IDENTIFICATION MECHANISM AND DESIGN STRATEGIES FOR STREAM DAYLIGHTING IN VANCOUVER

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Identification Mechanism and Design Strategies for Stream Daylighting in Vancouver

by

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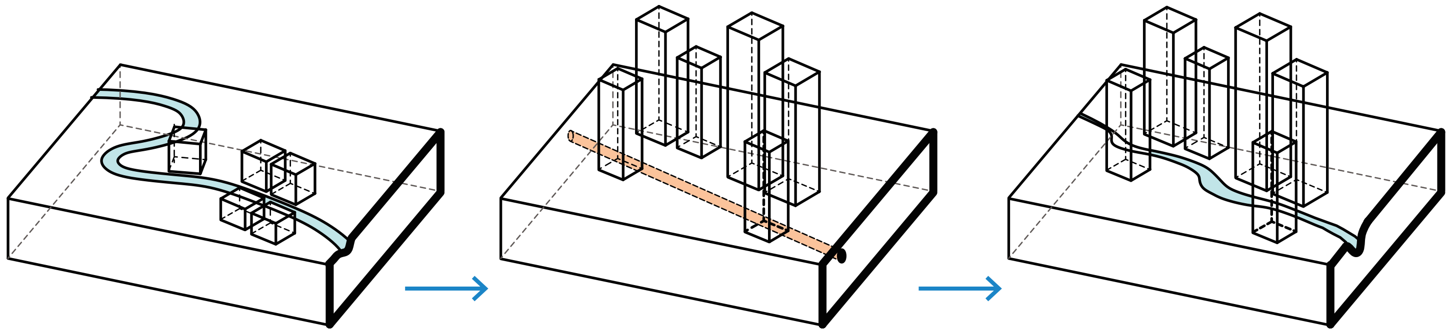
INTRODUCTION

Before massive urban development took place, natural features dominated the landscape. Many cities were largely wilderness with creeks and streams that provided valuable habitats for diverse wildlife. However, as cities developed rapidly, fast urbanization and population growth demanded more roads, buildings, and infrastructure, resulting in pollution and ecological degradation. As a result, many streams were polluted, diverted and buried in concrete pipes underground. The once vibrant river corridors became hidden and were inaccessible to the public and wildlife.

By the 1960s, nature has been recognized as a valuable asset to cities. People began to realize the ecological and social benefits of urban streams, and more efforts were made in maintaining natural waterways and restoring urban streams.

Stream daylighting is the process by which a concealed stream is deliberately exposed to once again flow on the Earth's surface (Pinkham, 2000). Uncovering buried streams could bring about a myriad of ecological, recreational, and aesthetic benefits to cities and neighbourhoods, such as improving water quality, providing natural habitats for wildlife, and enhancing public open spaces with amenities.

Despite the benefits of daylighting urban streams, there are challenges and trade-offs that need to be taken into account. Implementation of daylighting projects can be very costly, and not every daylighting project will result in commensurable ecological and social benefits to its cost. Identifying proper sites for stream daylighting projects and adopting appropriate design strategies are very important for the success of a daylighting project.



stream flowing in the city — *stream buried in culverts* — *stream brought back to daylight*

In this research project, current practices of urban stream daylighting are investigated in terms of their benefits and challenges. With a focus on the Vancouver context, current daylighting projects are studied, and opportunities for uncovering buried streams in the future are identified through a spatial overlay approach. Using this approach, a section of Tatlow Creek in the Kitsilano neighbourhood is identified as one potential daylighting site, and a concept design proposal is developed for it. This proposal explores stormwater management strategies on a neighbourhood scale, as well as design strategies for daylighting this creek within Tatlow Park and Volunteer Park.

Daylit stream in Kalamazoo, Michigan
(Image by Downtown Development Authority, City of Kalamazoo)

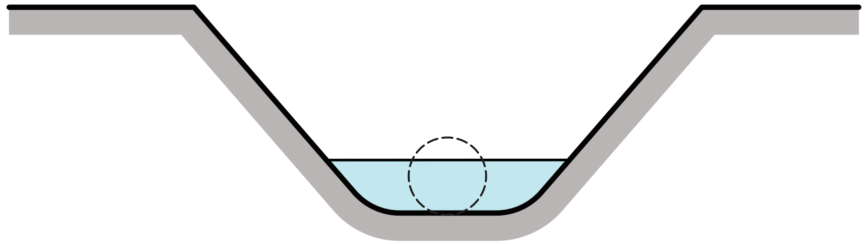
LITERATURE REVIEW

What is Daylighting?

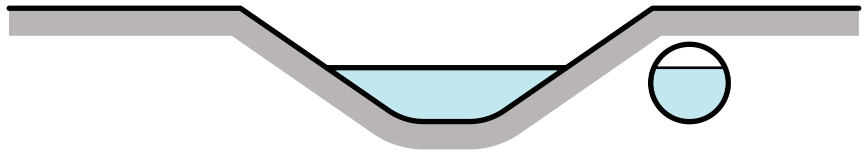
Richard Pinkham, commonly viewed as the leading author on stream daylighting, defined daylighting as "the deliberate exposure of some or all of the flow of a previously covered river, creek, or stormwater drainage... Daylighting re-establishes a waterway in its old channel where feasible, or in a new channel threaded between the buildings, streets, parking lots, and playing fields now present on the land. Some daylighting projects recreate wetlands, ponds, or estuaries" (Pinkham, 2000). Pinkham pointed out that daylighting can be carried out in a wide range of situations, from vacant land to residential backyards, and from parking lots to open spaces (Pinkham, 2000). Schueler & Brown identified daylighting as a stream repair practice that opens up and extends the network of headwater streams in a sub-watershed, which "consists of unearthing and re-establishing surface streams that had been enclosed in the past by pipes or culverts" (Schueler & Brown, 2004).

Lost river: St Pierre River, Montreal (Image by Andrew Emond)

Full flow daylighting



Partial flow daylighting

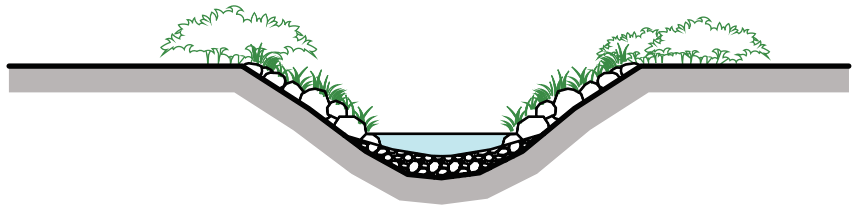


Depending on whether all or part of the stream flow is uncovered, daylighting projects fall into two categories: full flow daylighting and partial flow daylighting.

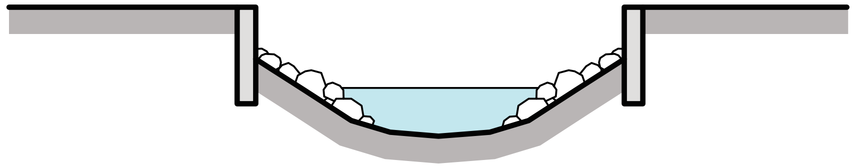
- Full flow daylighting uncovers the whole pipe and brings the stream to daylight completely.
- Partial flow daylighting uncovers part of the stream and leaves the rest in the culvert. This may be due to flooding control requirements, complexity of the utility lines underground, or other factors.

Daylighting projects also vary significantly in the degree to which a waterway is naturalized (Pinkham, 2000). Schueler & Brown pointed out that a daylit stream could be a naturalized stream, or a channelized/architectural stream. A naturalized stream is defined as having natural stream banks, a stable stream bed and "normal" stream geometry. A channelized/ architectural stream is created with hard bank stabilization practices to prevent the bed from erosion (Schueler & Brown, 2004). Symbolic or cultural restoration can be used to bring awareness of a buried stream. Instead of physically uncovering a culvert, it acknowledges the buried stream by various options such as installing interpretive signage, organizing educational programs, and marking historic stream pathways with tile (Pinkham, 2000). As local residents and practitioners gradually recognize the buried stream, opportunities may arise in the future for daylighting the stream.

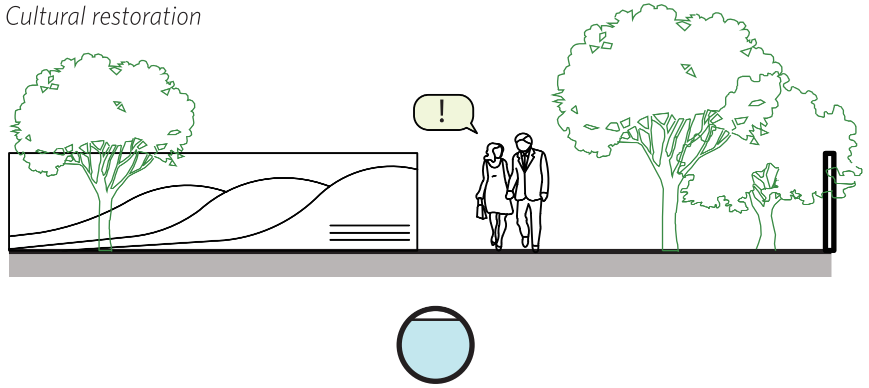
Natural restoration



Channelized/Architectural restoration

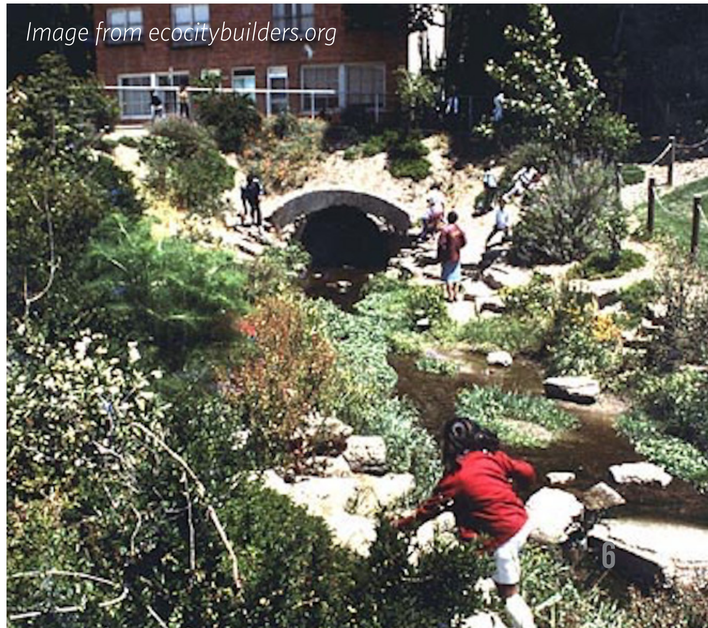


Cultural restoration

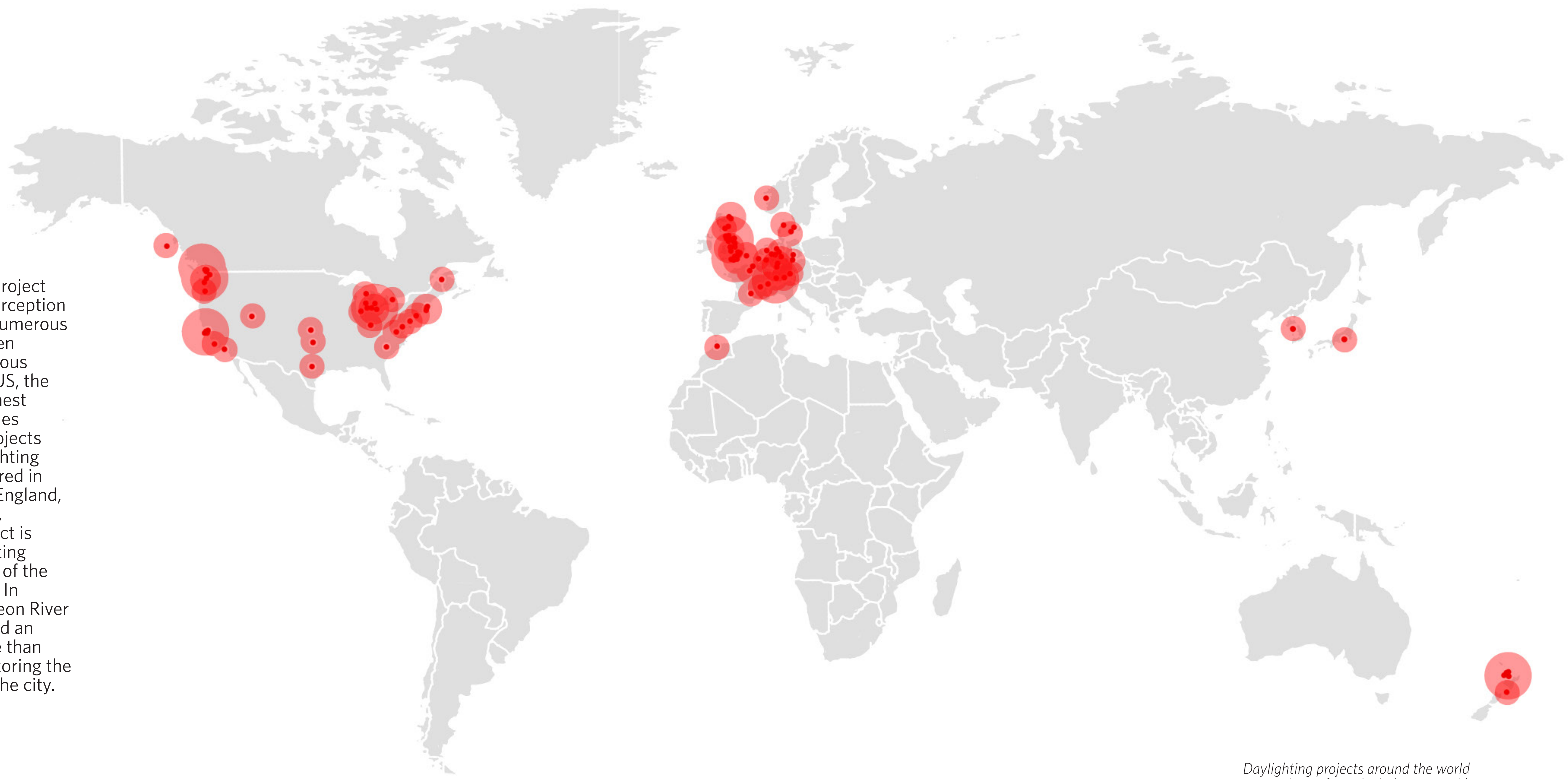


Urban stream daylighting was first sparked 40 years ago in Napa, California, USA. In the 1970s, the City of Napa undertook a redevelopment project and re-exposed a hidden stream (Pinkham, 2000). Although this project simply removed the top off of a concrete channel, it presented a new way of thinking about urban waterways.

The first real urban stream daylighting project is the restoration of Strawberry Creek in 1984. Strawberry Creek Park was built on an abandoned railroad right-of-way donated to the City of Berkeley by the Santa Fe Railroad company. A 200-foot section of the creek was removed from a culvert beneath an empty lot and transformed into Strawberry Creek Park. This daylighting project cost around $50,000. The park now offers a meadow, a picnic area, a children's playground, gardens, and sport courts. Native trees and groundcover flourish along the creek and in the uplands area.



The Strawberry Creek daylighting project marked an important shift in the perception of urban streams, and since then, numerous stream daylighting projects had been designed and constructed with various motivations and objectives. In the US, the San Francisco Bay area has the highest concentration of daylighting activities with over 20 stream daylighting projects (Pinkham, 2000). In Europe, daylighting activities and initiatives have occurred in many countries such as Denmark, England, Germany, and Switzerland (Sinclair, 2012). The Zurich daylighting project is one example of a city-wide daylighting initiative to restore streams as part of the stormwater management program. In Seoul, the ambitious Cheonggyecheon River daylighting project in 2003 removed an aging highway and uncovered more than three miles of the historic river, restoring the watershed as the "centerpiece" of the city.



Daylighting projects around the world (Data from daylighting.org.uk)

Benefits and Motivations

There is a substantial amount of literature that examines the benefits and motivations of daylighting projects.

Environmental Benefits

Daylighting restores ecological habitats that help to improve water quality and air quality (Pinkham, 2000). Many daylighting projects have significantly improved fish passage by removing migration barriers. The recreated aquatic habitats can support diverse wildlife.

Stream daylighting could be employed as a means to manage stormwater by municipalities (City of Vancouver, 1999). By adopting natural stormwater management strategies, a daylit stream can alleviate the burden to water treatment plants and protect the watershed from combined sewer overflow. Open waterways can also help to slow down runoff and facilitate stormwater infiltration, which reduces the chance of flooding and erosion (Pinkham, 2000).

Social Benefits

A daylit stream serves as valuable open space with substantial aesthetic value as a focal point of a park or green space, allowing for more vibrant public life (Pinkham, 2000). A daylit stream could be utilized as a tool by local schools for education purposes (Ekman and Murphy, 2000). Additionally, with more access to nature and the outdoor environment, residents could feel more connected to nature and their neighbourhood, and this could reinforce their sense of community. On a city scale, a daylit stream may be linked to urban greenways and improve the connectivity of the overall public space system.

Economic Motivations

Wild et al. found that although environmental objectives were the most common for daylighting projects, the ultimate "driver" for daylighting was often economic in nature. For example, in some cases daylighting was proved to be more affordable than replacing damaged or collapsed culverts (Wild et al., 2011). Additionally, with improved natural environment and neighbourhood vibrancy, a daylit stream can increase the value of nearby properties as well as benefit local businesses (Pinkham, 2000).

Challenges

Despite the significant benefits, daylighting could also encounter substantial technical, social and ecological challenges.

Technical Challenges

A myriad of technical issues can arise when uncovering a culvert. Site context needs to be considered, which includes soil and water flow, sediment condition and potential pollutants. A daylit stream must be carefully integrated into the overall urban stormwater management system with consideration of hydraulic performance. Channel geometry must be carefully designed for its gradient and discharge. Temporary water diversion is also required during the construction process (Pinkham, 2000).

Social Challenges

As a community may not be aware of an underground historic stream, comprehensive community outreach is necessary before carrying out the project. Expectations in the community may be conflicting as community members may be affected by the project in different ways. There are also safety concerns, as a stream may be considered a safety hazard to children or pets.

Institutional issues may arise that relate to the ownership of the property, responsibility for maintenance, liability issues, additional environment regulation issues, etc. (Pinkham, 2000).

Ecological Challenges

Daylighting a stream requires space along the new waterway. If the buffer area along the new waterway is limited, it would be very difficult to recreate natural channel geometry, and this will significantly limit the ecological benefits. Jones evaluated eleven daylighting projects in North America and found that most of the projects have low urban conservation value. Jones questioned the effectiveness of daylighting projects to realize urban conservation goals, as daylighting "fails to expose the entire watershed or provide adequate buffer zones or ecological corridors" (Jones, 2001). Regarding potential pollutants in soil, Baume raised the concern that daylighting may expose hidden toxins by stirring up toxic pollutants in the soil of industrial regions (Baume, 2010).

Costs

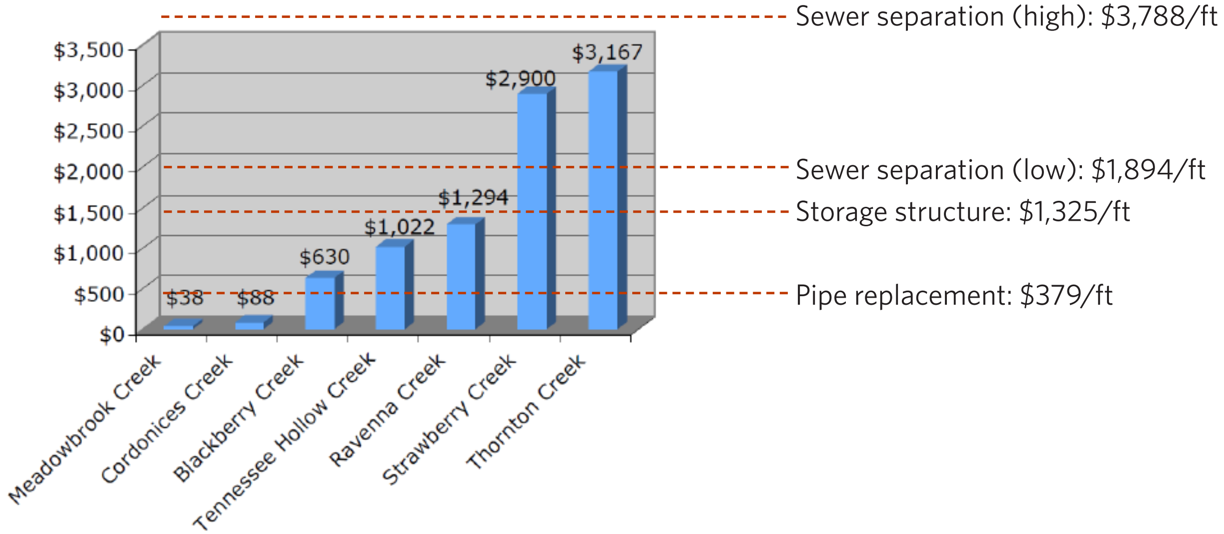
Daylighting projects can be very costly as they involve expensive activities and materials, including planning and design work, excavation and rough grading, hauling of fill, materials for in-channel structure and landscaping, as well as labour costs (Pinkham, 2000).

According to Pinkham, there is no "typical" daylighting cost, as each project varies considerably in the amount of excavation required, technical difficulties encountered, economies of scale in construction, etc. He pointed out that costs per linear foot may range from $15 to $5,000, and a general rule of thumb is $1,000 per linear foot of stream daylit (Pinkham, 2000). Schueler & Brown estimated the cost for each linear foot of stream daylit at $100 to $300, depending on the diameter of the pipe and the desired daylighting outcomes (Schueler & Brown, 2004).

Pinkham indicated that good design techniques, donations of services and materials, and volunteer labour could keep costs low if projects are expertly facilitated. Depending on location and the type of project, potential funding sources may include the budgets from city park boards, school districts, stormwater utility departments, and state or local environmental programs, as well as donations from local businesses and individuals (Pinkham, 2000).

While daylighting could be very expensive, a successful project may also generate significant economic benefits after completion. For example, Arcadia Creek was daylit as part of a flood prevention and downtown redevelopment plan at a cost of eighteen million dollars. The creek area is now a festival site, hosting events that generate twelve million dollars in annual revenues. Furthermore, annual property tax revenues near the restored creek have risen from $60,000 to $400,000 (Hamilton County Planning and Development, 2011).

Another way to evaluate the cost effectiveness of daylighting is to compare the cost of daylighting with that of replacing aging pipes and culverts (Buchholz & Younos, 2007). Smith compared the cost of daylighting ($38 to $3,167 per linear foot) and the cost of engineering solutions ($379 to $3,788 per linear foot) to flooding and combined sewer overflow problems in San Francisco. He concluded that daylighting alternatives could be cost comparable with conventional, infrastructure/material-intensive engineering solutions (Smith, 2007).



Capital costs of stream daylighting per linear foot in the San Francisco Bay Area and Seattle in comparison to alternative flood- and CSO-reduction strategies (Image adapted from Smith, 2007)

Feasibility Criteria

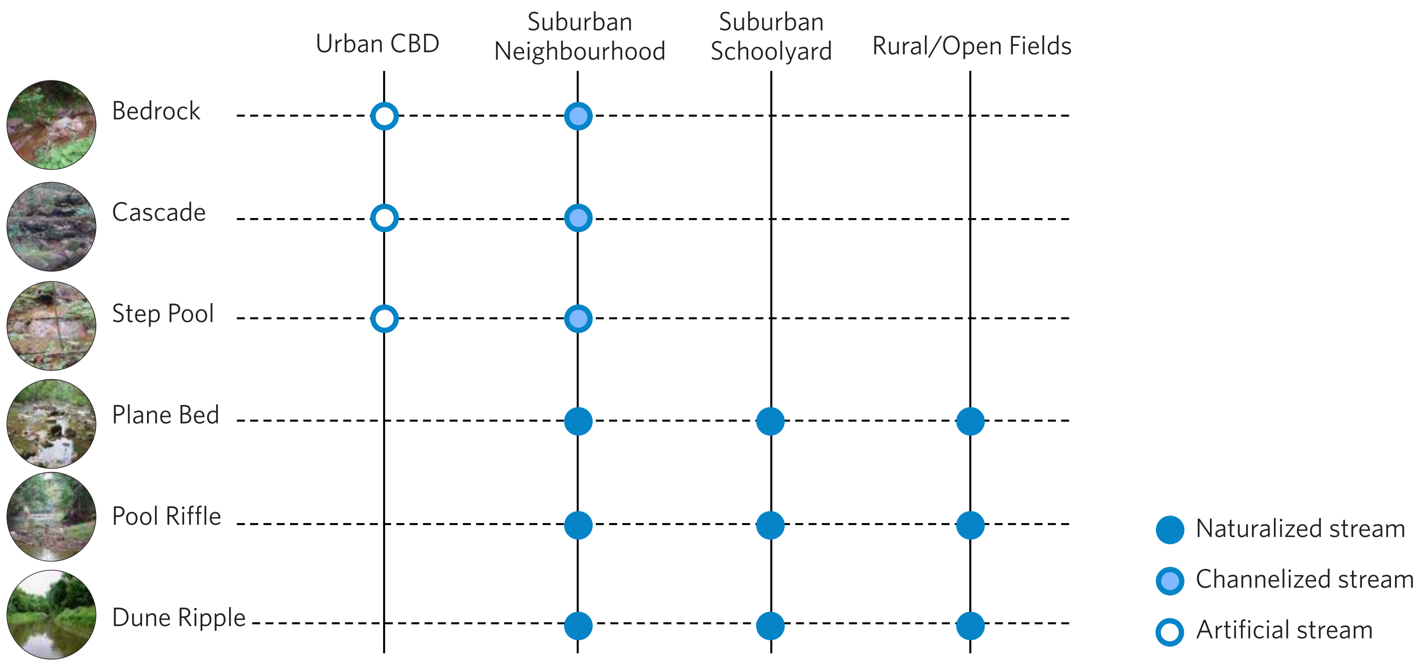
Clearly, not every hidden waterway can or should be daylit. Among the "doable" projects, not every one of them can be highly naturalized (Pinkham, 2000). Currently, most daylighting projects have been undertaken on a "trial and error" basis (Koshaley, 2008).

Pinkham identified a few "positive" criteria that contribute to the possibility of daylighting, including local support, funding opportunities, technical feasibility, and demonstration value. He also pointed out a few factors that make daylighting difficult or even impossible. These include buildings and extensive infrastructure over the culvert, "capture" of streams by combined sewer systems, high land values that preclude open space usage, steep slopes that would result in overly erosive stream velocities, high discharge rates due to upstream conditions, and sunk costs in recently culverted streams. Pinkham utilized these criteria to identify two out of eleven sites with high daylighting potential in "stream restoration and daylighting" projects in the Pittsburgh Region (Pinkham, 2001).

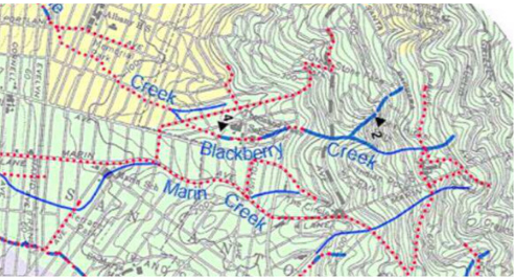
Similarly, Schueler & Brown identified several factors to assess whether daylighting is feasible. Most of these factors are related to the technical feasibility of daylighting a stream, including: outfall pipe diameters (the most cost-effective pipe diameter range is identified as 24 to 60 inches), presence of perennial flow, distance of unobstructed pipe, width of drainage easements or right-of-ways, depth of overburden above the pipe, invert of outfall in relation to stream, and connection with existing stream networks (Schueler & Brown, 2004).

Koshaley expanded the technical consideration to a wider context of urban economics and politics (e.g. property values, comparison of cost of daylighting and cost of repairing aging infrastructure), as well as institutional and ecological factors (e.g. habitat improvement, connection with existing stream networks) (Koshaley, 2008).

Regarding channel design and to what extent should a daylit stream be naturalized, Buchholz, Bork & Younos proposed a daylighting "Decision Matrix" for determining where to daylight and what kind of stream channel might work best in that location. A "Daylighting Design Matrix" combines six stream morphologies with four primary land use categories to create a quick reference chart for basic site selection and channel design. For example, a daylighting outcome for a highly built urban environment tends to be an artificial stream, while that for a rural setting tends to be a naturalized stream (Buchholz, Bork & Younos, 2007). As to how to determine which sites can not be daylit, three factors were summarized, including combined sewer systems, contaminated soils on site, and streams with poor stream health (Buchholz, Bork & Younos, 2007).



A "Daylighting Design Matrix" (Image adapted and redrawn from Buchholz, Bork & Younos, 2007)



Watershed map (Image from Creek and Watershed Map of Oakland and Berkeley)

Blackberry Creek in 1996 (Image by Wolfe Mason Associates)

Case Studies on Stream Daylighting

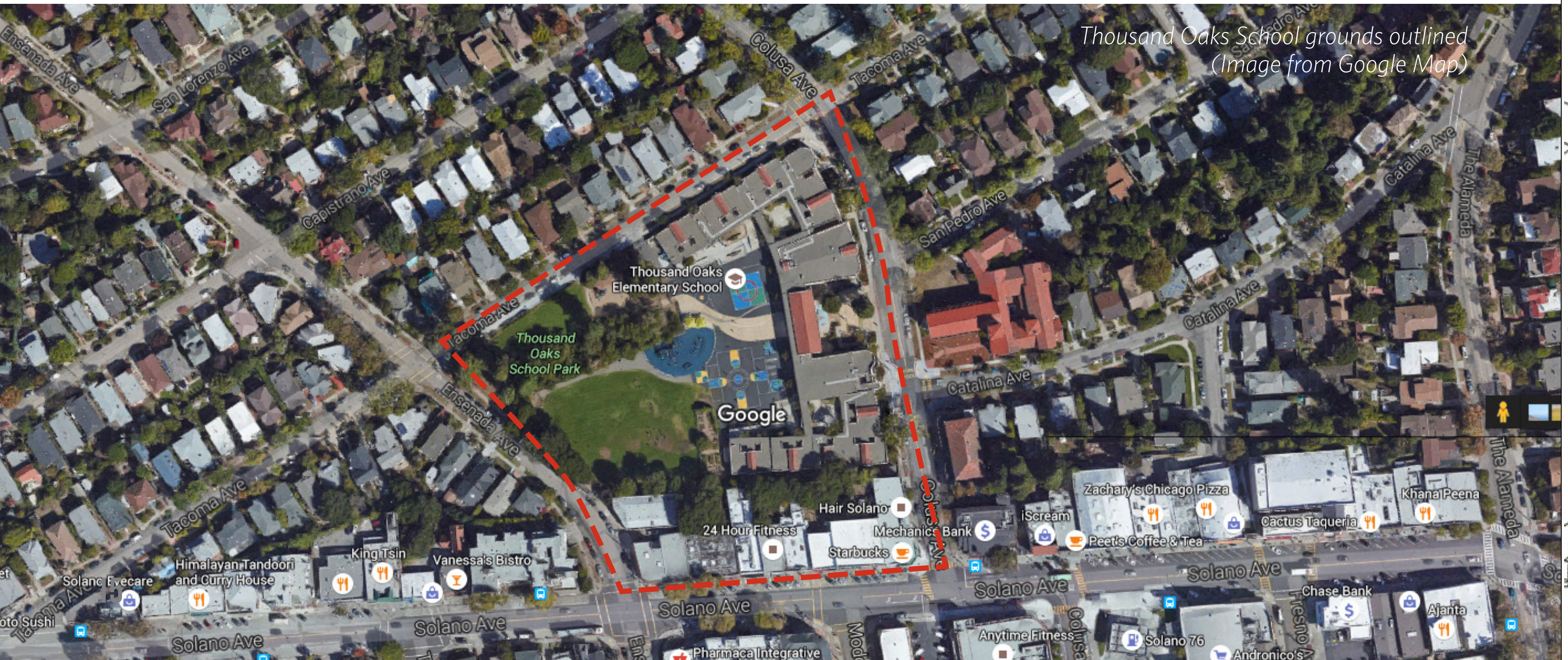
Blackberry Creek, Berkeley

Blackberry Creek was the first creek daylit on school grounds in Berkeley (Gerson, Wardani & Niazi, 2005). Blackberry Creek is a tributary of Middle Creek and runs into San Francisco Bay. It was buried in the late 1940s to 1960s due to urban development, and a portion of the creek was buried underneath Thousand Oaks Elementary School. After the creek was buried, this area experienced frequent flooding. When funds were available for upgrading the elementary school infrastructure, the idea of daylighting the creek was proposed as a means to mitigate flooding, as well as an education opportunity for the school as a living lab (Pinkham, 2000).

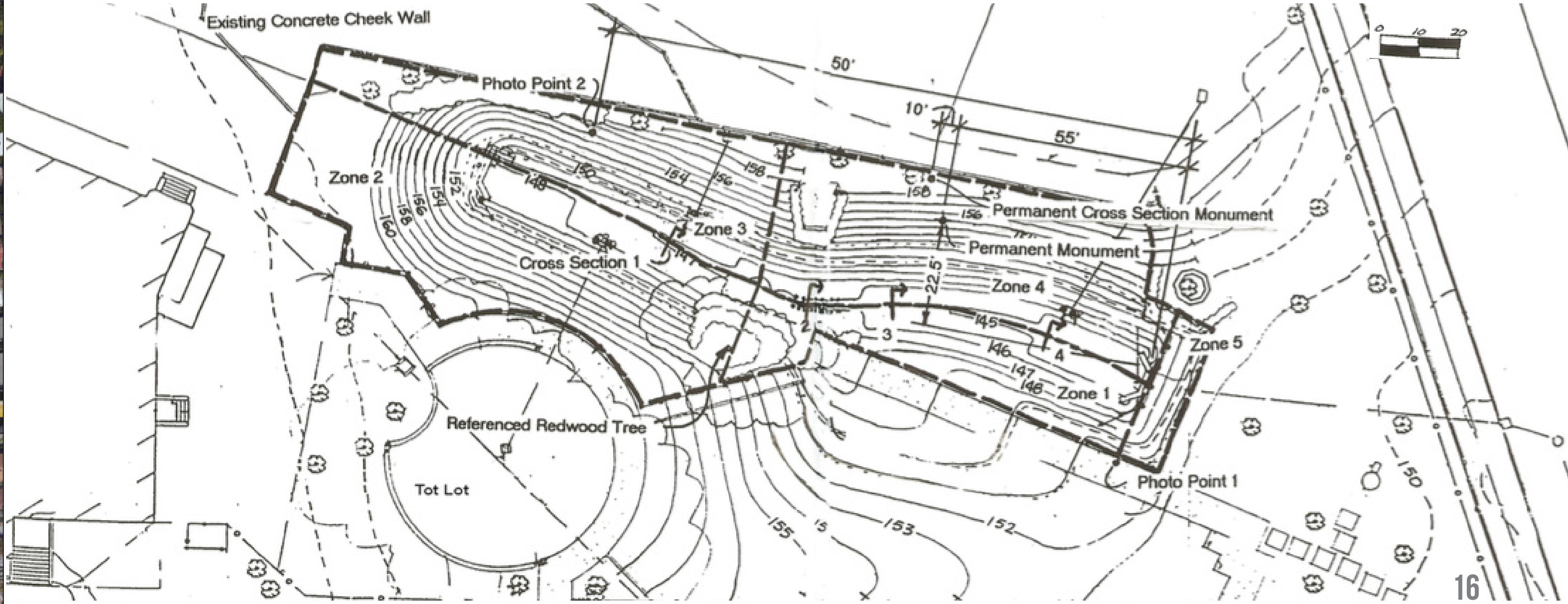
In 1995, a 200-foot section of Blackberry Creek was uncovered underneath the schoolyard by Wolfe Mason Associates in collaboration with the Urban Creeks Council (Gerson, Wardani & Niazi, 2005). To control the velocity and orient the channel, four shallow rock weirs were anchored in the stream bed. To control erosion on the banks, large rocks and other bioengineering techniques were utilized (Pinkham, 2000).

The daylit creek was contaminated with sewage after daylighting, rendering it inaccessible until 2003. Teachers at the elementary school used this as an opportunity to teach about environmental and local politics, and students successfully lobbied to investigate the source of contamination (Gerson, Wardani & Niazi, 2005). Presently, the daylit creek is used by the school in various curricula and provides numerous educational opportunities. Students learn to identify and understand organisms in the creek and investigate its connections to the larger watershed.

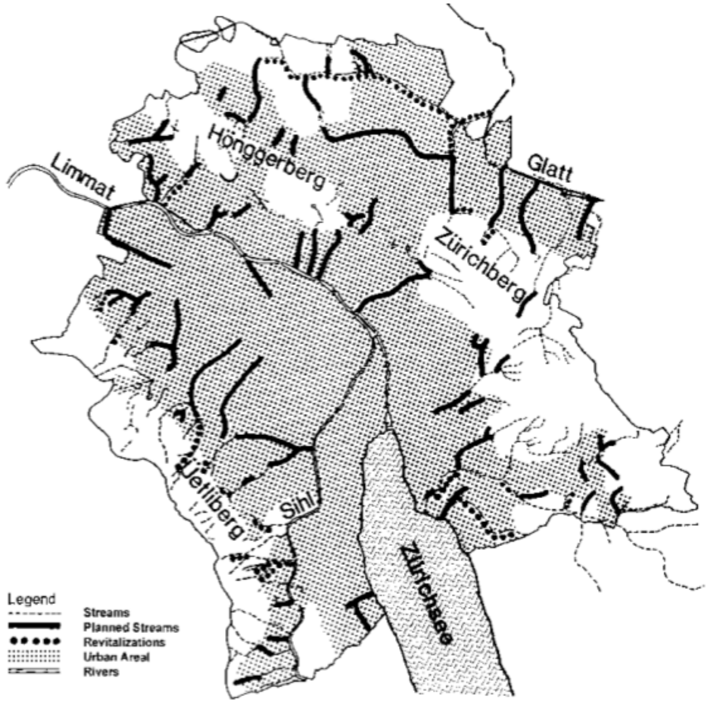
Image from acme.com



Thousand Oaks School grounds outlined (Image from Google Map)



Site Plan (Image from Wolfe Mason Associates, 1995; Askew 1996)



The Zurich "Stream Day-lighting Program"
(Image from Conradin & Buchli, 2008)

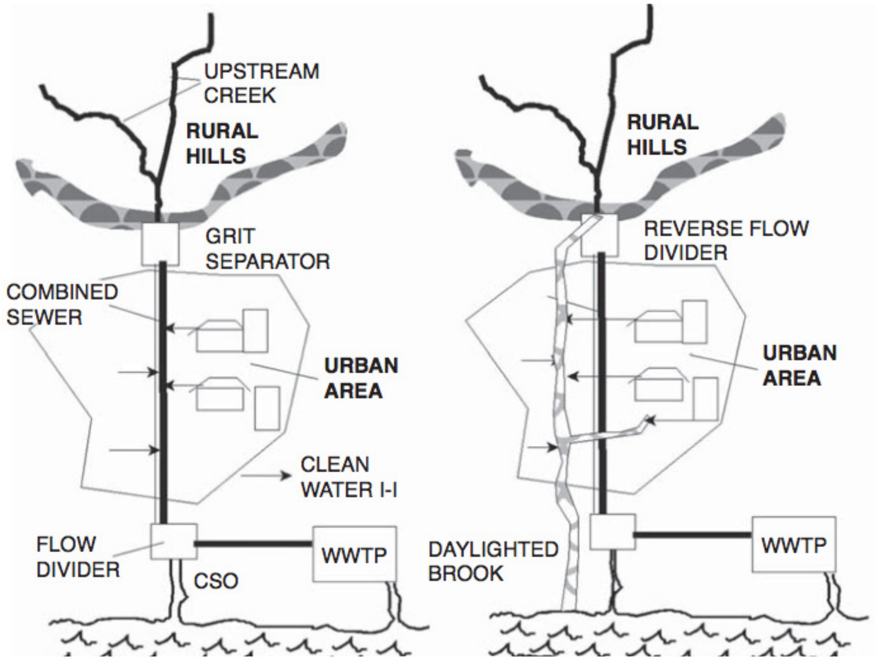
"Stream Day-lighting Program", Zurich

During the last 130 years of urban development, about 100 kilometers of open waterways disappeared from Zurich. Numerous small mountain streams were culverted upon entry into populated urban zones. Most of them were buried, channeled and mixed into the combined sewage system. As a result, about one third of the total flow in the combined system was clean water (Conradin & Buchli, 2008), adding significant pressure to the city's sewage treatment plants.

From the 1990s, Zurich started to modify the combined sewer system to a partially separated sewer system. The "Stream Day-lighting Program" was a city-wide program in the context of Zurich's urban drainage master plan. It was estimated that over 30 kilometers of brooks could be constructed in the city (Conradin & Buchli, 2008).

Zurich's naturalized "brook system"
(Images from ez.ch)

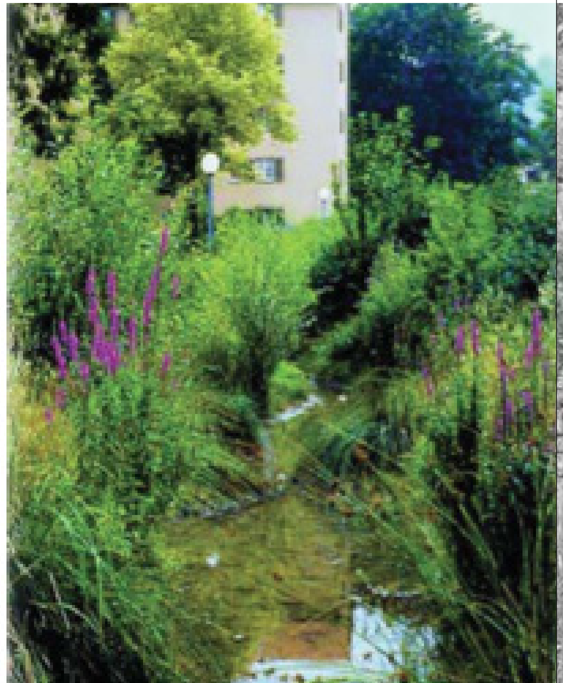
The diagram below compares the Zurich sewer system before and after implementing the stream daylighting concept. The original sewer system intercepted the upstream creeks with a grit separator before entering urban areas, and clean flow was mixed into the combined system. The clean water input significantly increased the total sewage sent to the wastewater treatment plant, as well as the frequency of combined sewage overflow (Conradin & Buchli, 2008). In the new sewer system, the city has created natural-looking surface conduits for clean water, and they serve to divert clean water from streams, springs, yard drainage, etc. Instead of sewer separation, streams were daylit and conveyed while the combined sewers containing the original stream flow were left in place (Novotny, Ahern & Brown, 2010).



Zurich's sewer system before and after implementing the stream daylighting program
(Image from Novotny, Ahern & Brown, 2010)

During the last 15 years, 16 kilometers of streams were daylit or revitalized in the city. This initiative was very effective in terms of separating the combined sewer system; of the estimated 800 L/s of clean water in the sewer system, approximately 300 L/s has been diverted to the new streams, allowing for a significant reduction of load onto the sewage treatment plant. The new brooks have become important assets to urban landscape and are especially popular with children, where they coincide with playgrounds and schools. They are also important assets in landscape and residential planning projects (Conradin & Buchli, 2008).

Zurich's naturalized "brook system"
(Images from ez.ch)



Cheonggyecheon River, Seoul

Historically, the Cheonggyecheon River runs through the heart of Seoul and has a history of flooding and sanitation issues. In the 1950s, the city decided to resolve these issues by installing concrete over the creek, and in the 1970s, the Cheong Gye Freeway was constructed on top of the buried creek (Linton, 2009).

After several decades, the aging elevated freeway and concrete deck covering the stream posed significant safety risks to the public and needed to be repaired. However, the city decided not to reinvest in the aging infrastructure, but instead, to bring back the historic stream to the city. From 2002 to 2005, the freeway was torn down and the historic stream was uncovered, with about 6 kilometers of the stream daylit. This ambitious project cost around $380 million USD (Linton, 2009).

The biggest concern for this project was the potential traffic congestion caused by tearing down the freeway. To combat this issue, ten automobile bridges were proposed to connect the two sides of the Cheonggyecheon River (Landscape Architecture Foundation, 2011). The city also invested in public transportation, including creating bus-only lanes and pedestrian

Cheong Gye Freeway in the 1990s
(Image from Seoul Metropolitan Government, 2006)

Cheong Gye Cheon Area
(Image from Seoul Metropolitan Government, 2006)

Historic Cheonggyecheon River
(Image from Seoul Metropolitan Government, 2006)

bridges, reforming parking policies, etc. This was to create a pedestrian-oriented environment rather than an automobile-oriented environment.

Currently there are many beautiful features around the daylit stream including art installations and pedestrian signature bridges. Moreover, the stream also increases biodiversity and helps to improve water quality. Native willow swamps, shallows, marshes and a fish spawning ground were constructed along the river, creating habitats for fish, amphibians, and birds.

This project restored the watershed as the centerpiece of the city, attracting an average of 64,000 visitors every day. If the original Cheong Gye freeway had remained, it would have required $90 million USD to repair the aging structure. Although this is $260 million USD less than the cost of the current option, the daylit stream serves as a catalyst for an estimated $1.98 billion USD worth of capital investment in the Cheonggyecheon area, which may not have otherwise been invested (Landscape Architecture Foundation, 2011).

One challenge for this project is that water is not naturally present in the Cheonggyecheon River for most of the year, except during the summer rainy season. This is because the upstream flow in the watershed was lost during the urbanization process. To address the variable flow of the Cheonggyecheon River, water from the Han River 15 kilometers

Image by Travel Oriented

downstream is treated and pumped to the Cheonggyecheon to create a consistent flow with an average depth of 40 centimeters (Novotny, Ahern & Brown, 2010). This requires significant energy consumption. Another limitation of the project is that it does not adopt other integrated stormwater management strategies, such as pervious pavement or other techniques to facilitate stormwater infiltration.

Nevertheless, daylighting the Cheonggyecheon River was a very inspiring and proactive endeavour in a highly urbanized area that brought nature back to the city.

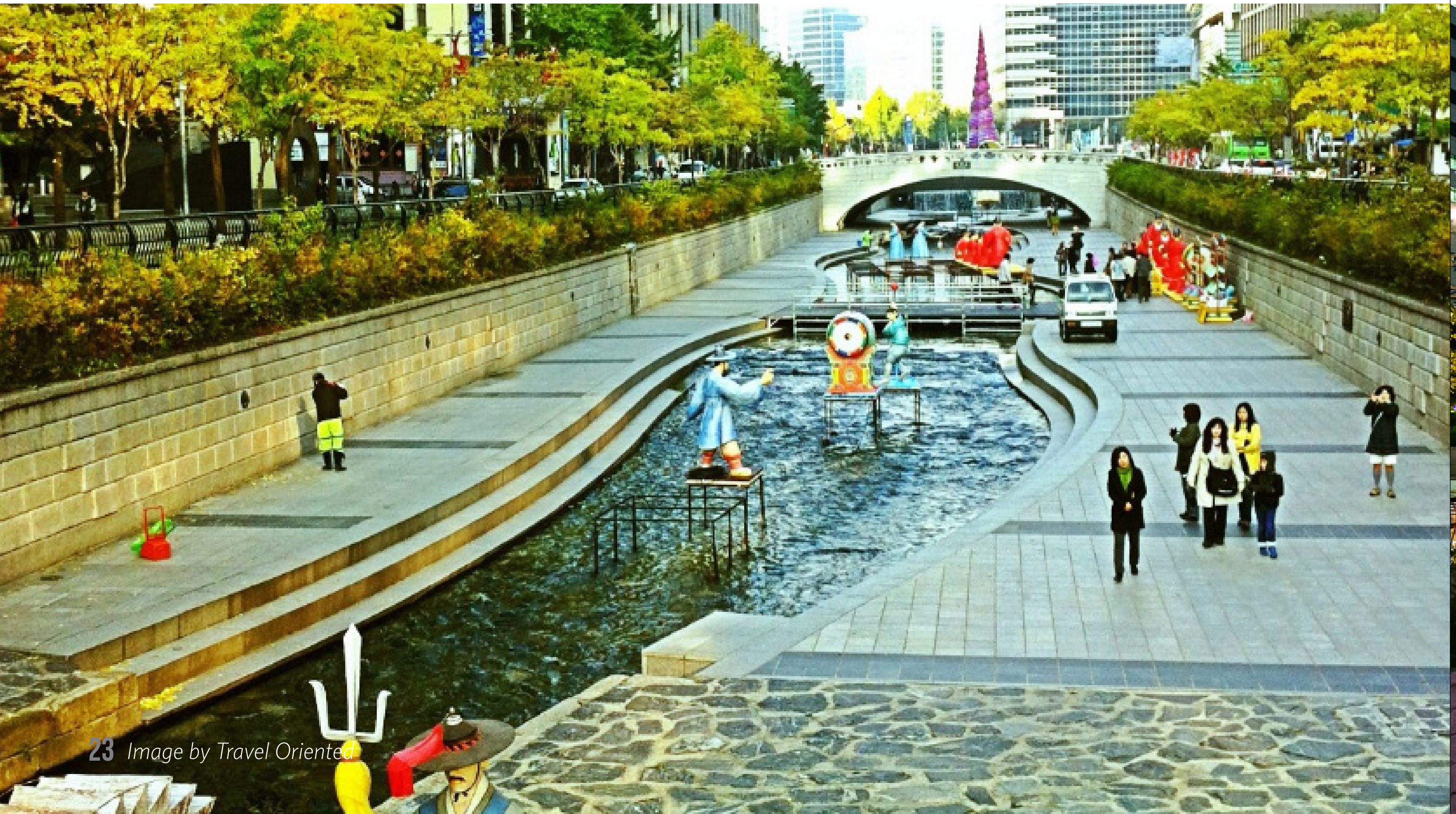


Image by Travel Oriented

Summary

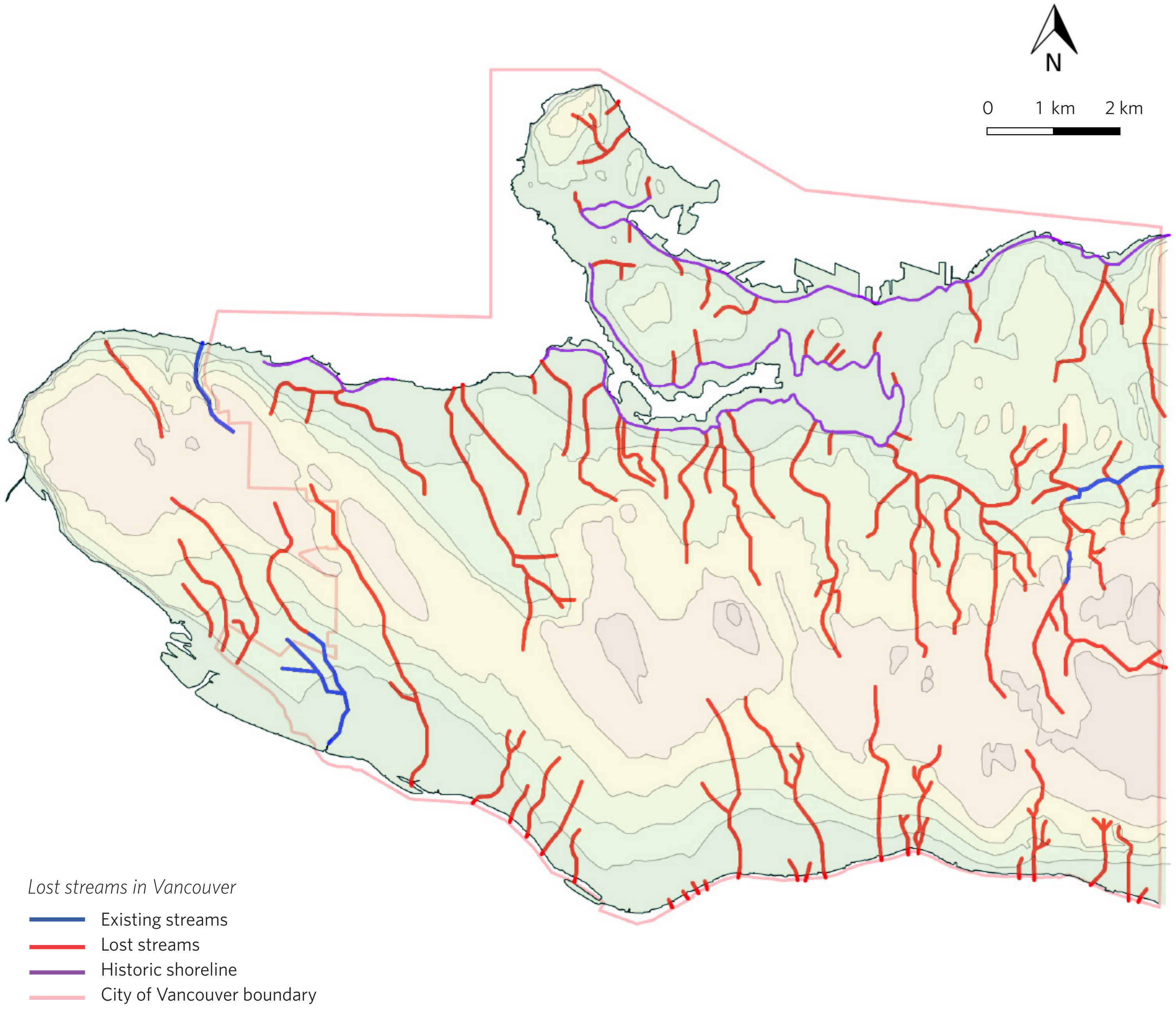
Daylighting a buried stream could result in significant benefits to urban ecology and local communities, such as improving water quality and natural habitats, reducing surface runoff and combined sewer overflow, and providing open space for local communities. However, daylighting could be very expensive, and it may be faced with a myriad of technical, social, and environmental challenges. If not conducted properly, the ecological and social benefits of a daylighting project may be limited. Therefore, two factors are very important in the success of a daylighting project: identifying proper sites with the most potential and technical feasibility, and utilizing appropriate design strategies to daylight the stream.

Image by Anthony Shane

DAYLIGHTING IN A VANCOUVER CONTEXT

Before massive urban development took place, Vancouver was largely wilderness with numerous creeks and streams. However, as the city rapidly developed, most of Vancouver's creeks and streams were placed in culverts underground.

Daylighting activities in Vancouver started from the 1990s. There were several "open culvert" daylighting projects that uncovered buried waterways, such as the Still Creek Enhancement Project, and the Spanish Creek Restoration Project. Other daylighting and restoration projects were aimed at improving watershed health, managing stormwater in a more sustainable way, and increasing community awareness of lost creeks. These included the Creekway Park Project and the St. George Rainway Project.



Lost streams in Vancouver

Relevant City Policies

Currently the City of Vancouver has completed or has been working on a series of plans and policies to facilitate stream restoration and sustainable stormwater management.

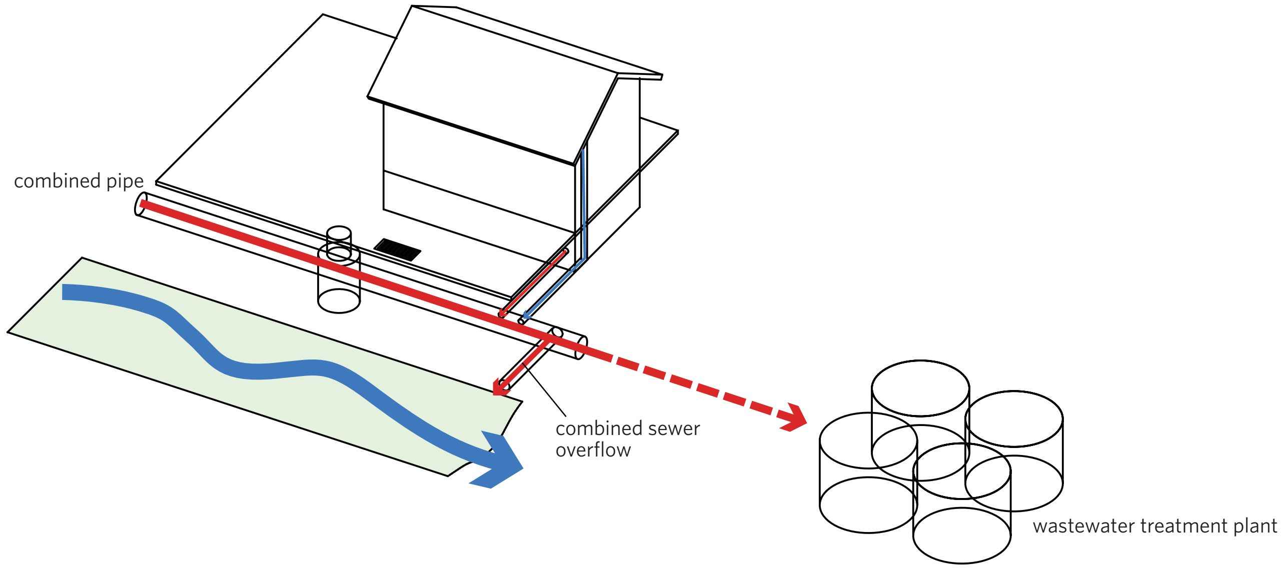
Combined Sewer Separation Program

Metro Vancouver operates a regional system to collect and treat wastewater, including 530 kilometers of trunk sewers, which are large pipes that connect to municipal sewers, and 5 wastewater treatment plants (Metro Vancouver, 2015).

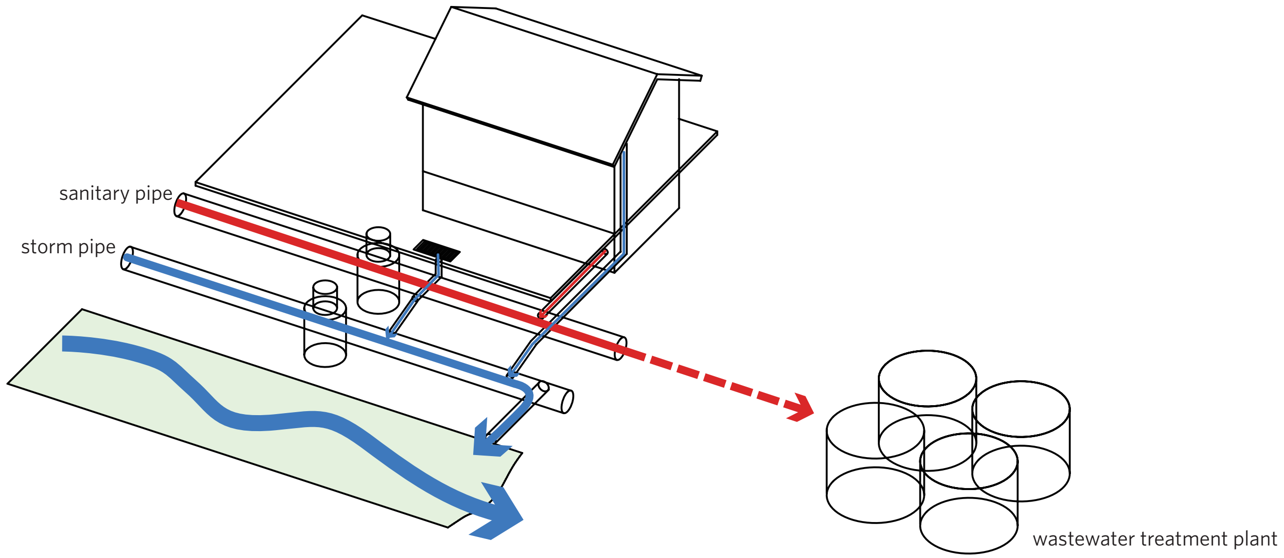
In areas with a combined sewer system in Vancouver, sanitary water and stormwater flows together into municipal sewer pipes once it leaves a building, and then into regional trunk sewers. Pumping stations keep wastewater moving throughout the system until it reaches the Iona Island Wastewater Treatment Plant. This system may generate combined sewer overflow in times of storm events and result in pollution of nearby waterbodies. In areas with a separated sewer system, only sanitary water flows into the treatment plant, and stormwater goes into a separate system, which discharges directly into the nearest body of water.

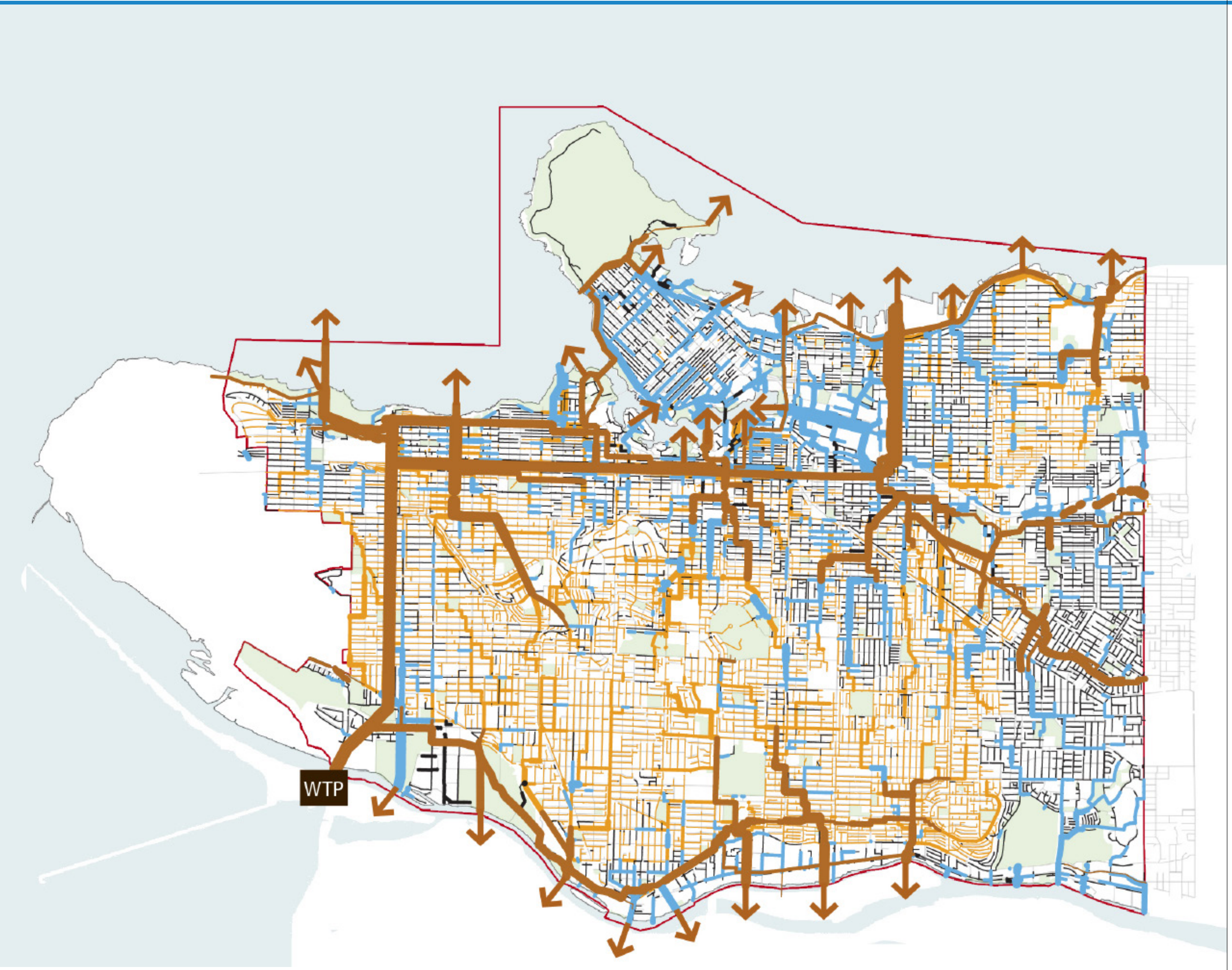
The City of Vancouver is working towards the Province of BC's environmental goal to eliminate sewage overflows by 2050. The combined sewer separation program is currently in progress to separate combined sewer pipes, so that storm drains carry storm runoff separately from sanitary water. So far, the city has a separated sewer system in the following areas: Downtown, West End, Fairview, Hastings, Killarney, Mt. Pleasant, Renfrew, Burrard Inlet and Fraser River shorelines. By 2020, the city plans to complete the sewer separation program in the following areas: Grandview, Kitsilano, Point Grey, Shaughnessy, and Sunrise (City of Vancouver, 2013).

A combined sewer system carries both stormwater and sanitary water into the wastewater treatment plant.

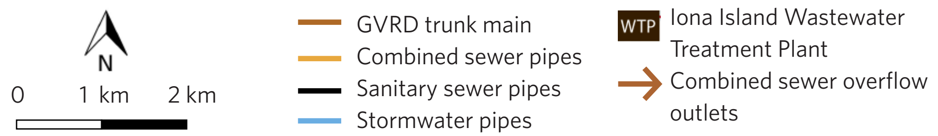


A separated sewer system carries stormwater and sanitary water separately.





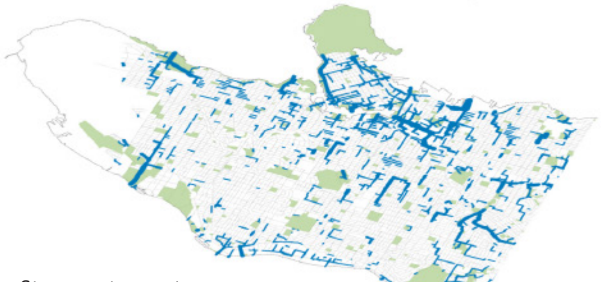
Vancouver sewer system



GVRD trunk main

Combined sewer system

Sanitary sewer system



Stormwater system

Stream Restoration and Daylighting

The City of Vancouver recognizes a variety of benefits from stream restoration, including serving as an educational tool for stream and environmental stewardship, a symbol of history, an aesthetic community amenity, and an enhancement to the natural environment (City of Vancouver, 2012). During the Still Creek Enhancement Project, the city worked with volunteers to restore the lost stream to a more natural state above ground.

Greenest City 2020 Action Plan

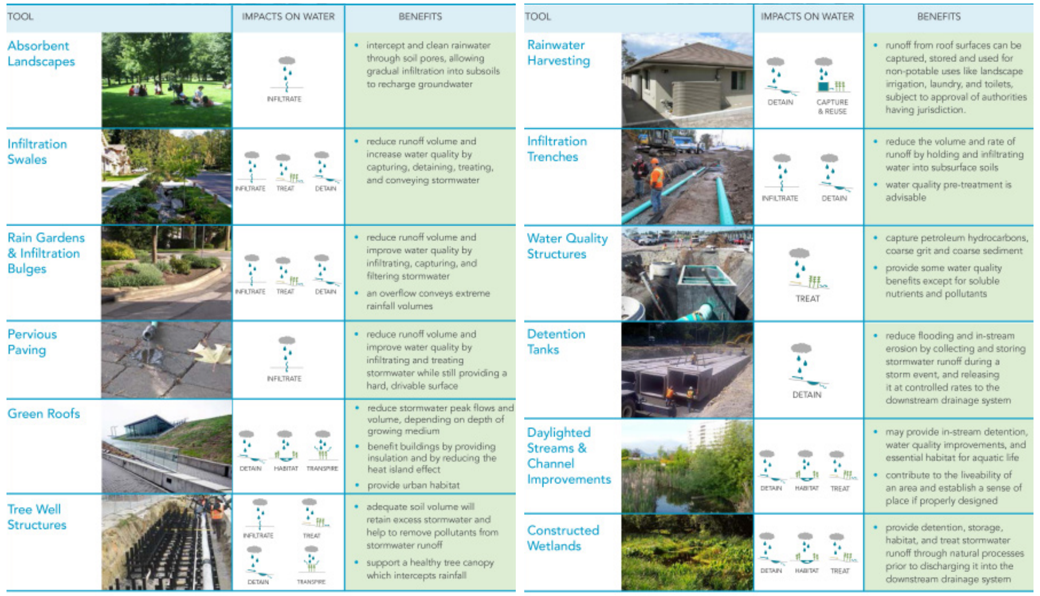
The Greenest City 2020 Action Plan was initiated in 2009, and aims to make Vancouver the greenest city in the world by 2020. The plan sets a course towards realizing a healthy, prosperous, and resilient future for the City of Vancouver (City of Vancouver, 2012). One policy for its clean water goal is to return rainwater to natural habitats as well as create cleaner creeks, healthier water tables, etc.

Climate Change Adaptation Strategy

In 2012, the Climate Change Adaptation Strategy was completed with a focus on understanding climate impacts, how the environment is expected to change, and actions to adapt to the changing climate (City of Vancouver, 2012). In response to the potential increase in the intensity and frequency of extreme storm events, the plan proposes actions to reduce the proportion of stormwater entering the engineered infrastructure. It includes a series of stormwater management techniques such as limiting impermeable surfaces, creating runoff storage and conveyance, adopting infiltration and detention practices, etc.

City-wide Integrated Rainwater Management Plan

The City of Vancouver has just completed a city-wide Integrated Rainwater Management Plan (IRMP). The IRMP provides a long-term Green Infrastructure Strategy to protect and improve water quality in the waterbodies surrounding Vancouver. This plan will treat Vancouver's abundant rainwater as a resource, reduce the demand for potable water, and restore the role of urban watersheds to support urban and natural ecosystems (City of Vancouver, 2016). Daylighting historic streams is identified as one of the best management practices in IRMP.



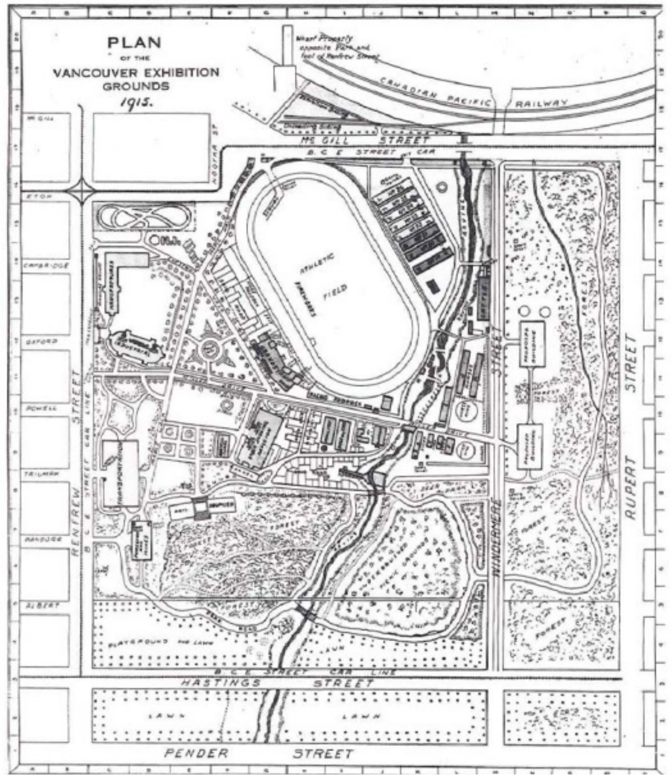
TOOL	IMPACTS ON WATER	BENEFITS
Absorbent Landscapes	INFILTRATE	• intercept and clean rainwater through soil pores, allowing gradual infiltration into subsoils to recharge groundwater
Infiltration Swales	INFILTRATE, TREAT, DETAIN	• reduce runoff volume and increase water quality by capturing, detaining, treating, and conveying stormwater
Rain Gardens & Infiltration Bulges	INFILTRATE, TREAT, DETAIN	• reduce runoff volume and improve water quality by infiltrating, capturing, and filtering stormwater • an overflow conveys extreme rainfall volumes
Pervious Paving	INFILTRATE	• reduce runoff volume and improve water quality by infiltrating and treating stormwater while still providing a hard, drivable surface
Green Roofs	DETAIN, HABITAT, TRANSPIRE	• reduce stormwater peak flows and volume, depending on depth of growing medium • benefit buildings by providing insulation and by reducing the heat island effect • provide urban habitat
Tree Well Structures	INFILTRATE, TREAT, DETAIN, TRANSPIRE	• adequate soil volume will retain excess stormwater and help to remove pollutants from stormwater runoff • support a healthy tree canopy which intercepts rainfall
Rainwater Harvesting	DETAIN, CAPTURE & REUSE	• runoff from roof surfaces can be captured, stored and used for non-potable uses like landscape irrigation, laundry, and toilets, subject to approval of authorities having jurisdiction.
Infiltration Trenches	INFILTRATE, DETAIN	• reduce the volume and rate of runoff by holding and infiltrating water into subsurface soils • water quality pre-treatment is advisable
Water Quality Structures	TREAT	• capture petroleum hydrocarbons, coarse grit and coarse sediment • provide some water quality benefits except for soluble nutrients and pollutants
Detention Tanks	DETAIN	• reduce flooding and in-stream erosion by collecting and storing stormwater runoff during a storm event, and releasing it at controlled rates to the downstream drainage system
Daylighted Streams & Channel Improvements	DETAIN, HABITAT, TREAT	• may provide in-stream detention, water quality improvements, and essential habitat for aquatic life • contribute to the liveability of an area and establish a sense of place if properly designed
Constructed Wetlands	DETAIN, HABITAT, TREAT	• provide detention, storage, habitat, and treat stormwater runoff through natural processes prior to discharging it into the downstream drainage system

Best management practices identified in IRMP (Image from City of Vancouver, 2016)

Daylighting Projects in Vancouver

Hastings Park Daylighting Project

Hastings Park is a 67-hectare lot, located in a highly urbanized area on Vancouver's east side. Historic Renfrew Creek was once the main feature of Hastings Park. The Hastings Park Restoration Plan was approved in 1997, which proposed to reintroduce natural features to the site, including daylighting Renfrew Creek as a way to manage stormwater and improve natural habitats for wildlife (City of Vancouver, 2011). Construction began in 1998 by demolishing buildings, ripping up asphalt and excavating soil to uncover the culvert. Over 80,000 cubic metres of soil were excavated to a 10-metre depth (Wong, 1998). Through this project, the City of Vancouver tested the feasibility of daylighting as an alternative method of separating combined

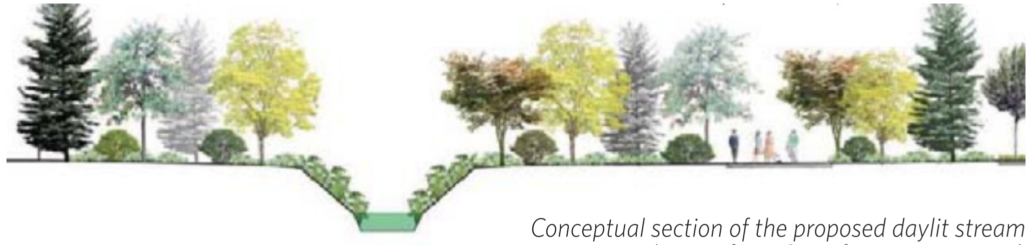


Renfrew Creek, 1915 Site Plan
(Image from City of Vancouver, 2011)

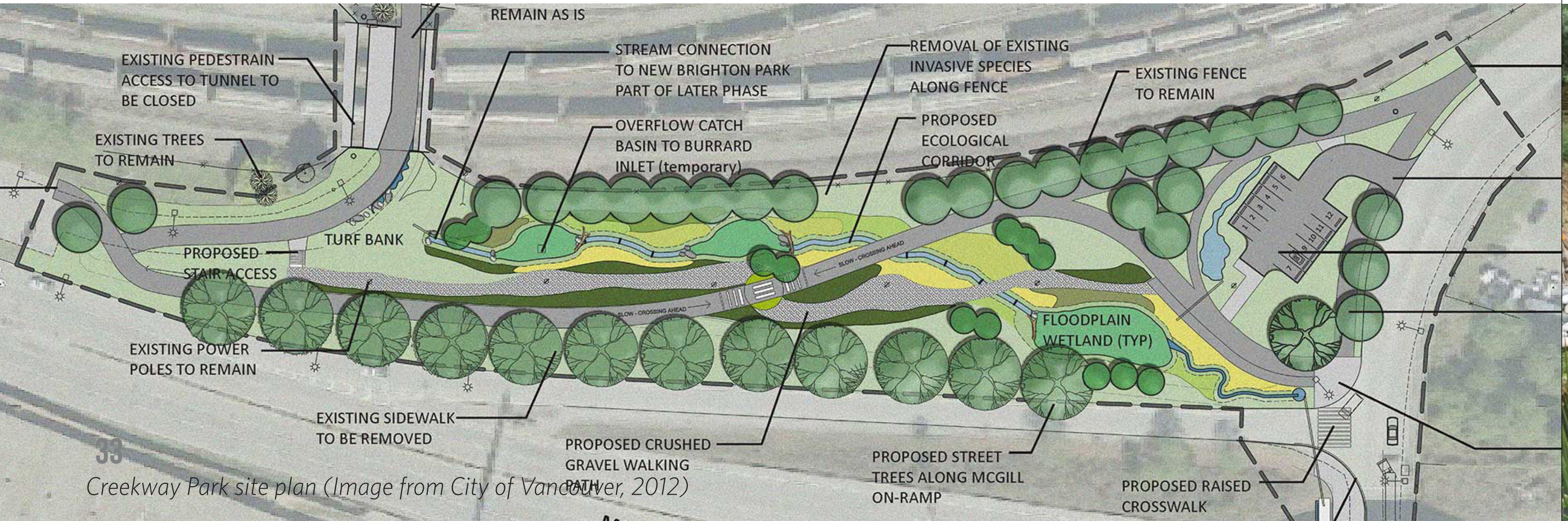
Proposed daylit stream connecting the Sanctuary to Burrard Inlet
(Image from City of Vancouver, 2011)

sewers. Stormwater from the surrounding residential area, as well as storm and ground water from the park itself was directed into the park, with the creation of several ponds, a freshwater marsh, pools, and riffles (Jones, 2001). Among the $45 million budget for the Hastings Park project, $10-12 million was allocated for stream restoration (Botelho, 1999).

The Hastings Park Master Plan, which was released in 2011, has proposed a continuous daylit stream connecting the Sanctuary to a saltwater marsh on Burrard Inlet. The proposed riparian corridor is between 45 and 100 metres in width, with a walking and cycling greenway next to it (City of Vancouver, 2011).



Conceptual section of the proposed daylit stream (Image from City of Vancouver, 2011)



Creekway Park site plan (Image from City of Vancouver, 2012)

In 2013, Creekway Park, located between McGill Street and the existing railway tracks, was completed. Once a parking lot, Creekway Park is now a green corridor connecting Hastings Park, New Brighton Park and the waterfront, where Renfrew Creek enters the ocean. As part of this project, a stream was created in the park that captures and filters stormwater and provides a rich habitat for many types of birds, amphibians, and butterflies (City of Vancouver, 2013).

Both the Sanctuary and Creekway Park projects restore the riparian corridor and natural habitats for wildlife. They also provide urban green space for residents with convenient pedestrian and bicycle pathways. However, as captured rainwater in the surrounding area is the main water source, there is insufficient year-round flow for the daylit creek during dry seasons. As a result, municipal water is added into the creek to maintain water flow during dry seasons.

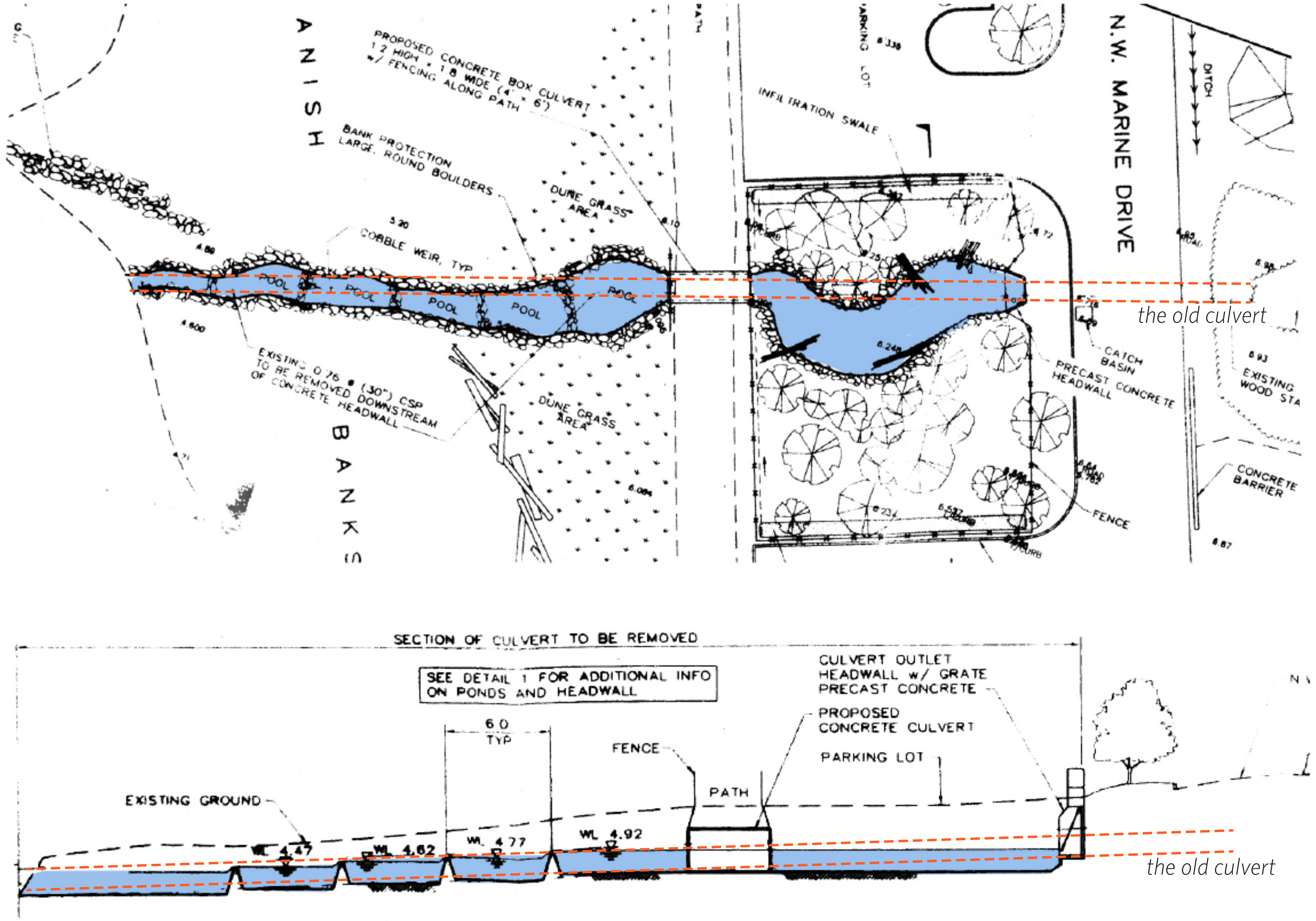
Creekway Park (Image from vancouver.ca)

Educational signage besides Spanish Bank Creek

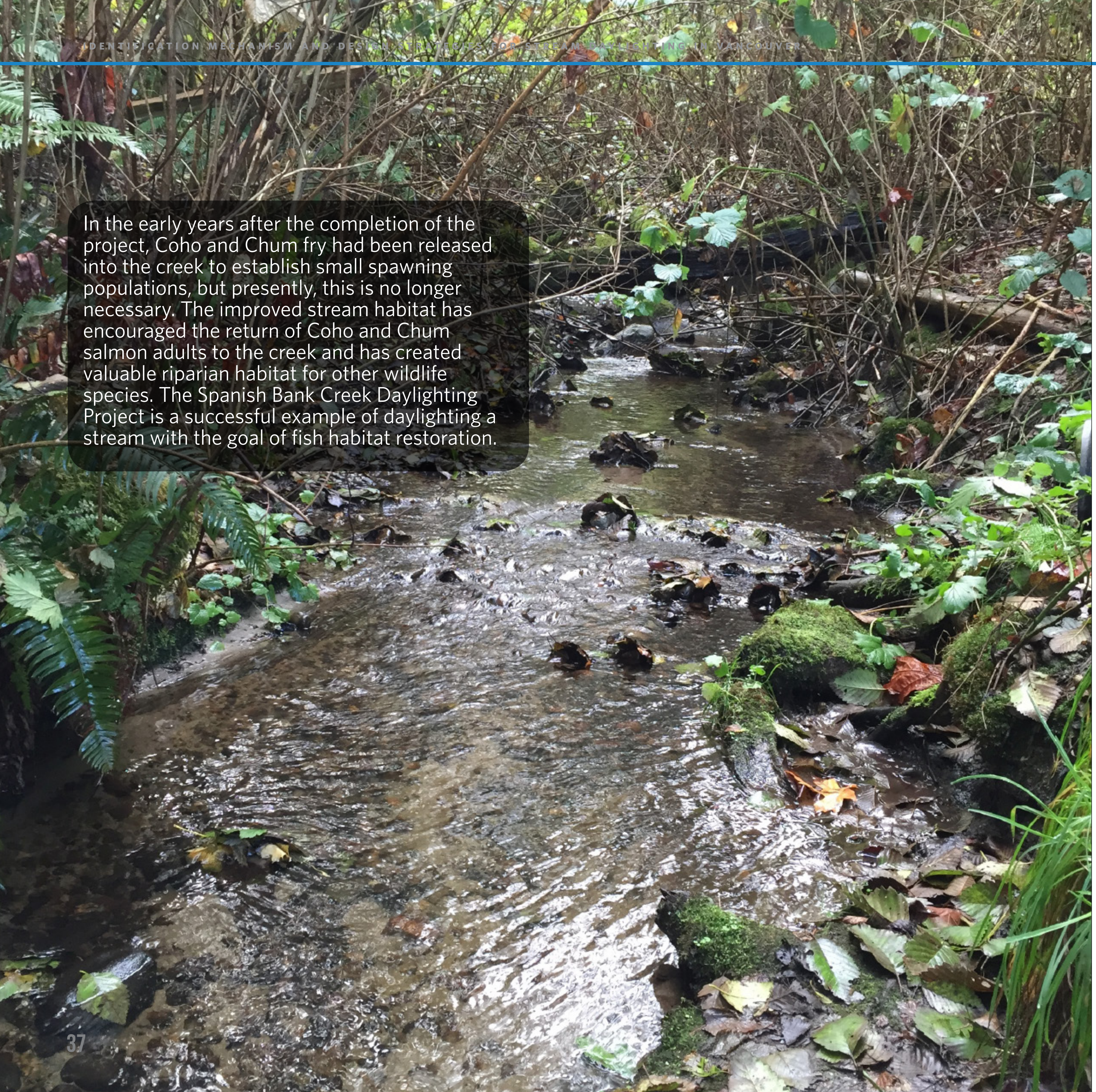
Spanish Bank Creek Daylighting Project

Spanish Bank Creek is located in the western area of the City of Vancouver. Before 1999, the creek flowed through Pacific Spirit Regional Park and entered a culvert under Northwest Marine Drive. It then proceeded underneath a parking lot to the foreshore of Spanish Bank Park. The creek was not accessible to salmon for more than 50 years (Miller, 2000).

Daylighting Spanish Creek had been actively pursued by the Vancouver Stream and Salmon Society for a long time, with the primary goal of restoring the salmon habitat. In 1999, 10 parking stalls and 52 meters of an existing culvert were removed. A natural stream was recreated, including a holding pond, pools and riffles, spawning gravel, and woody debris to provide cover for young fish (Scarth, 2012). The project also included restoring back shore and riparian communities with native species. As the project is located within a large park, there is sufficient buffer area along the daylit stream which increases its ecological functions. The stream is still culverted under the pedestrian/cycle path. Infiltration swales on the perimeter of the riparian area filter stormwater from adjacent parking lots. The total cost for the project was approximately $62,000 (City of Vancouver, 1999).



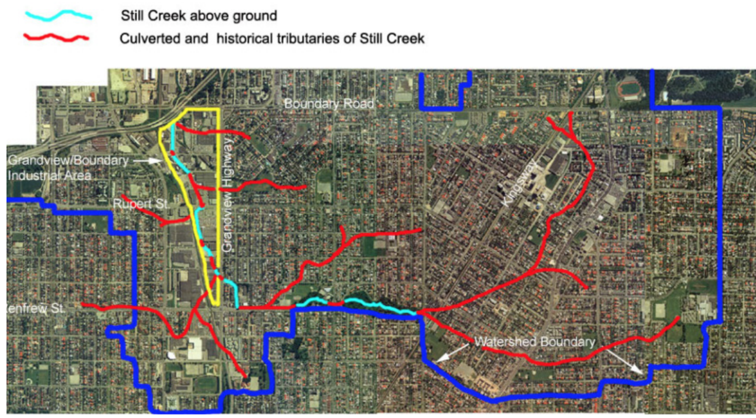
Site plan and section for daylighting Spanish Bank Creek (Image adapted from Department of Fisheries and Oceans, 1995)



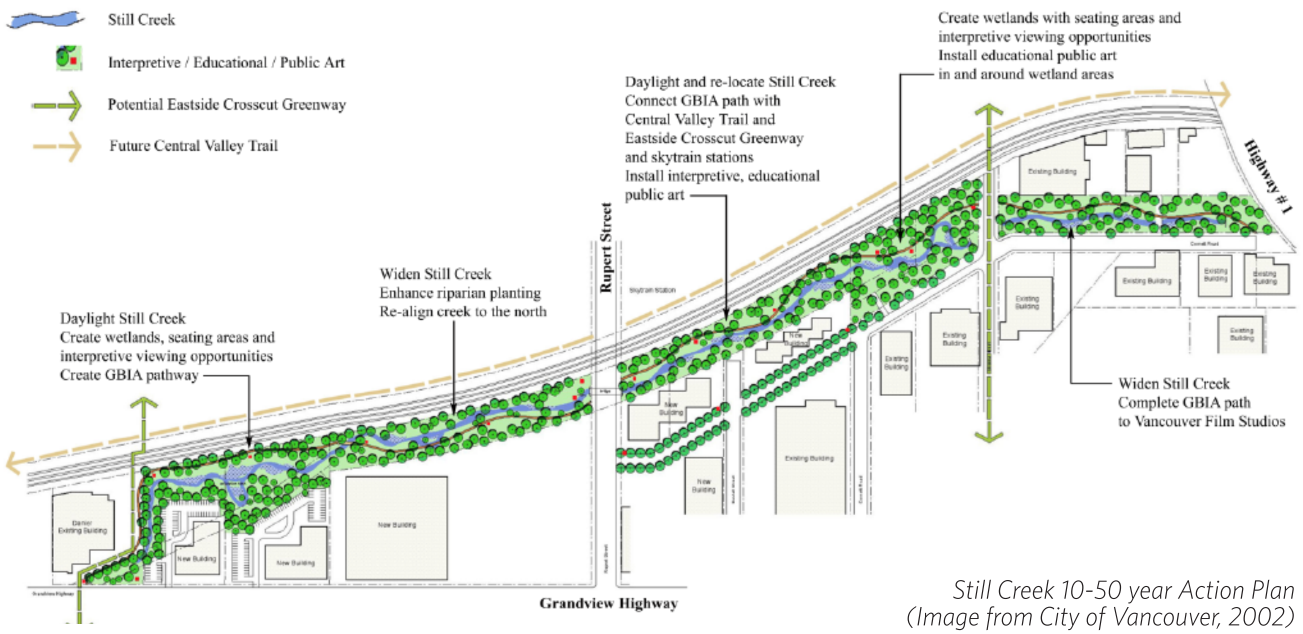
In the early years after the completion of the project, Coho and Chum fry had been released into the creek to establish small spawning populations, but presently, this is no longer necessary. The improved stream habitat has encouraged the return of Coho and Chum salmon adults to the creek and has created valuable riparian habitat for other wildlife species. The Spanish Bank Creek Daylighting Project is a successful example of daylighting a stream with the goal of fish habitat restoration.

Still Creek Rehabilitation and Enhancement Project

Still Creek flows for 17 kilometers, through a densely populated section of Burnaby and Vancouver, into the Fraser River. The creek is one of the few remaining open waterways in Vancouver and suffers from a high level of pollution. Approximately 70% of the original Still Creek and its tributaries have been put into underground storm sewer pipes (City of Vancouver, 2002). Due to rapid stormwater velocity, poor water condition and a lack of streamside vegetation, salmon population was eliminated in the creek. Like many other urban streams, Still Creek experiences an extremely low flow during the dry season, and frequent flooding during storm events. This mainly results from an increasing amount of impervious surface area and a lack of streamside vegetation.



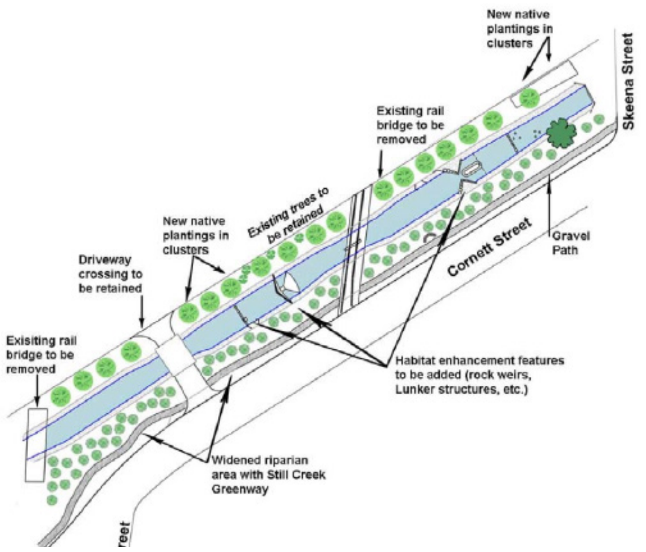
Still Creek watershed (Image from City of Vancouver, 2002)



Still Creek 10-50 year Action Plan (Image from City of Vancouver, 2002)

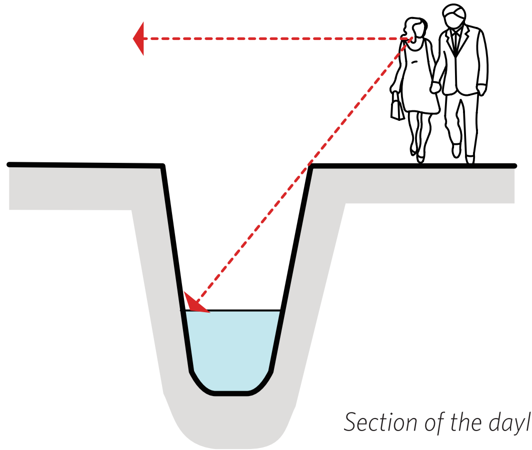
Beginning in 2002, the City of Vancouver initiated the Still Creek Rehabilitation and Enhancement Project to improve watershed health and bring natural life back to the stream. The main purpose of the project was to enhance ecological and recreational benefits by effective management of stormwater in the Grandview Boundary Industrial Area. Specific actions in this project included daylighting a section of the creek, removing concrete and naturalizing the creek bank, replanting native plants, and providing recreational and educational opportunities (City of Vancouver, 2014). The project proposed a 10-Year Action Plan (short-term) and a 10 to 50-Year Action Plan (long-term) for the Grandview Boundary Industrial Area.

A 75-meter section of the buried creek on Canadian Tire property was uncovered. Efforts to enhance stream health included widening the riparian area, introducing habitat features such as weirs and lunker structures, creating pedestrian greenway paths, replanting native species, improving stream beds, etc. The total cost of completing the enhancement work in this area was $433,633.50 (City of Vancouver, 2007).



Still Creek Enhancement Project - 3400 Cornett Avenue
(Image from City of Vancouver, 2002)

However, as the old pipe was previously buried very deep underground, the daylit creek is also very deep. As the site does not allow for sufficient buffer areas, the slope along the bank is steep, and this limits the visual and physical accessibility of the new waterway.



Section of the daylit creek

Overall, the Still Creek Enhancement Project has significantly improved the ecological functions of the stream. In 2012, for the first time in 80 years, Chum salmon returned to Still Creek. By 2015, salmon have returned for the fourth year in a row (City of Vancouver, 2015), bringing with them incredible environmental diversity in the waterway.

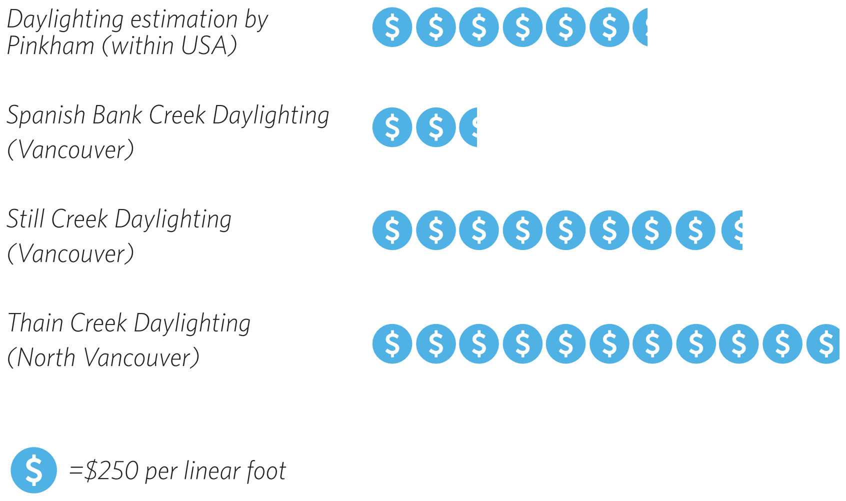
Salmon return to Still Creek (Image from cbc.ca)

Costs of Daylighting

According to Pinkham, the cost for daylighting projects in the US varies significantly from one project to another, and is about 1,000 USD per linear foot of stream daylit (Pinkham, 2000), which projects to approximately 1,600 USD present value (2016). The diagram below compares the costs of different daylighting projects in Metro Vancouver, including the Spanish Bank Creek Daylighting Project in Vancouver (1999), the Still Creek Rehabilitation and Enhancement Project in Vancouver (2002), and the Thain Creek Daylighting Project in North Vancouver (2000). The cost per linear foot of stream daylit varied significantly from about 600 USD to 2,700 USD (all converted to present value), which is generally in line with Pinkham's estimate. The reason for the wide range in costs from one project to another could be explained by substantial differences in site conditions, project objectives, and design strategies.

The cost of daylighting projects per linear foot

(*all converted to 2016 value in US dollars*)



DAYLIGHTING IDENTIFICATION MECHANISM

Uncovering buried streams could bring about a myriad of ecological, recreational, and aesthetic benefits to cities and local communities. However, as Pinkham indicated, not every hidden waterway can or should be daylit. Among the "doable" projects, not every one can be highly naturalized (Pinkham, 2000). Additionally, daylighting techniques and implementation could be very costly, and not all daylighting projects will result in commensurable ecological and social benefits compared to their costs. Therefore, identifying proper sites for stream daylighting projects that are feasible in terms of implementation is very important. This chapter investigates a proposed mechanism based on a spatial overlay approach for identifying potential sites for daylighting in Vancouver.

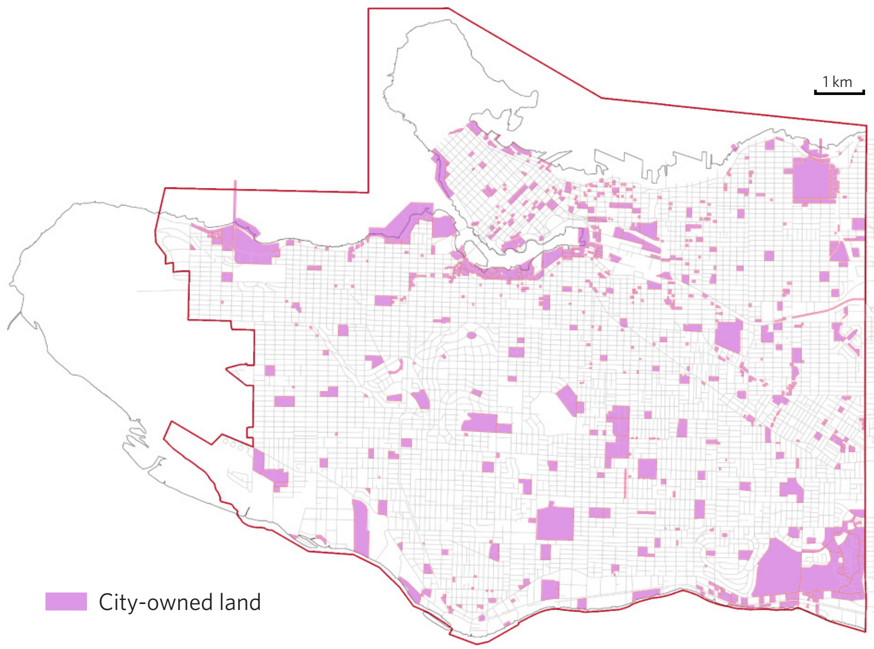
Criteria for the Spatial Overlay Approach

The criteria for selecting the most appropriate daylighting sites are identified based on previous literature review, case studies, interviews with practitioners, and field studies. Most data used in this mechanism, such as land use, hydrological conditions, and sewer pipe alignment in Vancouver, is obtained from the Vancouver Open Data Catalogue (http://vancouver.ca/your-government/open-data-catalogue.aspx) and VanMap (http://vanmapp.vancouver.ca/pubvanmap_net/default.aspx). Additional information is obtained from other resources such as presentations and reports conducted by the City of Vancouver.

The following criteria are identified for the spatial overlay approach:

City-Owned Land

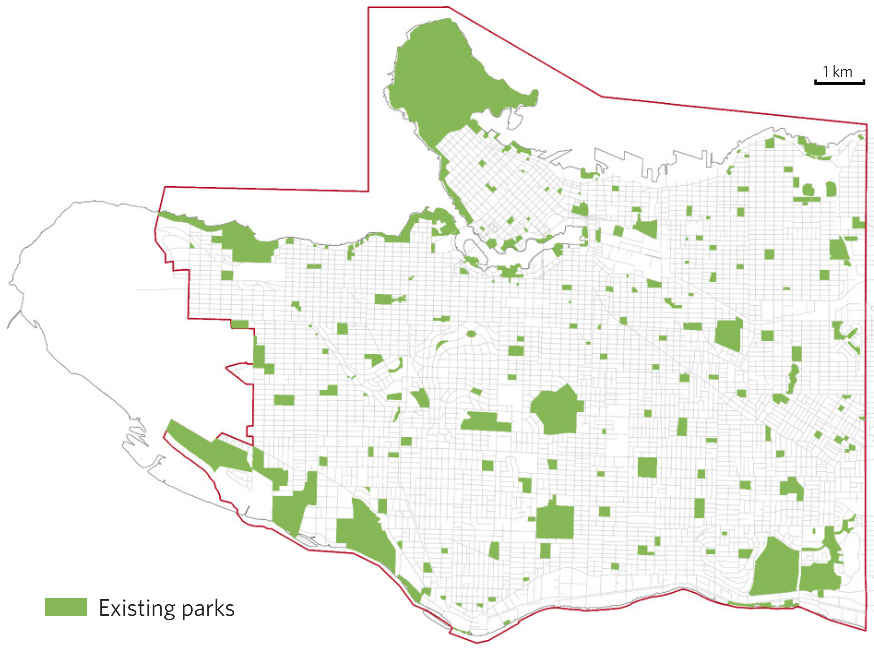
City-owned land is easier for the city to implement a potential daylighting project, as it does not require land acquisition. If the land is privately owned, a potential daylighting project would require additional funding for land acquisition, which may make the project economically infeasible. The land acquisition and negotiation process will also add to the complexity of the project.



Inclusion in a Park

Sufficient buffer areas are required along a potential daylit stream to ensure there is enough floodplain storage, and promote a healthy stream function. To simplify the analysis, parks are identified as locations with sufficient buffer areas.

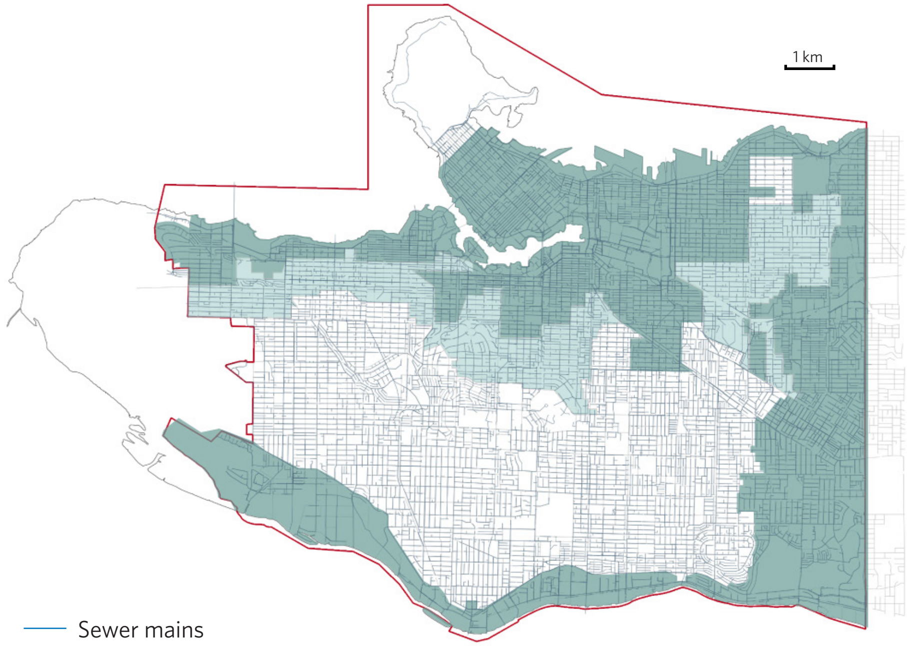
Additionally, a daylit stream could generate more public value if the site is already included in an existing public open space. It would be easier to integrate the daylit stream into the existing open space system as a public amenity.



Separated Sewage System

The City of Vancouver is currently working on separating its combined sewer systems. In areas with separated systems, storm pipes could be daylit or stormwater could be diverted for daylighting a stream. For areas with combined sewer systems, a combined sewer pipe cannot be daylit directly. However, daylighting could be employed as a means for separating stormwater from sanitary water, as in the case of the Zurich Stream Daylighting Program.

In this spatial overlay analysis in Vancouver, areas currently with separated sewer systems, and areas where the city plans to complete sewer separation by 2020 are identified.

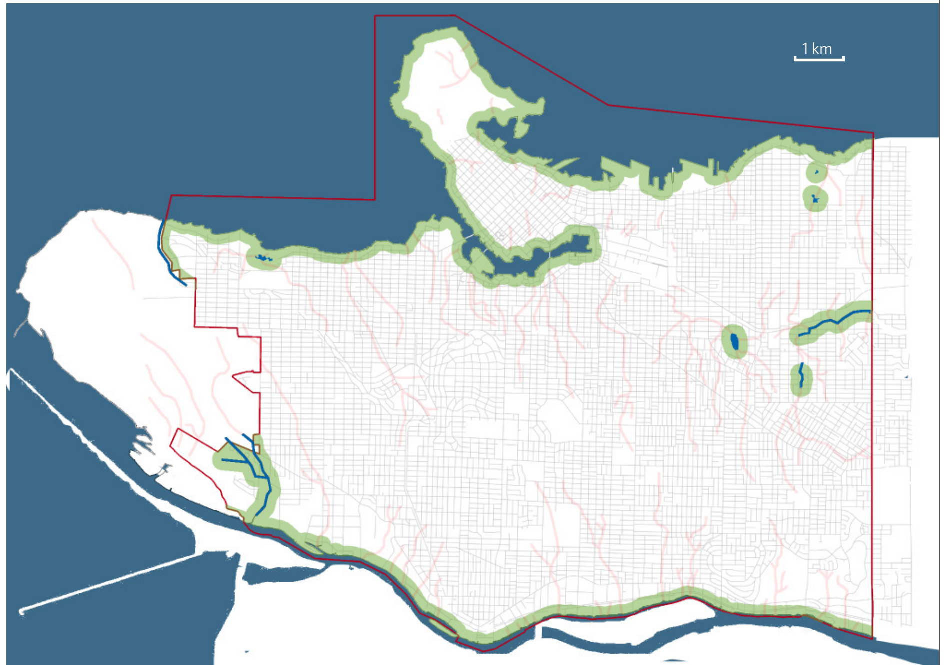


Sewer mains
Area currently with separated sewer systems
Area where the city plans to complete sewer separation by 2020

Connection with Existing Stream Networks

Areas are preferred if they are directly connected to existing stream networks in Vancouver. By daylighting a buried creek and expanding the existing waterways, a continuous riparian corridor can be created, which increases habitat connectivity and enhances ecological processes. In this spatial overlay analysis, areas within 200 meters from an existing waterway are identified.

Existing waterbodies
Lost streams
Area within 200 m distance from exsiting stream networks



Additional Criteria

Some additional factors are identified but not included in the spatial overlay approach, either due to a lack of data, or to difficulties in quantifying them. However, these factors should be taken into account when conducting site-specific analysis for the possibility of daylighting a stream.

Available Surface Space

Ideally, a potential daylit pipe travels unobstructed from surface confinements, including buildings, roads, crossings, utilities, trees, etc. This will provide more available space and buffer areas for a daylit stream.

Pipe Diameter

Regarding the dimension of a potential daylit pipe, small pipe diameters imply a smaller drainage area that might not be able to support perennial flow, while large pipes may be too expensive or constrained to be daylit effectively. According to Schueler and Brown, the most cost-effective outfall pipe candidates typically range from 24 to 60 inches in diameter (Schueler & Brown, 2004).

Pipe Depth

The deeper a pipe is buried underground, the larger amount of excavation and off-site hauling will have to be implemented, and the more buffer area will be required to create a healthy stream habitat.

Community Support

Many daylighting projects were driven by citizen action. With support from local citizen groups and organizations, a buried stream is likely to draw more attention from universities/ governments/individual designers, and this opens up more possibilities for daylighting. For example, in many daylighting projects in Seattle, efforts from grassroots organizations played crucial roles in the seeking for funding and project implementation phases. Citizen groups contributed substantial amounts of time, money and resources for daylighting urban streams (Smith, 2007).

Opportunities from Other Projects

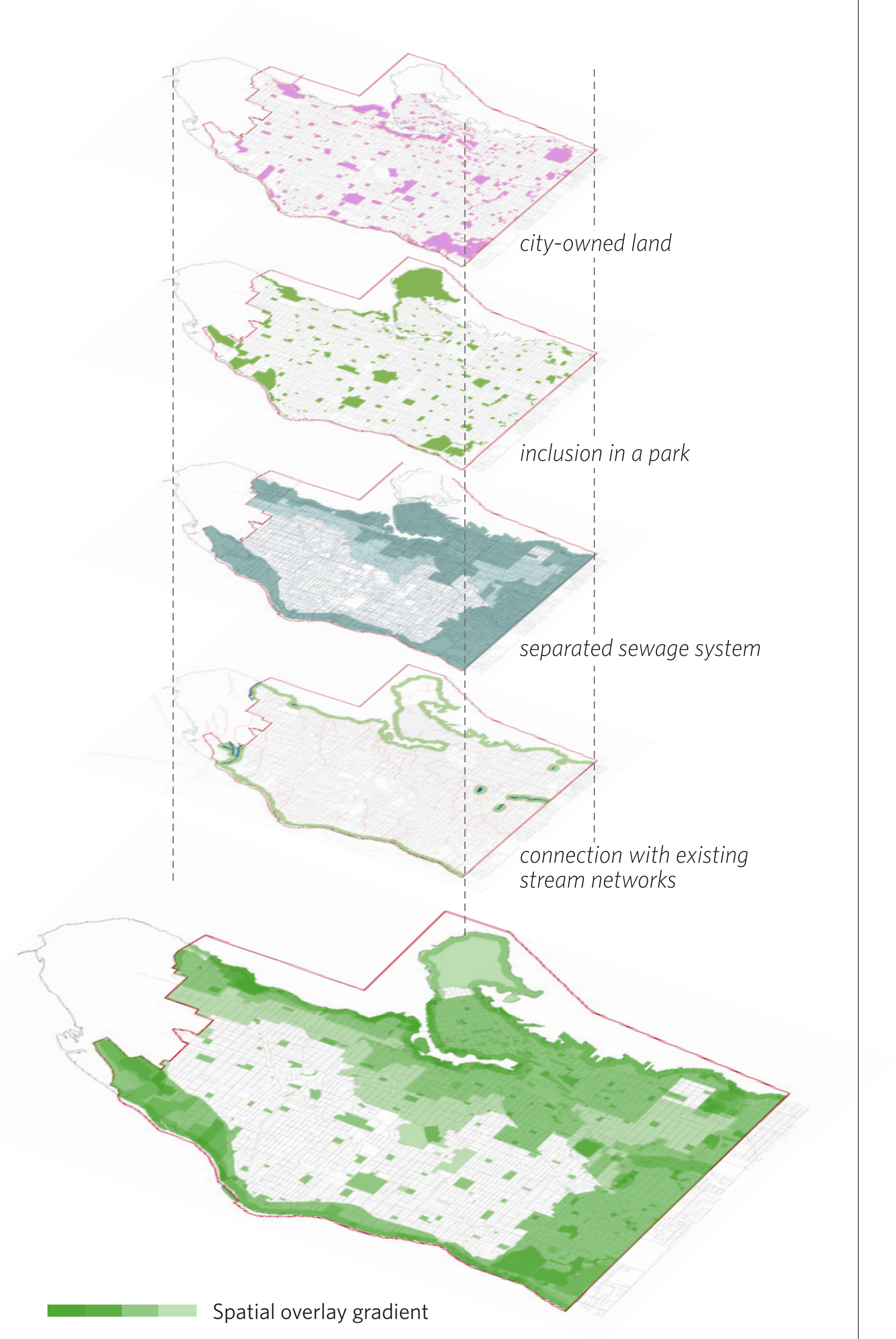
Many daylighting projects originated from other projects with the commitment of sustainable stormwater management or the goal of enhancing public open space. These projects may not have to occur on city-owned land or park land, but were implemented with a collaboration of municipalities, landowners, and other citizen groups. Additionally, funding opportunities may arise from these projects for daylighting the stream.

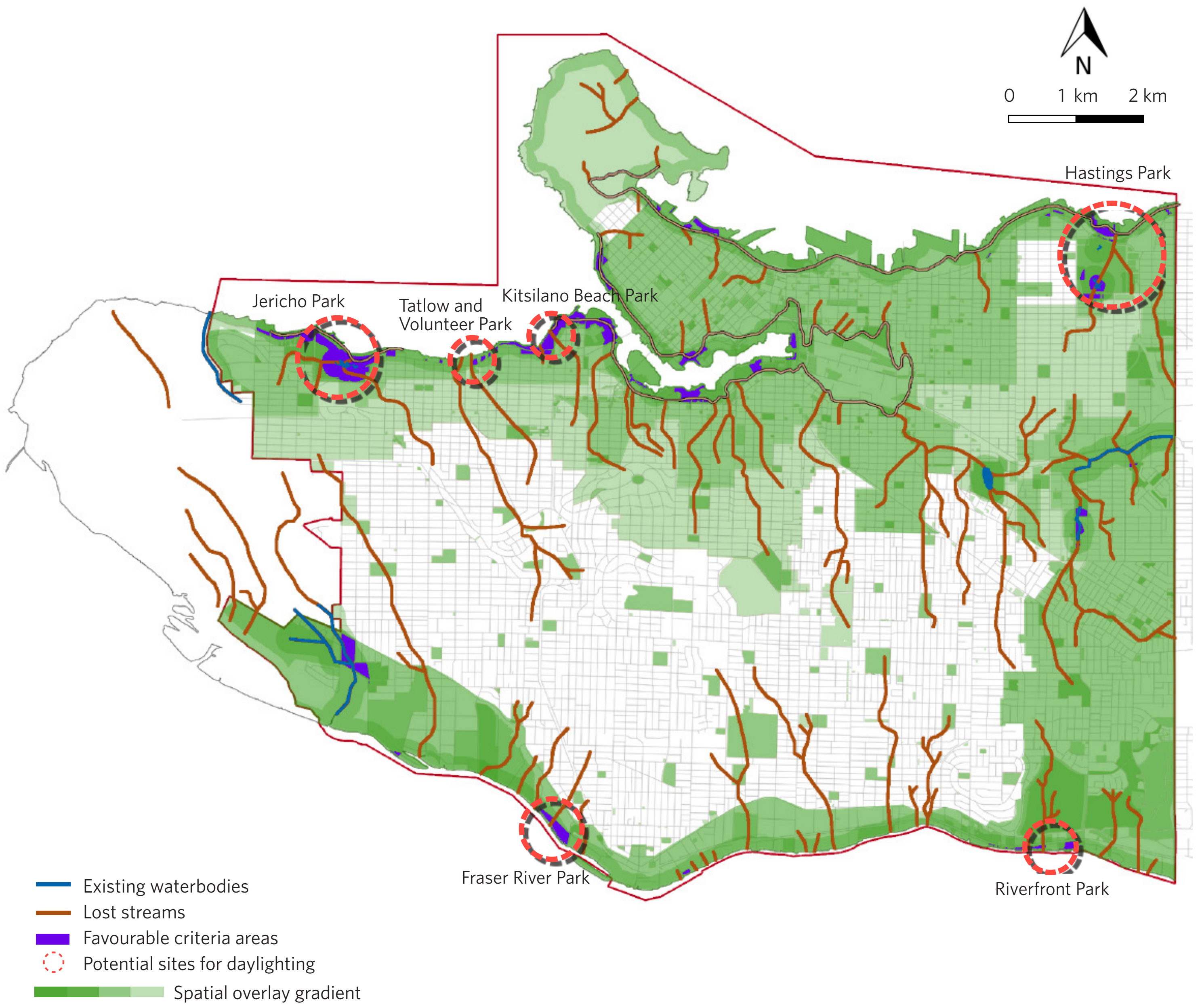
Spatial Overlay Results

Criteria for identifying potential daylighting sites are overlaid, including city-owned land, inclusion in a park, separated sewage system and connection with existing stream networks. A color gradient is generated, indicating the potential of a site for future daylighting projects. This color gradient is overlaid with the map of lost streams in Vancouver, and the final results indicate sites with the most potential and feasibility to be daylit.

Overall, potential areas in Vancouver for daylighting projects are parks along Burrard Inlet and the Fraser River. Sites with the most potential to be daylit include Jericho Park, Tatlow and Volunteer Park, Kitsilano Beach Park, Hastings Park, Fraser River Park, and Riverfront Park.

However, the spatial overlay approach and its results have not taken into account the additional criteria identified, such as pipe diameter, pipe depth, and community support. These factors are also important and could be essential for the implementation of daylighting projects. They should be analyzed in more detail when conducting site-specific studies.





CONCEPT DESIGN FOR DAYLIGHTING TATLOW CREEK

Among the sites identified in the previous chapter, Tatlow Creek is selected for further investigation and analysis. This chapter focuses on Tatlow Park and Volunteer Park in the Kitsilano neighbourhood, and develops a concept design proposal for daylighting Tatlow Creek in these two parks.

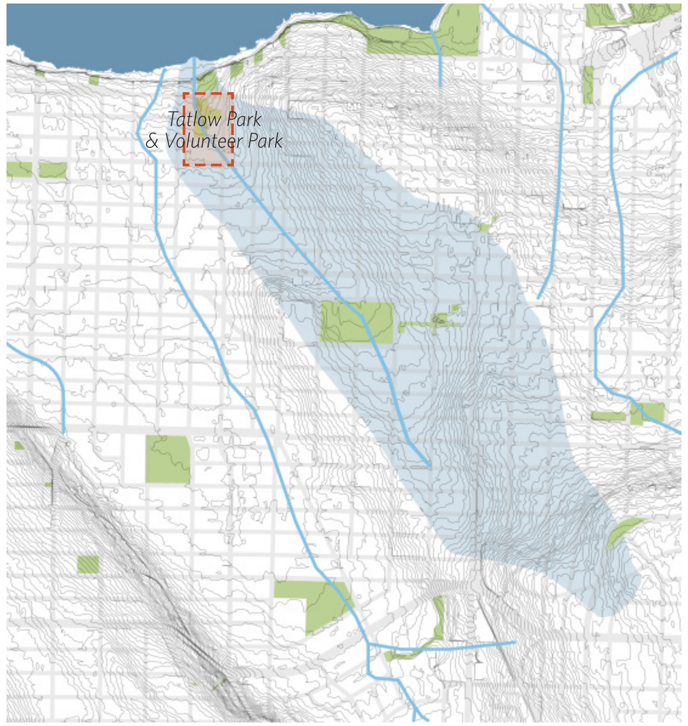
Site Context

The vision to daylight Tatlow Creek dates back to 1996 when the West Kitsilano Residents' Association brought together community experts, staff from the Vancouver Park Board, City Engineering, and the Department of Fisheries and Oceans to investigate the possibility of daylighting the creek (Lehan, 1996).

Watershed Context

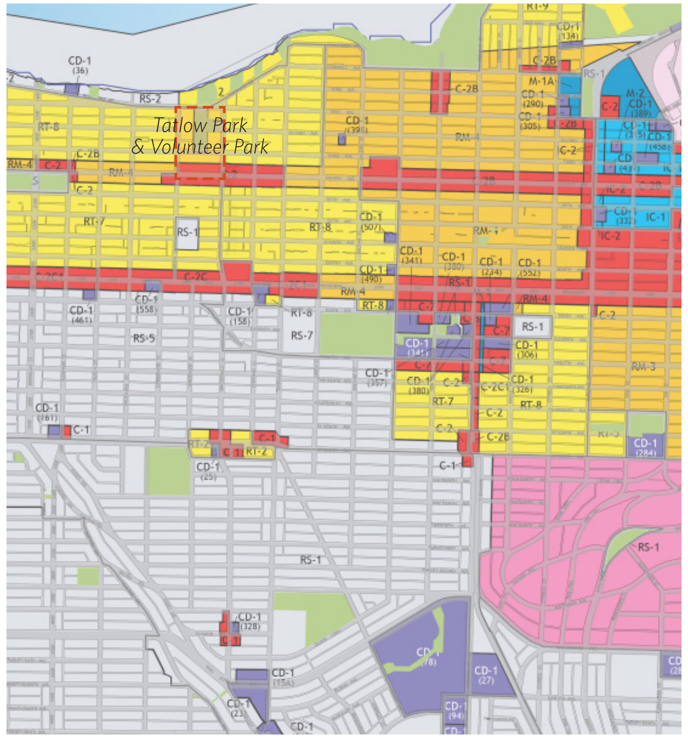
Historic Tatlow Creek, by its old name First Creek, flowed through the west of Tatlow Park and Volunteer Park before it reached its mouth at English Bay. The original Tatlow Creek Watershed area was about 1.41 km^2. The continual presence of water in Tatlow Creek was guaranteed by gradual and steady conveyance of groundwater to it; this constituted the base flow of the creek in both dry and wet seasons (Milley, 2003). Coho and Chum salmon used to spawn in the creek, and at the turn of the century, First Nations still traveled to the creek to catch both species (Vancouver Public Aquarium Association, 1989). However, with fast urban development, the original Tatlow Creek was diverted and buried underground, and the natural watershed has been replaced by engineered sewer-sheds. Although this area was within a "groundwater discharge zone", which is characterized by shallow water tables and year-round discharge to surface channels (Piteau Associates, 2000), urban development and the increasing amount of impervious surfaces have resulted in a deeper water table and have changed natural hydrological processes.

Surficial sediments within the Tatlow Creek watershed are typical of the Greater Vancouver area. Studies have shown that although these sediments are characterized as "relatively low permeability", there exist enough pockets of sand and gravel interspersed within the sub-surface as to ensure a regular infiltration capability (Milley, 2003).



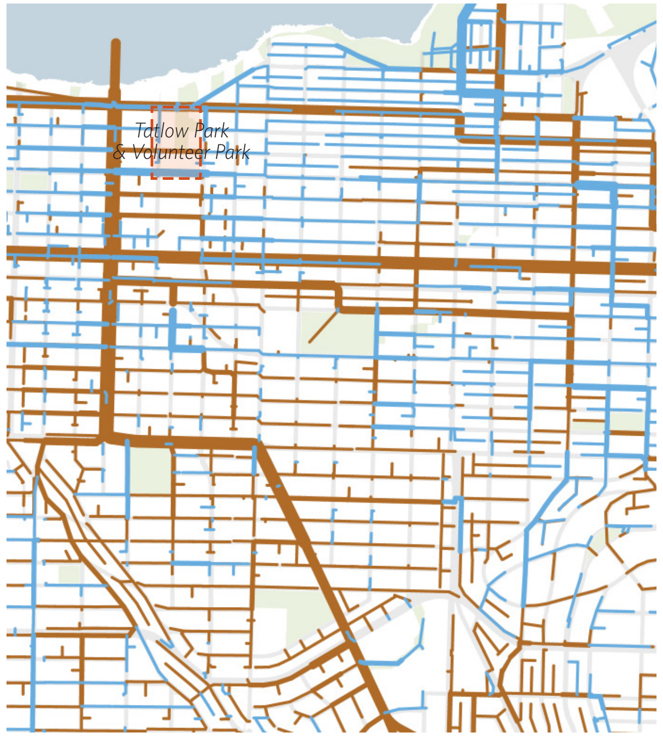
Historic Tatlow Watershed

- Lost streams
- Parks
- Estimated Tatlow Creek Watershed



Land use map

- One-Family Dwelling Districts
- Two-Family Dwelling Districts
- Commercial Districts
- Comprehensive Development Districts
- Light Industrial Districts
- Parks
- First Shaughnessy Districts



Sewer system in the neighbourhood

- Combined sewer pipes
- Stormwater pipes

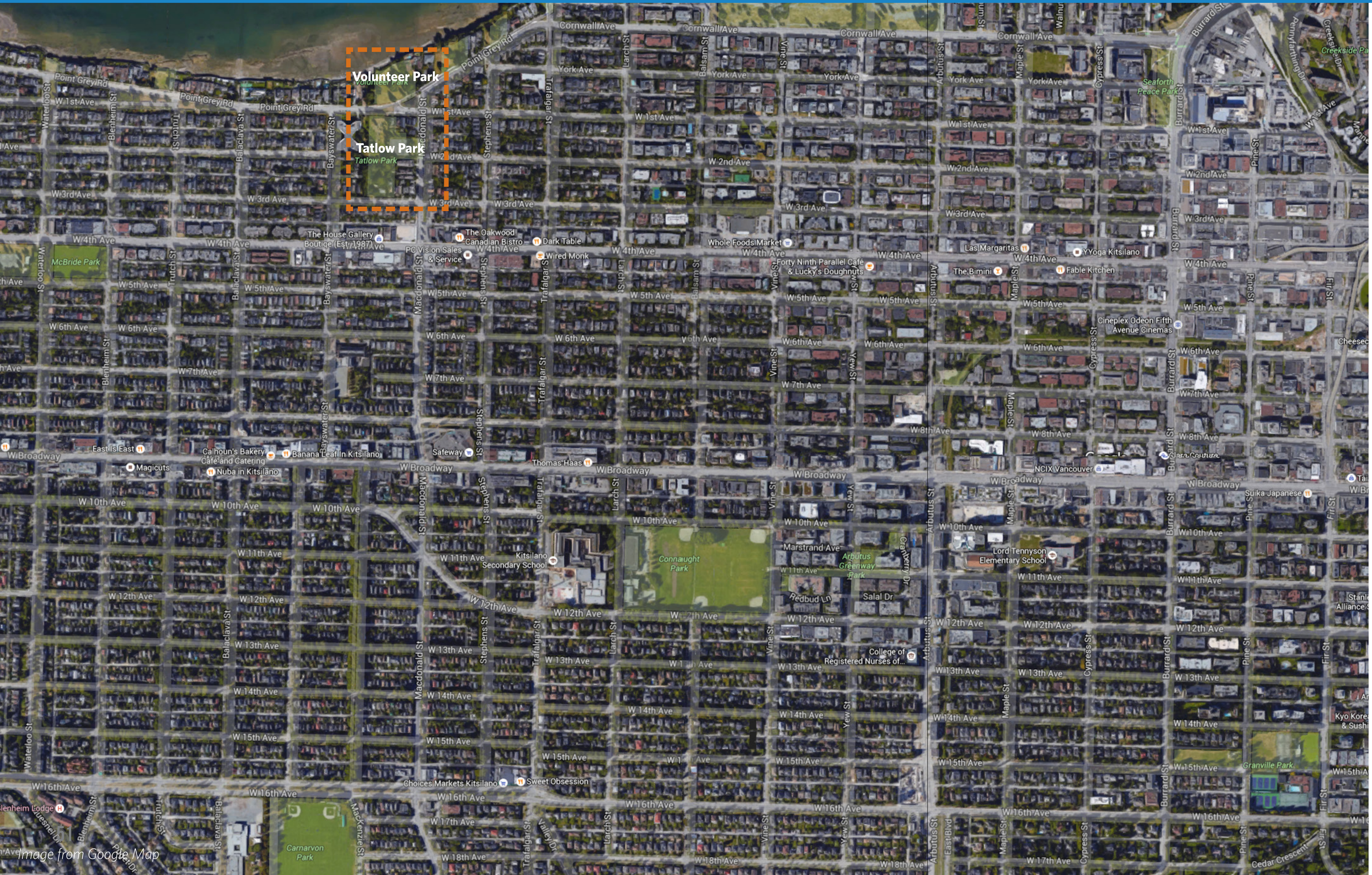


Image from Google Map

Currently the watershed is primarily comprised of residential and commercial areas, with a high percentage of impervious surfaces (e.g. roofs, driveways, parking lots). Some of the neighbourhood has separated sewer systems, with stormwater and sanitary water flowing through different pipes, but generally along the same route, while the remainder has combined sewer systems. For these systems, stormwater and sanitary water is mixed together and directed to the Iona Wastewater Treatment Plant. The impervious surfaces as well as the highly controlled, engineered sewer systems have significantly altered natural hydrological processes.

Tatlow Park

Tatlow Park is one of the oldest parks in the Kitsilano neighbourhood. It is a 1.4-hectare park located between MacDonald Street and Bayswater Street, south of Point Grey Road. Tatlow Park is characterized by a meandering creek along lined rocks, beautiful landscaping, and large trees over quiet seating areas. A children's playground lies in the south of the park, attracting children from the surrounding neighbourhood.

Tatlow Creek is currently fed by tap water during dry seasons from the existing Greater Vancouver Regional District (GVRD) pipe. The creek runs through the park between lined rocks, and is crossed by small wood bridges. After going through irregular, rock-lined channels, the creek exits Tatlow Park through an old culvert across Point Grey Road into Volunteer Park, before it finally reaches English Bay.

Neighbourhood context

Tap water entering Tatlow Park

Wood bridges in Tatlow park

Volunteer Park

Volunteer Park lies adjacent to Tatlow Park to the north, and the two parks are bisected by Point Grey Road. Volunteer Park was once the location of Seagate Manor and two smaller private residences. They were demolished in 1977 after being purchased through the Park Board's Land Acquisition Fund, with the aim of improving public access to the serene views of English Bay (City of Vancouver). The park is covered by empty lawns with several big trees. Aside from a number of benches in the north of the park, there are no other public facilities. The north side of Volunteer Park is flanked by a 3.5-metre high bluff, with fences to protect public safety.

Opportunities for Daylighting Tatlow Creek

Tatlow Park and Volunteer Park qualify for all the criteria identified for a potential daylighting project in Vancouver. Additionally, the site presents many opportunities for daylighting Tatlow Creek, which match the "additional criteria" for daylighting projects identified in the previous chapter.

1. The current combined sewer separation program in Vancouver offers a valuable opportunity for the implementation of integrated stormwater management strategies. As the Kitsilano neighbourhood is still in the process of combined sewer separation, it is possible that daylighting could be utilized to separate combined sewer systems. Additionally, there is an existing waterway that could be utilized for a potential daylit creek;
2. There is also very strong community support for daylighting Tatlow Creek. The vision for daylighting the creek has been pursued for decades, with many community members actively searching for ways to make headway;
3. Another opportunity arises from the Point Grey Road sidewalk and public realm improvements project. As Point Grey Road is included in the city-wide greenway system, there is strong potential and interest to improve public amenities and the design of the two parks.

Point Grey Road as a bike route

Volunteer Park with a spectacular view of the North Shore and downtown Vancouver

Current creek channel at Tatlow Park

Design Purpose and Goals

The main purpose of this concept design proposal is to daylight Tatlow Creek, utilizing sustainable stormwater management strategies, with the following goals:

- On a neighbourhood scale, increase watershed health through integrated stormwater management strategies with green stormwater infrastructure;
- Daylight a section of Tatlow Creek at Tatlow Park and Volunteer Park, restoring its environmental function as a wildlife habitat, as well as improving its aesthetic value;
- Increase the social value of Tatlow Creek and enhance Tatlow Park and Volunteer Park as the centers of the neighbourhood by improving their public amenities.

The strategies of sustainable stormwater management and stream daylighting are proposed to achieve these goals.

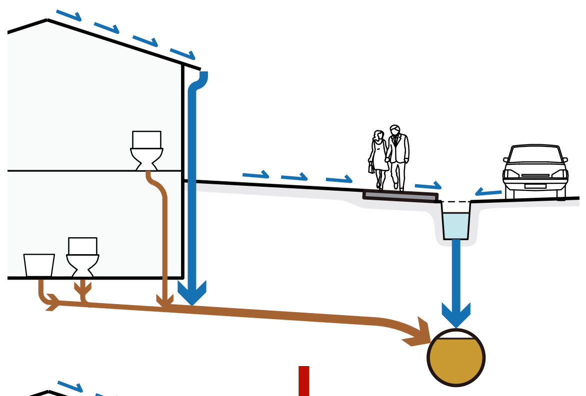
Strategy 1: Sustainable Stormwater Management

On a neighbourhood scale, in order to improve watershed health, a series of integrated stormwater management strategies with green stormwater infrastructure is proposed. The purpose is to reduce storm runoff and facilitate stormwater infiltration into the ground. This could be achieved by replacing combined sewer systems or artificial storm drains in the neighbourhood with green stormwater infrastructure where possible, including bio-swales, rain gardens, pervious surfaces, etc.

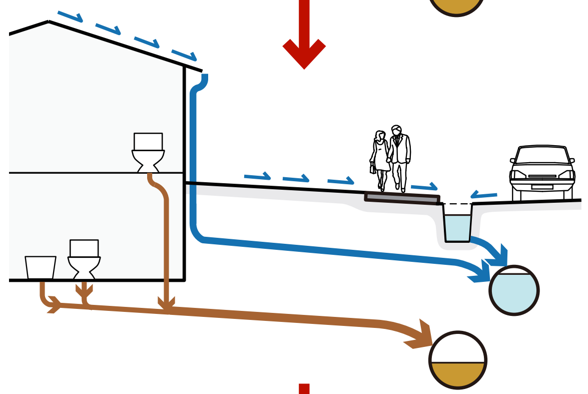
The sewer separation program is currently in progress in the Kitsilano neighbourhood, with most of the area already employing a separated sewer system. The entire Kitsilano neighbourhood is expected to complete sewer separation by 2020.

For areas with combined pipes that have not yet been separated, natural stormwater management strategies should be adopted in the sewer separation program where possible, rather than continuing to replace the combined sewer pipes with additional storm pipes. Green stormwater infrastructure, such as bio-swales and rain gardens, will bring about many benefits, including facilitating stormwater infiltration, improving water quality, creating public amenities, etc. For example, instead of adding a stormwater pipe, a vegetated bio-swale could be created along a curb, which collects rainwater from building roofs, driveways, and vehicle lanes. Another alternative is to replace an existing parking lane with a rain garden. In both scenarios, perforated pipes and overflow control structures could be utilized to divert stormwater into stream outlets during extreme rain events.

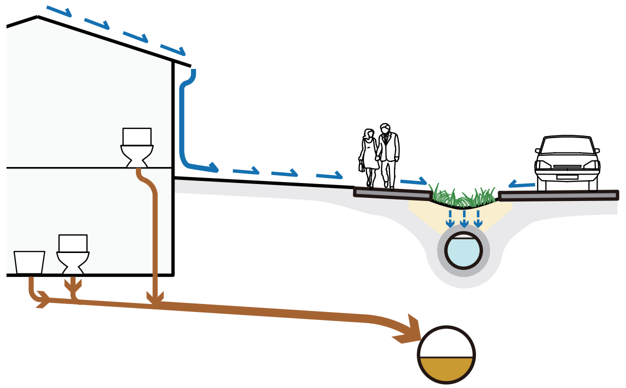
For areas with separated sewer systems, future stormwater management should focus on adding green infrastructure such as bio-swales and rain gardens where possible to the existing storm drain system. By directing road runoff into bio-swales and rain gardens, natural plants can help to remove contaminants in stormwater and facilitate stormwater infiltration. Flow control devices could be employed to allow for storm overflow from bio-swales or rain gardens to storm pipes when soil is saturated.



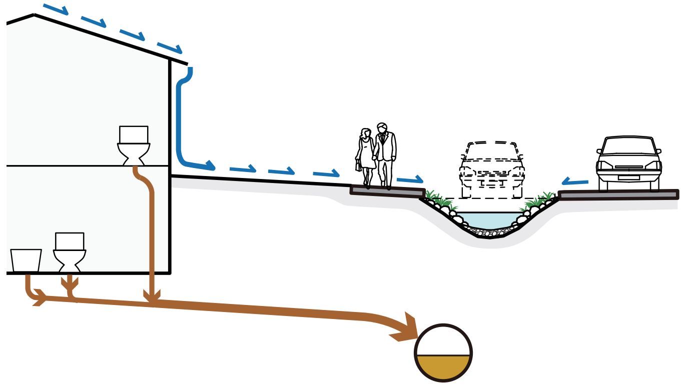
Combined sewer system
(combined sewer pipe)



Current sewer separation strategy
(sanitary pipe + storm pipe)



Alternative sewer separation strategy 1
(sanitary pipe + vegetated bio-swales + perforated storm pipe)

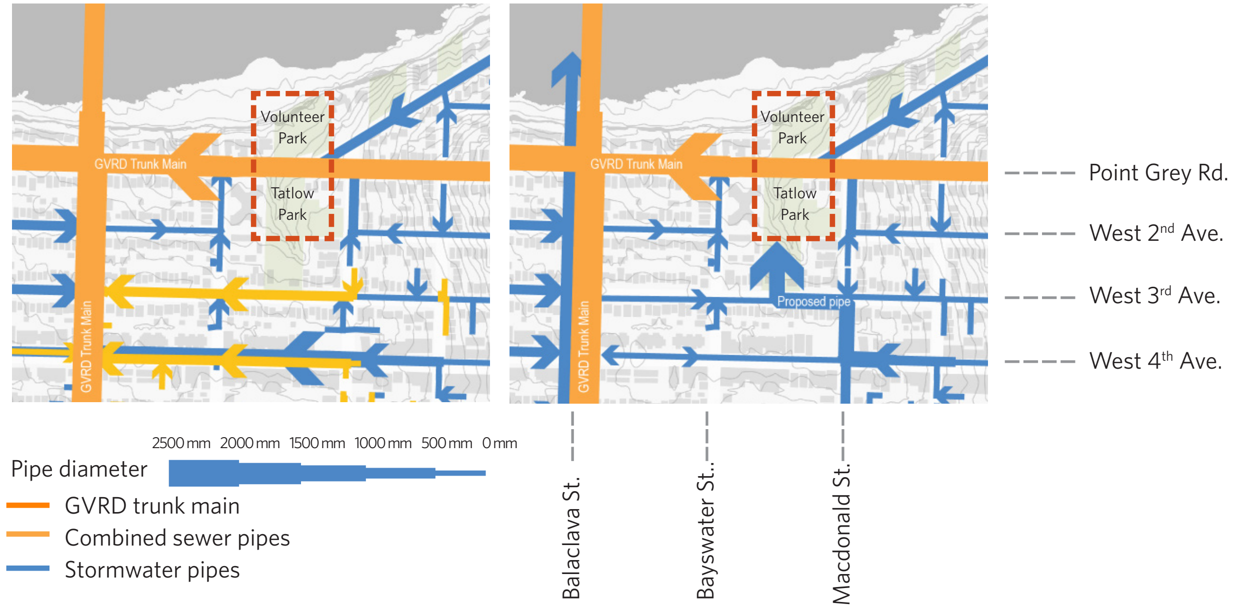


Alternative sewer separation strategy 2
(sanitary pipe + rain garden in replacement of on-street parking lane)

Strategy 2:
Stream Daylighting and Restoration

In order to daylight Tatlow Creek, stormwater from nearby storm drainage pipes can be diverted into Tatlow Park. Currently the largest storm pipe close to the park is the one along West 4th Avenue. It is a 1,050 mm diameter storm pipe installed in 2013. By diverting and extending this storm pipe along Macdonald Street to the north, and then along West 3rd Avenue to the west, stormwater in this large pipe could be diverted into Tatlow Park.

Existing storm drainage system *Proposed storm drainage system*



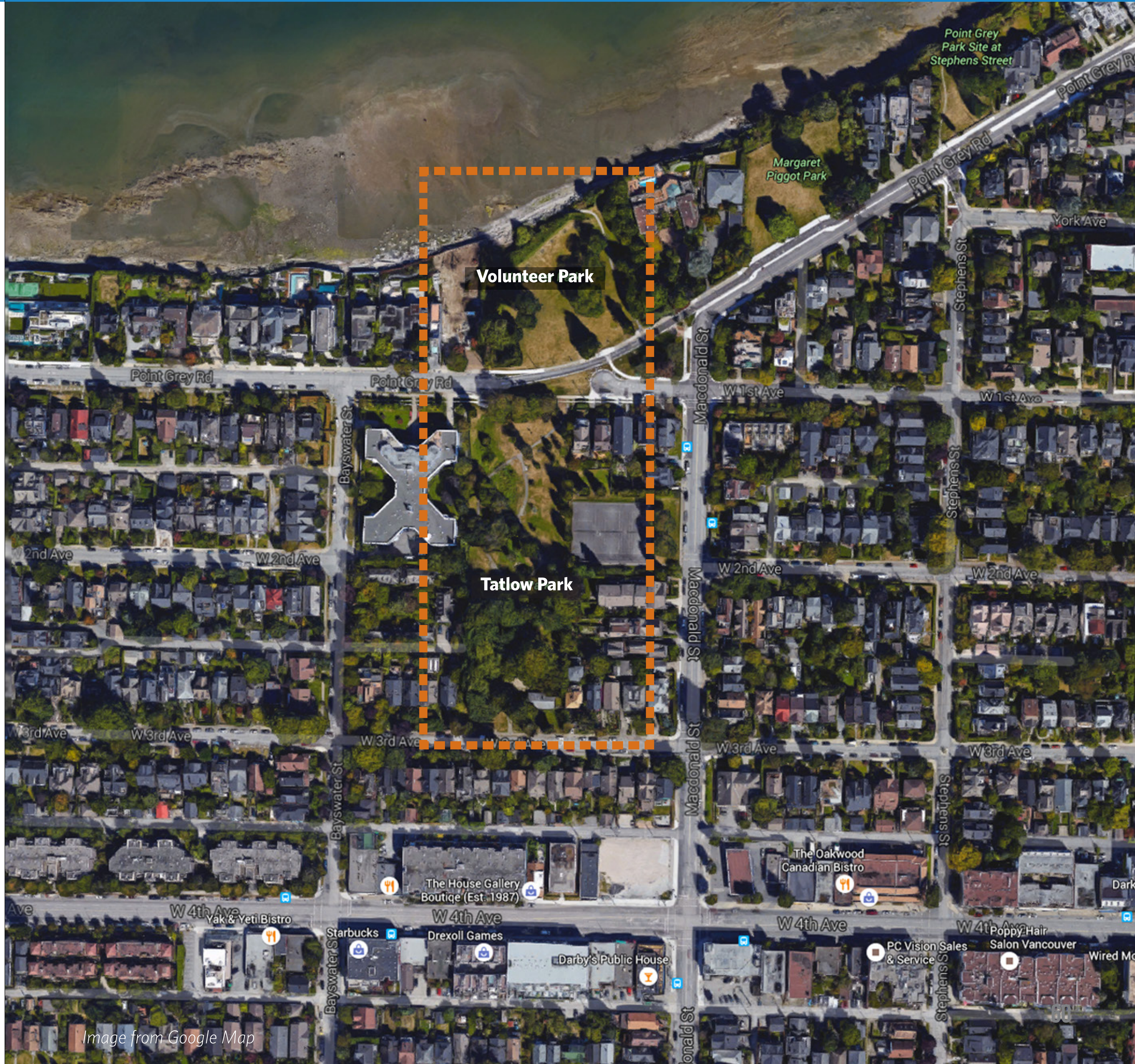
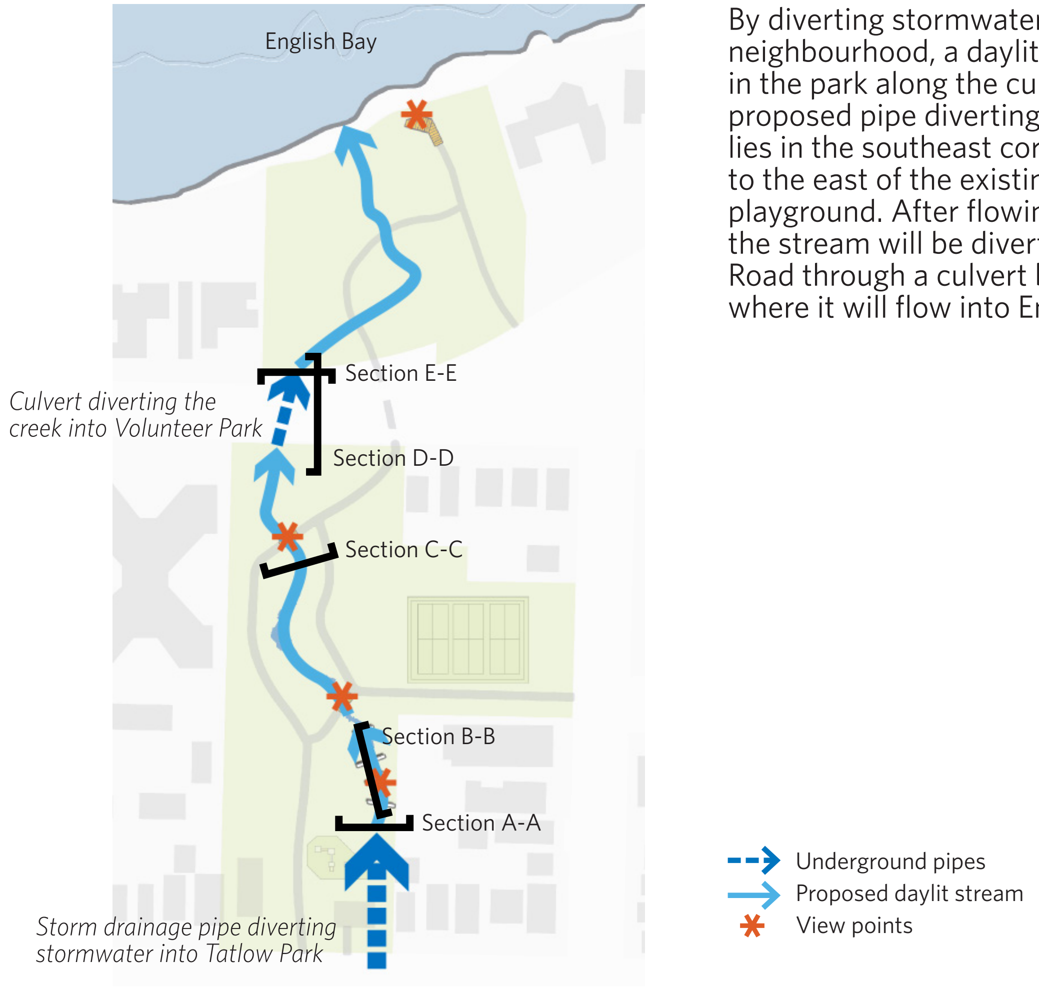


Image from Google Map

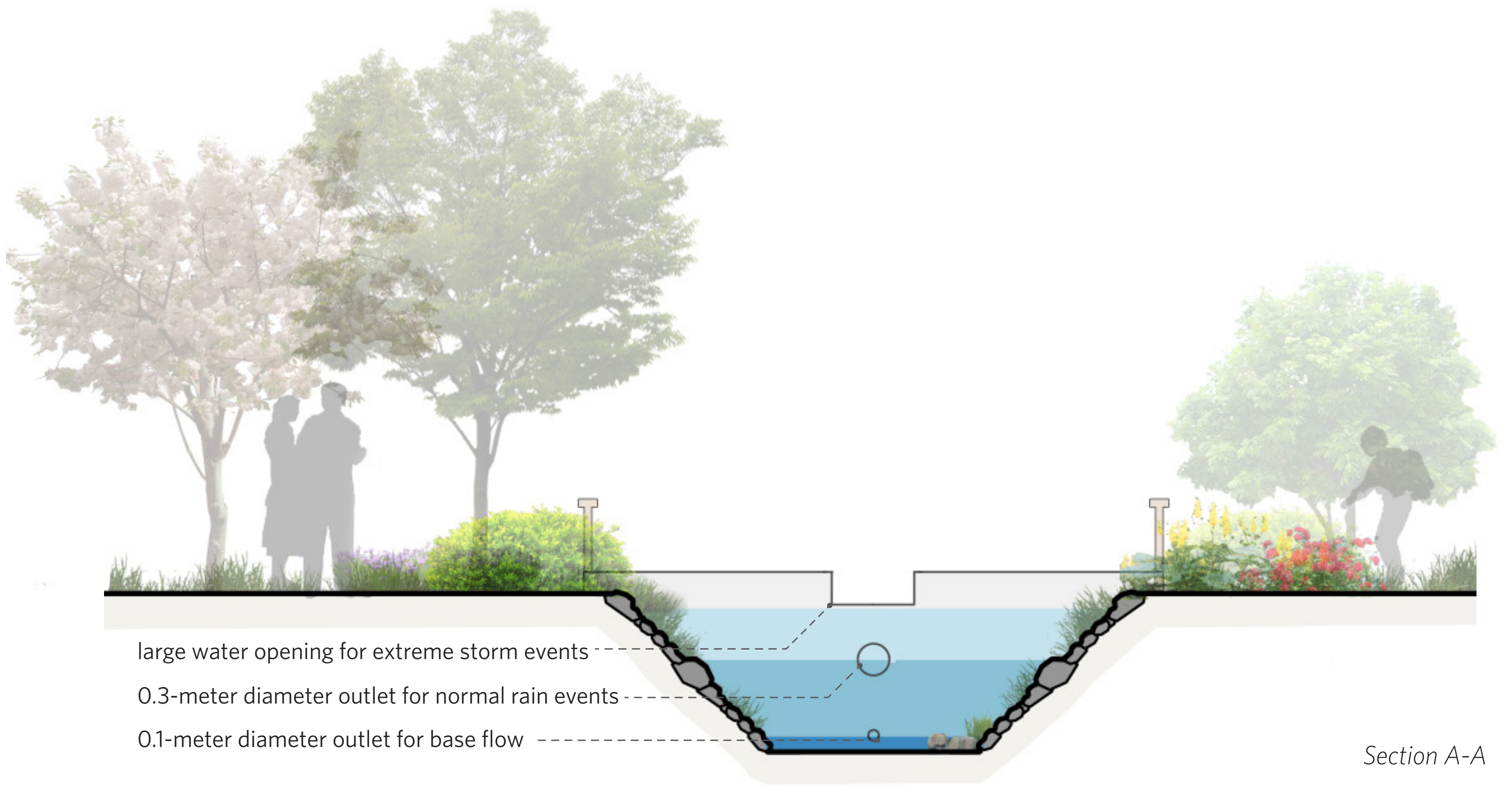


By diverting stormwater from the nearby neighbourhood, a daylit stream could be created in the park along the current stream channel. The proposed pipe diverting stormwater into the park lies in the southeast corner of Tatlow Park, and to the east of the existing building and children's playground. After flowing through Tatlow Park, the stream will be diverted underneath Point Grey Road through a culvert box into Volunteer Park, where it will flow into English Bay.

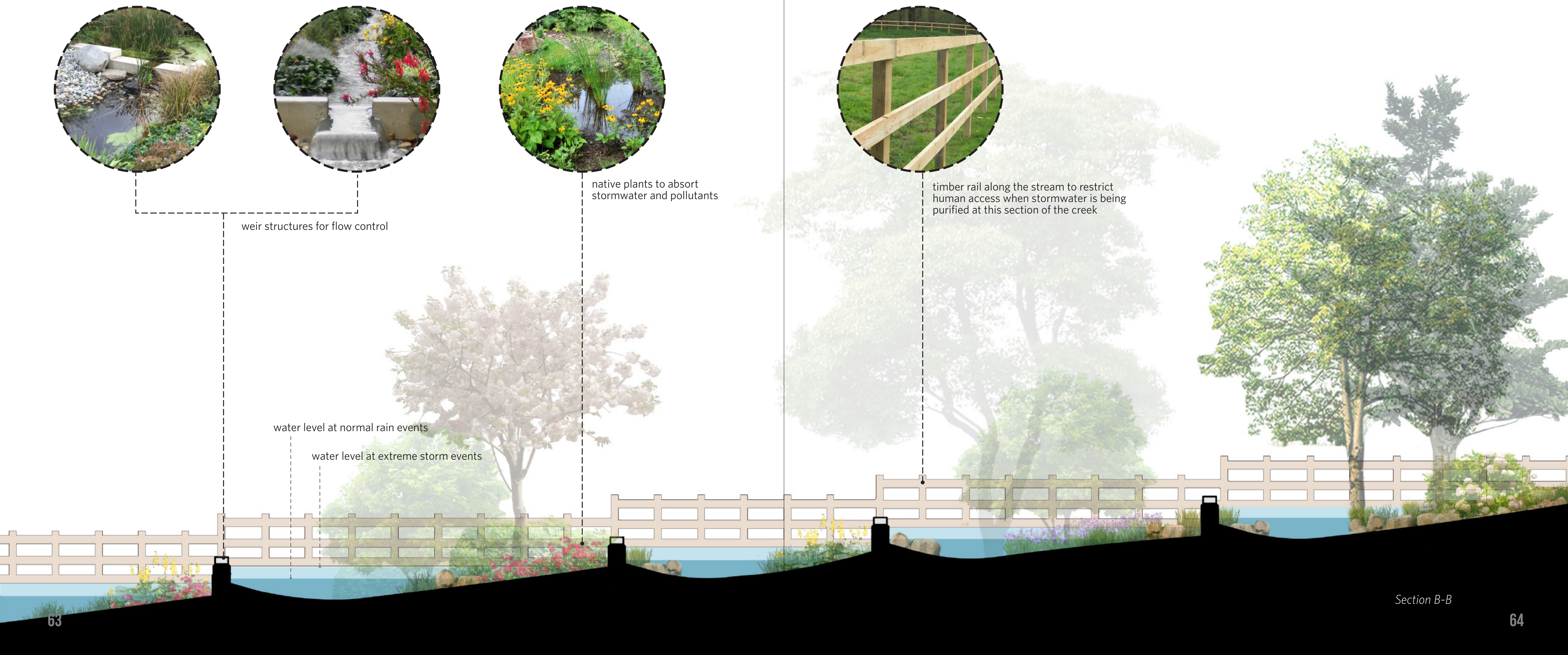
Flow Control

After entering Tatlow Park, the daylit stream passes through a series of terraced constructed wetlands with weir structures. The purpose of the proposed terraced wetlands is to control river flow as well as to purify water by bio-filtration processes. The weir structures are designed to control river flow through different sized outlets at various water levels. The outlet at the bottom of the weir structures is 0.1 meters in diameter.

It allows for a small amount of water to pass through as the year-round base flow of the creek, primarily generated from soil seepage. The outlet in the middle of the weir structures is 0.3 meters in diameter, and allows for water flow during normal rain events. The large opening at the top of the weir structures allows for a substantial amount of water to pass through, which is more likely to occur during extreme storm events.



Section A-A


native plants to absorb stormwater and pollutants
weir structures for flow control
timber rail along the stream to restrict human access when stormwater is being purified at this section of the creek
water level at normal rain events
water level at extreme storm events

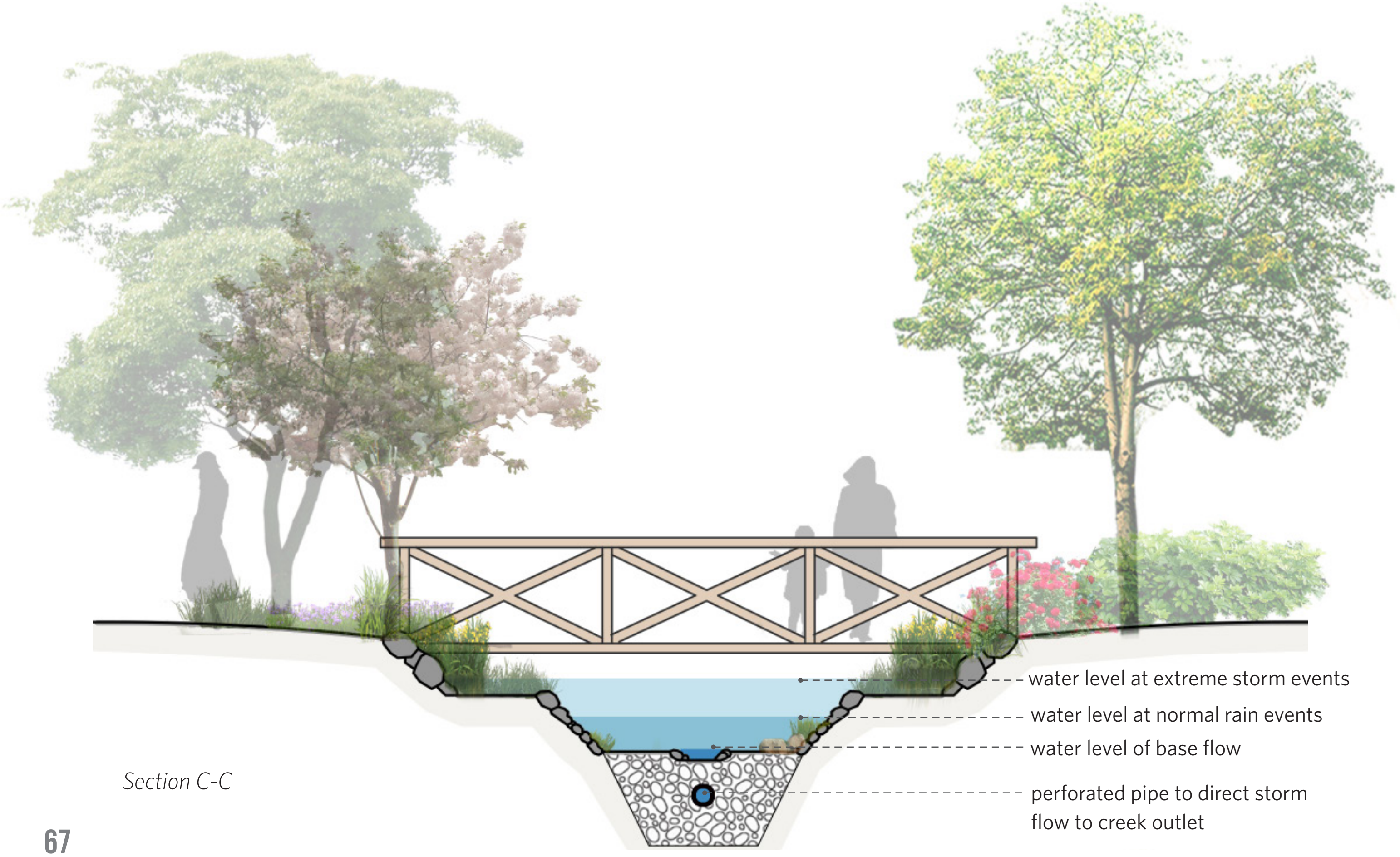
Section B-B

Native plants are selected to populate the terraced constructed wetlands, and they will serve to absorb runoff and pollutants in stormwater, and also function as a wildlife habitat in the park. As stormwater at the terraced constructed wetlands is in the process of being treated, human access to this section of the daylit stream will be discouraged by timber rails along the stream.

River Channel Design

Most of the current stream channel at Tatlow Park will have to be widened and stabilized to accommodate the potential increased annual flows. The daylit stream is designed to accommodate different levels of rain events. During dry seasons, soil seepage forms the base flow of the creek. During normal rain events and extreme storm events, water levels will fluctuate at different levels of the channel.

To increase the ecological functions of the daylit stream, at least 2 meters of buffer area should be maintained along the channel, populated by native species to absorb runoff and pollutants. To stabilize the river channel against erosion, rocks and gravel are proposed to be installed along the channel. A perforated pipe could be utilized below the channel to convey stormwater and facilitate its infiltration.



Section C-C

Strategy 3:
Public Amenities Improvement

Additional public amenities are proposed along the daylit stream with continuous pathways and native landscaping. The character of the existing parks is protected by integrating existing landscape elements with the daylit stream, such as the current wood bridges. In order to attract more visitors to the parks and promote their understanding of stream restoration and watershed health, education and outreach programs are proposed in the two parks.

Park Design

Native species can be planted in the park and along the stream to create a picturesque environment. Most of the current pedestrian path can be preserved, and new paths can be built to connect Tatlow Park to Volunteer Park, creating a continuous pedestrian pathway. The current wood bridges will be preserved to maintain the character of the park, and serve as important view points of the daylit stream. Benches and other seating areas will also be installed along the path.

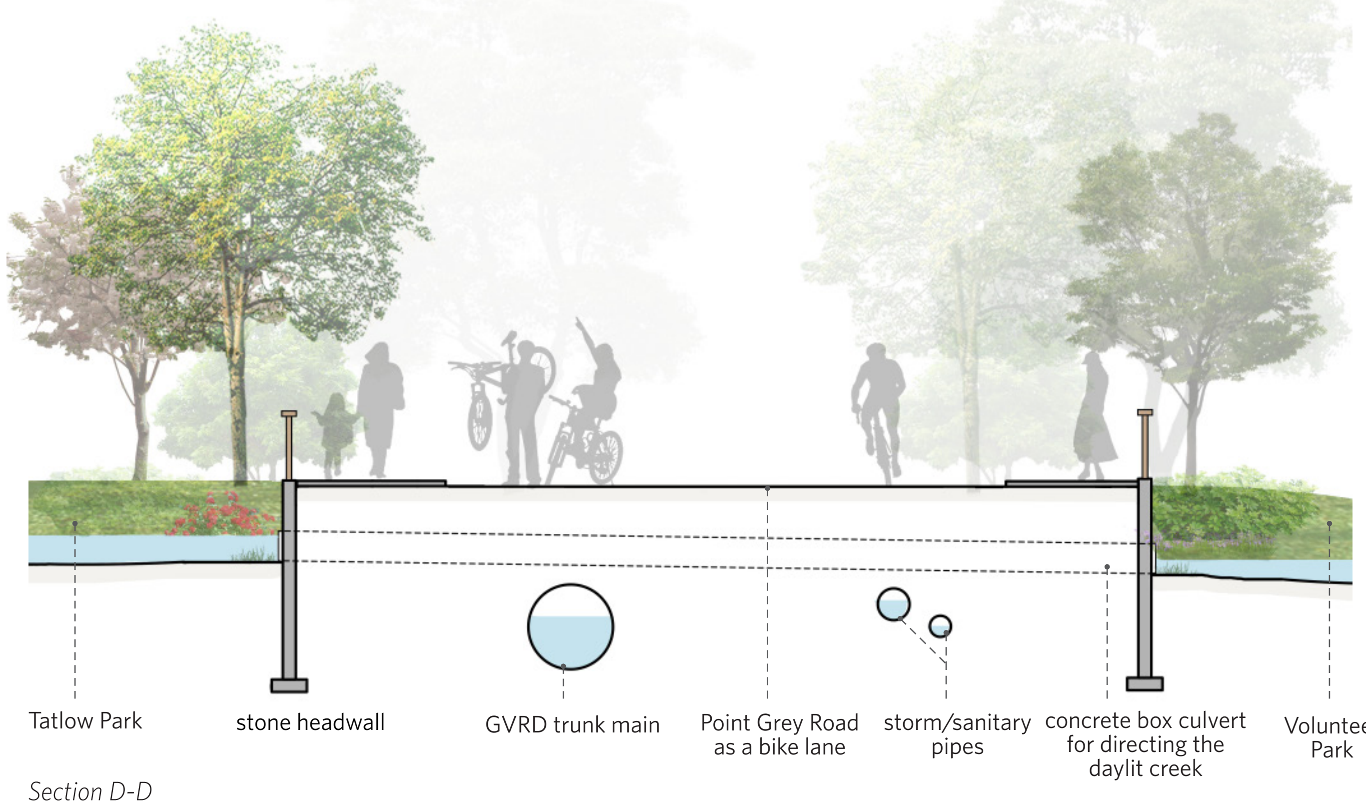
As the creation of a river channel in Volunteer Park requires additional excavation of soil, this material can be used to create mounds inside the park, instead of being hauled off site. This not only reduces construction costs, but also creates an undulated landscape with sloped lawns for visitors to enjoy the beautiful scenery of the North Shore and downtown Vancouver. At the end of the path at Volunteer Park, a lookout platform is proposed for visitors to rest and take in the beautiful views of the waterfront.

Views of the North Shore and downtown Vancouver at Volunteer Park

"Expression of a Bridge"

At the Tatlow Park stakeholder's group discussion, ideas emerged on transforming the current section of Point Grey Road between the two parks into a bridge. Considering Point Grey Road as a bike route, a bridge would allow for an open flowing creek from Tatlow Park to Volunteer Park. This would create a more natural environment for the daylit creek and make it more visible from Point Grey Road. However, with the complex utility pipes under Point Grey Road, including a GVRD trunk main, a stormwater pipe and a sanitary pipe, a full bridge would be very difficult to implement. Nevertheless, there is potential to create an "expression of a bridge" (Sharp, 2016) at Point Grey Road between the two parks.

The design proposes stone headwalls with handrails at both sides of Point Grey Road to

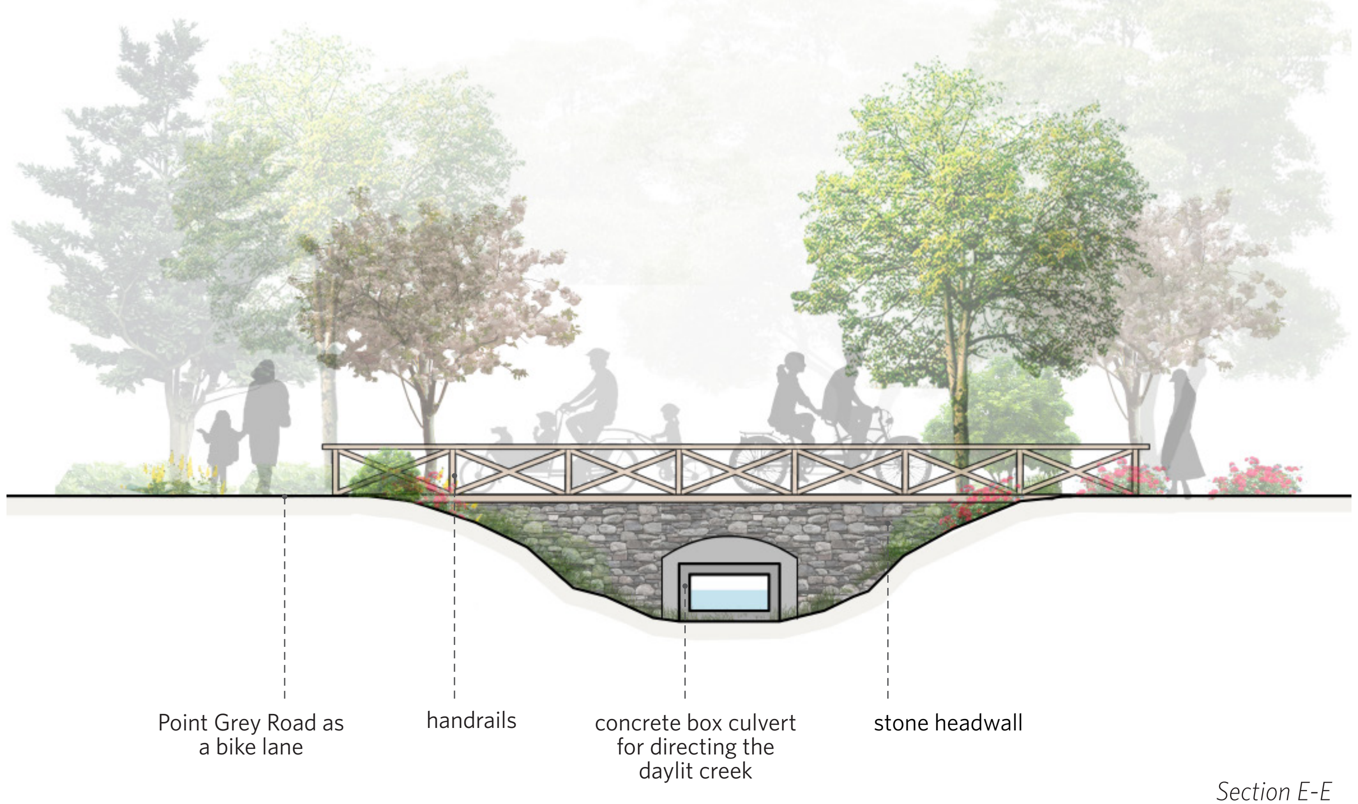


Section D-D

protect the current utility pipes. This "expression of a bridge" could be created with a concrete box culvert diverting the daylit stream under Point Grey Road. This way, pedestrians and cyclists on Point Grey Road will have more visual and physical access to the daylit creek, and a stronger sense of the urban stream environment. This would enhance the social and aesthetic value of Point Grey Road as part of the city bike lane system.

Education Programs

This daylit stream would be an invaluable asset for a variety of educational purposes, which will increase the parks' social value as the centres of the neighbourhood. Children from local schools could use the stream as a living lab to learn about watershed health, native species, wildlife habitat, etc. Engaging more visitors into these programs can create a stronger sense of community and neighbourhood character.



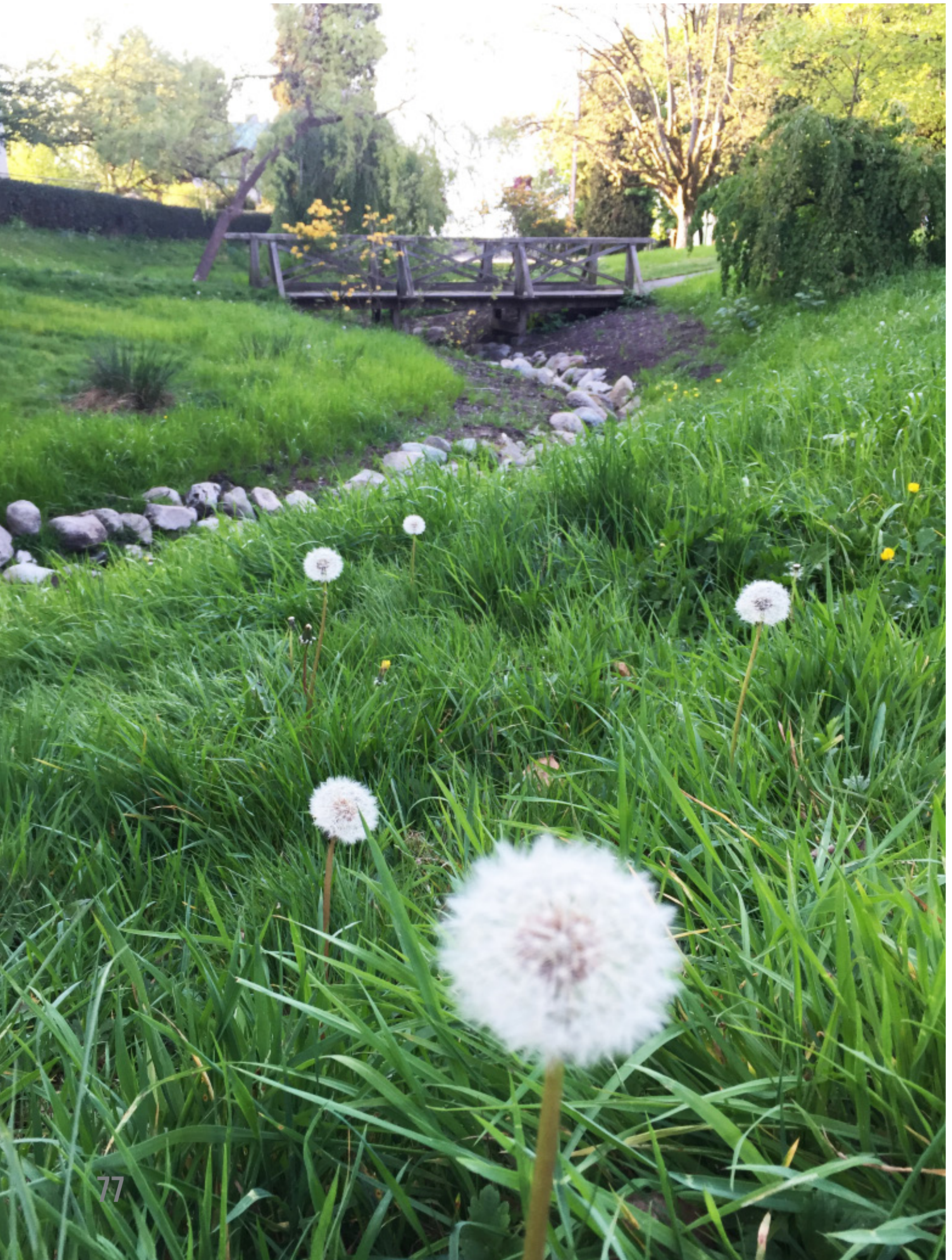
Section E-E

Discussion

In this design proposal, watershed health is improved by replacing artificial engineered storm infrastructure with soft, pervious, green stormwater infrastructure. Stormwater within the surrounding neighbourhood is diverted into the park for daylighting historic Tatlow Creek. After being purified by a series of terraced wetlands in Tatlow Park, the stream flows through the existing but widened route into Volunteer Park, where it finally flows into English Bay. Stream flow is controlled by water outlets of varied sizes and heights, and the stream bank is stabilized by stones and gravel. Native plants are used to absorb runoff and pollutants from stormwater and create a healthy riparian corridor, which serves as wildlife habitats. Public amenities are improved and enhanced along the daylit stream.

However, there are also significant challenges in daylighting Tatlow Creek. First, there are conflicting goals in daylighting the stream. On one hand, there is a strong vision from the community to restore historic salmon habitats, which will require buffer areas along the stream that minimizes human disturbance. On the other hand, being located in the center of the Kitsilano neighbourhood, a daylit stream that is accessible to visitors with various public amenities and programs will significantly increase the social value of the daylit stream. This reflects inevitable trade-offs that need to be balanced.

Additionally, technical challenges to daylighting the stream include a detailed study of the current utility pipe alignment on West 3rd Avenue and Point Grey Road, calculation of stormwater flow into the park, as well as excavation works to widen the existing stream route, and dealing with the significant amount of excavated soil. The initial cost of daylighting the creek would also be significant, and will include survey and design work, excavation and grading of the two parks, and materials for the new channel. Potential funding sources include capital funding from the Vancouver Park Board, funding from the sewer separation branch and greenway branch of the City of Vancouver, donations through the Vancouver Foundation, etc. Using donated materials and volunteer labour through educational programs could help reduce costs.



CONCLUSION

In this project, the benefits and challenges of urban stream daylighting are investigated through literature review, case studies, personal interviews, field studies, and a mock design proposal. Focused on a Vancouver context, this project explores plans and policies that encourage integrated stormwater management and daylighting, as well as existing daylighting projects in Vancouver and their benefits and limitations. A spatial overlay approach is proposed to identify future daylighting projects with the most potential and feasibility. These criteria include whether a site is on city-owned land, included in a park, utilizing a separated sewer system, and connected with existing stream networks. Other important factors to assess the potential of daylighting include pipe depth, pipe diameter, community support, etc. These factors should all be evaluated on a context-specific basis.

This project also develops a design proposal for daylighting Tatlow Creek at Tatlow Park and Volunteer Park in the Kitsilano neighbourhood in Vancouver. Stormwater within the surrounding neighbourhood is proposed to be diverted into the parks for daylighting the stream. The proposed daylit stream will bring about a myriad of benefits to the neighbourhood including improving stormwater quality by introducing wetlands and native species, and creating wildlife habitats along the stream for birds, insects, and other wildlife. Although many challenges exist, such as technical difficulties and potentially large expenses, a daylit stream will serve as an important center for the neighbourhood with significant environmental, recreational and educational opportunities.

Overall, this project aims to develop a systematic approach to identify future opportunities for daylighting projects. With a design proposal for daylighting Tatlow Creek in Vancouver, it tests potential design techniques and strategies for daylighting practices in the context of sewer separation and integrated stormwater management in Vancouver. Daylighting a stream could be an expensive project with a long timeframe for implementation. It may require strong collaboration among different city departments (including planning, sewer engineering, greenways and street engineering, the park board, etc.), communities and other organizations.

Through a comprehensive understanding of the benefits and trade-offs of daylighting, effective collaboration among city departments and surrounding communities, and the utilization of sustainable design techniques, a daylit stream can help restore the hydrological and ecological systems of a watershed. But even more than this, it can also engage the public and provide significant social value to a community, by bringing nature back to the city.

BIBLIOGRAPHY

Auckland Regional Council . (2008). Stream Daylighting Identifying Opportunities for Central Auckland: Concept Design .

Baume, M. (2010, 11). Bay area cities rediscover the creeks under their streets.

Botelho, Z. (1999). Once and future creeks. Alternatives Journal , 26 (Spring), 6.

Buchholz , T., & Younos, T. (2007). URBAN STREAM DAYLIGHTING Case Study Evaluations.

Buchholz, T., Bork, D. R., & Younos, T. M. (2007). Urban Stream Daylighting: Design Application to Stroubles Creek, Blacksburg, Virginia. Retrieved 2015, from Virginia Water Resources Research Center: http://vtechworks.lib.vt.edu/handle/10919/49483

City of Vancouver. Tatlow Park. Retrieved 2 2016, from City of Vancouver: https://cfapp.vancouver.ca/parkfinder_wa/index.cfm?fuseaction=FAC.ParkDetails&park_id=119

City of Vancouver. Volunteer Park. Retrieved 2 2016, from City of Vancouver: https://cfapp.vancouver.ca/parkfinder_wa/index.cfm?fuseaction=FAC.ParkDetails&park_id=121

City of Vancouver. (2015, 6). City-wide Integrated Stormwater Management Plan. Retrieved 1 2016, from City of Vancouver: http://vancouver.ca/home-property-development/city-wide-integrated-stormwater-management-plan.aspx

City of Vancouver. (2012). Climate Change Adaptation Strategy. Vancouver: City of Vancouver.

City of Vancouver. (2013). Creekway Park. Retrieved 2015, from City of Vancouver: http://vancouver.ca/home-property-development/creekway-park-completion-project.aspx

City of Vancouver. (2012). Greenest City 2020 Action Plan. Vancouver: City of Vancouver.

City of Vancouver. (2011). Hastings Park/Pacific National Exhibition Master Plan A New Vision for Hastings Park . Vancouver: City of Vancouver.

City of Vancouver. (2012, 7). Restoring streams. Retrieved 1 2016, from City of Vancouver: http://vancouver.ca/home-property-development/restoring-streams.aspx

City of Vancouver. (2013, 3). Separating sewage from rainwater. Retrieved 1 2015, from City of Vancouver: http://vancouver.ca/home-property-development/separating-sewage-from-rainwater.aspx

City of Vancouver. (1999). Spanish Banks Creek - Culvert Access Improvement. Vancouver: City of Vancouver.

City of Vancouver. (2015). Still Creek Enhancement. Retrieved 2015, from City of Vancouver: http://vancouver.ca/home-property-development/still-creek-enhancement.aspx

City of Vancouver. (2007). Still Creek Enhancement Project - 3400 Cornett Road . Vancouver.

City of Vancouver. (2002). Still Creek Rehabilitation and Enhancement Study. Vancouver: City of Vancouver.

Conradin, F., & Buchli, R. (2008). Separating clean water inputs from underground pipes. In Taylor, & Francis, Handbook of Regenerative Landscaping (pp. 47-60). CRC Press .

Gerson, S., Wardani, J., & Niazi, S. (2005). Blackberry Creek Daylighting Project, Berkeley : Ten-Year Post-Project Appraisal. Retrieved 2015, from Water Resources Collections and Archives University of California: http://escholarship.org/uc/item/0q3257n9

Hamilton County Planning and Development. 2011 "Community Revitalization Result- ing from Stormwater Management Strategies: Case Studies." Hamilton County Planning and Development.

Jones, S. W. (2001). Planning for wildlife: Evaluating creek daylighting as a means of urban conservation.

Klesius, M. (1999). Daylighting: the Untombing of City Rivers. River (Bozeman, Mont.) , 2 (6), 83-88.

Koshaley, D. H. (2008). Developing eligibility criteria for daylighting streams as applied to Dallas' Mill Creek.

Landscape Architecture Foundation . (2011). Cheonggyecheon Stream Restoration Project. Retrieved 2015, from Landscape Performance Series: http://landscapeperformance.org/case-study-briefs/cheonggyecheon-stream-restoration#/project-team

Linton, J. (2009). Daylighting in the Heart of Seoul: The Cheong Gye Cheon Project. Retrieved 2015, from LA creek Freak: https://lacreekfreak.wordpress.com/2009/04/24/daylighting-in-the-heart-of-seoul-the-cheong-gye-cheon-project/

Mel Lehan. (1996). Daylighting First Creek.

Metro Vancouver. (2015). How the System Works. Retrieved 2 2016, from Metro Vancouver: http://www.metrovancouver.org/services/liquid-waste/drainage/system/Pages/default.aspx

Milley, S. O. (2003).The Tatlow Creek Revitalization Project. The University Of British Columbia , Department of Landscape Architecture. Vancouver: The University Of British Columbia .

Novotny, V., Ahern, J., & Brown, P. (2010). IX. Restoring Urban Streams. In J. W. Sons, Water Centric Sustainable Communities: Planning, Retrofitting, and Building the Next Urban Environment. Hoboken, NJ, USA.

Pinkham, R. (2000). Daylighting: New Life for Buried Streams Kilgoblin Wetland. Land and

Water , 45 (1), 38-39.

Pinkham, R. (2001). Stream Restoration and Daylighting: Opportunities in the Pittsburgh Region.

Piteau Associates. (2000). Restoration of First Creek, Tatlow Park. Vancouver.

Poplar-Jeffers, I.O., Petty, J.T., Anderson, J.T., Kite, S.J., Strager, M.P. and Fortney, R.H. (2008) Culvert Replacement and Stream Habitat Restoration: Implications from Brook Trout Management in an Appalachian Watershed. USA Restor. Ecol., 17, 1–10.

Scarth, D. (2012, 7). Spanish Banks Creek Vancouver. Retrieved 12 2015, from Urban streams: http://www.urbanstreams.org/spanishbankscreek/

Schueler, T., & Brown, K. (2004). Urban Subwatershed Restoration Manual No. 4: Urban Stream Repair Process.

Schwarz, T. (2011). Re-thinking the places in between: stabilization, regeneration, and reuse. Reinventing America's legacy cities: strategies for cities losing population , 167-184.

Sinclair, C. (2012). An exploration of stream daylighting and urban attitudes towards the environment. JOURNAL OF GEOGRAPHY , 6, 68-79.

Smith, B. R. (2007). Assessing the Feasibility of Creek Daylighting in San Francisco, Part I: A Synthesis of Lessons Learned from Existing Urban Daylighting Projects. Retrieved 2015, from UC Berkeley: Water Resources Collections and Archives. : http://escholarship.org/uc/item/7rm646zk

Vancouver Public Aquarium Association. (1989). Vancouver Old Streams. Vancouver: Vancouver Public Aquarium Association.

Wild, T. C., Bernet, J. F., Westling, E. L., & Lerner, D. N. (2011). Deculverting: reviewing the evidence on the 'daylighting' and restoration of culverted rivers. Water and Environment Journal , 25 (3), 412-421.

Wong, S. (1998). Daylighting of Streams: Vancouver Parks Experience . Environment Feature , 26-27.

IDENTIFICATION MECHANISM AND DESIGN STRATEGIES FOR
STREAM DAYLIGHTING IN VANCOUVER

SCHOOL OF COMMUNITY AND REGIONAL PLANNING
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MAY 2016