Integrated Stormwater Management Plan

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Images from Cover – Left to Right: Mosquito Creek at Burrard Inlet (year unknown), Mouth of Lynn Creek prior to port development (1953), Mouth of Lynn Creek (2015)

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Section 1 – Commitment and Purpose

The City of North Vancouver (City) has made a commitment in the Official Community Plan to prepare and implement an Integrated Stormwater Management Plan in support of the regional Integrated Liquid Waste and Resource Management Plan (Metro Vancouver, 2011) as mandated by the Ministry of the Environment under the Environmental Management Act.

Integrated Stormwater Management Plans (ISMPs) are watershed based plans that are created to protect watershed values as development and redevelopment changes the landscape. Watershed values are often measured in terms of ecological health, such as abundance and diversity of aquatic and terrestrial animals, or density and health of forest areas. Watershed values also include social elements, which include public safety and health and traditional uses and values of First Nations citizens, and could be measured in terms of protection from floods, quality of water in streams, and access and recreation opportunities in stream corridor parks.

The Plan establishes a framework to recognize and integrate these different values, and focuses on evolving the established practice of managing rain as stormwater in storm sewers to support an overall goal of net change.

The City shares, to varying degrees, three streams with the District of North Vancouver, Squamish Nation and Port Metro Vancouver. These include: Mosquito Creek (and tributaries Wagg Creek, Thain Creek, and Mission Creek), Mackay Creek, and Lynn Creek (and tributary Keith Creek).

Section 2 - Problem Statement

Prior to settlement and development, the watersheds of North Vancouver were densely forested, with a rich layer of organic (humic) soil over a mantle of dense sand, silt, and gravel that was deposited following the last glaciation. On an average rainy day in the forest, most of the rain would be intercepted in the tree canopy, and the remainder captured in the forest soils where it would slowly move to the streams as shallow groundwater in a process that may have taken weeks. This natural hydrological process would temper the flow in streams, providing a steady source of streamflow during dry periods and limiting the streamflow peaks during rainy periods which provided an environment for an abundance of local and sea-faring (anadromous) fish and the natural food web that they are part of.

Development has introduced an artificial efficiency where the roads and roofs are directly connected to storm sewers to deliver rainfall to streams in minutes as stormwater instead of days or weeks. The introduction of hard (or impervious) surfaces (roads and roofs) and loss of tree cover and absorbent soil is the largest change to the hydrological response of watersheds, and is the prime reason for the environmental degradation in streams and coastal areas. The rapid delivery of rainfall to streams has resulted in channel instability and erosion, loss of habitat, and loss of species. In addition, the connection of roads and other areas to storm sewers is a direct route for pollutants (e.g. heavy metals and hydrocarbons) to reach streams, as well as biological pathogens such as fecal coliform bacteria (e.g. *Escherichia coli*).

While the development of our community and watersheds necessitated an efficient storm sewer network to safely drain areas, proper consideration of environmental consequences were not included between the 1940s and 1980s when much of this growth occurred. Research conducted in the 1990s in Puget Sound found that once a watershed became more than 10% impervious (total impervious area), that permanent cumulative impacts to aquatic habitat would begin to occur.

The recent *Living Planet Report* prepared by the World Wildlife Foundation (October, 2016) indicated that, on average, world populations of vertebrate species declined by 58% between 1970 and 2012. More significant is that freshwater habitats (rivers, streams, wetlands, and lakes) represent only 0.8% of the Earth's surface and only 0.01% of the world's water. Total populations of freshwater species (fish, birds, amphibians) are estimated to have declined by 81% in the same period from 1970 to 2012, while both freshwater and anadromous fish populations only declined by about 41%.[1]

The key identified threats to wildlife populations are: habitat loss and degradation, species over-exploitation, pollution, invasive species and disease, and climate change. Habitat loss is by far the most dominant driver to declining freshwater and terrestrial species, where the most common causes of loss are attributed unsustainable agriculture, logging, transportation, residential and commercial development, and other resource development.

These global estimates of species population decline are alarming, and they illustrate the magnitude of environmental loss that has already occurred and scarcity and importance of freshwater and freshwater habitats. They further underscore that all freshwater resources should be protected and enhanced to support what remaining wildlife still exists, even in urban streams.

The City's development began at the onset of the 20th century and saw periods of rapid growth in the early part of that period, and again in the 1950s and 1960s. By the 1980s, the last major new residential development in the City occurred as the Tempe Heights neighbourhood was developed, and since that time the overall extent of development in the City has not substantially changed. Since the 1990s the City has been in a period of redevelopment, where the first generation of development is being surpassed by a second generation that is being built to meet the present and future needs of the City. The second generation of development is generally increasing the impervious areas on an incremental level as smaller houses make way for larger ones, and more intensive use of hard surfaces is used to support all modes of transportation.

A multi-spectral image that assesses landscape cover, captured in 2010, was used to estimate the percentage of hard or impervious surfaces in the City. The analysis of this image allows for identification of different vegetation types, as well as identification of hard surfaces like paving and roofing, and could be used for future comparative analysis of land cover.

[1] 2016, *Living Planet Report 2016*, World Wildlife Federation (including images)

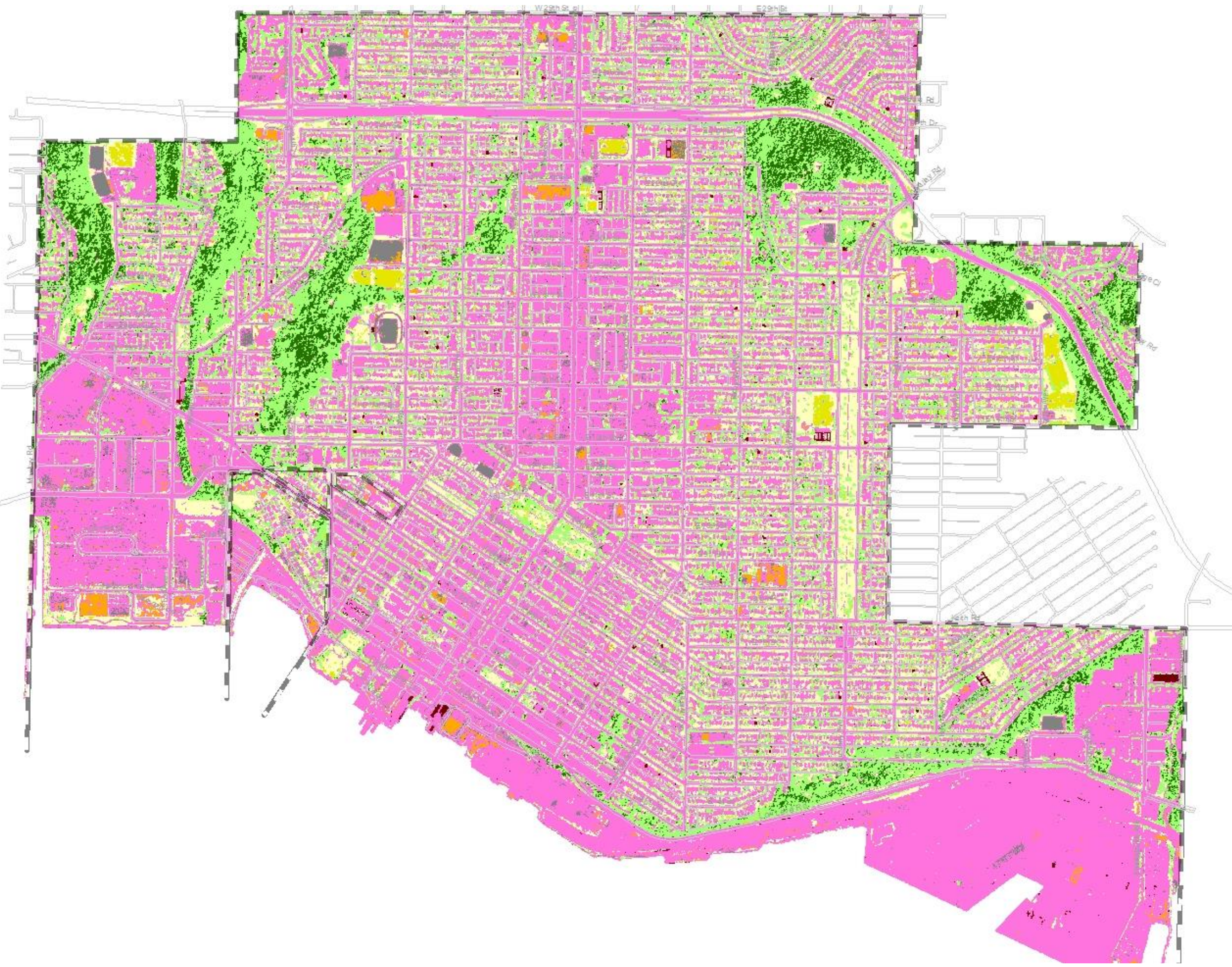


Figure 2-1: Map of Impervious Areas in the City

In Figure 2-1, the mass of pink area represents impervious surface, while the range of yellows to greens indicate a range of vegetation from grass to deciduous and coniferous trees. Based on this tool, the total impervious areas (TIA) in the City can be estimated as follows:

Table 2-1: Summary of Total Impervious Areas by Region

Area	Description	Percent Impervious
City-wide	Including all land-uses	55%
Wagg Creek watershed	Including District areas	50%
Mosquito Creek watershed	Including District and undeveloped areas	29%
City Street Right-of-Ways	About 17% of City area	83%
Typical Low Density City Lot	Range of older home to new build	35% - 65%

CURRENT STREAM HEALTH

The increase of total impervious area in the City has had an effect on health of streams. A common method to assess the biological productivity of streams and the effect of poor water quality and rapid runoff of rain is through stream insects or benthic invertebrates. Metro Vancouver began the first round of benthic invertebrate measurements in 1999, which included

Wagg Creek, and the City has continued a program of monitoring as part of the City's Environmental Protection Program (2000). The Biological - Index of Benthic Invertebrates (B-IBI) is the recommended system to evaluate the quantity and diversity of stream insects, where a very low value would be below 10.0 and a very high value would be above 35.0.

At the onset of the measurements in 1999, Wagg Creek measured a B-IBI of **11.5** and has steadily improved over the years with a peak measurement of **20.0** in 2012. Table 2-2 summarizes the B-IBI values of the three main benthic invertebrate measurement locations.

Table 2-2: Summary of Benthic Monitoring Data (B-IBI)

Year	Mackay Creek	Mosquito Creek	Wagg Creek
1999	-	-	11.5
2003	15.5	22.5	15.0
2004	-	-	15.0
2006	20.0	19.5	18.5
2008	18.0	20.0	17.0
2009	-	-	18.0
2010	17.5	21.0	14.0
2012	21.0	23.5	20.0
2014	22.0	27.5	19.0

Wagg Creek is the most urbanized stream in the City, has a total impervious area (TIA) of greater than 50%, and receives a large portion of runoff from roadways, including Highway 1, near Lonsdale. The B-IBI in 1999 is very similar to other very urbanized streams, most notably Still Creek in the City of Vancouver. A B-IBI score of **11.5** suggests that the stream is subjected to poor water quality (e.g. metals, hydrocarbons, etc.) and stream flows may be too high to allow the lowest level of the food web to establish.

A secondary issue associated with increase in TIA is a diminishing capacity of storm sewer infrastructure. The City storm sewers were first recorded to have been constructed in 1910, with only 10% of the present day storm system constructed by 1960, about 50% constructed by 1970, and more than 85% constructed by 1985. The majority of the City's current storm system was constructed during a short period in the 1960s at a time when the design of this infrastructure was based on the practice of the day, and likely did not foresee the level of impervious surfaces that are being presently introduced.

As green space on each property parcel lessens, the demand on the storm sewer infrastructure increases. The performance criterion for the storm sewer system is the ability to carry a rain storm that would on average only occur once every 10 years (10-year return period rain event). As impervious surfaces increase, the runoff associated with a 10-year return period rain storm will increase proportionally with TIA, and a 20% increase in hard surfaces would roughly result in 20% more flow into the storm sewers.

CLIMATE CHANGE

Climate change due to atmospheric forcing of greenhouse gases is anticipated to occur more rapidly in the coming decades and is foreseen to result in warmer temperatures, more rainfall, seasonally heavier rainfall, and increase in mean sea level. While the rate and magnitude of climate change is uncertain, global climate scientists have developed possible climate change estimates associated with possible carbon emissions scenarios.

For the Pacific Northwest, it is foreseen that total rainfall will increase during the three wetter seasons, with rainfall decreasing in the summer period. Based on a moderate carbon forcing scenario (RCP 4.5), a change in total seasonal rainfall is foreseen for this region, and is summarized in Table 2-3

Table 2-3: Summary of Total Rainfall by Season Change Under Moderate CO2 Emissions Scenario

Period	Fall	Winter	Spring	Summer
Current	0%	0%	0%	0%
2050	11%	5%	8%	-18%
2080	19%	14%	12%	-29%

In this region, there are two seasonal families of rain storms: long, moderately-heavy rain events that occur between October and January, and short, intense rain events that typically occur in the summer. The most notable storm in the City in recent history is the August 29, 2013 rain event that was centred over central Lonsdale resulted in over 60 mm/hour over a 10 minute period.

Using a higher carbon emissions scenario (RCP 8.5), an analysis using data from existing global climate models was used to estimate the frequency of future rain storm magnitudes. This preliminary analysis assumes that relationship between short rain events and daily rain events would be similar to the current climate. Under this possible future scenario:

- August 2013 storm would move from a 50-year event to that less than a 10-year return period event;
- 100-year events would roughly occur on a 10-year return period frequency; and
- 10 year events would occur approximately every two years.

Figure 2-2 below illustrates how the rainfall intensity curves would shift up relative to the indicator points for the 5 minute, 1 hour, and 24 hour storms. The hollow blue and red points indicate the August 29, 2013 storm, and how the 50-year return period storm in 2013 would be between a 2-year and 5-year event near the end of the century.

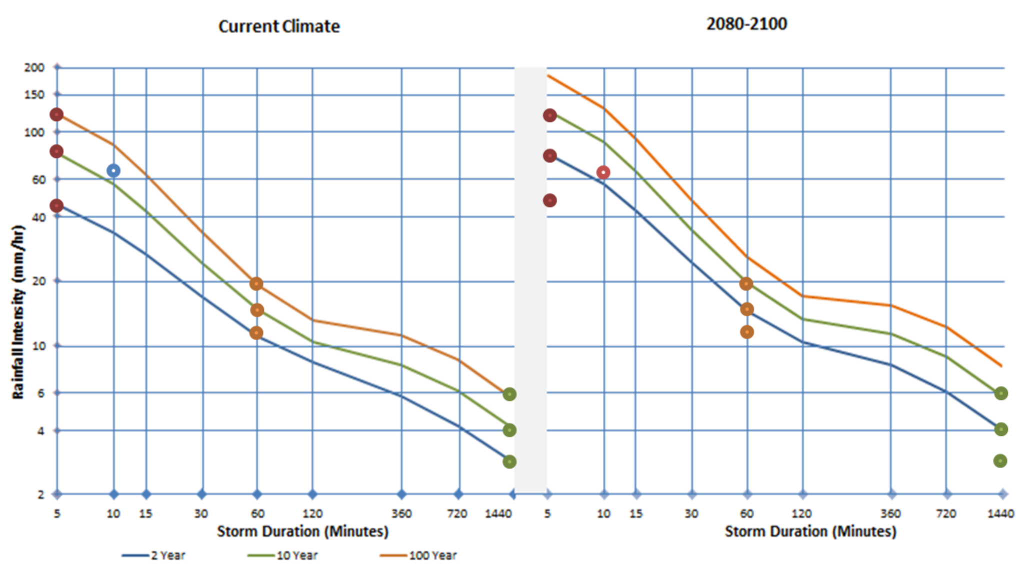


Figure 2-2: Estimate of Short Duration Storms For RCP 8.5 Scenario

Increased rain associated with climate change and an increase in impervious areas from ongoing redevelopment will further diminish the capacity of the storm sewer infrastructure and increase the risk associated with more frequent overland conveyance of storm water.

STORM SEWER AND INFRASTRUCTURE

The storm sewer system was first constructed in the 1910s with the construction of back-of-sidewalk drains that were typically constructed from 4" (100 mm) diameter clay tiles that collected local drainage and helped keep the sidewalks dry.

Since that time, the back-of-walk system has grown into a 148 km storm sewer system, where in some places the 4" back-of-walk system or laneway ditches are still the primary drainage infrastructure. Areas primarily relying on back-of-walk drains are considered "unserviced" and are a priority for new storm sewer construction. In addition to the 4" back-of-walk drains, we have a portion of the current storm sewer system that does not meet the current 10-year return period criteria. While these pipes are not normally problematic, capacity issues will increase with increased TIA and climate change. The following table summarizes the percentage of storm sewers that currently do not the design criteria, and the increase as TIA would be expected to increase under our current Official Community Plan and climate change.

Table 2-4: Pipe Capacity Summary

Condition	Length Undersized	Percent Undersized	Upgrade Cost
Current	32.1 km	21.7%	$16M
Future Total Impervious Area	72.6 km	49.2%	$36.3M
Future TIA and Climate Change	103 km	69.6%	$51.5M

The costs to upgrade storm sewer to meet the existing and changing drainage demand are substantial considering that most of the drainage infrastructure has not exceeded the current service life. In addition, upgrading pipes do not resolve the fundamental issue of water quality, and stream health. Upgrading pipes for capacity only is not an approach that would make efficient use of funding and is not the direction the City is proposing.

Addressing Urbanization and Climate Change:

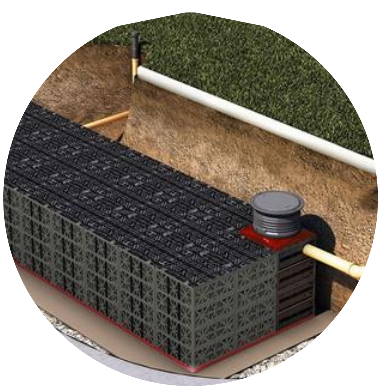
The solution to address ongoing increase in total impervious area and adapt to increased rain associated with climate change is to increase the efficiency of the landscape to capture and slowly release rainwater to the streams. While existing green public space can and should be preserved and property setbacks maintained on private property for the same purpose, new impervious areas must be connected back to the ground to establish an effective impervious area (EIA) that would re-establish the natural process of rainwater moving to the soil. This approach of managing stormwater at the source (source controls) is widely in effective for limiting the negative hydrological effects of urbanization and addressing a potential infrastructure gap associated with climate change.

Whereas Total Impervious Area (TIA) is a measure of all the hard surfaces in the landscape, Effective Impervious Area (EIA) is the measure of hard surfaces that are not directly connected to the ground. In our City, the TIA is about **55%** (including all private properties, public street area, and parks), while the EIA has been estimated to be between about **39% and 50%** based on data from the Wagg Creek streamflow gauging station for a period of seven years. Given that stream habitat and species begin to be adversely effected at about 10% TIA, the general goal for protection of aquatic species is to manage about 90% of the annual rainfall in source controls to achieve an EIA of 10%.

Source controls that can be employed to achieve this objective and include a wide variety of infiltration facilities like:

- underground infiltration chambers on private property;
- raingardens on private or public property;
- underground soil cells in our City boulevards that support healthy street trees and rainwater volume control.

All of these approached are currently used in the City for private sites and in public rights-of-way and are illustrated below in the three images.



The City's current guidelines for development are based on the 90% annual capture for high density sites (i.e. town homes and larger), and presently about 75% annual capture for single family sites and duplex. Based on a uniform capture and infiltration of 75% of average annual rainfall, the outlook for infrastructure is drastically improved.

Table 2-5: Pipe Capacity Summary with Source Controls Utilized

Condition	Length Undersized	Percent Undersized	Upgrade Cost
Current	32.1 km	21.7%	$16M
Future Total Impervious Area with source controls	2 km	1.4%	$1M
Future TIA and Climate Change with source controls	25 km	17%	12.5M

The effect of implementing source controls will address current infrastructure size deficits as the TIA of the City increases with redevelopment. Under a future increase in precipitation and TIA, the effect of source controls is still a net improvement over current conditions. This underscores the importance of implementing source controls for all levels of development and for street drainage infrastructure.

In order to achieve the objectives associated with source controls, it will be important to set goals for all new and existing impervious surfaces. There is presently a policy in place to implement source controls on all new private property developments. While challenging, City staff has been successful in having source controls applied to almost all new developments.

In addition, the City has been very active in the construction of raingardens, in addition to receiving contributed raingardens and soil cell facilities associated with development. Presently the City has more than 100 street drains that are managed by either raingardens or soil cells. This represents about **3%** of the 3,100 catchbasins we have in the City.

Section 3 - Our Environment

The City of North Vancouver sits on the lower flank of the North Shore Mountains, where steep, linear mountain streams with narrow watersheds occur regularly. The creeks are such a defining feature for the City, such that the western and eastern City boundaries coincide with Mackay Creek and Lynn Creek respectively. At the time of incorporation, these natural boundaries likely served as practical boundaries for the City. The majority of the City is within the Mosquito Creek watershed, with major tributary creeks including: Wagg Creek, Thain Creek, and Mission Creek.

MOSQUITO CREEK

The majority of the City is within the Mosquito Creek watershed, with major tributary creeks including: Wagg Creek, Thain Creek, and Mission Creek. Mosquito Creek and the associated watershed is the largest environmental feature in the City of North Vancouver. In the City, Mosquito Creek extends from 29th Street to 2nd Street, where the upper watershed is within the District of North Vancouver and the mouth of the creek is on Squamish Nation lands.

Historically Mosquito Creek would have been an important resource for First Nations people and would have supported a wide range of resident and anadromous fish species. The onset of development in the 1900s underscored the inherently hazardous nature of Mosquito Creek. Large floods in the 1950s led to damaging floods and channel instability. This led to the construction of the Evergreen debris flood basin by the Greater Vancouver Sewerage and Drainage District (Metro Vancouver) and the 1.2 km Evergreen Culvert upstream of Queens Road in the District, and resulted in decades of sediment management in the City portion of the creek downstream of Highway 1. The City still manages sediment in Mosquito Creek at Marine Drive with the most recent project occurring in 2016.

In addition to the Evergreen culvert, Mosquito Creek has seen fundamental modification when the Mission Creek tributary was diverted into the neighbouring Thain Creek tributary in the 1950s, and a large section of Mission Creek from 29th Street to 23rd Street was converted into a storm sewer network. The historical location of these streams has been interpreted from existing aerial photography and topography, which is shown in Figure 3-1. This figure is a first attempt to characterize these lost streams, and the lost streams have been named for the purpose of this study based present day features that indicate the alignment.

The Wagg Creek tributary watershed is the most dominant drainage area in the City, where about 3.7 km^2 (or roughly 25%) of the City contributes runoff to Wagg Creek. Wagg Creek captures water from areas like Tempe Heights and Greenwood Park, and is the central feature in Mahon Park. Given the area of Wagg Creek that is directly influenced by City decisions, the City has the greatest potential to improve and enhance the quality and habitat of Wagg Creek of all the City streams.

In the City, Mission Creek is a small tributary to Wagg Creek and generally resides in the Mahon Park ravine. Since the headwaters have been diverted to Thain Creek, Mission Creek has not been degraded as much by urbanization, and has many valuable habitat features that persist from when the stream was much larger. Presently, Mission Creek provides valuable habitat potential to the Wagg Creek system; however, this section of stream is limited by an ability to provide stable baseflows.

Thain Creek was historically a relatively small creek that was substantially altered with the addition of the Mission Creek watershed. Thain Creek joins Mosquito Creek just upstream of Highway 1, and flows along the deep ravine west of Westview Shopping Centre and the Cypress Gardens residential development before turning east to meet Mission Creek at Westview Drive and 29th Street. The consequence of the contribution of Mission Creek to Thain Creek was more rapid erosion of the creek and ravine and associated landslide hazards between 29th and about 23rd. Much of the initial erosion was controlled by protective works that were constructed by the original owners of the Cypress Gardens development. Since then the City has been actively monitoring hazards completing preventative maintenance work, and conducting small projects to stabilize erosion areas. The largest single change to the Thain Creek and (upper) Mission Creek system was the daylighting of the 250 m long Thain Creek culvert which provided access for anadromous fish to areas above 29th Street and valuable local spawning habitat.

MACKAY CREEK

Mackay Creek is the western-most stream and is the represents the second largest section of stream in the City. Extending from about 23rd Street (Highway 1) to about Mackay Avenue and Roosevelt Street (in the District), then entering the City again downstream of 1st Street, the City portion of Mackay Creek is about 1.2 km long. Mackay Creek is still a very important environmental resource in North Vancouver, with large areas of intact riparian area and natural channel area, and fish passage being possible up to Handsworth School.

The Mackay Creek estuary was used for a wide range of industrial port-related since the 1940s and the valuable mud flat habitats have largely been lost in the past 100 years. However, since the Harbourside lands have ceased to be Port based industrial lands, a substantial amount of work has been completed to maximize the environmental values in the Mackay Creek estuary with creation of valuable off-channel habitats by Seaspan (in the District), the restoration of intertidal habitats in the City, and restoration of the riparian areas along Kings Mill Walk park.

The majority of Mackay Creek in the City is protected in Heywood Park, and the smaller Hyak Park, west of Capilano Mall. In Heywood Park, the City has been very active in protecting Mackay Creek by relocating the park trail systems away from the stream channel, facilitating the restoration of the channel upstream of Marine Drive, and supporting the North Shore Streamkeepers fish hatchery.

Development and historical land-use in the City, such as the former landfill site, between Mackay Creek and the Lucas Centre site, has marginalized habitat and confined Mackay Creek. A fundamental issue in Mackay Creek is the management of flood hazards. Flooding on Mackay Creek occurs regularly from the lower sections of Heywood Park to 1st Street. In this section, the size of the channel, low-lying topography and undersized bridge crossings (in the City and District) all contribute to flooding that would occur on average every 10 years.

To address this, the City is currently working on a joint project to construct a flood protection dike in this section of Mackay Creek. This project, which is also funded by the Federal and Provincial government, will provide flood protection for all areas from Heywood Park to 1st Street, and considers the need for replacement of the Mackay Creek – Marine Drive Bridge, new setbacks for redeveloping areas south and west of Marine Drive, and incorporation of greenway networks with the new dyke.

LYNN CREEK

A small portion of Lynn Creek and the tributary stream Keith Creek, fall in the City. While small in area, the watershed includes lands on the east side of Tempe Heights, Greenwood Park, eastern Grand Boulevard, Loutet Park, Cedar Village, and Brooksbank areas. Lynn Creek was once the City’s source of drinking water, and is an important environmental resource in North Vancouver. As the only large stream system without a dam west of Indian Arm, Lynn Creek has the potential to support much more significant fish populations. Only a small section of Lynn Creek, from 5th Street to about Cotton Road lies in the City and in Lynnmouth Park, and is an important part of the Lynn Creek riparian protection area. This area is also an important recreational amenity as part of a greater park and future greenway system, as the eastern section of the Spirit Trail will connect to the District in this area.

Keith Creek is an entirely urbanized stream, with the headwaters originating on the east side of the Tempe Heights neighbourhood. Keith Creek is heavily segmented as the Highway 1 “cut” slices through the watershed, and proposed new Highway works to further impact Keith Creek. There is also a decommissioned landfill under Loutet Fields in the Keith Creek watershed, and the City collects and conveys contaminated drainage from this area for treatment.

The largest intact sections of Keith Creek in the City are in the Cedar Village neighbourhood, where Eastview Park, other park lands, and steep lands around the highway represent the small remaining sections of watershed forest.

BURRARD INLET (HISTORIC STREAMS)

In between the Mosquito Creek watershed and the Lynn Creek watershed is portion of the City, south of about Keith Road (west of Lonsdale) and south of 19th Street (around Grand Boulevard), that would have once been home to a number of small streams that may have occurred as regularly as every other block. Old subdivision maps, decommissioned culverts, and early storm sewers indicate that a larger stream originating from Greenwood Park would have crossed Lonsdale at 13th, as it travelled south to Burrard Inlet somewhere near Chesterfield. Another major stream would have flowed south east of St Andrews through present day Lower Lonsdale Parks to meet Burrard Inlet west of St Patricks. A third major stream would have flowed from the Grand Boulevard area to the Moodyville neighbourhood before reaching Burrard Inlet near the foot of Moody Avenue. The easternmost large stream would have flowed from the Calverhall – Cloverly neighbourhoods and portions of the creek channel can still be seen in Sunrise Park before disappearing under the Port lands. Figure 3-1 provides a first look at these lost streams.

As smaller streams with very steep sections around Low Level Road and lower Lonsdale, these streams likely did not have the same environmental resources and support as abundant fish populations as larger streams. They did however form part of the natural drainage system which effectively and safely managed rain prior to the development of the City. These streams were largely moved into the storm sewer network by the 1960s, and now provide a more direct connection from City streets and properties to Burrard Inlet. While the loss of stream habitat is almost entirely complete, there are still some small reminders of these lost historic streams.

STREAM HEALTH

Stream health has been strongly linked the percentage of impervious area (TIA or EIA), where at a level of 10% EIA irreversible stream quality impairment can be observed, and severe impairment (i.e. loss of fish species) occurs at about 30% TIA. In addition to impervious area, local studies have shown that there are direct relationships between the level of contaminants that enter the stream and the volume of traffic.

As discussed earlier, the basic health in streams have been assessed using the diversity and abundance of stream insects. Another method to understand cumulative water quality impacts in streams is through sampling of stream sediments. While contaminants (e.g. metals or hydrocarbons) may intermittently enter a stream, these contaminants tend to bind to fine sediments which can begin to tell the story of pervasive contaminant inputs. Finally, where possible, the presence and absence of fish species has been assessed as part of regular City operations, where all fish have been relocated to support an instream infrastructure project.

These parameters have been mapped symbolically in the Figure 3-2 where data is available, which begins to tell the story of the current status of stream.

Higher concentrations of metals were found in the Wagg Creek Pond, Wagg Creek downstream of Jones, and in Mackay Creek downstream of Roosevelt Crescent. Generally, the higher concentrations of metals were Lead, Zinc and Chromium, all metals that are known to come from automobiles (e.g. brake pads). The concentrations of metals in these areas at times exceed the limits for protection of aquatic life, and indicate that there is a need to address water quality from storm outfalls.

In the City, Mackay Creek, is almost entirely set in Heywood Park and Hyak Park, and there are no major fish passage issues in the lower reaches. For Mackay Creek, lower B-IBI values indicate that the stream is stressed, and could be due to a combination of water quality issues and potentially relatively regular high peak flows and/or low baseflows.

The Mosquito Creek mainstem from the City-District boundary to Larson Road is largely protected in Mosquito Park. Given the extensive decades of sediment removals in Mosquito Creek, the available habitat is degraded, but extensive stewardship has created and diversified habitat in the reach between Larson Road and Queens Road. Mosquito Creek is limited by fish passage issues. The Metro Vancouver weir due to the trunk sewer at 3rd Street limits fish passage, as passage is only provided via a small fish ladder. Initial discussions with Metro Vancouver indicated that they would be open to a joint project to reconstruct a series of channel steps at this location to improve fish passage. The next major fish passage barrier is at the Evergreen culvert at Queens Road in the District of North Vancouver.

Given the limited fish passage due to the Evergreen Culvert, the Wagg Creek, Mission Creek, and Thain Creek tributaries are even more important to the system. Some fish passage improvements can be made to the existing culverts on Wagg Creek at 3rd Street and Keith Road now that the Bewicke Avenue culvert has now been replaced. Mission Creek (in the City) has great habitat potential, but is limited by baseflows during drier periods and could be improved by connecting some drainage from Mission Creek at 29th to the Mission Creek storm sewer catchment.

Thain Creek, given the very deep ravine, has potential for good and protected fish habitat, and ongoing monitoring and minor management of local erosion is needed until Cypress Gardens is redeveloped and access to the stream and a top of bank setback can be restablished. Once fish passage is provided in the District at Queens Road, the potential for fish use in the Thain-Mission Creek system will increase substantially.

Wagg Creek currently supports fish passage up until Jones Avenue. Wagg Creek has the largest percentage of impervious area contributing to it and it is degraded due to the regular peak flows and water quality issues. The Wagg Creek watershed will benefit the most from implementation of source controls. Based on the monitoring data collected to date, current City policies and programs appear to be improving the health of Wagg Creek, which supports the continued course of action.

WATERSHED HEALTH

Watershed health is more than instream habitat and aquatic species. It includes a broad range of ecosystem functions and services that occur over large scales and also integrates all of the day-to-day actions by the people the live, work, and recreate in the City watersheds. Some basic environmental watershed health indicators include percent forest cover and riparian (near-stream) forest integrity. Baseline values for these parameters have been developed for parts of the lower developed parts of the watershed (City area) and are summarized in the Table 3-1 below.

Table 3-1: Watershed Health Parameters

Watershed	Riparian Forest (ha)	RFI
Mosquito Creek	53.9	69%
- Wagg Creek	8.6	67%
- Thain Creek	19.5	67%
- Mission Creek	6.0	90%
Mackay Creek	52.3	67%
All Creeks	140.3	69%

Overall, given the density of the City, the integrity of the riparian forest is quite good at an average of 69%. Since the establishment of the Streamside Protection Development Permit Area, there have been better tools to protect and retain riparian, over the past ten years there should have been little loss of riparian areas and gains at the site level. As land is redeveloped, it is important to look for opportunities to regain those setbacks, especially in the lower reaches of Mosquito Creek and Mackay Creek near Marine Drive where development often backs onto the stream channel.

Section 4 - Goals and Objectives

Given our shared watersheds, the City and the District of North Vancouver, with participation from the public and discussions with First Nations, have defined the **ISMP Goal** as **Improved Watershed Health**, where ongoing and incremental improvements throughout the City would result in cumulative positive change. Supporting this goal, nine main objectives were identified in the categories of Environment, Social, and Economic objectives.

The flow chart (shown as Figure 4-1) illustrates the ISMP goal and primary objective framework, where the objectives all support furthering the goal.

These nine objectives are intended to be broad in nature, where numerous sub-objectives can be developed to address more specific actions and reflect the integration of values throughout the plan. A policy, program, or project that addresses multiple objectives would be seen to be more effective than an action that would only achieve a single objective. Development of a unified goal and objectives is key to implementing a plan that can be implemented in shared watersheds across both municipalities and First Nation territories.

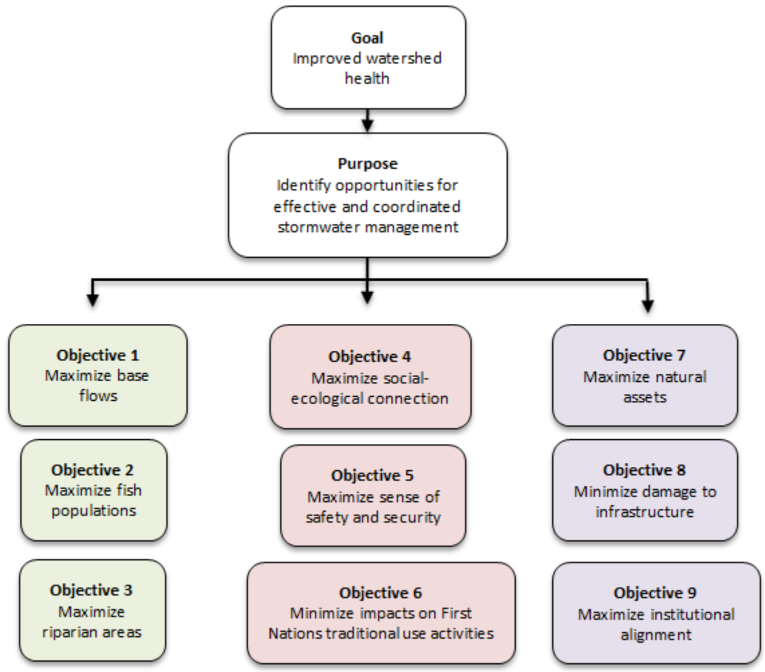


Figure 4-1: ISMP Goals and Objectives

Policy changes, creation of new programs, or implementation of a particular project would likely and ideally support more than one objective.

Environmental Objectives

The environmental objectives include initiatives around rainfall and runoff (hydrology), support of existing and potential aquatic species, and support of the lands surrounding the stream.

Objective 1 - Maximize Base Flows: this objective addresses the linkage between rainfall and runoff in streams. High total impervious area restricts infiltration and groundwater entering streams, providing the base flow that is very important to aquatic life, especially in summer periods. Transforming total impervious are to effective impervious area by implementing "green stormwater infrastructure" source controls will achieve this goal and also contribute to the decrease of regular peak flows which will extend the service life of the City storm sewer system and reduce physical damage to stream habitat.

Objective 2 – Maximize Fish Populations: a major indicator of good watershed health is the ability for natural indigenous fish species to thrive in streams. Many factors support maximizing fish populations, such as: improved water quality, stability of stream channels, and provision of abundant and diverse habitats.

Objective 3 - Maximize Riparian Areas: this objective is intended to support both instream and terrestrial habitats by providing the broadest and most continuous riparian area possible. Riparian vegetation provides food and shade directly to the stream and acts to buffer human disturbance to the stream.

Social Objectives

Objective 4 - Maximize Social-Ecological Connection: maximizing community connectivity and relationship with the ecological values of the watershed will foster a greater sense of the importance of these resources and should reflect in the behaviour around rainwater, pollutants, and other stewardship activities.

Objective 5 - Maximize Sense of Safety and Security: streams and watercourses are inherently hazardous, and minimizing risks associated with flooding, slope stability, and water quality has a positive social benefit to the community.

Objective 6 - Minimize Impacts on Traditional First Nations Uses: historically the streams included in this plan were fundamental to traditional First Nations life. Preservation and enhancement of environmental resources will allow local First Nations people to retain local contact with the environment.

Economic Objectives

Objective 7 - Maximize Natural Assets: streams, watersheds, and groundwater are all natural assets that have fundamental value to the City that is not accounted for. If streams were no longer part of the drainage system, the cost to replace them with hard infrastructure would be substantial. It is important that these natural assets are protected and maintained appropriately to ensure their continued ecosystem and drainage function.

Objective 8 - Minimize Damage to Infrastructure: the City drainage infrastructure was constructed over about 4 decades and has a replacement value in excess of $70M. The plan shall include actions to minimize damage to infrastructure and maximize useful life.

Objective 9 - Maximize Institutional Alignment: maximum benefit and efficiency of both funding and staff time is achieved by aligning policies, programs, and coordinating complementary projects. Initiatives that act to align institutions will be more beneficial to the City than individual efforts.

PROPOSED PLAN ACTIONS

Mackay Creek and Mosquito Creek ISMP is being developed to be specific to the watersheds, but also to include governance to be applied uniformly across all North Vancouver watersheds.

The key elements of the plan will include:

- Policy Recommendations
- Program Development Recommendations
- Project Recommendations

In order to meet the objectives and make progress on the overall goal, a number of proposed approaches to refine existing policy, develop new programs, and implement a series of projects have been developed. The following section outlines the key actions identified for the ISMP.

Proposed Policies

To support the City's goal of Improved Watershed Health and to specifically address the objectives of increasing baseflow to streams and improving fish habitat and the safety and security of receiving waters an overarching policy decision from this plan should be:

All newly constructed impervious surfaces shall be mitigated to meet the objectives with by source controls insofar as is practicable.

In doing so all new impervious surfaces (i.e. Roofs, concrete paving and sidewalks, and asphalt paths and roads) shall be effective impervious surfaces that allow all runoff to enter the ground or to be released slowly to streams. Presently, the Subdivision and Development Control Bylaw requires that all new impervious surfaces from private developments shall be managed in a source control. This policy decision will also ensure that all City projects (e.g. Multi-use paths, road expansion, new facilities), include source controls or shed water to pervious green space. For example, a multi-use path or sidewalk that sheds runoff to a grassy boulevard would be an effective impervious area and would not require any additional source control measures.

By implementing this policy, the City will ensure that:

- Source Controls are implemented on all new private development projects.
- Source controls are included in the public drainage features, where a new public frontage is constructed by a development.
- All new public capital projects that increase impervious space include source controls where either the runoff will reach a stream or downstream drainage infrastructure will be foreseeably undersized due to development under the current Official Community Plan.

A second guiding principal shall be that:

All instream infrastructure projects shall improve fish habitat and passage

The actions for implementation for this policy decision will include:

1. Update of the Subdivision and Development Control Bylaw to better describe the requirements.
2. Review and alignment of the Construction Regulation Bylaw to support the policy initiative.
3. Recognition of the policy for City projects and incorporation into future projects.

City Operational Programs

The City has been implementing a variety of green stormwater source controls for more than 10 years. The variety of green infrastructure has been achieved through careful coordination of road improvement projects, capital projects, and developer delivered improvements. Through this plan, a series of core green stormwater programs are proposed to support a variety of ISMP objectives. These include:

1. **Stormwater Quality Treatment Captial Program:** improvements to stormwater quality originating from City streets and right-of-ways, that could include controls at the source (e.g. Raingardens), treatment at the outfall (e.g. stormwater oil and grit separators, or treatment wetlands), or treatment in the stream (e.g. treatment ponds).

   The goal of the stormwater treatment program is that 30% of all road drains (catchbasins) have a source control and that 50% of all outfalls have a treatment structure by the end of the Official Community Plan planning horizon (about 25 new source controls per year). To meet this interim goal for stormwater treatment, the City will need to begin to fund and plan for the capital costs based on the utility rates, and incorporate developer delivered infrastructure in an efficient manner.

   As part of the stormwater quality treatment capital program, a Local Area Service fund would be established for neighbourhood raingardens. This program would fund the majority of the cost of a raingarden and would allow residents of a block to elect to "sponsor" a raingarden, constructed by Operations, but block residents would be involved in planting and maintenance. This would provide local stewardship opportunities and could help prioritize projects to areas desired.

2. **Riparian setbacks, enhancement and diversification:** the integrity and width of the riparian area around streams has a direct relationship to the stream health as measured through stream insects. The existing riparian area should be maintained, increased and enhanced to provide the largest benefit to streams.

   The ***Streamside Protection Development Permit Area*** is the City's primary tool to protect and enhance riparian areas. This guideline was developed in 2006 in response to changes to the Provincial Fish Protection Act and the creation of the Riparian Areas Regulation. The development permit area is based on participation from senior levels of government (Fisheries and Oceans Canada) which is no longer available due to policy changes in the Federal Fisheries Act. An update of the Development Permit Area guidelines is required to provide clarity to development applicants and provide clear opportunities for off-site enhancement of riparian areas.

3. **Operational Programs:** there is a strong correlation between volumes of traffic and pollutant concentrations in streams. Upgrading and regular maintenance of street catchbasins shall be a core goal for the City. This shall include bringing catchbasins to the current standard, introducing source controls, and conducting regular maintenance of catchbasins.

   The current standard for catchbasins includes a sump and hood to collect sediment and trap floating debris and oils. Catchbasins should be regularly cleaned (by vacuum truck) to ensure that the trapped sediment and oils are not remobilized into the storm sewer. This program shall include creating an inventory of older catchbasins for upgrading to the current standard, with a source control, and annual cleaning of priority catchbasins at key times (e.g. Late Spring to address the winter sediment).

   There would also be a benefit to for increased and improved communication and education around the protection of fish habitat for all of our operations staff. Many of our operational practices have a direct effect on fish and fish habitat. With our operations staff growing and evolving with staff taking on new roles and new staff joining the City, annual updates and reminders on best practices for work on the drainage system and creeks would be beneficial.

4. **Outreach and Education:** transfer of information to City residents is key to changing behaviour around watershed health, recognition of streams, ownership of source controls and street frontages.

   Based on all baseline data collection, new data can be added to CityMap around watershed features, and health parameters. This could include a map of stormwater ponds, raingardens, and other treatment facilities. It could also include health indicators such as B-IBI, fish presence, and sediment quality data. This initiative could be realized as part of the property search web tool that would include key watershed information, initiatives, and values (e.g. mywatershed.cnv.org).

   Dedicated outreach activities can be developed around key watersheds, such as Wagg Creek, where household contaminants are often spilled into drains leading to Wagg Creek. This would entail development of communications material that could sent to the entire watershed.

   The City could work to a larger degree with School District No. 44 to develop a school rain garden program, whereby local government could sponsor a project that would involve constructing raingardens at local schools. Under this program, there could be both some volunteer effort from students that would include ongoing stewardship. A similar program was developed in the Corporation of Delta and was found to be successful in terms of engaging students. This could be done in participation with the District of North Vancouver and the North Shore First Nations.

   Another approach to engage the community would be through a program of "Citizen Science". This would be similar to programs that the North Shore Streamkeepers have established where interested members of the community could use relatively simple and established methods to develop more information about the health of the North Vancouver streams. This would be coupled with a program to publish, or map the observations for general observation.

Capital Projects

Projects that support the ISMP would be unique capital works that are implemented to address a local problem or take advantage of a local opportunity. Projects could entail:

- Instream habitat projects (e.g. off-channel habitat, fish passage projects, etc.).
- Riparian vegetation projects (e.g. adding/diversifying near to stream vegetation that benefits the aquatic life the most).
- Watershed forest cover projects (e.g. looking at wildlife connections between forest patches with higher density or specific street tree plans).
- Green streets (e.g. selecting street for 100% stormwater capture and treatment, inclusion of street trees for canopy connection).
- Water quality treatment (e.g. biofiltration wetland, oil and grit separators, ponds, etc.).

Greater than 40 different unique projects watershed projects have been developed, in addition to the proposed objectives for new catchbasin source controls and general end of pipe treatment work. Implementation of these projects will improve local conditions in each stream, but projects alone do not solve the watershed level issue of imperviousness and source derived water quality problems. This initial list of projects was evaluated based on the total number of objectives that are achieved, and based on indicative costs and potential spatial impact of the project, a cost to benefit ratio was developed to rank these projects.

The following table, Table 4-1, summarizes the top ten ranked projects to illustrate the potential projects.

Table 4-1: Summary of Top Ten Ranked Capital Projects

Project Name	Stream	Description	Preliminary Cost	Cost to Area Benefited ($/m^2)
Larson Park Pond and reconnection to of storm sewer to Mission Creek at 29th Street	Mission	Fish Habitat and Stream Baseflow Objectives	$220,000	$0.3
Heywood Park - Biowetland - Hamilton Outfall	Mackay	Water Quality	$75,000	$4.8
Green Street - 23rd (St Georges to Grand Boulevard)	Wagg	Forest Integrity	$50,000	$7.9
Green Street - 21st (Eastern to Chesterfield)	Wagg	Forest Integrity	$50,000	$10.3
Metro Sanitary Weir Fish Channel	Mosquito	Fish Passage	$250,000	$25.0
West Keith Culvert Fish Passage and Upgrade	Wagg	Fish Passage	$150,000	$53.5
Keith Boulevard - Mahon Park Linear Raingarden / Stream	Wagg	Water Quality	$915,000	$80.9
Hyak Park – move creek right, obtain greater setbacks, deal with outfalls.	Mackay	Fish Habitat	$300,000	$91.0
Green Streets - 19th (Hamilton to Fell)	Mackay	Water Quality	$270,000	$92.3
Harry Jerome - Creek Daylighting	Wagg	Fish Habitat	$342,000	$131.5

Given the large number of projects and capital cost, it is neither foreseeable nor practical to commit or plan to achieve each project on a fixed timeline. Therefore, the list of potential capital projects is intended to serve as a “visionary blueprint” for long-term watershed improvement, where other initiatives in the City may create an opportunity for a complex project to be implemented.

For example, the proposed Mackay Creek flood protection project currently planned for construction in 2017 may provide an opportunity to enhance a portion of the Mackay Creek stream channel and improve a number of storm system outfalls in the area at much higher efficiency than implementing the project alone.

Funding

Implementation of capital projects under the ISMP will be subject to available funding and will compete with other storm drain system build out goals. Sources of existing funding for projects could include:

- Drainage Levy funding from utility rates.
- Capital funding from general revenue as part of other capital projects.
- Contributions from development.

The Drainage Levy currently funds all capital and operational drainage system costs, including storm system expansion and upgrading. Over time, the goal would be to allocate 20% of the capital drainage budget for green stormwater infrastructure projects.

Funding from general revenue (i.e. property taxes), is not typically used for drainage system projects. This source of funding may indirectly achieve the goals of the ISMP as other capital projects strive to meet the “no new total impervious areas” objective, but could also serve to support the community Raingarden Local Area Service (LAS) fund. Currently the annual project plan funds our Sidewalk LAS program, and a similar fund could be established for raingardens.

Currently new development contributes effective impervious roof areas for all scales of development, and larger developments add source controls to the local street area as it is reconstructed. In some cases local site conditions limit or do not allow for mitigation of the entire impervious area. For these sites, the preferred approach would be for the development to provide source controls for an equivalent area of street (ideally close to the site). Alternatively, the developer could provide cash in lieu of meeting the bylaw requirements. Any cash received in lieu of works would be held in a Green Stormwater Infrastructure fund.

The actions for implementation for this policy decision will include:

- create Green Stormwater Infrastructure fund to create efficiencies between bylaw requirements and capital funding of projects to use funding in the most efficient manner.
- allow possible developments to contribute to the Green Stormwater Infrastructure Fund where meeting the criteria is not feasible

Natural Asset Valuation

Natural capital assets, and the ecosystem services they provide, are a fundamental and integral part of drainage infrastructure. In general, natural capital assets provide clear advantages over engineered infrastructure, whereby they:

- are less costly to operate and maintain for the capacity provided;
- may provide “free” ecosystem services;
- do not depreciate if properly managed and are not permitted to degrade; and
- are carbon neutral or even carbon positive.

The Town of Gibsons is one of the first Canadian municipalities to explore managing the natural capital, such as green space, aquifers, foreshore area and streams by using infrastructure and financial management concepts for asset management. The rationale is that natural services provided by these systems, in the form of stormwater management have tangible value to the community, and have more benefit than engineered infrastructure. Bringing these natural assets into the same asset management system as engineered infrastructure recognizes the quantifiable value they provide to the community and integrates them into the municipal framework for operating budgets, maintenance and regular support. The concept of Natural Capital Assets has also been introduced into a number of American cities.

Considering streams and other features as Natural Assets will change the focus and the level of importance regarding care and maintenance. Currently there is not a process in the Canadian Public Sector Accounting Standards for natural assets and appreciation of natural assets; however, the conversation has started and under the ISMP the City could consider the benefits associated with Natural Assets accounting.

The ISMP proposes that existing streams be brought into the City's asset management framework (i.e. Infor Public Sector), so that the assets can be quantified and costs and improvements can be tracked.

Future Funding Model

Currently all new developments are implementing source controls to limit the volume of runoff resulting from rain on impervious surfaces, and these sites all benefit the storm drain system and stream health. Creation of a Storm Water Utility is an approach that is being adopted by local governments in North America, including the City of Victoria. Instead of a drainage levy, based on property assessment, a utility rate could be established that was more equitable for sites that have invested in source controls.

For example, a typical single family home would have the standard utility rate, and a discounted rate would be available for sites that constructed source controls. This approach, in additional to being equitable, could incent some older homes that would not foreseeably be torn down to upgrade and include a source control.

Larger developments may have a more involved process, given that there is greater diversity in the size and scale of development, and these sites may involve a combination of assessment of total impervious area and drainage connection size.

As part of the ISMP, it is proposed that a Storm Water Utility approach be investigated further to assess the benefits to the City and rate payers.

Objective – Actions Framework

A summary of the objectives have been expressed in the following Table 4-1, with respect to the proposed actions outlined above.

Table 4-1: Summary of Plan Objectives and Associated Action

No.	Objective	Action
1.	Maximize Baseflow	Policy: All new impervious areas shall be mitigated by source controls
2.	Maximize Fish Populations	Policy: All instream infrastructure projects shall improve fish

No.	Objective	Action
		habitat and passage
3.	Maximize Riparian Areas	Program: Riparian setbacks, enhancement and diversification; Capital Projects
4.	Maximize Social-Ecological Connection	Program: Outreach and Education
5.	Maximize Sense of Safety and Security	Policy: All new impervious areas shall be mitigated by source controls, Program: Stormwater Quality Treatment; Program: Education and Outreach
6.	Minimize Impacts on Traditional First Nations Uses	Policy: All new impervious areas shall be mitigated by source controls; Policy: All instream infrastructure projects shall improve fish habitat and passage; Capital Projects
7.	Maximize Natural Assets	Policy: All instream infrastructure projects shall improve fish habitat and passage
8.	Minimize Damage to Infrastructure	Policy: All new impervious areas shall be mitigated by source controls
9.	Maximize Institutional Alignment	Policy: All new impervious areas shall be mitigated by source controls – aligns development with environmental goals. Policy: All instream infrastructure projects shall improve fish habitat and passage

MONITORING

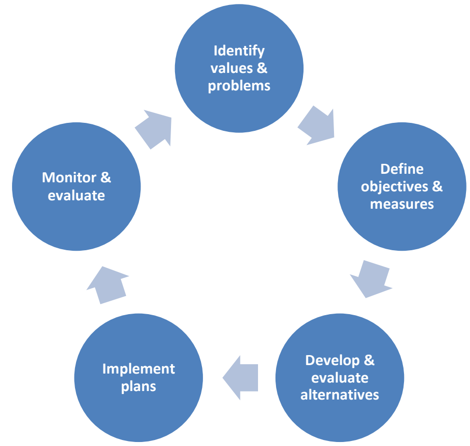
To determine the effectiveness of the ISMP, Metro Vancouver has developed a “Monitoring Adaptive Management Framework” (MAMF), or a standard for monitoring biological and hydrological indicators as part of the Plan.

The City already conducts some monitoring, including measurement of rainfall at City Hall, measurement of streamflow in Wagg Creek, and periodic measurement biological indicators as part of the City’s Environmental Protection Plan. To meet the MAMF, the general monitoring requirements would include:

- hydrometric (streamflow) monitoring of major streams
- continuous water quality measurement at hydrometric stations (e.g. temperature, conductivity, turbidity)

- Water quality monitoring every 2 years, with samples taken during two periods of the year – once in the wet season (Nov-Dec) and once in the dry season (July-Aug), including: dissolved oxygen, temperature, turbidity, pH, conductivity, nitrate, E. Coli, fecal coliforms, total iron, total copper, total lead, total zinc, and total cadmium
- Marine effluent monitoring station at the Foot of Lonsdale (in participation with the Vancouver Aquarium).

Section 5 – Plan Implementation



Integrated stormwater management planning is an ongoing and proactive process to provide the necessary tools to accommodate development growth and increase imperviousness while protecting property and aquatic habitat from stormwater. In the previous sections, the need for integrated stormwater management planning was explored, along with a framework to target objectives that support a goal of Increased Watershed Health.

The proposed actions under the plan include: two fundamental policies were proposed, in addition to a number of ongoing programs and an initial number of unique projects. Based on these actions, the following priority for implementation has been established:

The Plan

1. The City shall adopt the Integrated Stormwater Management Plan and all actions in principle
2. Engineering, Parks and Environment and Community Development will identify a departmental staff leader to coordinate interdepartmental efforts.
3. Staff will update and align the Subdivision and Development Control Bylaw and Construction Regulation Bylaw such that the bylaws support the objectives and goals of the Plan.
4. Staff will formalize a process for off-site contributions or cash in-lieu for Stormwater Management Source Controls that cannot be achieved due to development massing and site constraints.
5. Staff will provide input into the review of the Streamside Protection Development Permit Area Guidelines to support the ISMP.
6. Staff will initiate the ongoing capital program to provide street level source controls and end of pipe treatment.
7. Engineering Planning and Operations will plan to initiate priority street and catchbasin cleaning for the Wagg and Mission Creek watersheds for 2018.
8. Engineering Planning and Environment will work with communications to develop an initial strategy for outreach in the Wagg Creek watershed as a priority.
9. Engineering Planning will develop conceptual designs and costs to support the 10-Year Capital Plan. Projects will be implemented subject to funding, and based on efficiency to deliver the project.
10. Engineering Planning will initiate a process for tracking costs associated with Natural Assets, and explore alternate funding models for future plan implementation.
11. Engineering Planning will initiate a monitoring program to meet the ISMP requirements.