materials		1	1100	1100
Fallow Pools		10	280	2800
Staging Area		1	430	430
Work Area		1	4300	4300

Treatment plants used in the process of bioremediation

CONTAMINANT	PLANT	REFERENCE	SOURCE OF CONTAMINATION
Phytoremediation of Metals			
Cadmium	Indian mustard	Dushenkov et al., 1995	Industry process and roal pollution
	Water milfoil (Myriophyllum spicatum)	Wang et al., 1996	
	Duckweed, water hyacinth	Zayed et al., 1998; Zhu et al., 1999	
Chromium	Indian mustard	Dushenkov et al., 1995	Industry process and roal pollution
	Water hyacinth	Zhu et al., 1999	
Copper	Indian mustard	Dushenkov et al., 1995	Industry process and roal pollution
	Water milfoil (Myriophyllum spicatum)	Wang et al., 1996	
	Duckweed, water hyacinth	Zayed et al., 1998; Zhu et al., 1999	
Lead	Indian mustard	Dushenkov et al., 1995	Industry process and roal pollution
		Salt et al., 1997	
	Water milfoil (Myriophyllum spicatum)	Wang et al., 1996	
Manganese	Smart weed	Qian et al., 1999	Industry process and roal pollution
Mercury	Smart weed	Qian et al., 1999	Industry process and roal pollution
	Genetically altered Arabidopsis thaliana and tobacco (Nicotiana tabacum)	Meagher et al., 2000	
Nickel	Smart weed	Qian et al., 1999	Industry process and roal pollution
Zinc	Brassica juncea	Dushenkov et al., 1995	Industry process and roal pollution
Phytoremediation of Metalloids, Non-metals, Radionuclides, and Nutrients			
Metalloids/non-metals			
Arsenic	Egeria densa, and Lagarosiphon major,	Brooks and Robinson, 1998	sewage sludge
Selenium	Duckweed, water hyacinth	Zayed et al., 1998; Zhu et al., 1999	Open space/hillside runoff; nursery runoff; agricultural runoff
Nutrients			
Nitrgen	wetland microbes	Licht and Schnoor, 1993	Decaying Plant Debris, Wildlife, Fertilizers, Pet Waste
Phosphorous	Algae	http://www.richlandonline.com/Government/Departments/PublicWorks/Stormwater.aspx; Accessed: 9/2/2015	Soil and Rocks; Fertilizers; Pet Waste; Commercial Cleaning Preparations
Phytoremediation of Organic Contaminants			
Petroleum hydrocarbons/PAHS			

BTEX	Canadian wild Rye Agropyron Smithi, Western Wheat grass, Bermuda grass, Red fescue	Burken and Schnoor, 1998, 1999; http://www.superorg.net/archive/proposal/plant%20species%20phyto.pdf; Date Accessed: 9/2/2015	Grease, oil
Chlorinated solvents			
hene (PCE)	Waterweed (Elodea canidensis), a submergent aquatic plant	Nzengung et al., 1999	Swimming Pools, Irrigation
Pesticides			
Atrazine	Hybrid poplar (Populus deltoides × nigra DN34, Imperial Carolina)	Burken and Schnoor, 1999	
	Aquatic plants: coontail or hornwort (Ceratophyllum demersum), American elodea or Canadian pondweed (Elodea canadensis), common duckweed (Lemna minor)	Rice et al., 1997a	
EDB	Koa haole	Newman et al., 1998	
Bacteria	Indian Mustard; Water Milfoil	http://www.richlandonline.com/Government/Departments/PublicWorks/Stormwater.aspx; Accessed: 9/2/2015	Pet Waste, Animal Feeding Operations

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