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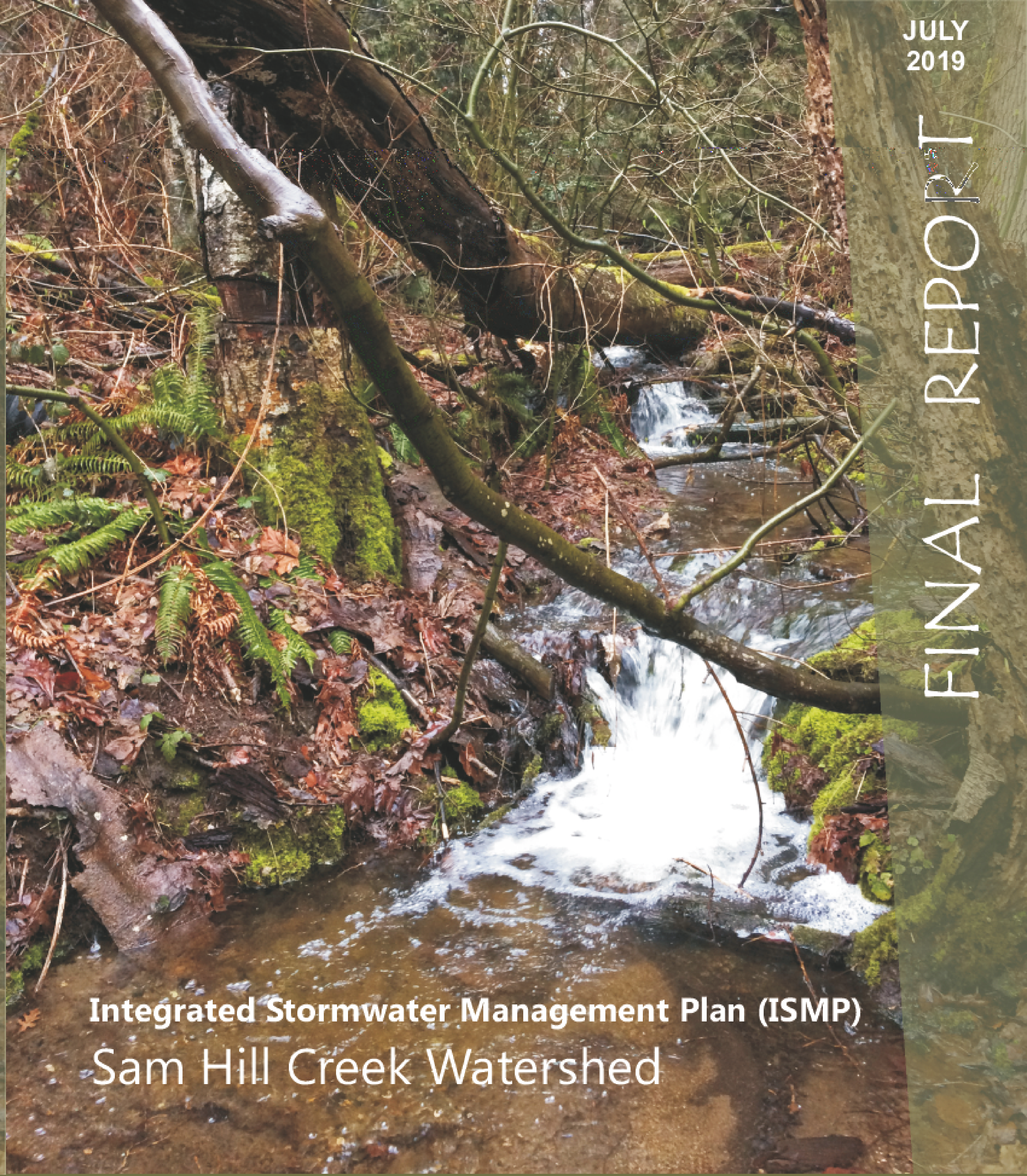
FINAL REPORT



Integrated Stormwater Management Plan (ISMP)

Sam Hill Creek Watershed

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Executive Summary

1 INTRODUCTION

The fundamental purpose of an Integrated Stormwater Management Plan (ISMP) is to maintain and enhance the overall health of a watershed while allowing for future development. An ISMP is a comprehensive planning document that addresses a wide variety of components related to watershed health while considering economic growth. The ISMP process encompasses stormwater management under existing development conditions; consideration of future development, as well as the potential hydrologic and hydraulic impacts; terrestrial and aquatic environmental assessments; public consultation stakeholder engagement; overall watershed health assessment; development of an implementation plan, including funding strategies and enforcement strategies; as well as monitoring and assessment strategies.

2 STUDY AREA OVERVIEW

The Sam Hill Creek study area is located in the south of Surrey and is roughly bounded by 24 Avenue to the north, 180 Street to the east, 8 Avenue to the south, and 168 Street to the west. With the headwaters originating near 24 Avenue between 168 Street and 176 Street, the catchment drains to the agricultural lowlands in the south. It is approximately 525 ha in area. From a maximum elevation of about 110 m above sea level, the study area gently slopes south and south-east to the confluence with Little Campbell River at an elevation of about 5 m above sea level.

North of 16 Avenue, the predominant land use is One Acre Residential, and this area encompasses the Grandview Heights NCP#3 area (GHNCP #3). South of 16 Avenue, the study area is designated as Agricultural Land Reserve.

The climate of the study area is relatively warm with the vast majority of precipitation falling as rain with an average depth of approximately 1100 mm per year. The City of Surrey's Design Criteria Manual shows the study area falling within the South Rainfall Area. The most applicable rain gauge for this region is the White Rock STP rain gauge.

There are four major watercourses in the Sam Hill ISMP study area; Upper Sam Hill Creek, Sam Hill Creek, and unnamed tributary (Tributary 1), and Thomson Creek. The existing drainage system that discharges into these watercourses is mostly composed of open, linear ditches running along roads and property lines with some short, piped sections. There are several significant culverts including large diameter round culverts (>750 mm) and box culverts.

3 GOALS AND OBJECTIVES

The overall goals for the ISMP study area are to:

- Protect and enhance the overall health and natural resources of the creek and watershed study area.
- Promote participation from all stakeholders to achieve a common future vision of the watershed.
- Minimize risk of life and property damages associated with flooding and provide strategies to attenuate peak flows.
- Protect and enhance watercourses and aquatic life.
- Prevent pollution and maintain/improve water quality.
- Prepare an inventory of watercourses and wildlife for the watershed study area.
- Protect the environment, wildlife and habitat corridors.
- Identify areas of existing and future industrial, residential, commercial, agricultural and recreational land uses.
- Integrate the potential impact of climate change on the ISMP area.
- Develop a cost effective and enforceable implementation plan.
- Establish a monitoring and assessment strategy to ensure goals are achieved, maintained, and enforced.

In consideration of the overall goals for the study area, the vision statement for the Sam Hill Creek ISMP is:

> *The vision for the Sam Hill Creek ISMP is to hold paramount public safety and the protection of the environment while accommodating community growth, in a way that enhances watershed health and aesthetics, and promotes the existing strategies aimed at conserving biodiversity. This ISMP presents a strategy for implementing stormwater best management practices and environmental enhancement opportunities that can balance the City's long-term environmental and economic goals.*

4 ENVIRONMENTAL ASSESSMENTS

Three assessments were carried out, an aquatic habitat assessment, a terrestrial environment assessment, and a hydrogeological assessment.

4.1 Aquatic Habitat Assessment

Aquatic habitat assessments were completed at 19 sites on a sub-sample of the watercourses and sections of watercourse in the study area. These assessments characterized the biophysical attributes of each site, evaluated current fish habitat conditions, evaluated salmonid use (i.e., rearing, overwintering, and spawning potential), identified specific issues related to erosion, bank instability, and barriers to fish passage; and verified existing information (e.g., watercourse classification). Opportunities for infrastructure improvement (e.g., culverts) and habitat enhancement and restoration (e.g., riparian planting) were also noted. No fish sampling was conducted.

Specific barriers to fish passage and sites for environmental improvements are listed in Table ES-1 and Map ES-1.

Table ES-1
Known Barriers and Obstacles to Fish Passage on Watercourses in the Study Area

Watercourse	Location	Type of Barrier	Description / Comments	Enhancement Opportunity	Source
Sam Hill Creek	Approximately 450 m east of 172 Street	Perched culvert	Barrier to fish passage at lower flows	Replace perched culvert with fish passable culvert at low flows.	Dillon 2005, Sam Hill Creek ISMP fieldwork
Upper Sam Hill Creek	North of 16 Avenue	Falls	Natural barrier to fish passage at lower flows	n/a	Sam Hill Creek ISMP fieldwork
Class A (red-coded) tributary ditch to Sam Hill Creek	176 Street, north of 12 Avenue	Rip rap bank armouring	Barrier to fish passage at lower flows	Regrade channel to allow fish passage at lower flows.	Sam Hill Creek ISMP fieldwork
Tributary to Sam Hill and Upper Sam Hill Creeks	From the 18 Avenue right-of-way south to the 16 Avenue right-of-way.	Concrete elevation barriers	Continuous concrete steps present barriers to fish passage.	Modify channel to create step pool features with maximum 0.3 m vertical height.	Sam Hill Creek ISMP fieldwork
Tributary to Sam Hill / Upper Sam Hill Creek	172 Street from 16 Avenue, approximately	Concrete culvert	Length (approximately 260 m) and gradient (9.8 %) is a barrier to fish passage.	Daylight channel, provide fish passable culverts at driveways, create step pool features with maximum 0.3m vertical height to accommodate steeper grades.	Sam Hill Creek ISMP fieldwork
Thomson Creek	12 Avenue	Blocked culvert	Barrier to fish passage at lower flows.	Replace with fish passable culvert.	Sam Hill Creek ISMP fieldwork.

In addition to the enhancement opportunities at these specific fish passage obstacles, we also identified several aquatic enhancement opportunities throughout the watershed, as noted below. The site numbers refer to our aquatic assessment locations, as shown on Map ES-1.

- Installing fencing between trails / private property and watercourses to protect environmentally sensitive areas from encroachment and access by humans and animals (including livestock) (i.e., Site 3, Site 4, Site 17). Sam Hill Creek for example, is often subject to cattle access, which has led to a degradation of water quality (Fee 1983).
- Improving storm water outfall west of 176 Street draining to Sam Hill Creek to prevent bank erosion and sediment transport.

- Removing instream vegetation (i.e., reed canary grass) from affected watercourses (e.g., Thomson Creek; Site 4) to improve flow, habitat availability, temperature regulation, and flood mitigation.
- Inventorying and removing invasive plant species (e.g., Himalayan blackberry) from riparian areas of affected watercourses (e.g., Tributary 1; Site 7 and Upper Sam Hill Creek; Site 17) and replanting with native trees and shrubs.
- Planting native riparian vegetation (i.e., trees and shrubs) and establishing a protected stream setback on both banks of Upper Sam Hill Creek, through the blueberry field (i.e., Site 17).
- Planting native riparian vegetation (i.e., trees and shrubs) and establishing a protected stream setback on both banks of Sam Hill Creek along 12 Avenue, from 172 Street to 176 Street.
- Re-establishing a hydraulic connection between the Sam Hill Creek Diversion at 172 Street and 12 Avenue, and the adjacent watercourse immediately east.

We made several recommendations for stream reclassification in accordance with Surrey's watercourse classification system as summarized in Table ES-2 and shown in Map ES-1.

Table ES-2
Recommended Changes to the City of Surrey's Watercourse Classification Map

Watercourse	Location	Classification at Onset of Sam Hill Creek ISMP	Recommended Classification based on ISMP Process	Current City of Surrey Classification (July 2019)
Upper Sam Hill Creek	South of 16 Avenue	The City of Surrey currently designates this section of the creek as **Class B**.	**Class AO**; Likely inhabited by fish, particularly for overwintering	**Class B**
Drainage Ditches	North of the 18 Avenue right of way to the 172 Street right of way	The City of Surrey currently designates these ditches as **Class C**.	**Class B**; Significant food and/or nutrient value to downstream fish habitat	**Class B**
Drainage Ditch	172 Street right of way, from 20 Avenue to the 18 Avenue right of way	The City of Surrey currently designates this ditch as **Class C**.	**Class B**; Significant food and/or nutrient value to downstream fish habitat	**Class B**
Sam Hill Creek	From 14 Avenue and 172 Street, east for approximately 380 m	The City of Surrey currently designates this channel as **Class A**. This section of the creek has been diverted south along 172 Street and is now dry; however, it can become reconnected during flood events.	**Class AO**; Potentially inhabited by fish if migration barriers are removed and during flood events.	**Class A**

Watercourse	Location	Classification at Onset of Sam Hill Creek ISMP	Recommended Classification based on ISMP Process	Current City of Surrey Classification (July 2019)
Sam Hill Creek	From 14 Avenue at 172 Street to the 12 Avenue right of way and 176 Street	The City of Surrey currently designates this watercourse as **Class AO**.	**Class A**; Inhabited by or potentially inhabited by fish year-round	**Class AO**
Tributary to Sam Hill / Upper Sam Hill Creeks	From the 18 Avenue right of way south to the 16 Avenue right of way.	The City of Surrey currently designates this ditch as **Class B**.	**Class AO**; Potentially inhabited by fish if migration barriers are removed/modified (Section 3.3). In addition, fish have been documented (Section 3.1.2).	**Class AO**
Tributary ditch to Sam Hill Creek	176 Street, north of 12 Avenue	The City of Surrey currently designates this ditch as **Class A**.	**Class AO**; The ditch is seasonally wetted and thus cannot support fish year-round. In addition, the rip rap bank armouring is a barrier to fish passage. This ditch is potentially inhabited by fish if migration barriers are removed.	**Class A**

4.2 Terrestrial Assessment

The terrestrial field assessment focused on visiting vegetated areas characterized as forest, riparian, wetland, and old field habitat and included 30 individual assessment sites. During the assessments, no species specific, rare plant, or wildlife surveys were completed.

Within the Sam Hill Creek watershed, there are a number of Green Infrastructure areas that have already been identified as part of the City's Biodiversity Conservation Strategy (BCS). In addition to these recognized Green Infrastructure Network (GIN) components, there are also several areas which function as corridors, sites, and hubs under existing conditions, even though they are not formally recognized in the BCS. Table ES-3 summarizes the existing and recommended GIN within the Sam Hill Creek watershed, which are also shown on Map ES-2.

In addition to the areas that are already recognized within the City's established GIN, we also identified habitat areas which are not part of the formal GIN, yet still contribute to the existing habitat connectivity within the study area.

4.3 Hydrogeological Assessment

We completed a high level hydrogeologic investigation of the study area. The hydrogeologic conditions in the uppermost sediments determine the feasibility of infiltration of stormwater to subsurface and general natural drainage and recharge to aquifers. Therefore, our investigation concentrated on establishing the characteristics of these surficial deposits through a combination of literature review and field assessment.

Information on the surficial geology and stratigraphy in the Lower Mainland area was compiled by observing and mapping of exposures along eroding coastlines and river banks, in gravel pits and other excavations, and through borehole logs (Armstrong and Hicock 1976). Two main surficial geologic units are exposed or are present at depth in the study area: Capilano Sediments with identifiers Cb, Cd, and Ce, and Vashon Drifts with identifiers Va and Vb.

Soils found in the lowlands are primarily Gleysols, indicating that they were developed under mostly saturated conditions. Soils in the uplands (Sam Hill) are primarily Podzols and drain well to moderately well. However, due to the presence of till below the soils, the soil is subject to telluric seepage, which basically means horizontal flow of water due to a soil layer with lesser permeability at depth (till).

The soils found in the lowlands have poor to very poor infiltration to deeper aquifers and infiltration is unlikely to be a suitable method for traditional enhanced drainage methods. The Bose soils found in the uplands area are considered to have potential for further investigation to determine their suitability for infiltration of stormwater.

Three aquifers are present in the study area with a total of 89 wells identified. None of those wells are identified as a B.C. Ministry of Environment observation wells. None of the well logs indicate that bedrock was encountered during drilling. There are generally two categories of wells.

- Relatively shallow wells that tap into the surficial groundwater "perched aquifer[1]" in the upper unconsolidated sediments overlying the till material. As the Study Area is primarily serviced by the municipal water system, it is inferred that there were many of these shallow-dug wells before the municipal water system was constructed.
- Deeper wells drilled through this till into underlying confined aquifers comprising sands and gravels. The top of the deeper confined aquifers are approximately 40 to 50 m below ground surface (m bgs), depending on the location.

The average reported groundwater level is 8.6 m bgs, although there are two wells (WTN 3605 and WTN 92483) located between HWY 15 and Sam Hill Creek that are reported to be flowing artesian[2]. Wells located on Sam Hill are generally deeper (> 45 m bgs) and have lower groundwater levels (deeper than 40 m bgs), when compared to wells in the low-lying area. This suggests that the groundwater elevation in the lower confined aquifer is relatively consistent across the Study Area, resulting in shallow groundwater (artesian in some cases) in the low-lying areas and deep groundwater levels on Sam Hill.

[1] An aquifer that exists above the regional aquifer. Primarily due to layers of impermeability.
[2] When the groundwater level is above ground surface, resulting in a naturally flowing well.

Table ES-3 – Green Infrastructure Network

Site Label	Habitat Description	Ecological Value	Connectivity	Disturbance	GIN Class
	CURRENTLY RECOGNIZED G.I.N. TO BE MAINTAINED				
C1	Riparian habitat and creek (Upper Sam Hill Creek) providing high valued habitat to amphibians, such as the red-legged frog, fish (i.e. Class A watercourse), passerines, and small mammals. Contains riparian sensitive ecosystem. Local and regional connections from the existing Green Infrastructure Network by connecting the Little Campbell River and associated riparian area (C6). Habitat suitability in this corridor ranges from moderate to very high.	High	High	Low	Corridor
C2	Riparian habitat and Creek (Thomson Creek) providing low quality habitat to amphibians such as the red-legged frog, fish (i.e. Class A watercourse), passerines, and small mammals, including the Pacific water shrew. Local connection north to south into C1 and H1. Habitat suitability is mainly moderate in this corridor.	Low	High	Low	Corridor
H1	Redwood forest park, provides high quality habitat to a diversity of wildlife (small and larger mammals, birds and amphibians), some disturbance from local trails. Contains a young mixed forest and old field sensitive ecosystem. Majority of area is rated as moderate high and moderate habitat suitability with small portions of very high and very low suitability.	High	High	Low	Hub
	CURRENTLY RECOGNIZED G.I.N. TO BE RELOCATED				
C3	High habitat quality in forested portions, however, along a busy road and discontinuous/disturbed due to development. Provides a connection between major hubs (H1 and H3). Habitat suitability in this corridor ranges greatly from nil to very high.	Low	High	High	Corridor
	RECOMMENDED G.I.N. ADDITIONS / CHANGES				
C4	Riparian habitat and creek (Unnamed Tributary to Sam Hill Creek; Tributary 1) providing high valued habitat to amphibians, such as red-legged frog, fish (i.e. Class A watercourse), passerines, and small mammals. Contains a wetland sensitive ecosystem. Local and regional connections from the existing Green Infrastructure Network by connecting C1 and H1. Habitat suitability is moderate and high.	Medium	Medium	Low	Corridor
C5	Riparian habitat and creek (Sam Hill Creek) providing high valued habitat to amphibians, such as red-legged frog, fish, passerines, and small mammals (i.e. Class A watercourse). Contains riparian sensitive ecosystem. Local and regional connections from the existing Green Infrastructure Network by connecting C1 and S1. Habitat suitability in this corridor ranges greatly from nil to very high.	Medium	High	Low	Corridor
C7	Mainly a mature deciduous/mixed forest dominated by alder and maple, and portions of the riparian areas of Class A(O), B, and C watercourses. Provides habitat for small mammals, raptors, and passerines. Contains some young forest and urban areas. Connects two major hubs (H1 and H3). Majority of area is rated as moderate high habitat suitability, with some areas rated as very low, moderate and high.	Medium	High	Medium	Corridor
S1	Mature mixed wood forest dominated by alder, cedar and aspen. Provides high valued habitat to passerines, amphibians (such as red-legged frog) and small mammals (potentially including Pacific water shrew for forage, shelter, and breeding opportunities). Contains riparian fringe forest sensitive ecosystems. Connects to proposed corridor (C5) which connects to a major hub (H3) outside the ISMP Study Area. Rated as moderate high habitat suitability.	Medium	Medium	Low	Site
S2	Mature mixed wood forest with wetlands dominated by alder forest. Provides habitat to passerines, amphibians and small mammals. Contains sensitive wetland ecosystem. Connects to proposed corridor (C4), an existing corridor (C2), which connect to major hub (H1) Rated as moderate high and very high habitat suitability.	Medium	Medium	Low	Site
S3	Mature deciduous/mixed forest dominated by alder and maple, and riparian areas of Class B watercourses and Upper Sam Hill Creek. Provides a potentially large amount of habitat for small mammals, raptors, and passerines. Contains young forest and riparian sensitive ecosystems. Surrounded by a suburban residential area, connects to C3. Majority of area is rated as moderate high habitat suitability, with some areas rated as moderate and high.	Medium	High	Medium	Site

Table ES-4 summarizes these infiltration rates and provides subjective headings for each that can be seen on Map ES-3.

Table ES-4
Summary of Local Soil Infiltration Rates

Location	Soil Type	Estimated Infiltration Rate (mm/hr)	Infiltration Capacity
Sam Hill	Podzol. Sand and gravel.	>300[A]	Moderate infiltration capacity
Low-lying area	Gleysol. Silt and clay.	0.2-2.5[B]	Low infiltration capacity

Sources:
A – Gregory et al. 2006
B – AECOM 2012

There are two different soil types in the Study Area with different drainage capacities. The sand and gravel podzols of the uplands area (Sam Hill) drain moderately well (higher infiltration rates) while the clay and silt gleysols of the lowlands drain very poorly (lower infiltration rates) as evidenced by the hydrophilic vegetation and ponding water in topographically low areas.

The sediments underlying the surficial soils on Sam Hill are predominately comprised of very firm till and fine-grained material to an appreciable depth (from the well logs, in places up to 70 m bgs). As such, any infiltration through the upper surficial soils (60 to 80 cm) would be limited, as the water would tend to flow vertically downwards to the shallow till, then mound and possibly resurface.

Once infiltrated to the subsurface, the groundwater may "daylight" (seep) at excavations that extend into the till layer, at ditches that intersect the till layer, and at any point where the surficial sediments pinch out resulting in till at surface. The latter scenario was not observed in the field. In addition, for residential homes located down-gradient from a potential infiltration facility, sub-basements and perimeter drains could be affected by heavy rains.

5 WATERSHED HEALTH ASSESSMENT

The Template for Integrated Stormwater Management Planning (Metro Vancouver, 2005) provides guidance on assessing the health of a watershed by using two physical characteristics: total impervious area and percent riparian forest integrity. Also, in principle the Benthic Index of Biotic Integrity (B-IBI), if available, can provide further information on watershed health from a biological perspective.

- Total Impervious Area (TIA) provides an estimate of the fraction of paved and hard surface areas within a watershed.
- TIA calculations assume that impervious surfaces do not provide any infiltration, which is not necessarily the case if source controls are implemented. As such, a common supplement to TIA is

the Effective Impervious Area (EIA), which assumes the disconnection of a portion of impervious surfaces from watercourses.

- Riparian Forest Integrity (RFI) describes the fraction of riparian forest that remains intact within a 60 m buffer zone from watercourses within the watershed (30 m on either side of the stream).

We calculated the Total Impervious Area of the watershed as 25.8%, and the Effective Impervious Area of the watershed as 16.9%.

When calculating the RFI, we separated the study area into three zones:

- Zone 1: The area north of 16 Avenue that is predominantly large-lot residential.
- Zone 2: The transitional area between 16 Avenue and 12 Avenue.
- Zone 3: The agricultural lowland area south of 12 Avenue.

The results of our analysis are provided in Table ES-5.

Table ES-5
Riparian Forest Integrity Assessment Results

	Riparian Area (ha)	Intact Forested Area (ha)	RFI
Zone 1	23.8	17.5	73.4%
Zone 2	64.5	24.9	38.6%
Zone 3	19.4	6.2	31.9%
All Zones	107.7	48.5	45.1%

5.1 Watershed Health Tracking System

The Watershed Health Tracking System (WHTS) methodology outlined in the ISMP Template (Metro Vancouver, 2005) provides a qualitative indicator of watershed health.

Based on the results for the entire watershed, the estimated EIA is 16.9%, and the estimated RFI is 45%. However, as noted, we also considered the portion of the watershed north of 16 Avenue (i.e. outside the ALR) separately. Based on the results of the study area to the north of 16 Avenue, the estimated EIA is 22.1%, and the estimated RFI is 73.4%. The results for this portion of the study area plot closer to the upper left corner of the figure, indicating a healthier watershed. Recognizing that this area is beyond the ALR, there is a greater opportunity for the City to protect the existing habitat.

Based on the methodology of the WHTS, the B-IBI scores at the lower end of Sam Hill Creek (i.e. considering the entire watershed) would be expected to have a score in the range of 18 to 19. Upstream of 16 Avenue, the B-IBI score would be expected to be in the range of 19 to 20. The City has provided B-IBI sampling data from the nearby Fergus Creek and Little Campbell River watersheds. The Fergus Creek watershed averaged a value of 14.7 from 2017 to 2018 while the Little Campbell River watershed averaged a value of 24 over the same time period. When compared to these results, the Sam Hill Creek calculated scores place the B-IBI results in between these other watersheds.

6 RIPARIAN SETBACKS

Riparian zones are the areas that surround watercourses and wetlands. These 'riparian buffer' areas are intermittently wetted during rainfall events as water levels rise and directly support aquatic habitat by providing nutrient inputs, woody debris, and resisting bank erosion. The preservation and reinstatement of riparian areas is critical in protecting the health of watercourses and the watershed at large. This protection is most often provided by ensuring a certain setback is maintained between the high-water level of a stream and any existing or proposed development. Table ES-6 presents the recommended setbacks outlined in the BCS.

Table ES-6
City of Surrey BCS - Riparian Setback Recommendations

Watercourse Classification	Riparian Setback
A, A(O), ponds and lakes	30 m
B, wetlands	15 m
C	5 m

7 AT-RISK AREAS

We identified at-risk areas as those areas which are expected to be re-developed and which have been identified as part of the GIN. Development is expected to occur within the Sam Hill Creek Watershed in three general locations:

- Between 168 Street and 176 Street, and between 16 Avenue and 20 Avenue, redevelopment will occur as per the Grandview Heights #3 NCP.
- North of 20 Avenue, future redevelopment will occur under Grandview Heights #5 NCP (NCP has not yet been developed).

We also note that there is potential for redevelopment along the east side of 176 Street between 16 Avenue and 18 Avenue in the future.

Map ES-4 shows the extents of the various development areas overlain on top of the existing and proposed Green Infrastructure Network.

8 HYDROLOGIC / HYDRAULIC MODELLING

We created a hydraulic and hydrologic model of the existing drainage system within the study area using PCSWMM version 5.1.011. The model represents major open channels, culverts, and piped storm systems and excludes more minor pipes, driveway culverts and service connections. This level of investigation is typical for ISMPs where only the main conveyance system is analyzed. The study area was divided into 34 subcatchments with an average area of approximately 15 ha and ranging from 4 ha to 40 ha in area.

To assess the existing drainage system for deficiencies we used Intensity Duration Frequency (IDF) data provided in the DCM (2016 version) for the White Rock STP rainfall gauge. The IDF curve is based on a period of record of 44 years. We used this data to create All Duration Storm (ADS) curves for our models. These curves are shown in Figure ES-1.

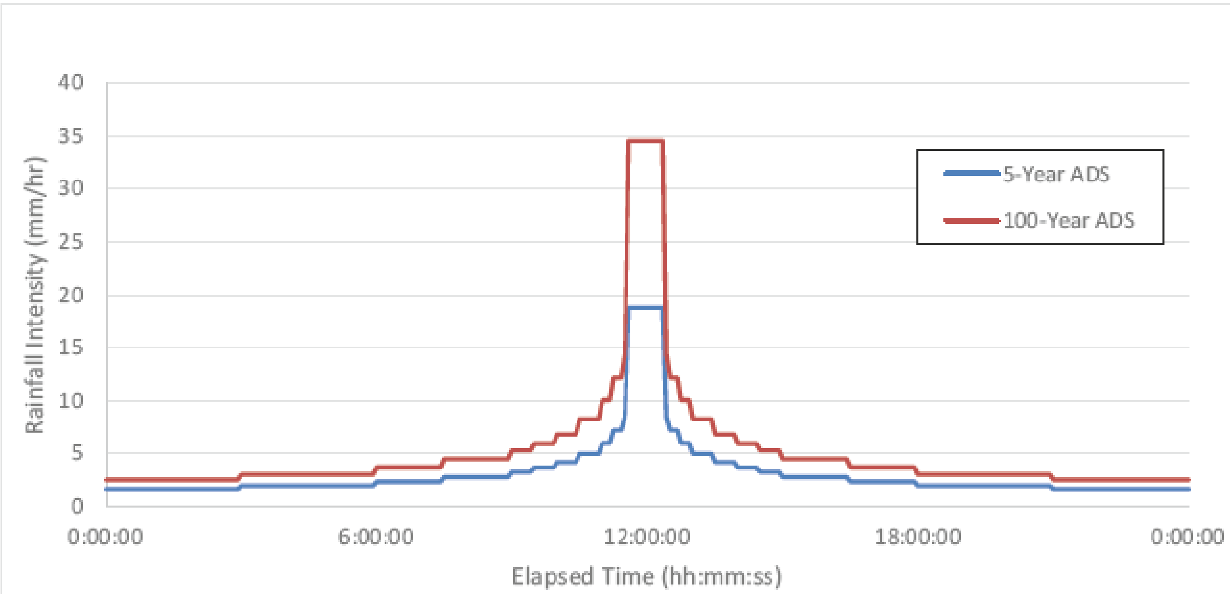


Figure ES-1
ADS Design Storms

We calibrated our model using recorded flow data to evaluate the existing condition.

8.1 Hydraulic/Hydrologic Model Results

Based on conversations with the City and reviewing the City's Design Criteria Manual (DCM), we confirmed a set of design criteria used to assess the existing storm network and develop recommended upgrades. We used our model to develop recommendations for potential stormwater detention pond volumes and locations, storm sewer upgrades, and culvert upgrades. These results are summarized in Table ES-7, ES-8, and ES-9.

Table ES-7
Potential Stormwater Storage Facilities

Storage Location	Total Catchment Area [ha]	Criteria 1: Control 5-year Post-Development Flow to 50% of 2-year Post-Development Flow*	
		Maximum Design Outflow [m^3/s]	Required Storage Volume [m^3]
1	42	0.3325	12,391
2	47	0.314	13,362
3	32	0.1705	4,222
4	32	0.242	9,104
5	32	0.247	10,595
6	32	0.127	10,644

Table ES-8
Storm Sewer Upgrades

Storm Sewer Reference Location	Modelled Pipe	Length [m]	Existing Pipe	Proposed Pipe
A 172 Street north of 20 Avenue	P107*	48	450 mm dia Conc.	750 mm dia Conc.
	P108*	15	450 mm dia Conc.	750 mm dia Conc.
	P109*	15	450 mm dia Conc.	750 mm dia Conc.
B 20 Avenue west of 176 Street	P509_1	191	525 mm dia Conc.	675 mm dia Conc.
	P509_2	135	525 mm dia Conc.	900 mm dia Conc.
	P508	53	450 mm dia Conc.	900 mm dia Conc.
	P507	13	525 mm dia Conc.	900 mm dia Conc.

* Sized to 100-year return period design event.

Table ES-9
Recommended Culvert Upgrades

Culvert Reference Location	Location Description	Existing Pipe	Proposed Pipe	Future Development, 100-year ADS (with upgrades)		
				Peak Flow [m³/s]	HGL [m]	Freeboard [m]
2*	Crossing 18 Ave. along 172 St.	600 mm dia Conc.	1500 mm dia Conc.	2.838	72.72	0.18
3*	Crossing 20 Ave. along 172 St.	600 mm dia Conc.	1500 mm dia Conc.	1.705	90.53	0.37
4	Crossing 171 St. at 21 Ave.	450 mm dia Conc.	750 mm dia Conc.	0.547	98.91	0.19
5	Crossing 12 Ave. at 17800 Block	600 mm dia Conc.	675 mm dia Conc.	0.625	11.49	0.21
7	Crossing 12 Ave. at 17900 Block	300 mm dia Conc.	375 mm dia Conc.	0.159	12.34	0.46
11*	Crossing 170 St. on 16 Ave.	450 mm dia Conc.	750 mm dia Conc.	0.381	42.45	0.25
13*	Crossing 18 Ave. along 172 St. ROW	600 mm dia Conc.	1500 mm dia Conc.	2.366	72.61	0.19

* Within the boundaries of NCP#3 drainage capacity issues will be managed by future developers as the NCP is realized. As a result, the City should not need to address culvert upgrades as separate issues.

8.2 Assessment of Potential Impacts

We ran several four-year Extended Period Simulations (EPSs) of the drainage network to compare the existing and future conditions in the watershed. This allows us to analyze the potential impacts of development in the Sam Hill Creek study area, with and without mitigative measures such as Low-Impact Developments (LIDs) and Best-Management Practices (BMPs). We used the Water Balance Model (WBM) to evaluate the effectiveness of the potential Best Management Strategies for the study area.

The purpose of the simulation is to assess the impact of development on the hydrologic regime in natural watercourses. This provides an indication of changes in flow-duration characteristics following development, which can indicate locations where accelerated stream erosion may arise. Accelerated erosion poses a risk for developments situated near the edges of ravines, can detrimentally affect aquatic habitat, and can cause sediment accumulation that leads to reduced channel capacity and possible flooding in lowland reaches.

We created flow-duration-exceedance curves at four locations:

- Sam Hill Creek Diversion, along 12 Avenue between 172 Street and 176 Street
- Sam Hill Creek, between 14 Avenue and 12 Avenue
- Tributary 1, north of 12 Avenue
- Thomson Creek, north of 12 Avenue

The indicators of increased erosion potential in a natural watercourse are the tractive force and stream impulse. Using the results from our EPS, we calculated the increase in both maximum tractive force and stream impulse. The reporting locations are the same as those used for the flow exceedance curves. Recognizing that future development would increase the volume of runoff and erosion potential, we used water balance modelling to develop mitigative measures.

8.3 Water Balance Modelling

The Water Balance Model is a web-based tool that allows the user to determine hydrologic benefits of applied source controls. We modelled single family and multi family residential lot types to estimate the change in runoff coefficient attainable using different Best Management Practices (BMPs) scenarios. The results are summarized in Table ES-10.

Table ES-10
Water Balance Modelling Results

Land Use	Base Runoff Coefficient	Modified Runoff Coefficient	Percentage Change
Single Family Residential	0.645	0.527	-18.3%
Multi-Family Residential	0.757	0.639	-15.6%

Using the change of runoff coefficient achieved in the water balance models, we modified our EPS models to reflect different BMP implementation scenarios. From these model runs, we extracted the following results and flow exceedance curves on Sam Hill Creek and the Sam Hill Creek Diversion.

Table ES-11
Maximum Tractive Force Results

Scenario	Maximum Tractive Force (N/m^2) and Percent Change from Existing			
	Sam Hill Creek Diversion		Sam Hill Creek	
	A		B	
(1) Existing	34.2		28.5	
(2) Future	43.8	28%	35.7	25%
(3) Future with BMP	40.7	19%	33.2	16%
(4) Future with BMPs and Ponds	30.2	-12%	24.6	-14%
(5) Future with Max BMPs and Ponds	27.8	-19%	23.2	-19%
(6) Future with Max BMPs Ponds, and Bypass	29.3	-14%	24.4	-14%

Table ES-12
Total Stream Impulse Results

Scenario	Total Stream Impulse (kNh/m) and Percent Change from Existing			
	Sam Hill Creek Diversion		Sam Hill Creek	
	A		B	
(1) Existing	180		262	
(2) Future	252	40%	370	41%
(3) Future with BMP	227	26%	333	27%
(4) Future with BMPs and Ponds	235	31%	346	32%
(5) Future with Max BMPs and Ponds	205	14%	301	15%
(6) Future with Max BMPs Ponds, and Bypass	198	11%	291	11%

9 RECOMMENDED DRAINAGE UPGRADES

We have completed hydraulic modelling based on future conditions and performed an environmental assessment of the study area. We analyzed the results and have determined a number of location specific drainage upgrades and environmental improvement projects. These projects address a range of issues including barriers to fish passage, undersized culverts, or proposed storage ponds. See Table ES-13 for a complete list of projects and Map ES-5 for locations.

Table ES-13
Recommended Drainage Upgrades and Environmental Improvements

Location Reference	Reason for Project	Description/Action	Cost
1	Barrier to fish passage	Stepped concrete barriers should be replaced with stepped pools 0.3 m in height with each step (350 m)	$150,000
2	Long sewer	260 m of sewer should be daylighted and returned to open channel	$250,000
3	Blocked culvert	Clear debris from culvert	$10,000
4	Fish passage	Re-establish hydraulic connection between the Sam Hill Creek Diversion and the watercourse to the east.	$50,000
5	Vegetation	Re-plant native vegetation in riparian areas and establish setbacks	$70,000
S1	Detention Storage	Implement 12,391 m^3 stormwater storage.	$5,810,000***
S2	Detention Storage	Implement 13,362 m^3 stormwater storage.	$6,260,000***
S3	Detention Storage	Implement 4,222 m^3 stormwater storage.	$1,980,000***
S4	Detention Storage	Implement 9,104 m^3 stormwater storage.	$4,270,000***
S5	Detention Storage	Implement 10,595 m^3 stormwater storage.	$4,970,000***
S6	Detention Storage	Implement 10,644 m^3 stormwater storage.	$4,990,000***
A	Storm Sewer Upgrade	Replace existing sewer with upgraded pipe. See Table 9-9.	$105,000**
B	Storm Sewer Upgrade	Replace existing sewer with upgraded pipe. See Table 9-9.	$385,000**
C02*	Culvert	Upgrade culvert to 1200 mm dia.	$80,000**
C03*	Culvert	Upgrade culvert to 1500 mm dia.	$90,000**
C04	Culvert	Upgrade culvert to 750 mm dia.	$80,000**
C05	Culvert	Upgrade culvert to 675 mm dia.	$55,000**
C07	Culvert	Upgrade culvert to 375 mm dia.	$50,000**

Location Reference	Reason for Project	Description/Action	Cost
C11*	Culvert	Upgrade culvert to 750 mm dia.	$65,000**
C13*	Culvert	Upgrade culvert to 1500 mm dia.	$90,000**

* Within NCP#3. Drainage changes recommended here are likely to be revisited as significant changes to the stormwater network are expected as the NCP is implemented.

** Based on similar projects in the City's 10-year Servicing Plan

*** Based on similar projects in the Redwood Heights NCP as supplied by the City.

10 RECOMMENDED BMPS

In addition to these specific projects, we have developed a strategy of BMP and LID implementation that is applicable to areas expecting new development or re-development. The performance targets are summarized in Table ES-14.

Table ES-14
Recommended BMP and Detention Pond Performance Targets

	Single Family (Urban Single Family, Semi-Detached Residential)	Multi-Family Residential (Multiple Residential Cluster, Low-Density Multiple Residential, Medium Density Residential, and Townhouse Residential)	Commercial, Institutional, and School Land Uses	Road Rights-of-Way
BMP Rainfall Capture Target*	72% of the 2-year return period event (38.3 mm)			
BMP Maximum Allowable Release Rate*	0.25 L/s/ha			
5-year Stormwater Storage**	278 m^3/ha			
5-year Maximum Allowable Release Rate***	6.6 L/s/ha			

* As recommended in the Metro Vancouver Stormwater Source Control Design Guidelines.

** Criteria is to control the 5-year post development flow to 50% of the 2-year return period post-development flow. Value presented is based on an average of calculated storage volumes for each subcatchment.

*** Average maximum release rate of proposed detention ponds (see Table 8-6).

Single Family Land Uses

- Hydraulically disconnecting impervious areas from downstream conveyance systems
- Absorbent landscaping
- Underground storage where possible
- Infiltration trenches

Multi-Family Land Uses

- Hydraulically disconnecting impervious areas from downstream conveyance systems
- Absorbent landscaping
- Pervious pavement
- Underground storage where possible
- Infiltration trenches

Commercial, Institutional, and School Land Uses

- Bioswales
- Green roofs
- Rain gardens
- Water quality devices
- Underground storage facilities

Road Rights-of-Way

- Bioswales,
- Rain gardens
- Absorbent landscaping and street trees
- Structural soils

11 IMPLEMENTATION STRATEGIES

11.1 Funding Strategies

A variety of funding sources are available to support the implementation, operation and maintenance of the stormwater management components recommended within the Sam Hill Creek ISMP. Individual land owners are responsible for funding and implementing source controls and BMPs specific to their own properties. Off-site upgrades to City-controlled infrastructure directly related to development activities will also be chargeable to the subject property owner / developer in the form of Development Cost Charges (DCCs).

For infrastructure upgrades on City owned property, the Capital Construction Program allocates funds for infrastructure projects throughout the City and includes drainage, sewer, water and roads projects that maintain and renew existing City infrastructure or support growth and development.

11.2 Enforcement Strategies

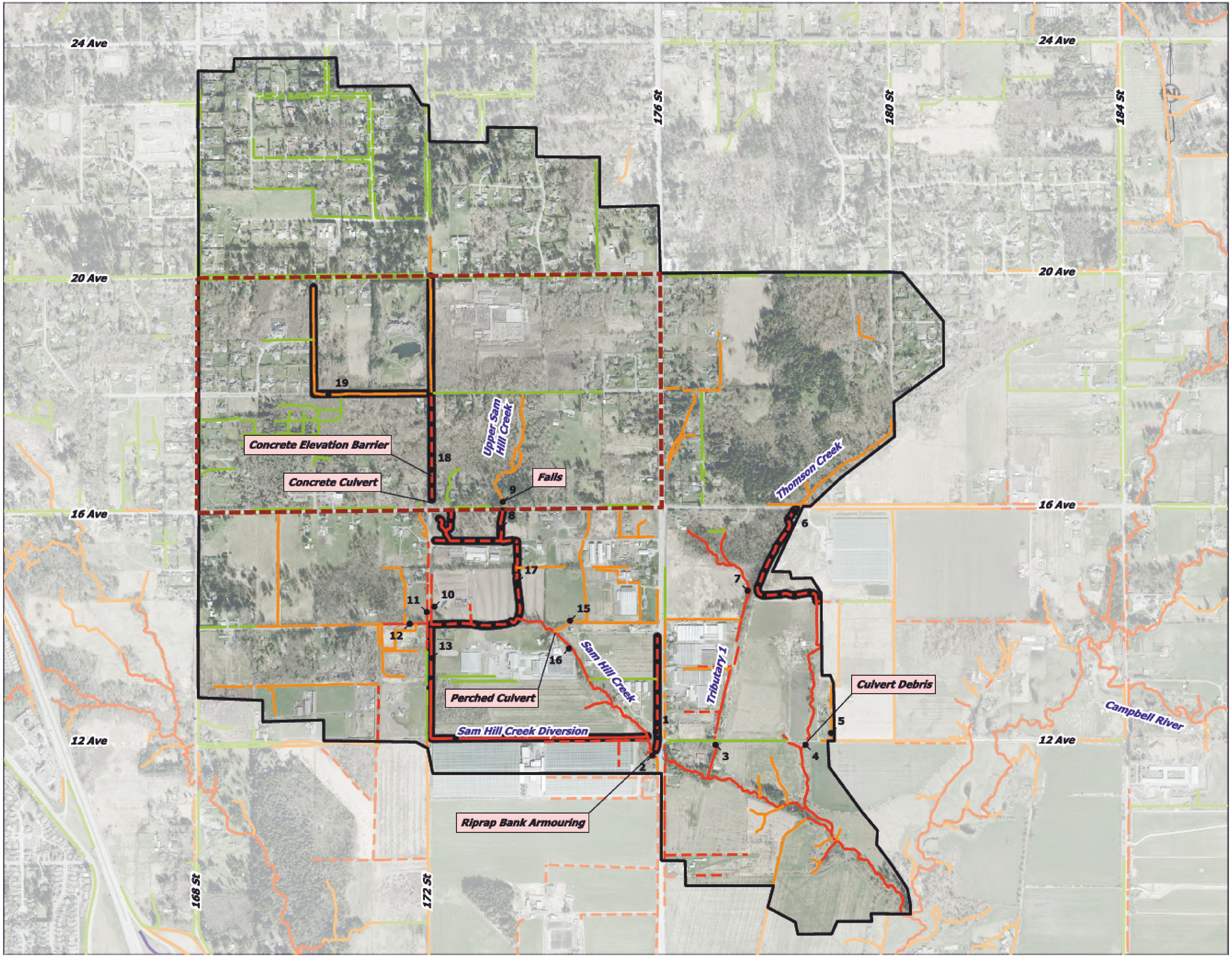
The City is aware of the difficulties in enforcing policies regarding stormwater management and has developed a number of tools to do so including:

- City of Surrey Engineering Design Criteria Manual – Section 5 Storm Drainage System
- City of Surrey Zoning Bylaw, 1993, No. 12000
- City of Surrey Drainage Parcel Tax Bylaw, 2001, No. 14593
- City of Surrey Stormwater Drainage Regulation and Charges Bylaw, 2008, No. 16610
- City of Surrey Erosion and Sediment Control Bylaw, 2006, No. 16138
- City of Surrey Supplementary Master Municipal Construction Documents, 2016
- City of Surrey Official Community Plan Bylaw, 2013, No. 18020 - Streamside Development Permit Areas
- *City of* Surrey Invasive Species Management Plan

11.3 Monitoring Strategy

As part of the Integrated Liquid Waste Resource Management Plan Metro Vancouver published the Monitoring and Adaptive Management Framework for Stormwater (AMF). This document outlines a framework for establishing a baseline understanding of watershed health and tracking changes to it over time. The City of Surrey has adopted this framework within its watersheds to track the success of implementing stormwater management goals and targets, such as those set out in ISMPs.

The City has established a water quality monitoring site on Sam Hill Creek south of 16 Avenue in the low gradient reaches of the creek, at the intersection of 172 Street and 14 Avenue. We recommend that monitoring efforts be expanded within the watershed. We also recommend that benthic invertebrates health be measured using the B-IBI in accordance with Metro Vancouver's AMF within the watershed.



LEGEND

ISMP Study Area
Grandview Heights #3 NCP

Watercourse Classification

- A
- AO
- B
- C
- UN

Aquatic Habitat Assessment Site
12 Assessment ID

Recommended Reclassification

text Fish Passage Obstacle (See Table 4-5)

SCALE:	AS SHOWN		
PROJECT NO.	2017-2991	INITIAL	DATE
DRAWN		JT	17-11-10
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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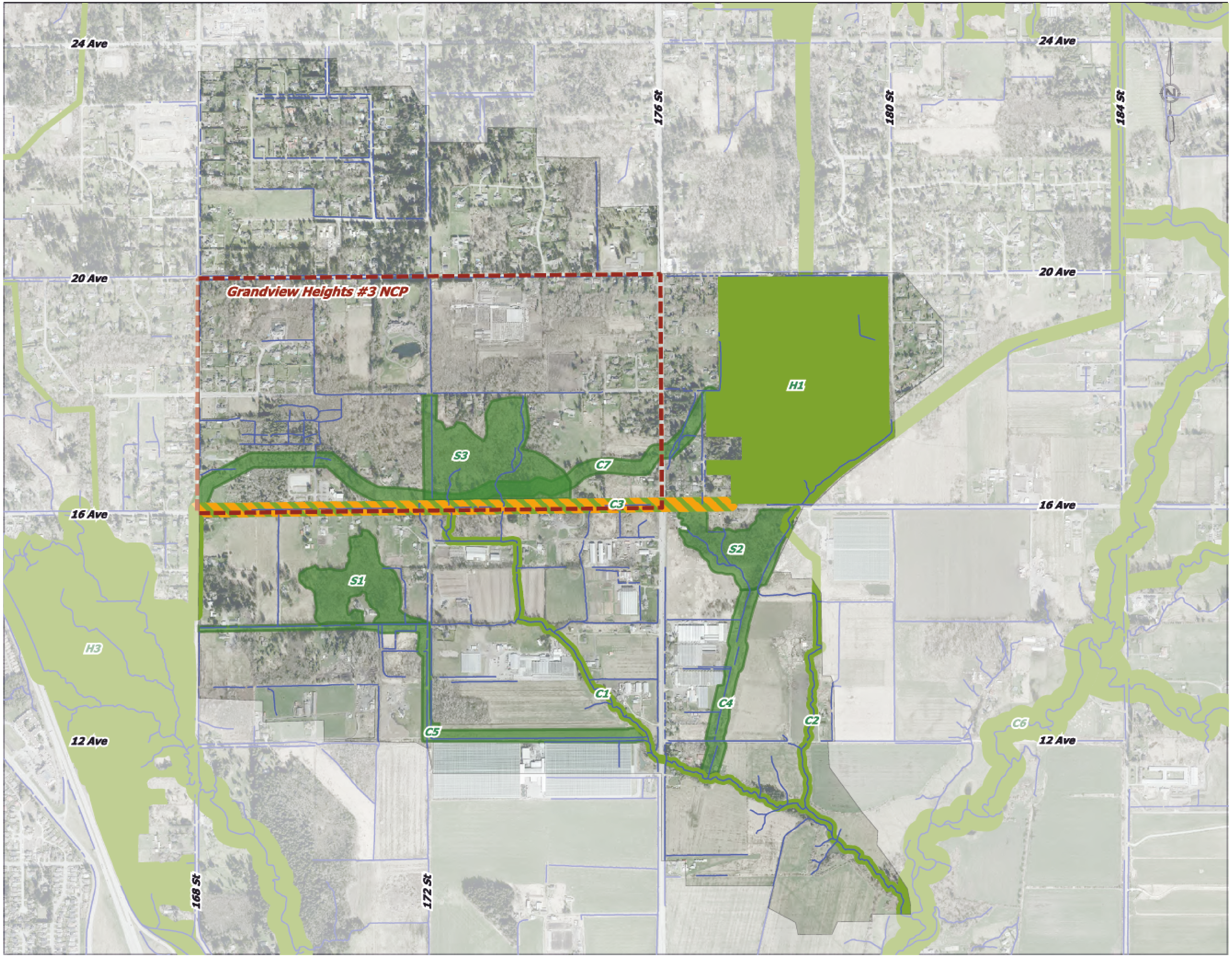
SAM HILL CREEK ISMP

RECOMMENDED STREAM CLASSIFICATION

DRAWING NUMBER	REV. NO.	SHEET
MAP ES-1		



LEGEND

ISMP Study Area
Grandview Heights #3 NCP
Watercourse

Existing GIN

Green Infrastructure Network (Recognized GIN)

Proposed GIN

Proposed GIN
Proposed Removal of GIN Corridor

SCALE:	AS SHOWN		
PROJECT NO.	2017-2991	INITIAL	DATE
DRAWN		EF	17-11-10
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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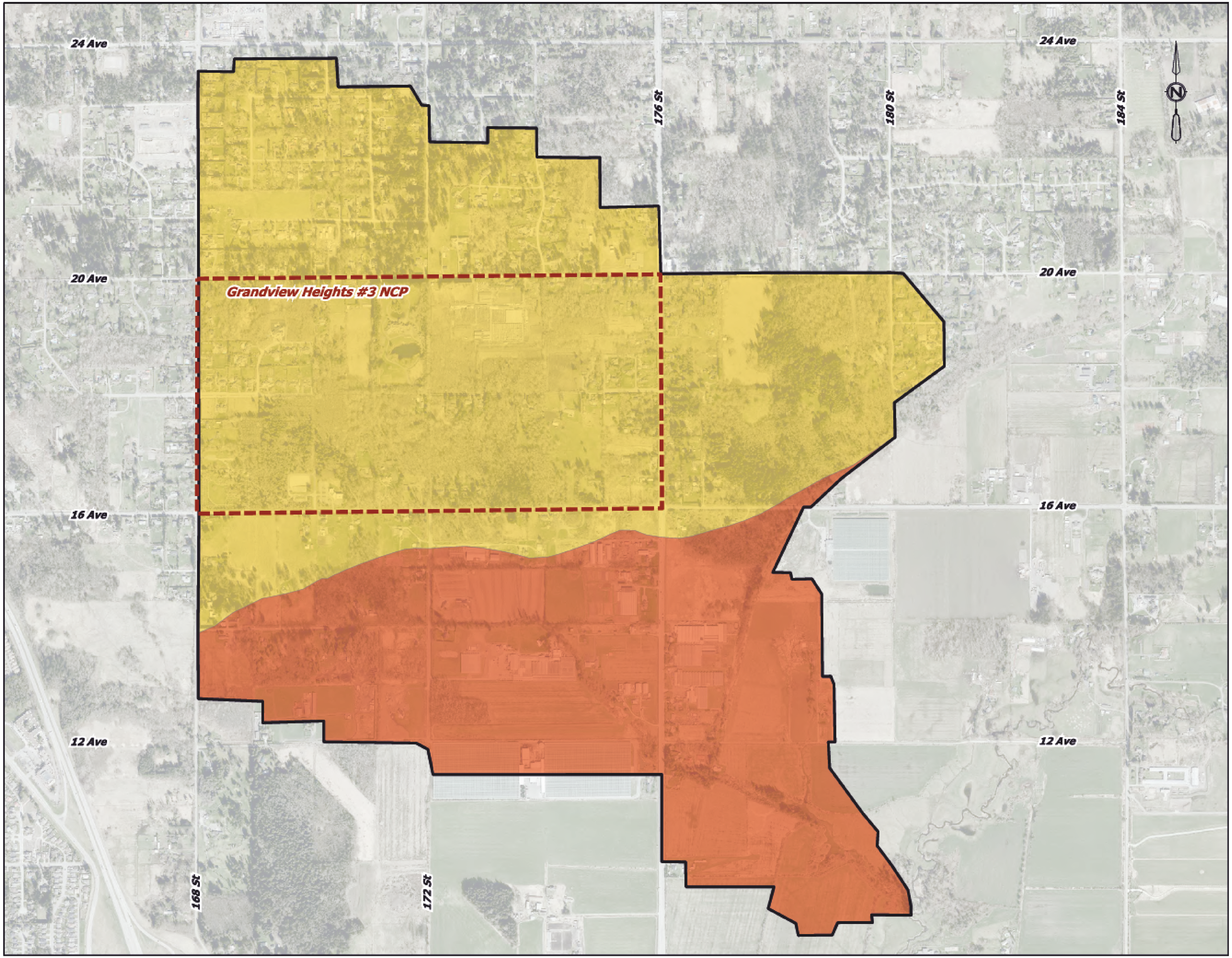
GREEN INFRASTRUCTURE NETWORK

DRAWING NUMBER	REV. NO.	SHEET
MAP ES-2		

Map File: C:\Users\fmneye\Desktop\map_Surrey_SamHill_20180118.map



LEGEND

- Moderate Infiltration Potential
- Low Infiltration Potential

SCALE:	AS SHOWN		
PROJECT NO.	2017-2991	INITIAL	DATE
DRAWN		JT	17-06-23
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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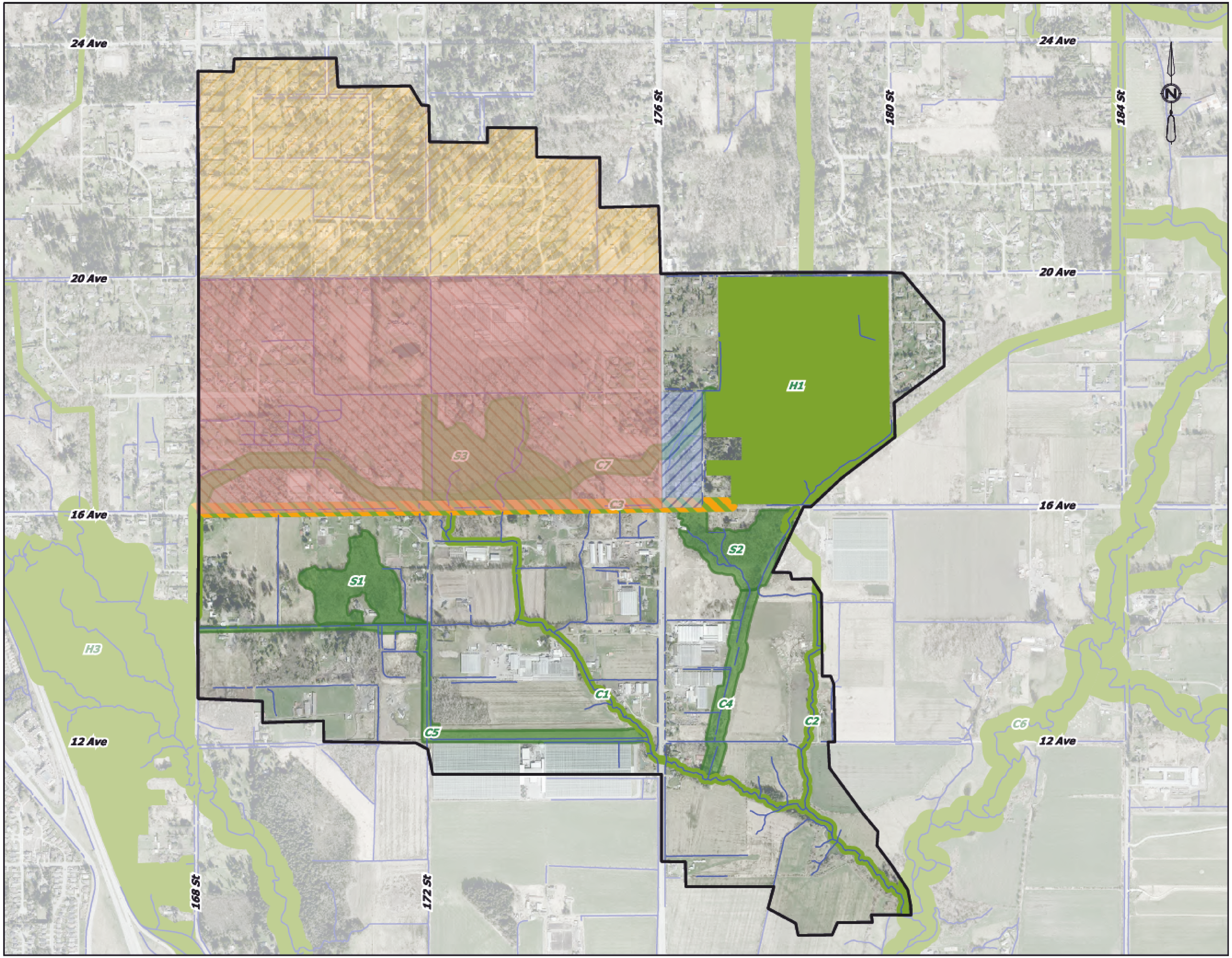
INFILTRATION POTENTIAL

DRAWING NUMBER	REV. NO.	SHEET
MAP ES-3		



LEGEND

ISMP Study Area
Watercourse

Green Infrastructure Network

Existing GIN

Green Infrastructure Network (Recognized GIN)

Proposed GIN

Proposed GIN

Proposed Removal of Corridor

Future Development Areas

Grandview Heights #3 NCP
Grandview Heights #5 NCP
Townhouse

SCALE:	AS SHOWN		
PROJECT NO.	2017-2991	INITIAL	DATE
DRAWN		EF	17-11-10
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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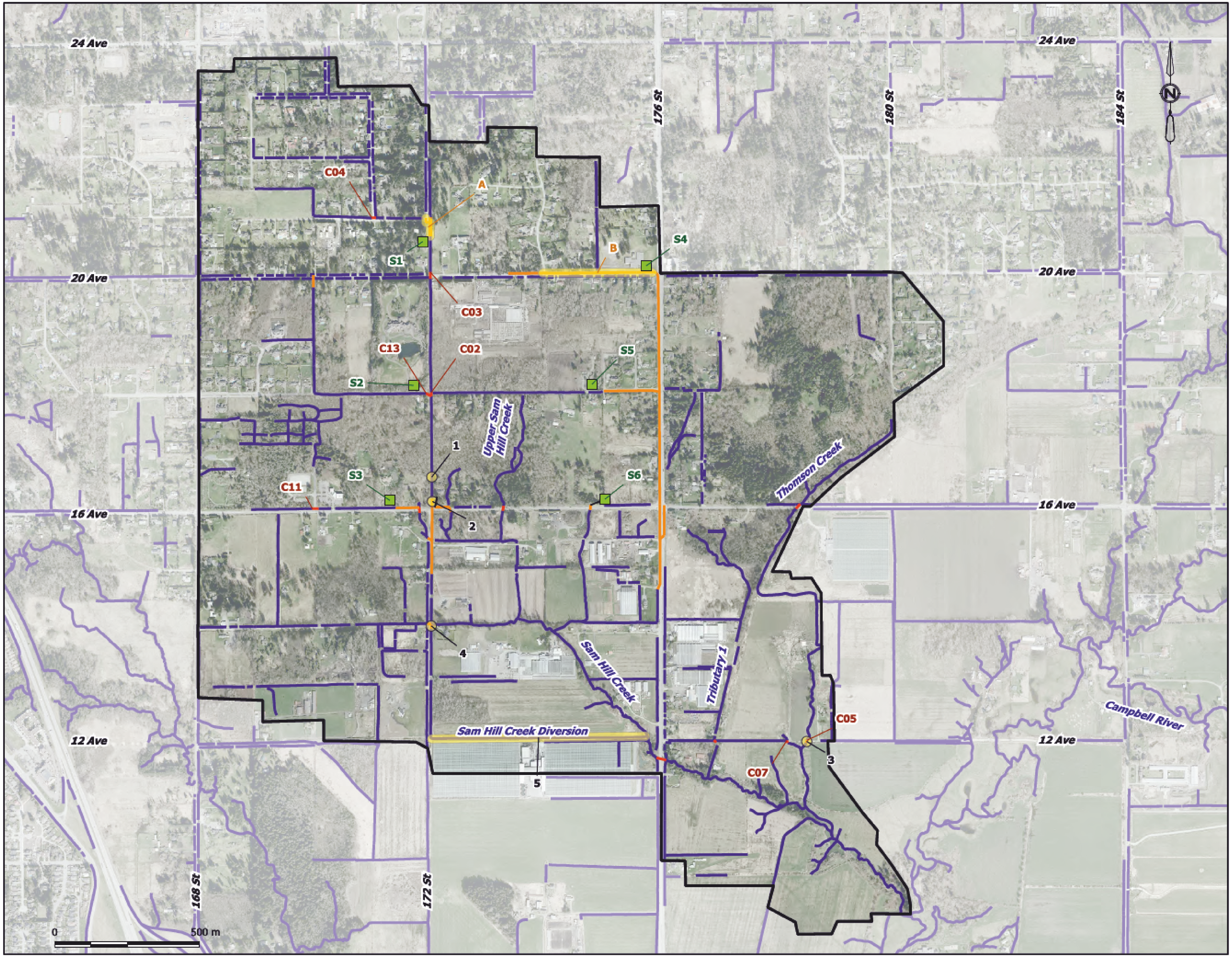
AT RISK AREAS
GREEN INFRASTRUCTURE NETWORK

DRAWING NUMBER	REV. NO.	SHEET
MAP ES-4		



LEGEND

	Storage Facilities
	Storm Sewer
	Culvert
	Watercourse
01	Environmental Improvement
S01	Storage Facilities ID
A	Storm Sewer Location ID
C01	Culvert Labels
	Upgrade or Improvement

SCALE:	AS SHOWN		
PROJECT NO.	2017-2991	INITIAL	DATE
DRAWN		EF	18-09-21
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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SAM HILL CREEK ISMP

DRAINAGE AND ENVIRONMENTAL UPGRADES

DRAWING NUMBER	REV. NO.	SHEET
MAP ES-5		

Table of Contents

List of Tables

List of Figures

List of Maps

1 Introduction

The City of Surrey has engaged Associated Engineering (AE) to develop an Integrated Stormwater Management Plan (ISMP) for the Sam Hill Creek watershed.

Two prior studies have paved the way for the initiation of the Sam Hill Creek ISMP project. As a product of the Little Campbell River Integrated Stormwater Scoping Study in 2011, a list of recommended sub-watershed ISMP study areas was created that included Sam Hill Creek. As part of the Grandview Heights General Land Use Plan, five Neighbourhood Community Plans (NCPs) have been initiated to guide future development; in particular, Grandview Heights NCP #3 falls almost entirely within the Sam Hill ISMP study area. The Grandview Heights #3 NCP is being completed in parallel with the Sam Hill Creek ISMP.

The Sam Hill Creek ISMP project bridges the gap between the smaller scale Grandview Heights NCP #3 and the larger Little Campbell River Integrated Stormwater Scoping Study. It is intended to provide guidance for future development while maintaining or enhancing the overall health of the watershed.

The study area is located in south Surrey and is approximately 525 ha in size. From the low-density residential upland areas to the north, the study area gently slopes south and south-east through agricultural lowlands to the confluence with Little Campbell River. Major watercourses include Upper Sam Hill Creek, Sam Hill Creek, Thomson Creek, Sam Hill Creek Diversion, and an unnamed tributary (Tributary 1). See Map 1-1 for an overview of the study area. The ISMP template is divided into four distinct stages.

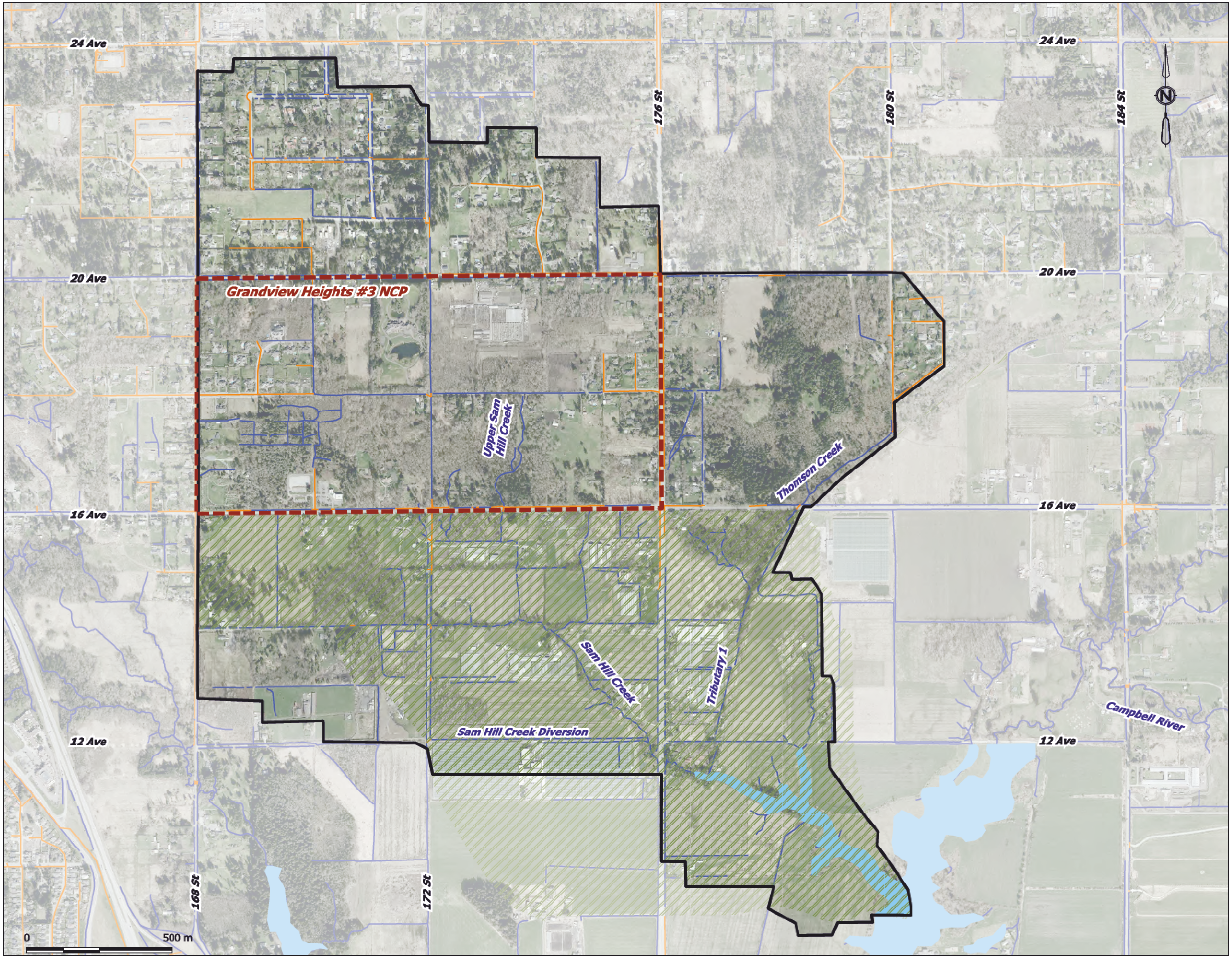
Stage 1 provides an overview of the watershed under existing conditions, and answers the question "What do we have?" We assessed terrestrial, aquatic, hydrogeological, and stormwater management components. We created a hydrologic and hydraulic model of the watershed and used design rainfall events to identify key deficiencies within the existing drainage system.

Stage 2 addresses the question "What do we want?" for the watershed. To answer this, we set out a vision for the future of the watershed and identify the constraints and opportunities relevant to achieving that vision. We developed riparian setback mapping, evaluated the effects of climate change and changing land uses on the existing drainage system, identified the impact on watercourses and environmentally sensitive areas due to expected development, and identified several Low Impact Development (LID) techniques and Best Management Practices (BMPs) that would address these impacts.

Stage 3 discusses the question "How do we get there?" by developing an implementation plan to achieve the vision set out in Stage 2. This plan includes specific recommendations for drainage system upgrades, environmental site improvements, suggested funding options, and bylaw revisions.

Stage 4 considers "How do we stay on track?" by addressing monitoring efforts that can help measure changing watershed health.

This final ISMP report presents our findings and recommendations from the preceding reports. We have also included an ISMP Summary Sheet of this report for easy reference.



LEGEND

ISMP Study Area
Grandview Heights #3 NCP
ALR
Open Channel
Storm Drain
200-year Floodplain

SCALE:	AS SHOWN		
PROJECT NO.	2017-2991	INITIAL	DATE
DRAWN		JT	17-06-23
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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SAM HILL CREEK ISMP

WATERSHED OVERVIEW

DRAWING NUMBER	REV. NO.	SHEET
MAP 1-1		

2 Study Area Overview

2.1 PHYSIOGRAPHY

The Sam Hill Creek study area is located in the south of Surrey and is roughly bounded by 24 Avenue to the north, 180 Street to the east, 8 Avenue to the south, and 168 Street to the west. With the headwaters originating near 24 Avenue between 168 Street and 176 Street, the catchment drains to the agricultural lowlands in the south.

The ISMP study area is approximately 525 ha. From a maximum elevation of about 110 m above sea level, the study area gently slopes south and south-east to the confluence with Little Campbell River at an elevation of about 5 m above sea level.

North of 16 Avenue, the predominant land use is One Acre Residential, and is designated as 'Suburban – Urban Reserve' in the Official Community Plan (OCP). This area encompasses the Grandview Heights NCP#3 area (GHNCP #3). The land use for the GHNCP #3 is shown in Figure 2-1. East of 176 Street is Redwood Park, a significant wooded area. South of 16 Avenue, the study area is designated as part of the Agricultural Land Reserve.

Watercourses tend to drain south and south-east within the study area. Upper Sam Hill Creek originates between 172 Street and 176 Street crossing 16 Avenue before draining into Sam Hill Creek. The majority of watercourses draining to Upper Sam Hill Creek are linear drainage ditches. Sam Hill Creek flows south-east through the study area crossing 176 Street before it is joined near 12 Avenue by an unnamed tributary stream. The unnamed tributary stream runs south, roughly parallel to 176 Street. Downstream of this confluence, Sam Hill Creek is joined by Thomson Creek, a creek which receives runoff from the eastern part of the study area. Ultimately, Sam Hill Creek is tributary to Little Campbell River at the southeastern extreme of the study area.

2.2 CLIMATE

The climate of the study area is relatively warm with the vast majority of precipitation falling as rain with an average depth of approximately 1100 mm per year. Rainfall patterns are typical for watersheds in the Lower Mainland with the highest amounts of precipitation occurring during the fall and winter months with cyclonic storms that can linger for several days at a time. Rainfall amounts during the drier summer months tend to be lower and less frequent.

The City of Surrey's Design Criteria Manual shows the study area falling within the South Rainfall Area. The most applicable rain gauge for this region is the White Rock STP rain gauge. We have referenced the City provided data and design storms in our analysis.

The 1981 to 2010 climate normal for the White Rock STP rain gauge are presented in Table 2-1.

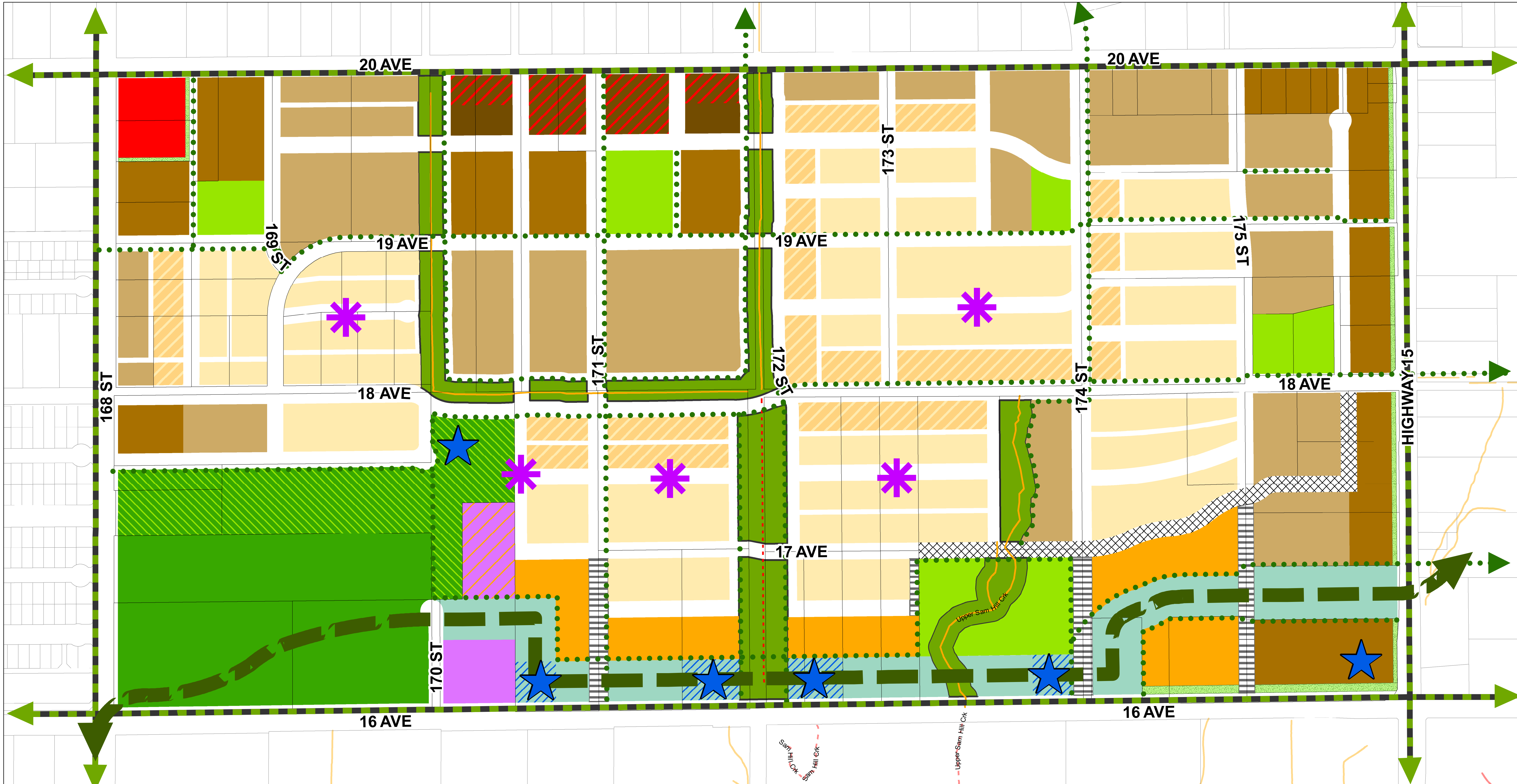

FIGURE 2-1 Grandview Heights NCP #3 Land Use Concept Plan

- Neighbourhood Commercial
- Mixed Use Apartment [4
- Apartment [4 Storeys]
- Townhouse (25-28 UPA)
- Rowhouse/Townhouse (20-23 UPA)
- Multiple Residential (15-20 UPA)
- Semi-Detached or Detached Residential (12-15 UPA)
- Detached Residential (10-12 UPA)
- Institutional
- Institutional or Multiple Residential Flex
- Potential School Site
- Landscaped Buffer
- Riparian
- Future City Park
- Future Neighbourhood Park
- Existing City Park
- Biodiversity Corridor Park
- Biodiversity Corridor Pond
- Potential Detenion Pond
- Special Road (Consideration to Steep Slopes)
- Flex Road
- Pedestrian Walkway
- Greenway
- Existing Lots
- A Fish Classifications
- AO Fish Classifications
- B Fish Classifications

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CITY OF SURREY PLANNING AND DEVELOPMENT DEPARTMENT

V:\Policy&Long Range\GIS_ANALYSIS\GRANDVIEW_HEIGHTS_AND_SOUTH_SURREY\NCP_3\Grandview_Heights_NCP3_LANDUSE_May2018\GH NCP3 Preferred Land Use Concept May 2018.mxd

Table 2-1
Climate Normal for White Rock STP Rain Gauge

White Rock STP	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Precipitation (mm)	146.8	99.3	97.5	83.4	73.2	59.6	41.1	39	46.4	111	171.2	139.7	1108.2
Rain (mm)	134.7	93.6	96.7	83.4	73.2	59.6	41.1	39	46.4	110.7	169	130.5	1077.8
Snow (mm) (Snow-water equivalent)	12.1	5.7	0.9	0	0	0	0	0	0	0.3	2.2	9.2	30.4

We note that while the above climate data are developed through the analysis of historical data, future climate data and the resulting design storms may be considerably different as a result of a changing climate.

2.3 EXISTING DRAINAGE

There are four major watercourses within the Sam Hill ISMP study area:

- Upper Sam Hill Creek
- Sam Hill Creek
- An unnamed tributary (Tributary 1)
- Thomson Creek

The existing drainage system that discharges into these watercourses is mostly composed of open, linear ditches running along roads and property lines. Some areas have short piped sections with most of the piped sections within the study area running under 20 Avenue and 176 Street before discharging into Sam Hill Creek.

The most significant culverts crossings and storm sewers include:

- 1800 mm wide x 1200 mm high concrete box culvert crossing 176 Street along Sam Hill Creek.
- 750 mm circular concrete culvert crossing 16 Avenue along Thomsen Creek.
- 1400 mm wide x 950 mm tall corrugated steel arch culvert crossing 12 Avenue along the unnamed tributary.
- 900 mm circular concrete culvert crossing 16 Avenue along Upper Sam Hill Creek.
- 2400 mm x 1200 mm concrete box culvert under driveway at 172 Street and 14 Avenue.
- 750 mm circular concrete sewer crossing 16 Avenue along a tributary to Sam Hill Creek.

2.4 CITY OF SURREY RAVINE ASSESSMENTS

On a semi-regular basis, the City engages consultants to perform a Ravine Stability Assessment throughout the city to identify high-risk erosion sites, debris blockages, and other areas of concern. In general, these assessments provide important detail on key drainage features throughout the City.

As part of the background data provided by the City, we reviewed the reports from the 2011, 2014, and 2016 ravine assessments. The 2011 report noted a medium risk location along Thompson Creek crossing 12 Avenue where the culvert is mostly blocked, and little flow was passing. However, subsequent assessments of the site classify the site as low-risk. Based on our review of the data, no significant instability sites have been identified within the current study area.

3 Goals and Objectives

The fundamental purpose of an ISMP is to maintain and enhance the overall health of a watershed while allowing for future development and this is true for both the Sam Hill Creek ISMP, as well as the Grandview Heights #3 NCP.

As outlined in the Terms and References for this ISMP, the overall goals for the study area are to:

- Protect and enhance the overall health and natural resources of the creek and watershed study area.
- Promote participation from all stakeholders to achieve a common future vision of the watershed.
- Minimize risk of life and property damages associated with flooding and provide strategies to attenuate peak flows.
- Protect and enhance watercourses and aquatic life.
- Prevent pollution and maintain/improve water quality.
- Prepare an inventory of watercourses and wildlife for the watershed study area.
- Protect the environment, wildlife and habitat corridors.
- Identify areas of existing and future industrial, residential, commercial, agricultural and recreational land uses.
- Integrate the potential impact of climate change on the ISMP area.
- Develop a cost effective and enforceable implementation plan.
- Establish a monitoring and assessment strategy to ensure goals are achieved, maintained, and enforced.

To support achieving these goals, this ISMP includes the following specific measures where possible:

- Preserve existing green space and undeveloped lands.
- Restore riparian corridors where redevelopment opportunities allow.
- Maintain and improve watershed biodiversity by supporting the maintenance and enhancement of terrestrial movement corridors in accordance with the recommendations in the City's Biodiversity Conservation Strategy (BCS).
- Reduce the overall Effective Impervious Area (EIA) by hydraulically disconnecting impervious areas from watercourses through the use of source controls.
- Enhance fisheries habitat through the mitigation of aquatic constraints and the restoration of degraded habitat through considering fish presence, fish potential, and inputs to downstream fish habitat.
- Define and enforce stormwater quality management objectives.
- Promote the management of rainfall at the source to improve the hydrologic characteristics of the study area.

In consideration of the overall goals and specific measures identified above, the vision statement for the Sam Hill Creek ISMP is:

> *The vision for the Sam Hill Creek ISMP is to hold paramount public safety and the protection of the environment while accommodating community growth, in a way that enhances watershed health and aesthetics, and promotes the existing strategies aimed at conserving biodiversity. This ISMP presents a strategy for implementing stormwater best management practices and environmental enhancement opportunities that can balance the City's long-term environmental and economic goals.*

4 Environmental Assessments

4.1 BACKGROUND / OBJECTIVE

This section provides a summary of aquatic and terrestrial habitat features identified within the Sam Hill Creek watershed (the Study area). The objective of this section is to provide an overview of the existing environmental features. It includes the identification of ecologically significant areas (i.e., watercourses, fish and fish habitat, wildlife and wildlife habitat/corridors, species at risk habitat, significant and valuable tree stands), potentially sensitive or hazardous terrain, and natural recreation areas.

This assessment is consistent with the City of Surrey's BCS (Diamondhead 2014) following three core principals of biodiversity conservation:

- Preserving large core habitat areas;
- Ensuring connectivity between habitat areas; and
- Providing a diversity of habitat features throughout the City.

4.2 APPROACH / METHODS

We compiled and reviewed the following information to characterize existing environmental conditions:

- Habitat Wizard database (MOE 2017a);
- Fisheries Information Summary System database (MOE 2017b);
- BC Conservation Data Centre Species and Ecosystem Explorer database and associated reports (MOE 2017c);
- Sensitive Ecosystem Inventory Mapping (MOE 2017d);
- Species at Risk Public Registry (Government of Canada 2017);
- City of Surrey's Biodiversity Conservation Strategy (BCS; Diamondhead 2014);
- City of Surrey's Watercourse Classification Map (CoS 2011);
- City of Surrey's Online Mapping System (COSMOS; CoS 2017);
- Published Soil Survey and Soil Management Reports (Luttmerding 1980); and
- Other relevant consultant and government reports and journals.

A significant amount of terrestrial habitat information has been assembled as part of the City's BCS. This habitat assessment relied on the following information contained in the City's BCS:

- Existing park natural areas.
- Existing Green Infrastructure Network (GIN; wildlife corridors, sites, and hubs).
- Habitat type mapping.
- Habitat suitability mapping.
- Representative species (mammals, amphibians/reptiles, fish, birds).

We conducted a field assessment on May 9, 2017 of the Study area to validate available information regarding potential habitat and species at risk presence. Map 4-1 shows the existing GIN.

4.2.1 Aquatic Environment

Aquatic habitat assessments were completed at 19 sites on a sub-sample of the watercourses and sections of watercourse in the study area (see Map 4-2). These assessments characterized the biophysical attributes of each site, evaluated current fish habitat conditions, evaluated salmonid use (i.e., rearing, overwintering, and spawning potential), identified specific issues related to erosion, bank instability, and barriers to fish passage; and verified existing information (e.g., watercourse classification). Opportunities for infrastructure improvement (e.g., culverts) and habitat enhancement and restoration (e.g., riparian planting) were also noted. No fish sampling was conducted.

The field assessment was conducted at each site in accordance with the Resource Inventory Standards Committee protocols (RISC 2001). Each site was georeferenced with GPS and photographed. Streams were assessed on foot and detailed information was collected, including:

- Channel width (m);
- Wetted width and depth (m);
- Channel gradient (%);
- Substrate composition (i.e., organics, fines, gravels, cobble, boulders);
- Habitat quality (i.e., spawning, rearing and overwintering potential);
- Obstacles and barriers to fish movement (e.g., hanging or perched culverts, debris jams);
- Incidental fish observations;
- General riparian vegetation conditions (i.e., intactness and major species composition); and
- Unique or critical features (e.g., significant overwintering pools or spawning grounds).

4.2.1.1 Stream Classification

The City of Surrey developed a classification system for watercourses, tributaries and ditches in each watershed within the City (City of Surrey 2011). The classification provides an overall fish habitat value rating based on fish presence, duration of water flow and water source and surrounding vegetation potential. The term “fish” refers to both salmonids and regionally significant fish. The four classifications are summarized in Table 4-1.

Table 4-1
City of Surrey Watercourse Classification System

Classification	Map Symbol	Description
Class A	Solid red line	Inhabited by or potentially inhabited by fish year-round if migration barriers are removed.
Class A (O)	Dashed red line	Inhabited by or potentially inhabited by fish, if migration barriers are removed, primarily during the over-wintering period.
Class B	Solid yellow line	Significant food and/or nutrient value, no fish present.
Class C	Solid green line	Insignificant food and/or nutrient value or road-side ditches.

The field assessment results were used to verify the City of Surrey's existing watercourse classification map and identify potential changes to current classifications based on habitat quality and connectivity to existing fish-bearing watercourses to ensure that proper setbacks are adhered to during future potential development.

4.2.2 Terrestrial Environment

The terrestrial field assessment focused on visiting vegetated areas characterized as forest, riparian, wetland, and old field habitat and included 30 individual assessment sites. During the assessments, no species specific, rare plant, or wildlife surveys were completed.

In addition to the areas that are already recognized within the City's established Green Infrastructure Network (GIN), we also identified habitat areas which are not part of the formal GIN, yet still contribute to the existing habitat connectivity within the study area. Habitat areas were classified into three types based on their size and habitat function following the definitions provided in the City of Surrey's Green Infrastructure Network (Diamond Head 2014):

- **Hubs** - areas greater than 10 ha in size with a diverse habitat structure;
- **Sites** - areas less than 10 ha in size, which may support fewer species; and
- **Corridors** - linear habitat areas that encourage the movement of species between fragmented hubs and sites, including riparian areas with 30 metre setbacks from the highwater mark.

Criteria used to describe the level of connectivity, ecological value and level of disturbance is provided in Table 4-2. An overview of the existing GIN and proposed changes can be seen in Map 4-1. We note that the unrecognized GIN areas contained in this report are based on environmental value alone, whereas habitat areas that are included in the recognized GIN were also assessed for their community development potential and recreation potential.

Table 4-2
Criteria Used to Validate Existing Green Infrastructure Network Mapping and Propose New Green Infrastructure Network Additions

Criteria	Rating	Description
Connectivity	High	Connectivity to major Hubs, Sites, and Corridors already designated in the Green Infrastructure Network (City of Surrey), Conservation Areas and Park as designed by the City of Langley, or other proposed Hubs, Sites or Corridors that are naturalized and designed to provide movement for a wide range of species.
	Medium	Connectivity to Conservation Areas and Parks as designed by the City of Langley, or to proposed Hubs, Sites, and Corridors that are naturalized and designed to provide movement for a wide range of species.
	Low	Connectivity between Hubs and Sites or smaller Conservation Areas or Parks that provide movement for species more adapted to urban habitat.
Ecological Value	High	Important habitat that is considered a key component of the Green Infrastructure Network. Connectivity, locally and regionally, wildlife sightings, particularly species at risk, and the potential to support significant wildlife communities.
	Medium	Important Habitat that enhances connectivity and supports significant wildlife communities.
	Low	Moderately important habitat that supports the GIN and can benefit from enhancement opportunities.
Disturbance	High	Areas surrounded by moderate to high-density suburban and urban areas with consistent traffic or industrial noise
	Medium	Areas surrounded by low-density suburban to urban areas with consistent traffic noise.
	Low	Areas surrounded by low-density suburban to urban areas and parks, or conservation areas with consistent or irregular traffic noise.

Source: Adapted from Surrey's Green Infrastructure Network (Diamond Head 2014)

4.3 AQUATIC CONSTRAINTS AND ENHANCEMENT OPPORTUNITIES

4.3.1 Grandview Heights #3 NCP Environmental Study

In addition to broad, city-wide initiatives such as the BCS, Neighbourhood Community Plans (NCPs) are being created to help guide development in more focused areas. In the Sam Hill Creek watershed, the Grandview Heights #3 NCP is being developed in conjunction with this ISMP.

To support the specific needs of the NCP, Associated Engineering completed the "Grandview Heights #3 NCP Environmental Study." The Environmental Study built upon the existing environmental information that was previously assembled for the City through various reports and included the following primary objectives:

- Compile additional detailed environment information specific to the NCP Area #3 available in previous reports, and update based on recent knowledge gained during the Sam Hill Creek ISMP. The environmental information included:
  - Watercourses, watercourse classifications, and recommended setbacks.
  - Vegetation resources, wildlife resources and wildlife habitat values (including species at risk (SAR).
  - Terrestrial Ecosystem Mapping (TEM) with rankings of vegetation values and presence of significant trees.
  - Wildlife habitat suitability mapping.
  - the Green Infrastructure Network (GIN) (i.e. hubs, sites and corridors).
  - Description of soils and terrain.
  - Terrain mapping.
- Provide conservation recommendations and enhancement opportunities available within NCP Area #3 including proposed GIN protection.

Additional details regarding the environmental assessment that was completed in support of the Grandview Heights #3 NCP are provided in the Associated Environmental Study, which is included in Appendix A. In addition to this study, subsequent assessments within the Grandview Heights NCP #3 area were completed by various consultants at the City's direction. For details regarding the most current assessments that have been completed, refer to the "Grandview Heights Neighbourhood Concept Plan Area 3 – Watercourse Classification Assessment" (Enkon Environmental, 2018) and "Classification of Watercourse at 172 Street, North of 16 Avenue, Surrey" (Envirowest Consultants Inc., 2018).

4.3.2 Aquatic Environment

There are four major watercourses within the Study area: Sam Hill Creek, Upper Sam Hill Creek, Thomson Creek, and an Unnamed tributary to Sam Hill Creek (Tributary 1) (Map 4-2). These watercourses drain south/southeast into the Little Campbell River. There are also numerous smaller tributaries and drainage features (i.e., roadside ditches, agricultural drainage) that flow into these major watercourses.

4.3.2.1 Biophysical Descriptions

Fish habitat characteristics and features at each site measured and recorded during the field investigation are summarized in Table 4-3. A map of field assessment sites is provided as Map 4-2; we note that this map includes the recommended reclassification of various watercourses (Section 4.3.2.3). Representative photographs are provided in Appendix A. A biophysical description of these major watercourses and the smaller tributaries and roadside ditches that were assessed are provided below.

Sam Hill Creek

The headwaters of Sam Hill Creek, from east of 168 Street to 172 Street between 16 Avenue and 12 Avenue are comprised of drainage from adjacent rural residential properties. In its lower reaches, downstream and east of 172 Street, the creek flows through agricultural land. Land developments in these areas, such as channel re-alignments, drainage structures (i.e., storm water outfalls and road culverts), and agricultural land practices (i.e., field cultivation, planting, and harvesting,) have greatly impacted the creek and its riparian area. Historically, Sam Hill Creek flowed east, crossing 172 Street. Sam Hill Creek has since been realigned and flows south on 172 Street to 12 Ave where it then flows east, crossing 176 Street and eventually flows into Little Campbell River (Map 4-2).

In the upper section at 172 Street (Sites 10 and 13), the creek is characterized by a narrow, linear, fast flowing riffle-pool with a gravel/fines substrate providing good spawning, rearing, and overwintering habitat, but has limited instream complexity (e.g., large woody debris, boulder clusters, etc.) and riparian cover. Riparian vegetation in this section is limited to a narrow stand of young red alder (*Alnus rubra*) and willow (*Salix* spp.) primarily on the east bank. West of 172 Street, the creek transitions back to a wider, slower flowing glide with a fines substrate providing good rearing and overwintering habitat but no spawning habitat.

The section of creek along 12 Avenue (Site 14) is characterized by a linear, fast flowing riffle-pool with fine substrate providing good rearing and overwintering habitat and poor spawning habitat. This section of Sam Hill Creek is nearly devoid of mature riparian vegetation except for a few shrubs, grasses, and Himalayan blackberry (*Rubus armeniacus*) providing trace instream and overhanging vegetation cover.

Further downstream at 176 Street (Site 2) the creek is characterized by a wide meandering slow flowing deep glide with fine (silty) substrate providing good rearing and overwintering habitat but no spawning habitat for salmonids. The narrow but intact riparian corridor consists primarily of red alder, western hemlock (*Tsuga heterophylla*), western redcedar (*Thuja plicata)*, salmonberry (*Rubus spectabilis*), and willow.

Upper Sam Hill Creek

Upper Sam Hill Creek originates in a mature forested area north of 16 Avenue and flows south, crossing 16 Avenue through agricultural land to 176 Street (Map 4-2).

There is a tributary along the east side of the 172 Street right of way, north of 16 Avenue (Site 18) that flows into Sam Hill / Upper Sam Hill Creek through closed drainage. The pipe from the inlet of this tributary to Sam Hill Creek is approximately 260 m long with a gradient of 9.8 % (CoS 2017) is a barrier to fish passage. This watercourse is a high gradient (approximately 12%), straight, fast-flowing, modified step-pool with boulder and cobble substrate providing good rearing and overwintering habitat. There is no spawning habitat. The riparian vegetation is mature and intact on the east bank with the 172 Street right-of-way on the west bank. Fish presence would be unexpected in this watercourse due to the steep gradient and

Table 4-3
Fish Habitat Characteristics for a Subsample of Watercourses in the Study Area

Site #	Stream Name	Location	CW (m)	WW (m)	WD (m)	Subst. (D/Sd)	Grad. (%)	Morph.	Habitat Features	Fish Use	Photo #	Stream Class[1]
1	Tributary ditch to Sam Hill Creek	West of 176 St., north of 12 Ave.	2.2	1.6	0.20	F	2	-	Slow moving linear channel, significant instream vegetation.	Potential rearing and overwintering habitat at very high flows but poor quality in general; shallow and potentially seasonally wetted.	A	AO
2	Sam Hill Creek	12 Ave. at 176 St.	4.0	3.0	0.46	F	2	G	Meandering slow flowing deep glide. Overhanging vegetation, undercut banks, LWD.	Good rearing and overwintering habitat. Poor spawning habitat.	B, C	A
3	Unnamed tributary (Tributary 1) to Sam Hill Creek	12 Ave., east of 176 St.	2.8	1.7	0.22	F/G	2	RP	Meandering riffle-pool. LWD, undercut banks, overhanging vegetation.	Good rearing habitat. Poor spawning habitat.	F, G	A
4	Thomson Creek	12 Ave., east of 176 St.	-	0.8	0.10	F/O	1	-	Undefined channel. Very limited flow (trickle), dense instream vegetation.	Poor rearing and overwintering habitat. No spawning habitat but a wider and deeper wetted channel north of 12 Avenue likely provides good rearing and overwintering habitat.	H, I	A
5	Agricultural drainage	12 Ave., east of 176 St.	1.0	0.7	0.10	O	1	-	Linear, stagnant channel. Dense instream vegetation growth.	No rearing or overwintering habitat available due to lack of water flow and depth.	J, K	B
6	Thomson Creek	16 Ave., east of 176th St.	2.0	1.2	0.10	F	2	RP	Shallow meandering riffle-pool. Undercut banks and good canopy cover.	Limited rearing habitat (due to shallow depth) but good overwintering habitat. Poor spawning habitat.	L, N	AO
7	Unnamed tributary (Tributary 1) to Sam Hill Creek	East of 176 St., south of 16 Ave.	0.6	0.4	0.15	F/O	2	RP	Linear slow flowing riffle-pool. Extensive blackberry growth.	Narrow and shallow; limited rearing and overwintering habitat. No spawning habitat.	M	A
8	Upper Sam Hill Creek	Upper reach, south of 16 Ave.	1.7	1.0	0.12	G/F	2	RP	Meandering riffle-pool. Overhanging vegetation.	Limited rearing but good overwintering habitat. Moderate quality spawning habitat.	P	AO
9	Upper Sam Hill Creek	Upper reach, north of 16 Ave.	1.4	1.2	0.11	F/O	15	SP	Natural barriers (i.e., debris, steps), LWD, overhanging vegetation.	Steep gradient and natural barriers likely prevent upstream passage for fish.	R	B
10	Sam Hill Creek	East of 172 St., south of 16 Ave.	1.7	1.1	0.15	G/F	2	RP	Linear riffle-pool. Good canopy cover but little instream complexity.	Good spawning, rearing and overwintering habitat.	W	A
11	Ditch	West of 172 St., south of 16 Ave.	1.2	0.2	0.05	O	2	-	Linear stagnant ditch. Dense instream vegetation, no cover.	Poor rearing and overwintering habitat. No spawning habitat. Potentially connected to Sam Hill Creek at higher flows.	X	AO
12	Sam Hill Creek	West of 172 St., south of 16 Ave.	2.8	2.3	0.12	F/O	2	RP	Linear, slow flowing glide. SWD, overhanging vegetation, moderate canopy cover.	Good rearing and overwintering habitat. Poor spawning habitat.	Y	A
13	Sam Hill Creek	East of 172 St., south of 16 Ave.	2.8	2.3	0.07	F/G	2	RP	Linear, fast flowing riffle-pool. Little to no canopy cover. Minor instream vegetation.	Fish observed (Stickleback). Good spawning, rearing and overwintering habitat.	Z	A
14	Sam Hill Creek	East of 172 St., at 12 Ave.	2.2	1.9	0.17	F	1	RP	Linear, fast flowing riffle-pool. Little canopy cover. Moderate instream and overhanging vegetation.	Good rearing and overwintering habitat. Poor spawning habitat.	AA	A
15	Unnamed tributary to Sam Hill Creek	West of 176 St., east of 172 St.	1.0	0.8	0.05	F/O	3	RP	Narrow and shallow meandering, slow flowing riffle-pool.	Limited flow provides limited rearing and overwintering habitat. No spawning habitat.	AB	B
16	Upper Sam Hill Creek	West of 176 St., east of 172 St.	2.1	1.0	0.07	F/G	2	RP	Wide and shallow meandering riffle-pool. Culvert is currently an obstacle to fish passage.	Good rearing and overwintering habitat. Poor spawning habitat.	AC, AD	A
17	Upper Sam Hill Creek	West of 172 St., south of 16 Ave.	2.0	0.6	0.28	O/F	2	RP	Linear, slow flowing riffle-pool. No canopy cover. Poor riparian vegetation (treated invasive plants). Significant instream vegetation.	Limited rearing habitat, moderate overwintering habitat. No spawning habitat.	AE	AO

Associated Engineering GLOBAL PERSPECTIVE. LOCAL FOCUS.

Table 4-3
Fish Habitat Characteristics for a Subsample of Watercourses in the Study Area

Site #	Stream Name	Location	CW (m)	WW (m)	WD (m)	Subst. (D/Sd)	Grad. (%)	Morph.	Habitat Features	Fish Use	Photo #	Stream Class[1]
18	Tributary to Upper Sam Hill Creek	172 Street, north of 16 Ave.	2.2	1.2	0.30	B/C	12	SP	Linear, modified, fast flowing step-pool.	Likely not accessible to fish due to gradient, falls, and length and gradient of the downstream culvert. Good rearing and overwintering habitat. No spawning habitat.	AF	**AO**
19	Ditch	North of 14 Ave. ROW, east of 168 St.	2.7	1.4	0.08	F/O	2	RP	Linear, slow flowing ditch. Good canopy cover, overhanging vegetation, SWD.	Likely seasonally wetted. Limited flow and depth provide no rearing and overwintering habitat; however, provides significant food and nutrient value to downstream fish habitat.	AH	**B**

Notes: Subst. – substrate; Grad. – gradient; Morph. – morphology; CW – channel width; WW – wetted width; WD - wetted depth; RP – Riffle/Pool; SP – Step/Pool; F - fines; O – organics; G – gravel; B – boulder; C - cobble, "-" – not applicable; * - **Bolded** classifications are recommended changes to the existing classification.

boulder/concrete barriers (Section 4.3.2.2). Although fish have been documented, the City has indicated that this information may be erroneous.

North of 16 Avenue (Site 9), the creek is narrow, steep (approximately 15%), and is characterized by a step-pool morphology with fines/organic substrate. The riparian vegetation consists primarily of mature black cottonwood (*Populus balsamifera* ssp. *Trichocarpa*), paper birch (*Betula papyrifera*), western redcedar, Douglas maple (*Acer glabrum*), western hemlock, and bigleaf maple (*Acer macrophylum*). Canopy and instream cover (i.e., large woody debris) is abundant. Natural large woody debris jams and a steep gradient are likely a barrier to fish passage; however, this section of Upper Sam Hill Creek is a significant source of food and nutrients to downstream fish habitat.

South of 16 Avenue (Site 8), the creek is a lower gradient (2%) meandering riffle-pool with a gravel/fines substrate and considerable overhanging vegetation provided by salmonberry shrubs. This section of the creek provides limited rearing but good overwintering habitat and moderate quality spawning habitat.

East of 172 Street (approximately 250 m upstream from Site 16), Upper Sam Hill Creek flows through a blueberry field for approximately 180m (Site 17). This section of the creek is characterized by a linear, slow flowing riffle-pool with no riparian canopy cover. Riparian vegetation is limited to grasses and invasive Himalayan blackberry providing instream and overhanging vegetation cover; however, the Himalayan blackberry appeared to have been recently treated. Due to the lack of riparian vegetation, rearing and overwintering habitat is limited.

Between 176 Street and 172 Street (Site 16) the creek is a low gradient (2%), wide, meandering riffle-pool with a fines/gravel substrate providing good rearing and overwintering habitat and poor spawning habitat. A perched culvert at this location presents a barrier to fish passage at lower flows. The riparian vegetation consists primarily of red alder, Himalayan blackberry, and salmonberry. There is an unnamed tributary that flows into Upper Sam Hill Creek immediately north of Site 16. This tributary (Site 15) is a narrow and shallow meandering slow flowing riffle-pool with a fines/organic substrate. Limited flow in this stream provides limited rearing and overwintering habitat and no spawning habitat; however, the direct connection to Upper Sam Hill Creek likely provides occasional (i.e., seasonal) access to this stream during higher flows.

Thomson Creek

Thomson Creek originates along the edge of a mature forested area at the east boundary of the Study area. The creek flows south, crossing 16 Avenue with diminishing riparian cover as it continues flowing south through agricultural land, crossing 12 Avenue to a wide floodplain, and into Sam Hill Creek approximately 200 m south of 12 Avenue (Map 4-2).

In the upper reach, south of 16 Avenue (Site 6), Thomson Creek is a shallow, meandering riffle-pool characterized by undercut banks with fine substrate. During higher winter flows, this section of Thomson Creek likely provides good overwintering habitat. However, due to limited water depth and poor substrate, rearing and spawning habitat is poor.

Further downstream at 12 Avenue (Site 4), Thomson Creek is a low gradient (1%) linear channel that flows through a wide floodplain and is heavily overtaken be reed canary grass (*Phalaris arundinacea*). As a result, the channel is undefined with limited flowing water with a wetted width of 0.8 m and water depth of only 0.1 m during the field assessment. Substrate was primarily composed of fines and organics. North of 12 Avenue, Thomson Creek runs through private property and was inaccessible during the field visit; however, it appeared to be wider and deeper. Due to the lack of flow and depth and poor substrate quality, rearing and overwintering habitat is limited and there is no spawning habitat.

Tributary 1

Tributary 1 originates in a forested area south of 16 Avenue and flows south through agricultural land and crosses 12 Avenue before flowing into Sam Hill Creek (Map 4-2).

In the upper reach, south of 16 Avenue (Site 7), Tributary 1 is a linear, narrow, and shallow, slow flowing riffle-pool heavily grown over with Himalayan blackberry. Substrate is comprised of fines/organics. Due to the lack of water depth, rearing and overwintering habitat is limited. There is no available spawning habitat.

Further downstream at 12 Avenue (Site 3), Tributary 1 is generally a meandering riffle-pool characterized by large woody debris, undercut banks, overhanging vegetation, and a substrate of fines/gravel providing good rearing and overwintering habitat and moderate quality spawning habitat.

Roadside Ditches and Agricultural Drainage

Typical roadside ditches in the Study area generally consist of linear channels, with uniform dimension that are approximately 1 to 2 m wide and approximately 0.5 m deep when full. These drainages typically have a grassy bottom and lack a scoured channel and were generally dry or not flowing at the time of the field assessment.

In general, these roadside drainages are classified as Class C in Surrey's Watercourse Classification Map; however, some roadside ditches in the Study area can potentially become connected to fish-bearing watercourses (i.e., Sam Hill Creek) during high flow events particularly in the southern half of the Study area (south of 16 Avenue) (e.g., Site 1) and as a result, are currently classified as A or AO.

Other roadside ditches currently classified as Class C such as the ditch along the 18 Avenue right of way, east of 168 Street (Site 19), and the ditch along the 172 Street right-of-way, from 20 Avenue to 18 Avenue, are characterized by a scoured channel and flow through relatively intact riparian corridors, contributing significant food and nutrient supply to downstream fish habitat (i.e., Sam Hill Creek) and should be reclassified as Class B.

4.3.2.2 Fish Species

Steelhead (*Oncorhynchus mykiss*), cutthroat trout (*O. clarkii*), coho salmon (*O. kisutch*), and three-spine stickleback (*Gasterosteus aculeatus*) have been documented in Sam Hill Creek (MoE 2017a). A three-spine stickleback was observed at Site 13 during the field assessment. Coho salmon and cutthroat trout have also been documented in a tributary to Upper Sam Hill Creek (north of 16th avenue, within the Grandview Heights Neighbourhood #3) (MoE 2017a). Although there are no documented occurrences of fish in Thomson Creek or Tributary 1, there is high potential that the same fish species occupy these systems at certain times of the year as well. Although not documented in Sam Hill Creek, Salish sucker (*Catostomus* sp.; Red-listed), were historically present in the Little Campbell River watershed (i.e., previously captured in Little Campbell River; Yip et al. 2012) and were believed to be extirpated from the area (DFO 2016). However, a recent study completed in 2018 confirmed the presence of Salish Sucker in the Little Campbell River watershed (Bull, H., and L. Newberry 2019), and therefore, have the potential to occur in the lower reaches of Sam Hill Creek. Natural recolonization in the watershed will require the restoration of degraded habitat and mitigating against invasive species (DFO 2016).

4.3.2.3 Stream Classification

The lower section of Sam Hill Creek, the lower section of Thomson Creek, and Tributary 1 are currently classified as Class A watercourses while Upper Sam Hill Creek and the upper section of Thomson Creek are classified as a Class B watercourses (CoS 2011). Smaller tributaries and ditches linked to these creeks are either Class A, A(O), or B (CoS 2011).

Most of the ditches / watercourses north of 16 Avenue are currently classified as Class C (i.e., insignificant food/nutrient value) with a relatively small number of Class B watercourses also present.

Based on the habitat features and conditions observed during the field assessment, changes are recommended to the classification of several watercourses or sections of watercourses in the study area. A summary of the recommended watercourse classification changes are provided in Table 4-4 and shown in Map 4-3. We understand that the City made some of these reclassifications prior to the final version of this ISMP. The current stream classifications as of July 2019 are shown in Map 4-10.

Table 4-4
Recommended Changes to the City of Surrey's Watercourse Classification Map

Watercourse	Location	Classification at Onset of Sam Hill Creek ISMP	Recommended Classification based on ISMP Process	Current City of Surrey Classification (July 2019)
Upper Sam Hill Creek	South of 16 Avenue	The City of Surrey currently designates this section of the creek as Class B.	Class AO; Likely inhabited by fish, particularly for overwintering	Class B

Watercourse	Location	Classification at Onset of Sam Hill Creek ISMP	Recommended Classification based on ISMP Process	Current City of Surrey Classification (July 2019)
Drainage Ditches	North of the 18 Avenue right of way to the 172 Street right of way	The City of Surrey currently designates these ditches as Class C.	Class B; Significant food and/or nutrient value to downstream fish habitat	Class B
Drainage Ditch	172 Street right of way, from 20 Avenue to the 18 Avenue right of way	The City of Surrey currently designates this ditch as Class C.	Class B; Significant food and/or nutrient value to downstream fish habitat	Class B
Sam Hill Creek	From 14 Avenue and 172 Street, east for approximately 380 m	The City of Surrey currently designates this channel as Class A. This section of the creek has been diverted south along 172 Street and is now dry; however, it can become reconnected during flood events.	Class AO; Potentially inhabited by fish if migration barriers are removed and during flood events.	Class A
Sam Hill Creek	From 14 Avenue at 172 Street to the 12 Avenue right of way and 176 Street	The City of Surrey currently designates this watercourse as Class AO.	Class A; Inhabited by or potentially inhabited by fish year-round	Class AO
Tributary to Sam Hill / Upper Sam Hill Creeks	From the 18 Avenue right of way south to the 16 Avenue right of way.	The City of Surrey currently designates this ditch as Class B.	Class AO; Potentially inhabited by fish if migration barriers are removed/modified (Section 3.3). In addition, fish have been documented (Section 3.1.2).	Class AO
Tributary ditch to Sam Hill Creek	176 Street, north of 12 Avenue	The City of Surrey currently designates this ditch as Class A.	Class AO; The ditch is seasonally wetted and thus cannot support fish year-round. In addition, the rip rap bank armouring is a barrier to fish passage. This ditch is potentially inhabited by fish if migration barriers are removed.	Class A
Thomson Creek	Upper reach, south of 16 Avenue	The City of Surrey currently designates this ditch as Class B.	Class AO; This section of Thomson Creek provides sufficient habitat particularly	Class B

Watercourse	Location	Classification at Onset of Sam Hill Creek ISMP	Recommended Classification based on ISMP Process	Current City of Surrey Classification (July 2019)
			overwintering habitat and thus, is inhabited by or potentially inhabited by fish, if migration barriers are removed.	

4.3.2.4 Aquatic Constraints and Enhancement Opportunities

As part of the Aquatic Assessment that we completed, we identified several barriers or obstructions to fish passage within the study area based on a review of existing information as well as our fieldwork. Table 4-5 summarizes these barriers and obstructions, as well as the potential enhancement opportunities. The locations for these obstructions are shown on Map 4-3.

Table 4-5
Known Barriers and Obstacles to Fish Passage on Watercourses in the Study Area

Watercourse	Location	Type of Barrier	Description / Comments	Enhancement Opportunity	Source
Sam Hill Creek	Approximately 450 m east of 172 Street	Perched culvert	Barrier to fish passage at lower flows.	Replace perched culvert with fish passable culvert at low flows.	Dillon 2005, Sam Hill Creek ISMP fieldwork
Sam Hill Creek	16 Avenue	Perched Culvert	Barrier to fish passage at lower flows.	Replace perched culvert with fish passable culvert at low flows.	City of Surrey
Upper Sam Hill Creek	North of 16 Avenue	Weirs	Natural barrier to fish passage at lower flows.	Remove weirs, restore channel.	Sam Hill Creek ISMP fieldwork
Class A (red-coded) tributary ditch to Sam Hill Creek	176 Street, north of 12 Avenue	Rip rap bank armouring	Barrier to fish passage at lower flows.	Regrade channel to allow fish passage at lower flows.	Sam Hill Creek ISMP fieldwork

Watercourse	Location	Type of Barrier	Description / Comments	Enhancement Opportunity	Source
Tributary to Sam Hill and Upper Sam Hill Creeks	From the 18 Avenue right-of-way south to the 16 Avenue right-of-way.	Concrete elevation barriers	Continuous concrete steps present barriers to fish passage.	Modify channel to create step pool features with maximum 0.3 m vertical height.	Sam Hill Creek ISMP fieldwork
Tributary to Sam Hill / Upper Sam Hill Creek	172 Street from 16 Avenue, approximately	Concrete culvert	Length (approximately 260 m) and gradient (9.8 %) is a barrier to fish passage.	Daylight channel, provide fish passable culverts at driveways, create step pool features with maximum 0.3m vertical height to accommodate steeper grades.	Sam Hill Creek ISMP fieldwork
Thomson Creek	12 Avenue	Blocked culvert	Barrier to fish passage at lower flows.	Replace with fish passable culvert.	Sam Hill Creek ISMP fieldwork.

In addition to the enhancement opportunities at these specific fish passage obstacles, we also identified several aquatic enhancement opportunities throughout the watershed, as noted below. The site numbers refer to our aquatic assessment locations, as shown on Map 4-2 and Map 4-3.

- Installing fencing between trails / private property and watercourses to protect environmentally sensitive areas from encroachment and access by humans and animals (including livestock) (i.e., Site 3, Site 4, Site 17). Sam Hill Creek for example, is often subject to cattle access, which has led to a degradation of water quality (Fee 1983).
- Improving storm water outfall west of 176 Street draining to Sam Hill Creek to prevent bank erosion and sediment transport.
- Removing instream vegetation (i.e., reed canary grass) from affected watercourses (e.g., Thomson Creek; Site 4) to improve flow, habitat availability, temperature regulation, and flood mitigation.
- Inventorying and removing invasive plant species (e.g., Himalayan blackberry) from riparian areas of affected watercourses (e.g., Tributary 1; Site 7 and Upper Sam Hill Creek; Site 17) and replanting with native trees and shrubs.
- Planting native riparian vegetation (i.e., trees and shrubs) and establishing a protected stream setback on both banks of Upper Sam Hill Creek, through the blueberry field (i.e., Site 17).
- Planting native riparian vegetation (i.e., trees and shrubs) and establishing a protected stream setback on both banks of Sam Hill Creek along 12 Avenue, from 172 Street to 176 Street.
- Re-establishing a hydraulic connection between the Sam Hill Creek Diversion at 172 Street and 12 Avenue, and the adjacent watercourse immediately east.

4.4 TERRESTRIAL ENVIRONMENT

Several environmental features exist within the Study area. A summary of these features is provided within this section.

4.4.1 Biogeoclimactic zone

Sam Hill Creek is located within the Coastal Douglas Fir biogeoclimactic zone, moist maritime subvariant (CDFmm; Meidinger and Pojar 1991). This area lies within the rainshadow of the Vancouver Island and Olympic mountains resulting in warm, dry summers and mild, wet winters.

4.4.2 Vegetation

The Sam Hill Creek watershed is zoned as agricultural land south of 16th Avenue. North of 16th Avenue and west of 176th Street, it designated as suburban-urban reserve under Surrey's OCP, and east of 176th Street there is a mix of rural and conservation and recreation areas. In the watershed, there are five major vegetation classes have been identified within the watershed, many of which are mapped under MOE's sensitive ecosystem inventory (SEI; Map 4-4):

- Forest;
- Riparian;
- Wetlands;
- Agricultural; and
- Suburban vegetation.

Forests in the watershed are structurally diverse, including both young and mature mixed forest stands and a variety of overstory, understory and ground species. Dominant tree species include red alder, western red cedar, big leaf maple, trembling aspen (*Populus tremuloides*), and black cottonwood with lesser amounts of Douglas-fir (*Pseudotsuga menziesii*), Pacific dogwood (*Cornus nuttallii*), Pacific crab apple (*Malus fusca*), Douglas maple (*Acer glabrum*) and willow species (*Salix* spp.). The understory is mainly composed of salmonberry, vine maple (*Acer circinatum*), thimbleberry (*Rubus parviflorus), with lesser amounts of bitter cherry (Prunus emarginata), oval-leaved blueberry (Vaccinium ovalifolium), red huckleberry (Vaccinium parvifolium) and elderberry (Sambucus racemosa). Forest floor cover is mainly* piggyback plant (*Tolmiea menziesii*), vanilla leaf (*Achlys triphylla*), *lady fern (Athyrium filix-femina),* sword fern (*Polystichum munitum*), Henderson's checker mallow (*Sidalcea hendersonii*) *and* stair step moss (*Hylocomium splendens*).

Redwood Park is located on the east side of the watershed north of 16th Avenue. This forest is more structurally diverse than other forests in the watershed as it also contains more than 30 European species and 50 different tree species in total. These include giant sequoia (Sequoiadendron giganteum), monkey puzzle tree (*Araucaria araucana*), wych elm (*Ulmus glabra*), and katsura (*Cercidiphyllum japonicum*). These trees were planted by tree-collector brothers when they were gifted the lands in 1893. Although many of the tree species are not native to BC, the park displays exceptional vegetation structural diversity (i.e., mix of vegetation heights and densities).

The riparian habitat in the watershed is largely disturbed and runs through agricultural lands. Where riparian habitat was in-tact, vegetation was similar to that described for mixed forest communities. The riparian forests were dominated by red alder, bigleaf maple, aspen and willows, with salmonberry, devil's club (*Oplopanax horridus*), horsetail (*Equisetum* spp.), and reed canary grass (*Phalaris arundinacea)* present in the understory.

Wetlands, such as marshes and shallow open water wetlands, are associated with low lying portions of Sam Hill Creek and Thomson Creek exhibiting saturated soil conditions. These areas are dominated by skunk cabbage *(Lysichiton americanus*), horsetail *(Equisetum arvense and E. fluviatile),* cattails *(Typhaceae* spp.) and bulrushes *(Cyperaceae* spp.).

Agricultural areas include both actively cultivated and old unmanaged fields. Agricultural areas are often bordered by riparian habitats, associated with drainage ditches or channelized watercourses, remnant vegetated corridors, or urban development. Agricultural edge habitats are dominated by r*eed canary grass, red alder, Douglas maple, and Himalayan blackberry* (*Rubus discolour*).

Within the suburban-urban reserve there are small farms and acreages along with large landscaped lots. Acreages often have forest species and lawn scattered throughout or along edges of properties. Landscaped lots contain lawns and primarily planted native and ornamental species.

Invasive species occur in the watershed, and can limit productivity, biodiversity, reduce soil stability and water quality, destroy habitat in the area and out complete native flora and fauna (Ministry of Agriculture 2013). Invasive plant species occur along ditches, in unmanaged agricultural areas and other disturbed sites. Invasive species observed include Himalayan blackberry (prevalent in disturbed portions of the watershed), English holly (*Ilex aquifolium*), Canada thistle (*Cirsium arvense*), reed canary grass, and false lamium (*Lamium* spp. *L. galeobdolon*).

4.4.3 Wildlife

Wildlife communities present in the watershed are generally comprised of small, medium and large-sized mammals, birds, reptiles and amphibians. Habitat suitability mapping developed by Surrey indicates that riparian areas and wetland habitats have "high" to "moderately high" suitability habitat, forested areas contain "moderately high" to "moderate" suitability habitat, and agricultural fields offer "low" suitability habitat related to wildlife biodiversity (Map 4-5).

Forested habitat provides food resources (e.g., fruits and seeds), and/or hunting opportunities (i.e., predators), shelter, and nesting for bird species, and habitat supporting various smaller mammals including mice (e.g., *Peromyscus spp.*), voles (*Microtus spp.*), skunks (*Mephitis mephitis*), raccoons (*Procyon lotor*), squirrels (*Tamiasciurus douglasii* and *Sciurus carolinensis*), and rabbits (*Sylvilagus* spp.). Larger forested areas provide shelter for larger mammals including black–tailed deer (*Odocoileus hemionus*) and coyotes (*Canis latrans*). Birds may breed, forage or take refuge in forested habitats during seasonal use. Wildlife trees and coarse woody debris are important features for a range of wildlife living in forested habitat

(Meidinger and Pojar 1991). Wildlife trees are found throughout the watershed, in young to mature forests. These trees provide forage for insectivorous bird species as well as nesting cavities for birds during the breeding season and additionally cover and refuge for small to medium sized mammals including bats. During the field assessment, a wide suite of bird species (e.g., songbirds, raptors) and cottontail rabbits were detected as well as evidence (i.e., tracks, scat) of coyote observed within forested areas.

Riparian areas also provide cover and food resources for mammals, nesting and foraging habitat for bird species, reptiles, amphibians and invertebrates. During the field assessment, a variety of song birds, mallards (*Anas platyrhynchos*) and osprey (*Pandion haliaetus*) were observed in the riparian areas.

Wetlands typically provide unique ecosystems and provide habitat to a variety of wildlife. Wildlife found in these areas may include amphibians (e.g. Pacific chorus frogs [*Pseudacris regilla*] and long-toed salamanders [*Ambystoma macrodactylum*]), small mammals (e.g. muskrats [*Ondatra zibethicus*])., raptors, waterfowl, and songbirds, which were observed in wetland areas.

Agricultural fields (especially old fields) and other open areas provide ample hunting opportunities for predator species (i.e. raptors and coyotes) as they typically support abundant small mammal populations and songbird use. During the field assessment, song birds and cottontail rabbits were observed and there was evidence (i.e. scat) of small mammals observed in the old fields.

Suburban areas/ man made structures and infrastructure also offer wildlife habitat as some birds will use (at least partially) any available habitat (e.g. structures and gardens), and lawn or treed areas are often used by small mammals. Predators such as raccoons, coyotes, or owls are also typical wildlife found utilizing suburban areas.

4.4.4 Species at Risk

The BC Conservation Data Centre (CDC) maintains records of known occurrences of rare and endangered vertebrates, invertebrates, plants, and ecosystems in the province (CDC 2016). These records are individual, verified occurrences of species and ecosystems that the CDC has mapped. Hendersons checker mallow (blue-listed) has been documented through the CDC within the watershed and observed during the field assessment. No other listed species were observed during the assessment. However, there is some potential for rare plants, fish, and wildlife to be present especially in forested, riparian and wetland areas (higher potential for wetland and stream-side plants, as well as small mammals, fish, and amphibians).

Species at risk with the likelihood or potential to occur within or adjacent to the Project area, based on geographic range and habitat associations, are listed in Table 4-6. Of these 44 species, nine have documented known occurrences within 5 km of the watershed (CDC 2016; Map 4-4).

In forested areas, potential species at risk include Trowbridges Shrew (*Sorex trowbridgii*), snowshoe hare (*Lepus americanus washingtonii*), and Oregon forest snail (*Allogona townsendiana;* observed just south of the watershed). In wetland and riparian areas, potential species at risk include Pacific water shrew (*Sorex bendirii*; observed just east of the watershed), northern red-legged frog (*Rana aurora*), painted turtle

(*Chrysemys picta*), and American bittern (*Botaurus lentiginosus*). In agricultural areas, potential species include the barn owl (*Tyto alba*), peregrine falcon (*Falco peregrinus anatum*), and monarch butterfly (*Danaus plexippus*).

4.4.5 Green Infrastructure Network

The City's Green Infrastructure Network includes hubs, sites, and corridors, all of which are necessary to support biodiversity. Hubs and sites act as core habitat areas that have ecological integrity (provide ecological services: nutrient cycling, diverse habitat types, support species with larger home ranges etc.). Corridors encourage the movement of species between fragmented hubs, they allow species to access hubs with different features and movement encourages genetic diversity (Diamondhead 2014).

Within the Sam Hill Creek Watershed, established Green Infrastructure Areas include Redwood Park (H1), two local corridors that follow Sam Hill Creek (C1) and Thomson Creek (C2), and 16th Avenue (C3). However, one of the existing corridors (C3; along 16th Avenue) likely has reduced function as it is located beside a busy roadway contributing to sensory disturbance (i.e., noise) and is frequently fragmented by housing and other developments. See Map 4-1 for an overview.

In addition to the areas currently included in the City's GIN, there are additional areas which function as corridors, sites, and hubs under existing conditions, even though they are not formally recognized. These include two corridors (C4, C5), two sites (S1, S2), and a hub (H2). These additional areas have been identified based on the value of the existing habitats (i.e. from habitat suitability mapping in the BCS), and have been confirmed based on field observations, recognizing their ability to connect with other existing GIN locations. Additional descriptions of each of the hubs, sites and corridors in the watershed are provided in Table 4-7. Criteria used to rate ecological value, connectivity and disturbance is provided in Table 4-2.

4.4.6 Terrestrial Constraints and Enhancement Opportunities

Recognizing the importance of preserving existing greenspace to the function of the ecosystems, the City has identified the Green Infrastructure Network (GIN) as part of the BCS. The GIN identifies areas of significant ecological value and categorizes them as "hubs", "corridors", and "sites".

Hubs, sites, and corridors are necessary to support biodiversity. Hubs and sites act as core habitat areas that have ecological integrity (provide ecological services: nutrient cycling, diverse habitat types, support species with larger home ranges etc.). Corridors facilitate the movement of individual species between hubs, they allow species to access hubs containing potentially different features and habitat conditions and movement also encourages genetic diversity (Diamondhead 2014).

Within the Sam Hill Creek watershed, there are a number of Green Infrastructure areas that have already been identified as part of the City's BCS. In addition to these recognized GIN components, there are also several areas which function as corridors, sites, and hubs under existing conditions, even though they are not formally recognized in the BCS. Table 4-8 summarizes the existing and recommended Green Infrastructure Network within the Sam Hill Creek watershed, which are also shown on Map 4-1. The

Table 4-6
Potential Species at Risk Within the Watershed

Class	Scientific Name	Common Name	COSEWIC	BC List	SARA	MKO w/in 5 km	MKO #
Vegetation	*Claytonia washingtoniana*	Washington springbeauty		Red		No	
	Eutrochium maculatum var. *bruneri*	Joe-pye weed		Red		No	
	Lupinus rivularis	streambank lupine	E (2002)	Red	E (2005)	No	
	Navarretia intertexta	needle-leaved navarretia		Red		No	
	Carex feta	green-sheathed sedge		Blue		No	
	Carex interrupta	green-fruited sedge		Blue		No	
	Eleocharis rostellata	beaked spike-rush		Blue		No	
	Anagallis minima	chaffweed		Blue		**Yes**	799,879,981
	Sidalcea hendersonii	Hendersons Checker Mallow		Blue		**Yes**	14445
	Rupertia physodes	California Tea		Blue		**Yes**	14563
Reptile/amphibian	*Chrysemys picta* pop. 1	Painted Turtle - Pacific Coast Population	T (2016)	Red	E (2007)	**Yes**	60851
	Anaxyrus boreas	Western Toad	SC (2012)	Blue	SC (2005)	No	
	Rana aurora	Northern Red-legged Frog	SC (2015)	Blue	SC (2005)	**Yes**	55693
Bird	*Falco peregrinus anatum*	Peregrine Falcon, *anatum* subspecies	SC (2007)	Red	SC (2012)	No	
	Nycticorax nycticorax	Black-crowned Night-heron		Red		No	
	Tyto alba	Barn Owl	T (2010)	Red	SC (2003)	No	
	Ardea herodias fannini	Great Blue Heron, *fannini* subspecies	SC (2008)	Blue	SC (2010)	No	
	Asio flammeus	Short-eared Owl	SC (2008)	Blue	SC (2012)	No	
	Botaurus lentiginosus	American Bittern		Blue		**Yes**	3898
	Brachyramphus marmoratus	Marbled Murrelet	T (2012)	Blue	T (2003)	No	
	Buteo lagopus	Rough-legged Hawk	NAR (1995)	Blue		No	
	Butorides virescens	Green Heron		Blue		No	
	Contopus cooperi	Olive-sided Flycatcher	T (2007)	Blue	T (2010)	No	
	Cypseloides niger	Black Swift	E (2015)	Blue		No	
	Hirundo rustica	Barn Swallow	T (2011)	Blue		No	
	Megascops kennicottii kennicottii	Western Screech-Owl, *kennicottii* subspecies	T (2012)	Blue	SC (2005)	No	
	Patagioenas fasciata	Band-tailed Pigeon	SC (2008)	Blue	SC (2011)	No	
	Progne subis	Purple Martin		Blue		No	

Table 4-6
Potential Species at Risk Within the Watershed

Class	Scientific Name	Common Name	COSEWIC	BC List	SARA	MKO w/in 5 km	MKO #
Gastropod	*Allogona townsendiana*	Oregon Forestsnail	E (2013)	Red	E (2005)	**Yes**	29668
	Cryptomastix devia	Puget Oregonian	XT (2013)	Red	XX (2005)	No	
Insect	*Carychium occidentale*	Western Thorn		Blue		No	
	Euphyes vestris	Dun Skipper	T (2013)	Red	T (2003)	No	
	Danaus plexippus	Monarch	E (2016)	Blue	SC (2003)	No	
	Epargyreus clarus	Silver-spotted Skipper		Blue		No	
	Ophiogomphus occidentis	Sinuous Snaketail		Blue		No	
	Sympetrum vicinum	Autumn Meadowhawk		Blue		No	
Mammal	*Lepus americanus washingtonii*	Snowshoe Hare, *washingtonii* subspecies		Red		No	
	Mustela frenata altifrontalis	Long-tailed weasel, *altifrontalis* subspecies		Red		No	
	Myodes gapperi occidentalis	Southern Red-backed Vole, *occidentalis* subspecies		Red		No	
	Sorex rohweri	Olympic Shrew		Red		No	
	Sorex bendirii	Pacific Water Shrew	E (2016)	Red	E (2003)	**Yes**	4014
	Corynorhinus townsendii	Townsend's Big-eared Bat		Blue		No	
	Myotis keenii	Keen's Myotis	DD (2003)	Blue		No	
	Sorex trowbridgii	Trowbridge's Shrew	E (2016)	Blue	E (2016)	**Yes**	2632

Table 4-7 – Green Infrastructure Network

Site Label	Habitat Description	Ecological Value	Connectivity	Disturbance	GIN Class
	CURRENTLY RECOGNIZED G.I.N. TO BE MAINTAINED				
C1	Riparian habitat and creek (Upper Sam Hill Creek) providing high valued habitat to amphibians, such as the red-legged frog, fish (i.e. Class A watercourse), passerines, and small mammals. Contains riparian sensitive ecosystem. Local and regional connections from the existing Green Infrastructure Network by connecting the Little Campbell River and associated riparian area (C6). Habitat suitability in this corridor ranges from moderate to very high.	High	High	Low	Corridor
C2	Riparian habitat and Creek (Thomson Creek) providing low quality habitat to amphibians such as the red-legged frog, fish (i.e. Class A watercourse), passerines, and small mammals, including the Pacific water shrew. Local connection north to south into C1 and H1. Habitat suitability is mainly moderate in this corridor.	Low	High	Low	Corridor
H1	Redwood forest park, provides high quality habitat to a diversity of wildlife (small and larger mammals, birds and amphibians), some disturbance from local trails. Contains a young mixed forest and old field sensitive ecosystem. Majority of area is rated as moderate high and moderate habitat suitability with small portions of very high and very low suitability.	High	High	Low	Hub
	CURRENTLY RECOGNIZED G.I.N. TO BE RELOCATED				
C3	High habitat quality in forested portions, however, along a busy road and discontinuous/disturbed due to development. Provides a connection between major hubs (H1 and H3). Habitat suitability in this corridor ranges greatly from nil to very high.	Low	High	High	Corridor
	RECOMMENDED G.I.N. ADDITIONS / CHANGES				
C4	Riparian habitat and creek (Unnamed Tributary to Sam Hill Creek; Tributary 1) providing high valued habitat to amphibians, such as red-legged frog, fish (i.e. Class A watercourse), passerines, and small mammals. Contains a wetland sensitive ecosystem. Local and regional connections from the existing Green Infrastructure Network by connecting C1 and H1. Habitat suitability is moderate and high.	Medium	Medium	Low	Corridor
C5	Riparian habitat and creek (Sam Hill Creek) providing high valued habitat to amphibians, such as red-legged frog, fish, passerines, and small mammals (i.e. Class A watercourse). Contains riparian sensitive ecosystem. Local and regional connections from the existing Green Infrastructure Network by connecting C1 and S1. Habitat suitability in this corridor ranges greatly from nil to very high.	Medium	High	Low	Corridor
C7	Mainly a mature deciduous/mixed forest dominated by alder and maple, and portions of the riparian areas of Class A(O), B, and C watercourses. Provides habitat for small mammals, raptors, and passerines. Contains some young forest and urban areas. Connects two major hubs (H1 and H3). Majority of area is rated as moderate high habitat suitability, with some areas rated as very low, moderate and high.	Medium	High	Medium	Corridor
S1	Mature mixed wood forest dominated by alder, cedar and aspen. Provides high valued habitat to passerines, amphibians (such as red-legged frog) and small mammals (potentially including Pacific water shrew for forage, shelter, and breeding opportunities). Contains riparian fringe forest sensitive ecosystems. Connects to proposed corridor (C5) which connects to a major hub (H3) outside the ISMP Study Area. Rated as moderate high habitat suitability.	Medium	Medium	Low	Site
S2	Mature mixed wood forest with wetlands dominated by alder forest. Provides habitat to passerines, amphibians and small mammals. Contains sensitive wetland ecosystem. Connects to proposed corridor (C4), an existing corridor (C2), which connect to major hub (H1) Rated as moderate high and very high habitat suitability.	Medium	Medium	Low	Site
S3	Mature deciduous/mixed forest dominated by alder and maple, and riparian areas of Class B watercourses and Upper Sam Hill Creek. Provides a potentially large amount of habitat for small mammals, raptors, and passerines. Contains young forest and riparian sensitive ecosystems. Surrounded by a suburban residential area, connects to C3. Majority of area is rated as moderate high habitat suitability, with some areas rated as moderate and high.	Medium	High	Medium	Site

rankings for Ecological Value, Connectivity, and Disturbance are based on the criteria presented in the City's BCS, as reported in Table 4-2.

4.4.6.1 Limitations on Terrestrial Enhancement Opportunities

As noted, corridor C7 is based on the City's preferred alignment for relocating existing corridor C3 further north away from 16 Avenue. The City's preferred alignment reflects a balance between environmental and planning objectives within the Grandview Heights #3 NCP area. From an environmental perspective, protecting the corridor C7 along the City's preferred alignment would maintain connectivity between two regional hubs, would conserve more moderately high to high value vegetation including old conifer stands, and would conserve more moderately high to high value wildlife habitat and preserve a resting site for wildlife travelling between hubs.

Proposed corridors C4 and C5, as well as proposed sites S1 and S2, are all located within Agricultural Land Reserve (ALR). We note that ALR areas are already identified in the City's BCS.

4.5 INVASIVE SPECIES

Our overview terrestrial and aquatic field assessments of the study area revealed the presence of invasive species within the watershed. Invasive species can limit productivity, biodiversity, reduce soil stability and water quality, destroy habitat in the area and out-compete native flora and fauna (Ministry of Agriculture 2013). Invasive plant species occur along ditches, in unmanaged agricultural areas and other disturbed sites. Invasive species observed include Himalayan blackberry (prevalent in disturbed portions of the watershed), English holly (*Ilex aquifolium*), Canadian thistle (*Cirsium arvense*), reed canary grass, and false lamium (*Lamium* ssp. *L. galeobdolon*).

The Invasive Species Council (ISC) of BC identifies American bullfrogs (*Lithobates catesbeiana*) as an invasive species in the lower mainland (ISC 2017). There is potential for this species in the watershed. This species competes for natural resources with native species and are highly predacious eating native frogs, including the listed red legged frog and Oregon spotted frog (B.C. Frogwatch 2013). Eastern grey squirrel (*Sciurus carolinensis*) was observed in the watershed and is also an invasive species identified by the ISC. This species out-competes and potentially introduces disease to native squirrel populations, displaces native birds from their nesting habitats and feeds on bird eggs (ISC 2017). It also competes with native mice and voles for food and habitat (ISC 2017).

4.5.1 Natural Recreation

Redwood Park is a recreational attraction as it contains the largest stand of Redwoods north of California and a wide selection of other tree species from around the world. The park contains several trails, picnic areas, playgrounds, and wildlife viewing areas. This park provides habitat conditions potentially supporting a wide suite of wildlife while also while also providing recreation and educational services to the community. There are no other natural recreational areas within the watershed.

4.6 HYDROGEOLOGICAL ASSESSMENT

4.6.1 Assessment Objectives and Scope

We completed a high level hydrogeologic investigation of the study area. The hydrogeologic conditions in the uppermost sediments determine the feasibility of infiltration of stormwater to subsurface and general natural drainage and recharge to aquifers. Therefore, our investigation concentrated on establishing the characteristics of these surficial deposits through a combination of literature review and field assessment. The results will allow for the planning of future assessment phases and help to determine the suitability and effectiveness of infiltration-based stormwater management techniques, including Best Management Practices (BMPs) and Low-Impact Development (LID) / Source Controls.

We note that infiltration is not the only approach for reducing runoff volumes but is often relied upon if existing development has significantly reduced vegetative cover / forest canopy and created a high proportion of impervious surface in a watershed.

The hydrogeological assessment focused on existing information to help characterize groundwater levels and surficial soil stratigraphy to identify areas where stormwater infiltration may be feasible.

The investigation included two main components:

- Desktop Study*:* review of available maps, studies and reports as they pertain to the study area.
- Field Investigations*:* "Ground-truthing" surficial soil sediments, indicating areas of groundwater upwelling and areas where BMPs and LIDs may be appropriately used.

4.6.2 Methods of Investigation

4.6.2.1 Desktop Study

The desktop study included a search for pertinent documents as they relate to the hydrogeology of the Study Area. We searched The BC Ecological Reports Catalogue (EcoCat) (MOE 2017a) database for relevant hydrogeologic studies or contaminated sites reports, but no documents were found pertaining to the Study Area.

Soils and surficial geology mapping (Luttmerding 1980, Armstrong and Hicock, 1976) for the Study Area were included in our investigation, as the shallow groundwater system is strongly dependent on the material type present at surface. We also searched the online BC Ministry of Environment (MOE) Water Resources Atlas database for more general information, including but not limited to aquifers that have been mapped and available water well information (MOE 2017b).

4.6.2.2 Field Investigation

We completed a site visit on June 1, 2017. The days prior to the site visit involved heavy rainfall in the area while the day of the site visit was sunny with no precipitation. This provided optimal conditions for locating groundwater discharge areas.

For the purposes of this investigation, the Study Area can be split into two general areas: the uplands area which include smaller residential and One Acre Residential dwellings on Sam Hill, and the lowlands area which are predominantly agricultural and extend from the toe of Sam Hill southwards. Surface water in the area flows through man made ditches through much of Sam Hill and enters more natural stream channels in the flat lower lying areas. Road cuts, stream paths, and ditch lines provided the best locations for assessment, as the natural geological and soil units are typically exposed or accessible in these areas.

Our field investigation included:

- Investigating soil conditions at exposures in the natural banks and road cuts adjacent to the watercourses.
- Observing groundwater conditions, including seepages and the presence of flowing water from natural soil exposures, erosional features and vegetation patterns along the natural drainages.

4.6.3 Desktop Study Results

4.6.3.1 Surficial Geology

Information on the surficial geology and stratigraphy in the Lower Mainland area was compiled by observing and mapping of exposures along eroding coastlines and river banks, in gravel pits and other excavations, and through borehole logs (Armstrong and Hicock 1976). Two main surficial geologic units are exposed or are present at depth in the study area as shown in Table 4-8. Map 4-6 shows the distribution of surficial geology units within the study area.

Table 4-8
Summary of Surficial Geology Units

Unit	Identifier	Age	Description
Capilano Sediments[1] (post-glacial)	Cb	11,000 – 13,000	Raised beach medium sand to coarse sand 1 – 5 m thick containing fossil marine shell casts.
	Cd		Marine and glaciomarine stone (including till-like deposits) to stoneless silt loam to clay loam with minor sand and silt normally less than 3 m thick but up to 30 m thick, containing marine shells.

Unit	Identifier	Age	Description
	Ce		Marine silt loam to clay loam with minor sand, silt, and stony glaciomarine material, up to 60+m thick.
Vashon Drift (Fraser Glaciation)	Va	13,000 – 18,000	Lodgement till (with sandy loam matrix) and minor flow till containing lenses and interbeds of glaciolacustrine laminated stony silt
	Vb		Glacioflucial sandy gravel and gravelly sand outwash and ice-contact deposits

Note:

1. While Ca is not mapped within the Study Area, it is reported to cover Cc and Cd in many upland areas. Ca is described as raised marine beach, spit, bar, and lag veneer, poorly sorted sand and gravel (except in bar deposits) normally less than 1 m thick but up to 8 m thick. Exists up to 175 mamsl.

4.6.3.2 Surficial Soils

There are five soil types classified as being a dominant or secondary soil material within the study area. Table 4-9 provides descriptions for the soil types found in the study area, and Map 4-7 displays their respective spatial distribution across the study area.

Table 4-9
Summary of Surficial Soil Types

General Area	Soil Name	Symbol	Soil Material	Drainage	Classification
Uplands – Sam Hill	Bose	BO	30-160 cm of gravelly lag or glacial outwash deposits over moderately coarse textured glacial till and some moderately fine textured glaciomarine deposits	Well to moderately well; telluric seepage.	*Duric Humo-Ferric Podzol*
Lowlands	Carvolth	CV	Moderately fine textured stream deposits.	Poor to very poor; perched water table, susceptible to flooding.	*Rego Humic Gleysol*
	Cloverdale	CD	Moderately to fine-textured marine deposits	Poor; perched water table	*Humic Luvic Gleysol*
	Heron	HN	Coarse textured littoral deposits over moderately coarse textured glacial till or moderately fine textured glaciomarine deposits	Poor; perched water table	*Rego Humic Gleysol*
	Summer	SR	Less than 100 cm of coarse textured littoral and glacial outwash deposits over moderately fine or fine-textured glaciomarine and marine deposits.	Imperfect; perched water table	*Gleyed Orstein Ferro-Humic Podzol*

Source: Luttmerding 1980

Soils found in the lowlands are primarily Gleysols, indicating that they were developed under mostly saturated conditions. Soils in the uplands (Sam Hill) are primarily Podzols and drain well to moderately well. However, due to the presence of till below the soils, the soil is subject to telluric seepage, which basically means horizontal flow of water due to a soil layer with lesser permeability at depth (till).

The soils found in the lowlands have poor to very poor infiltration to deeper aquifers and infiltration is unlikely to be a suitable method for traditional enhanced drainage methods. The Bose soils found in the uplands area are considered to have potential for further investigation to determine their suitability for infiltration of stormwater.

4.6.3.3 Hydrogeology

The assessment of hydrogeological parameters within the study area relied heavily on data available from the B.C. Water Resources Atlas. Three aquifers are present in the study area, as shown on Map 4-8, and as described in Table 4-10.

Table 4-10
Aquifers within the Study Area

Aquifer No.	53	54	55
Aquifer Name	Hazelmere Valley	Hazelmere	Grandview
Aquifer materials	Confined sand and gravel	Confined sand and gravel	Confined sand and gravel
Productivity	Moderate	Low to moderate	Moderate
Vulnerability	Low	Low	Low
Demand	Low	Low to moderate	Moderate
Aquifer Classification	IIIC	IIIC	IIIC

Source: B.C. Water Resources Atlas

There are 89 wells identified within the Study Area, but none of those wells are identified as a B.C. MOE observation well. None of the well logs indicate that bedrock was encountered during drilling.

Well logs in BC prior to approximately 1980 are limited and have little useful data nor verified coordinates. More recent well logs have more relevant useful data with positions recorded more accurately due to advancement of GPS systems. Based on the data used between 1920 and present, the highest producing well has the Well Tag Number (WTN) 2630 and is estimated to produce 3,000 litres per minute (L/min). However, the majority of wells range between 38 and 230 L/min and, with only 9 above 380 L/min. 42 wells have recoded yields of 0 L/min, which indicates the well was either dry or the well yield was not entered into the database.

The average well depth in the Study Area is 29 m with the deepest verified well at 137 m on Sam Hill and 32 older wells drilled less than 9 m. Shallow wells (<9 m) probably targeted the overlying sediments on top of the low permeability silts and clays. These shallow wells tap into the surficial groundwater "perched aquifer[3]" in the upper unconsolidated sediments overlying the till material. As the Study Area is primarily serviced by the municipal water system, it is inferred that there were many of these shallow-dug wells before the municipal water system was constructed. The other category of wells are drilled through this till into underlying confined aquifers comprising sands and gravels. The top of the deeper confined aquifers are approximately 40 to 50 m below ground surface (m bgs), depending on the location.

The average reported groundwater level is 8.6 m bgs, although there are two wells (WTN 3605 and WTN 92483) located between HWY 15 and Sam Hill Creek that are reported to be flowing artesian[4]. Wells located on Sam Hill are generally deeper (> 45 m bgs) and have lower groundwater levels (deeper than 40 m bgs), when compared to wells in the low-lying area. This suggests that the groundwater elevation in the lower confined aquifer is relatively consistent across the Study Area, resulting in shallow groundwater (artesian in some cases) in the low-lying areas and deep groundwater levels on Sam Hill (Figure 4-1).

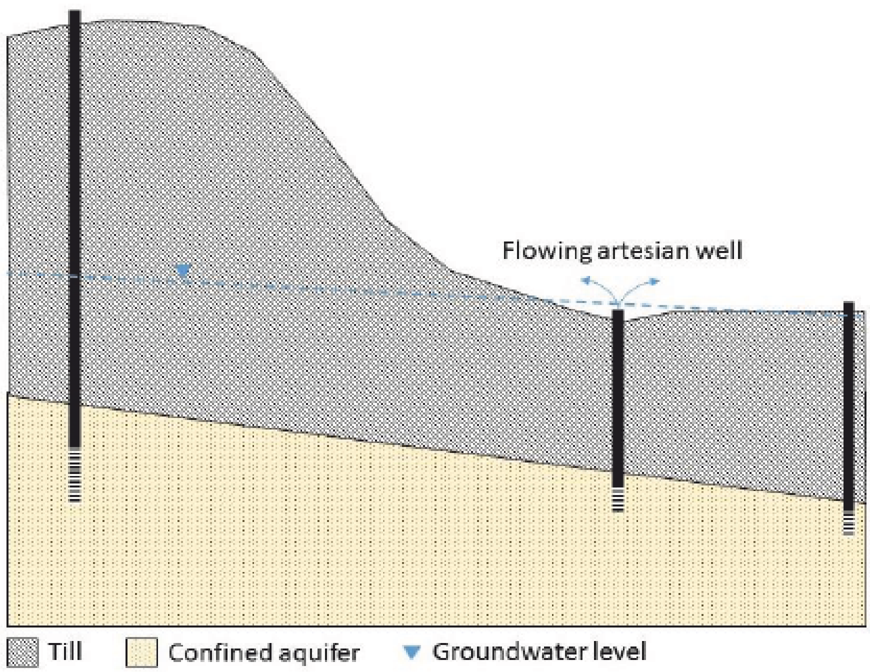


Figure 4-1
Conceptual Illustration of Groundwater Elevations in the Study Area. Not to Scale

No specific infiltration rate or hydraulic conductivity values for the upper sediments in the Study Area were obtained from the literature review; although studies in nearby and similar surface sediments provide values from sites with similar soils to those found in the low-lying areas. Based on these published values, the estimated infiltration rate into the low-lying area soils likely ranges from approximately 0.2 to 2.5 mm/hour (AECOM 2012). The limited local data; however, suggests that the infiltration rates in clay could be at the

[3] An aquifer that exists above the regional aquifer. Primarily due to layers of impermeability.
[4] When the groundwater level is above ground surface, resulting in a naturally flowing well.

lower end of this range and even an order of magnitude lower. Unfortunately, no infiltration tests have been completed in soils similar to those found on Sam Hill in the Surrey area. However, literature values indicate infiltration in non-compacted podzols can be in excess of 300 mm/hr (Gregory et al. 2006). Table 4-11 summarizes these infiltration rates and provides subjective headings for each that can be seen on Map 4-9.

Table 4-11
Summary of Local Soil Infiltration Rates

Location	Soil Type	Estimated Infiltration Rate (mm/hr)	Infiltration Capacity
Sam Hill	Podzol. Sand and gravel.	>300[A]	Moderate infiltration capacity
Low-lying area	Gleysol. Silt and clay.	0.2-2.5[B]	Low infiltration capacity

Sources:
A – Gregory et al. 2006
B – AECOM 2012

The soils on Sam Hill are not considered to have a high infiltration capacity due to the potential for telluric seepage which likely reduces the infiltration capacity.

4.6.4 Field Investigation Results

4.6.4.1 Surficial Deposits

The field observations were consistent with the soil mapping discussed above and presented in Map 4-6 and Map 4-7.

The surficial soils observed in the lower lying topographical areas were characterized by a thin (1-2 cm) topsoil horizon overlying gleysol clays and silts (Photograph 1). The soils drained very poorly, hydrophilic vegetation[5] was observed in low-lying areas, and ponded water was observed in some of the agricultural land.

The surficial soils in the highlands (Sam Hill) were predominantly sand and gravel to a depth of 20-80 cm in the areas visited (Photograph 2 and Map 4-7). Beneath this was a layer of very firm till, similar in consistency to concrete. Shallow excavations into the till (10 cm) yielded dry soils, which indicates water does not readily infiltrate the till. Therefore, water draining through the overlying sand and gravel above is directed horizontally once it contacts the till. At higher elevations on Sam Hill (>90 mamsl) roadside ditches were dry. Below 90 mamsl water was observed to be flowing slowly or was stagnant in ditches with less relief. Towards the base contour of Sam Hill, where the topography flattens into the lower lying areas (20 – 40 mamsl) water was readily flowing to the south in all ditches observed.

[5] Vegetation found where soil is saturated with water for prolonged periods of time.

Photograph 1 - Typical gleysol soil of lowlands

Photograph 2 - Typical podzol soil of uplands (Sam Hill).

4.6.4.2 Hydrogeological Observations

A well located south of Sam Hill Creek near HWY 15 was located but did not have any identification. The well appeared to be outfitted with a pump but was not operating at the time of the site visit. A groundwater level of 3.305 m below top of casing was measured at an elevation of approximately 18 mamsl. A nearby well to the south (WTN 39199) was inaccessible but the well log indicates the aquifer was intersected from 59.4 to 68.9 m below ground.

As indicated previously, surface water was observed in ditches in the uplands below approximately 90 mamsl. It had been approximately 24 hours since the last rainfall, so the water flowing in the ditches on Sam Hill is presumed to be resulting from base flow seeping out of the overlying sand and gravel perched aquifer upon contacting the underlying till. Figure 4-2 shows a conceptual model of flow into the ditches.

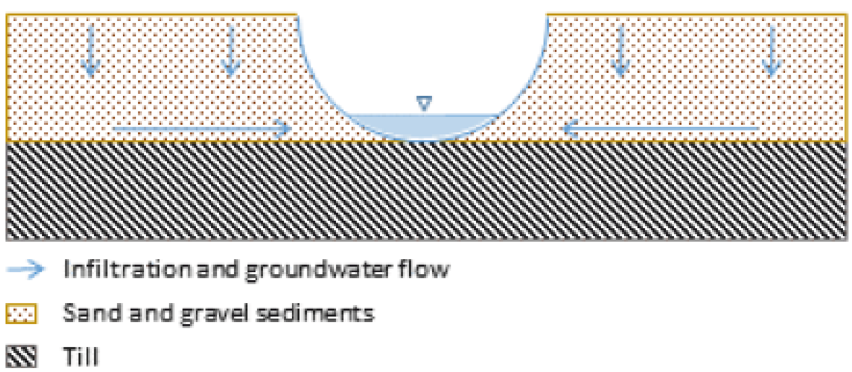


Figure 4-2
Conceptual Model of Telluric Groundwater Seepage into Ditches

In the southern, lower lying portions of the study area, the presence of hydrophilic vegetation and saturated soils are indicative of a shallow groundwater level, and prolonged saturation of surficial soils.

4.6.5 Conclusions

There are two different soil types in the Study Area with different drainage capacities. The sand and gravel podzols of the uplands area (Sam Hill) drain moderately well (higher infiltration rates) while the clay and silt gleysols of the lowlands drain very poorly (lower infiltration rates) as evidenced by the hydrophilic vegetation and ponding water in topographically low areas.

The sediments underlying the surficial soils on Sam Hill are predominately comprised of very firm till and fine-grained material to an appreciable depth (from the well logs, in places up to 70 m bgs). As such, any infiltration through the upper surficial soils (60 to 80 cm) would be limited, as the water would tend to flow vertically downwards to the shallow till, then mound and possibly resurface.

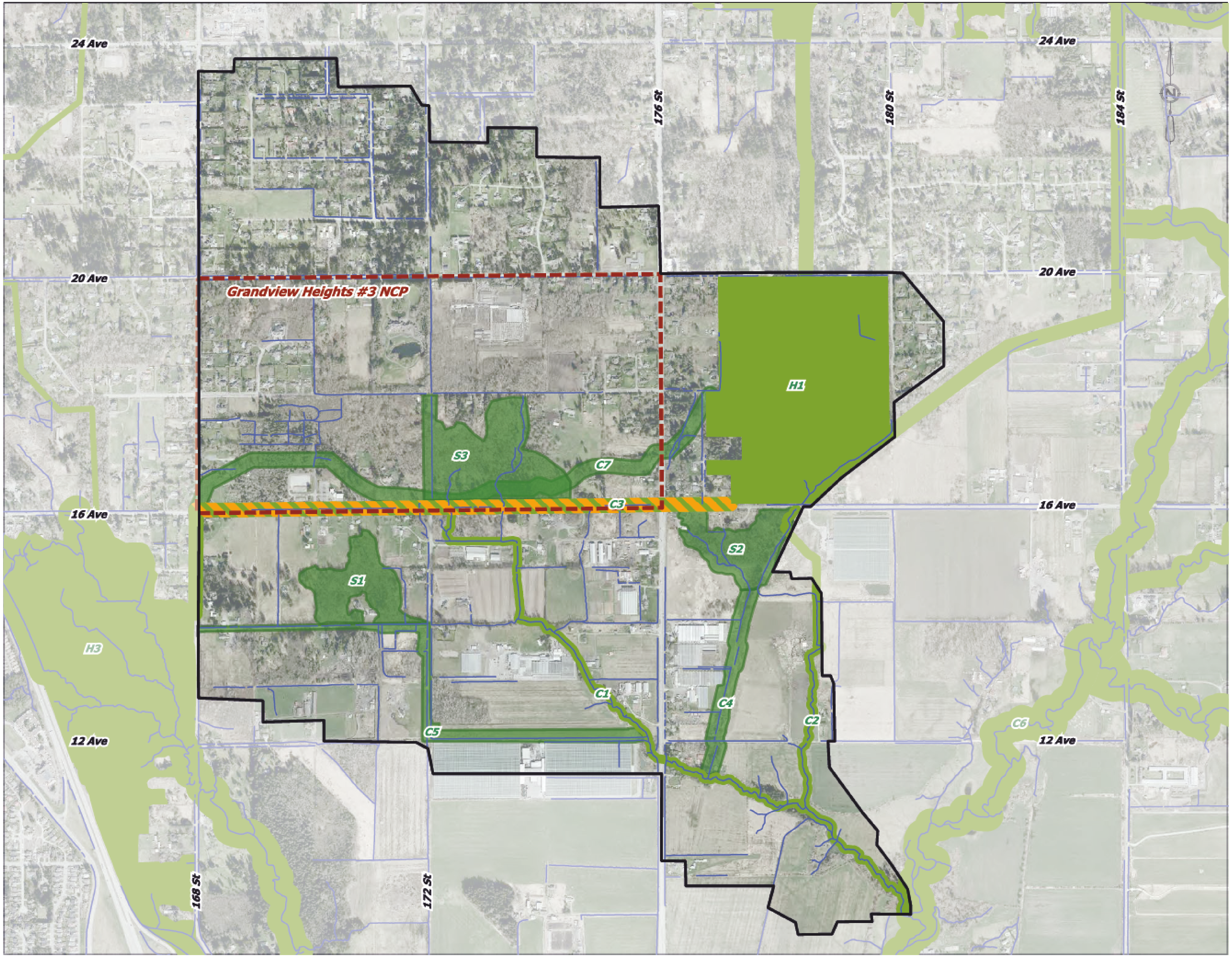
Map 4-9 shows the infiltration potential within the Sam Hill Creek Watershed. Once infiltrated to the subsurface, the groundwater may "daylight" (seep) at excavations that extend into the till layer, at ditches that intersect the till layer, and at any point where the surficial sediments pinch out resulting in till at surface. The latter scenario was not observed in the field. In addition, for residential homes located down-gradient from a potential infiltration facility, sub-basements and perimeter drains could be affected by heavy rains.

4.6.6 Limitations

Due to the limited information on the soils of Sam Hill, site-specific investigations should be completed prior to using the soils as an infiltration medium. These investigations should involve:

- Mapping the depth to the till contact,
- Determining the flow direction/velocity of water in the perched aquifer, and
- Calculate the infiltration rate of the soil.

These investigations are important to confirm the extent of mounding or if groundwater flows away at a high enough rate to prevent mounding and serve as an effective drainage method.



LEGEND

ISMP Study Area
Grandview Heights #3 NCP
Watercourse

Existing GIN

Green Infrastructure Network (Recognized GIN)

Proposed GIN

Proposed GIN
Proposed Removal of GIN Corridor

SCALE:	AS SHOWN		
PROJECT NO.	2017-2991	INITIAL	DATE
DRAWN		EF	17-11-10
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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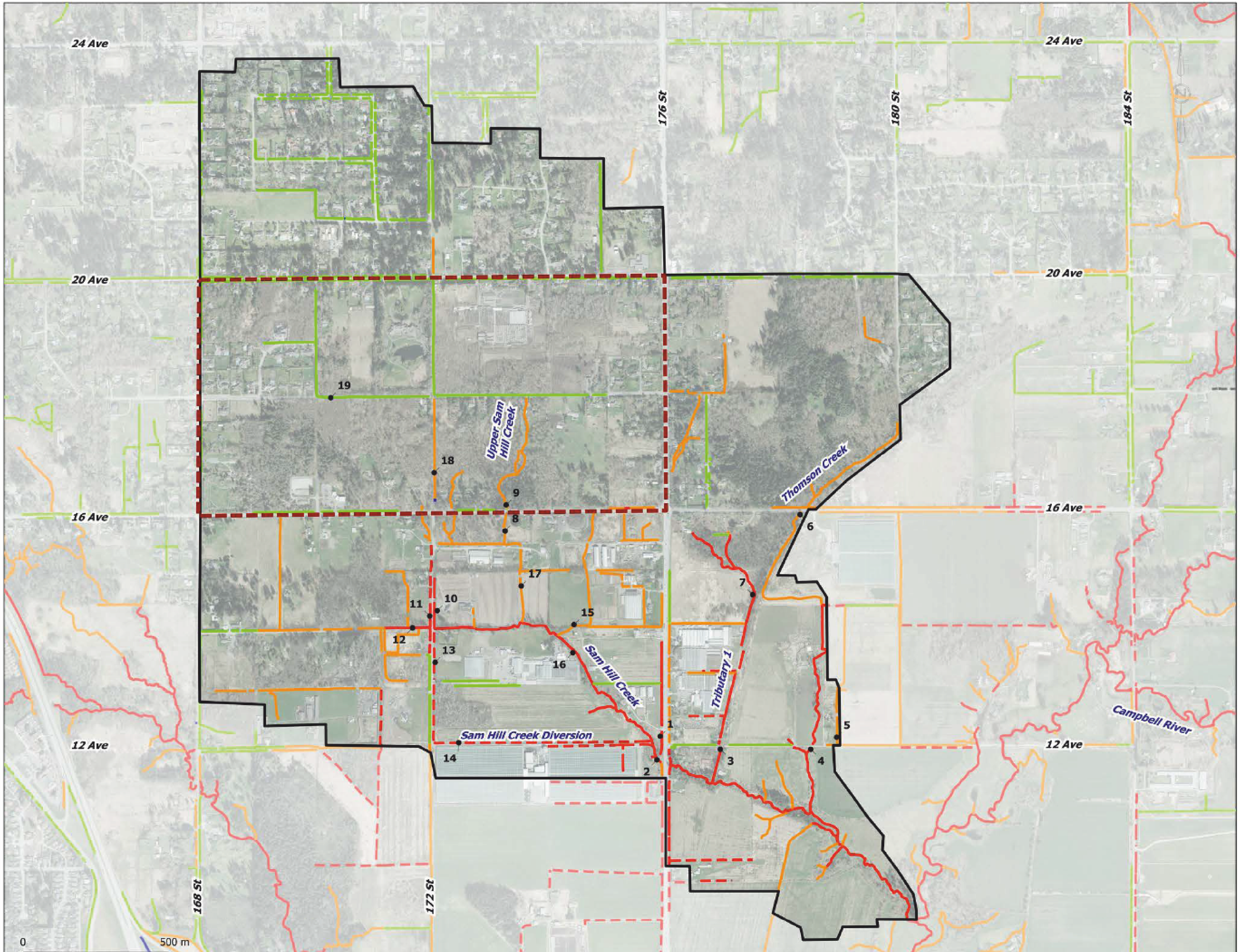
SAM HILL CREEK ISMP

GREEN INFRASTRUCTURE NETWORK

DRAWING NUMBER	REV. NO.	SHEET
MAP 4-1		



LEGEND

ISMP Study Area
Grandview Heights #3 NCP

Watercourse Classification

A
AO
B
C
UN

Aquatic Habitat Assessment Site
12 Assessment ID

SCALE:	AS SHOWN		
PROJECT NO.	2017-2991	INITIAL	DATE
DRAWN		JT	17-06-23
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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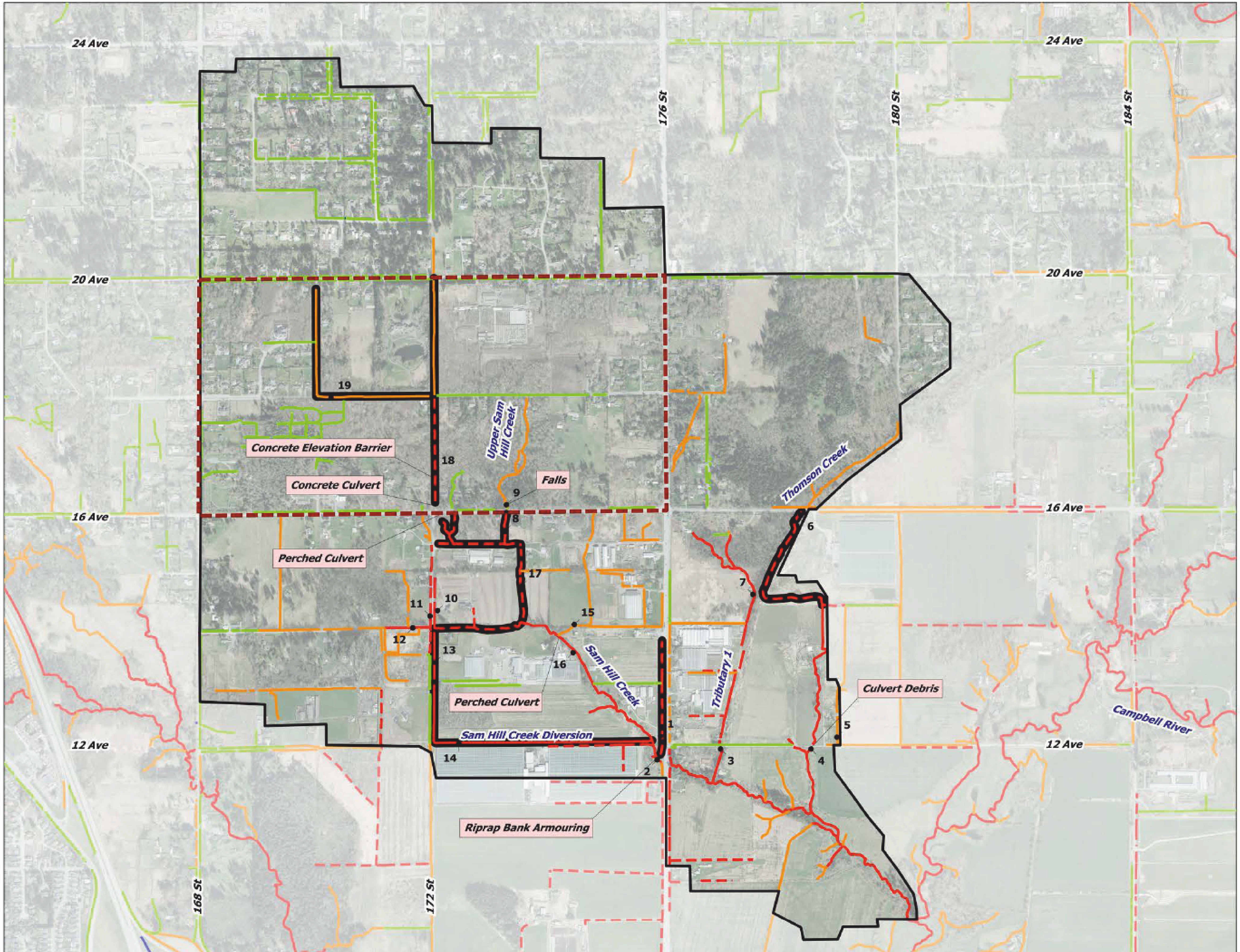
SAM HILL CREEK ISMP

STREAM CLASSIFICATION AT ONSET OF SAM HILL CREEK ISMP

DRAWING NUMBER	REV. NO.	SHEET
MAP 4-2		



LEGEND

ISMP Study Area

Grandview Heights #3 NCP

Watercourse Classification

A

AO

B

C

UN

Aquatic Habitat Assessment Site

12 Assessment ID

Recommended Reclassification

text Fish Passage Obstacle (See Table 4-5)

SCALE:	AS SHOWN		
PROJECT NO.	2017-2991	INITIAL	DATE
DRAWN		JT	17-11-10
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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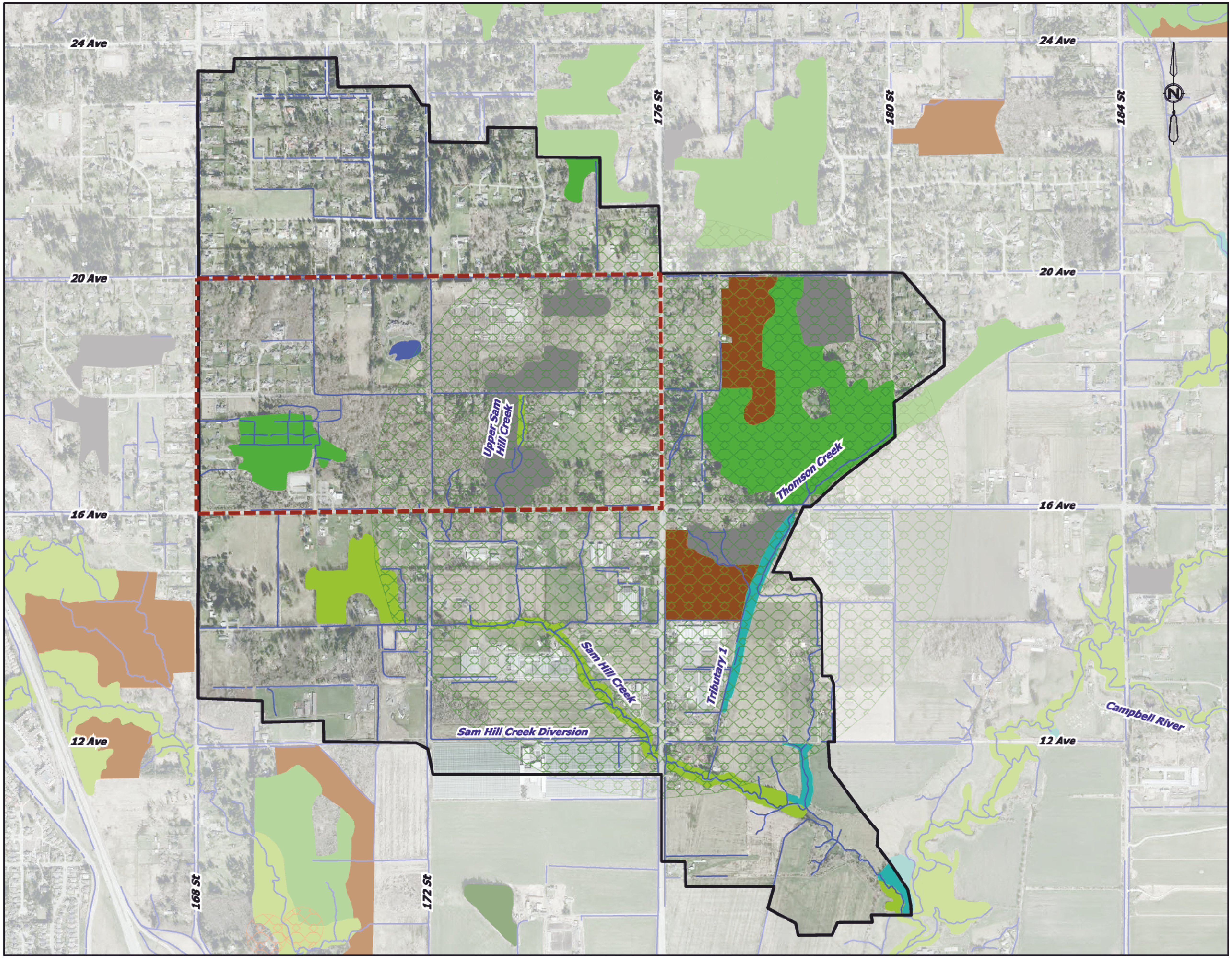
SAM HILL CREEK ISMP
RECOMMENDED STREAM CLASSIFICATION BASED ON ISMP PROCESS

DRAWING NUMBER	REV. NO.	SHEET
MAP 4-3		



LEGEND

Grandview Heights #3 NCP
ISMP Study Area
Watercourse

Species and Ecosystems at Risk (BCCDC)

Plant - Vascular
Animal - Vertebrate

Metro Vancouver Sensitive Ecosystem Inventory

Estuarine
Freshwater
Freshwater Reservoirs
Herbaceous
Intertidal
Mature Forest (ME)
Old Field
Riparian
River (Riparian subclass)
Wetland
Young Forest
Non SE/ME

SCALE:	AS SHOWN		
PROJECT NO.	2017-2991	INITIAL	DATE
DRAWN		JT	17-06-23
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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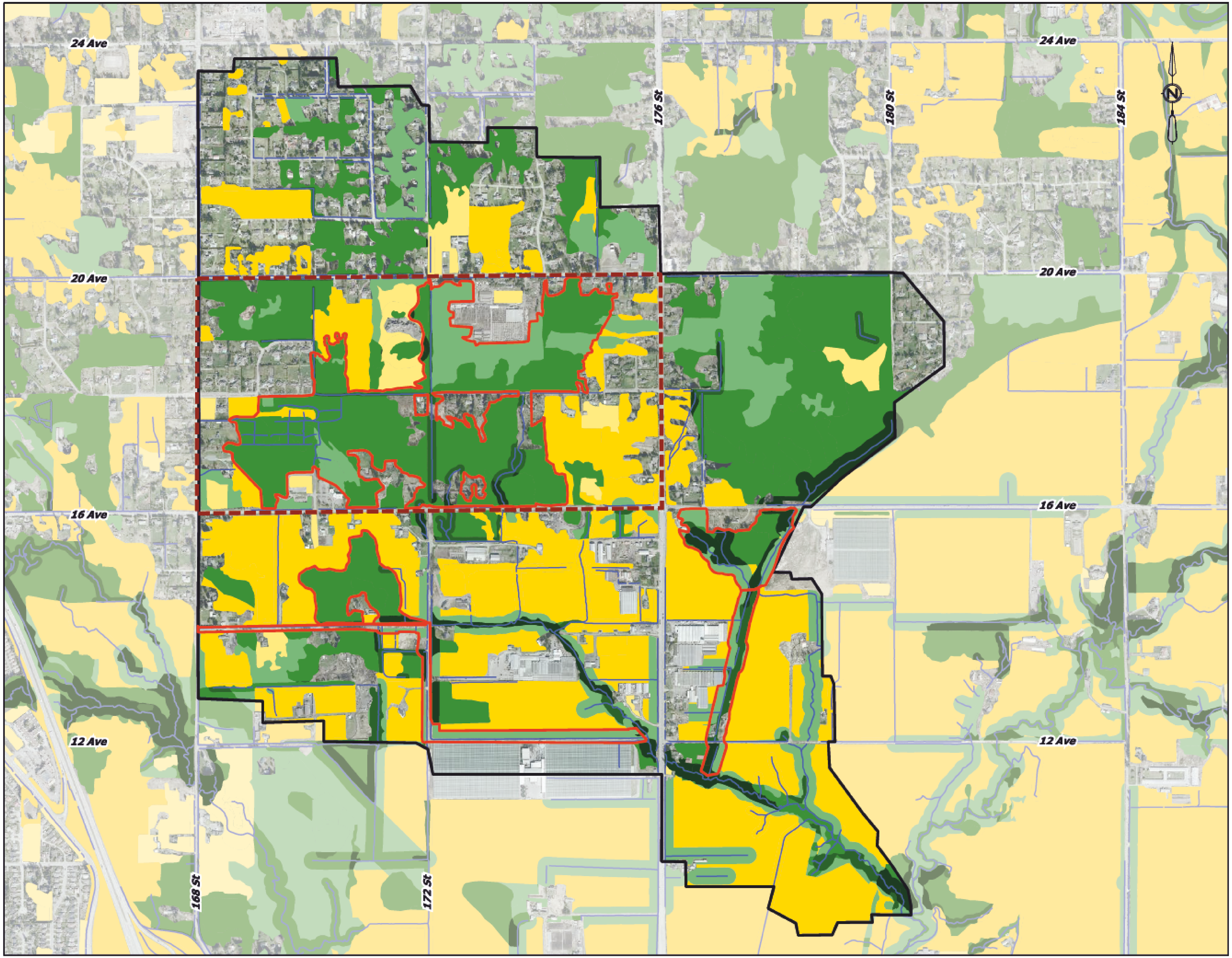
SENSITIVE ECOSYSTEM INVENTORY

DRAWING NUMBER	REV. NO.	SHEET
MAP 4-4		



LEGEND

ISMP Study Area
Grandview Heights #3 NCP
Open Channel

Habitat Suitability

Very High
High
Moderate High
Moderate
Low
Very Low

Unrecognized Site / Hub / Corridor

SCALE:	AS SHOWN		
PROJECT NO.	2017-2991	INITIAL	DATE
DRAWN		JT	17-06-23
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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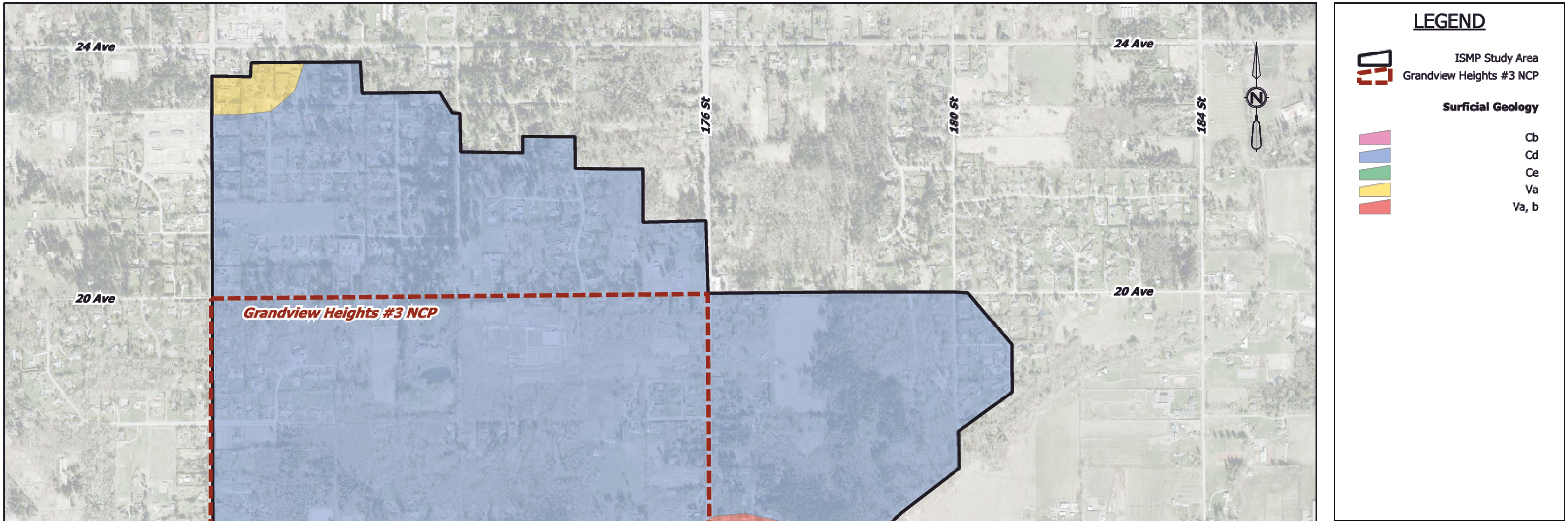
HABITAT SUITABILITY

DRAWING NUMBER	REV. NO.	SHEET
MAP 4-5		

Map File: C:\Users\fnneye\Desktop\map_Surrey_SamHill_20190118.map



SCALE:	AS SHOWN		
PROJECT NO.	2017-2991	INITIAL	DATE
DRAWN		JT	17-06-23
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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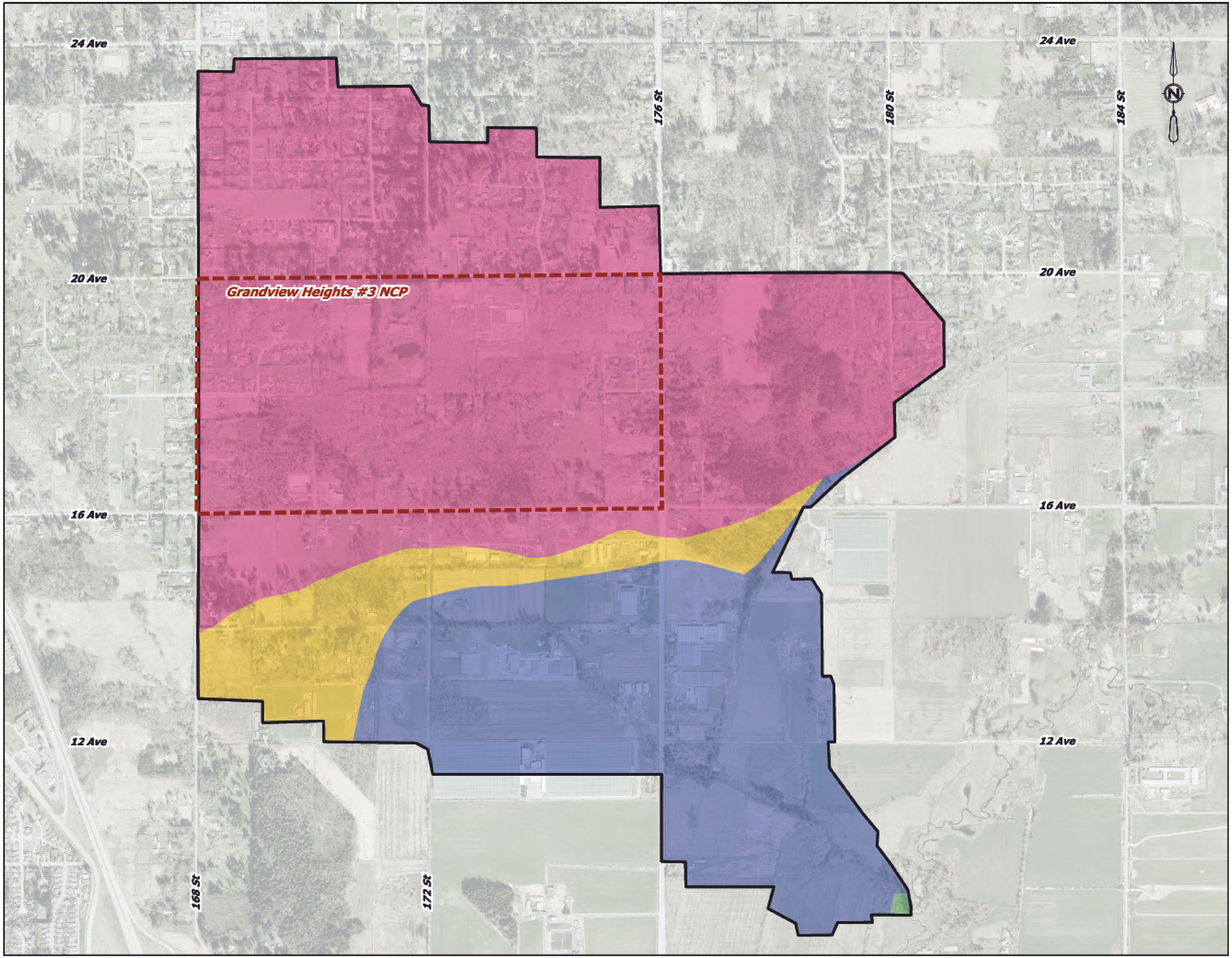
SAM HILL CREEK
ISMP

SURFICIAL GEOLOGY

DRAWING NUMBER	REV. NO.	SHEET
MAP 4-6		



LEGEND

Grandview Heights #3 NCP

ISMP Study Area

Soil Type

BO - Bose

CD - Cloverdale

CV - Carvoth

HN - Heron

SCALE:	AS SHOWN		
PROJECT NO.	2017-2991	INITIAL	DATE
DRAWN		JT	17-06-23
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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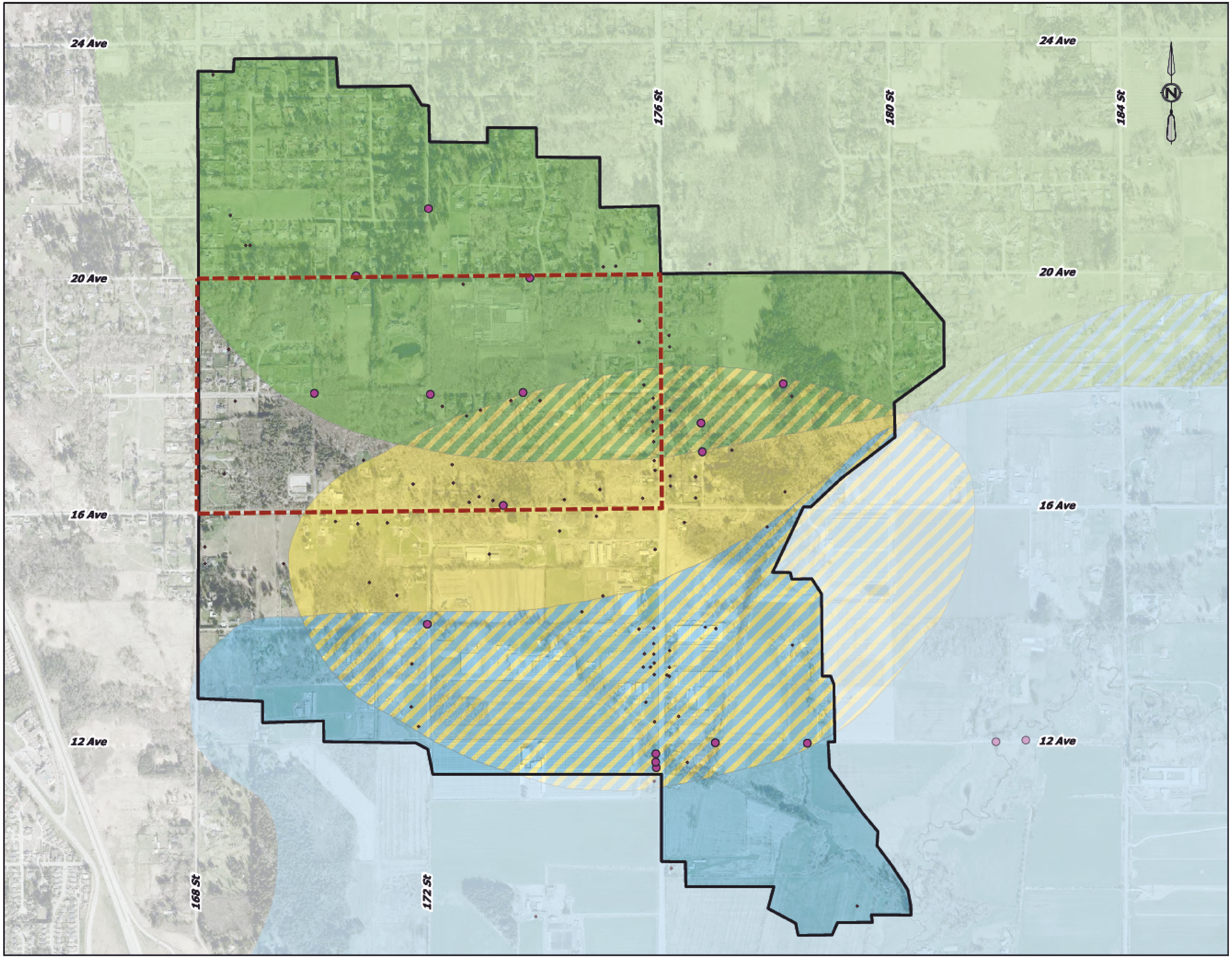
SOIL TYPES

DRAWING NUMBER	REV. NO.	SHEET
MAP 4-7		

Map File: C:\Users\fnneye\Desktop\map_Surrey_SamHill_20190118.map



Map File: C:\Users\fnneye\Desktop\map_Surrey_SamHill_20190118.map

LEGEND

Grandview Heights #3 NCP
ISMP Study Area

Well
Assessment Site

Aquifers

Grand
Hazel
Valley

SCALE:	AS SHOWN		
PROJECT NO.	2017-2991	INITIAL	DATE
DRAWN		JT	17-06-23
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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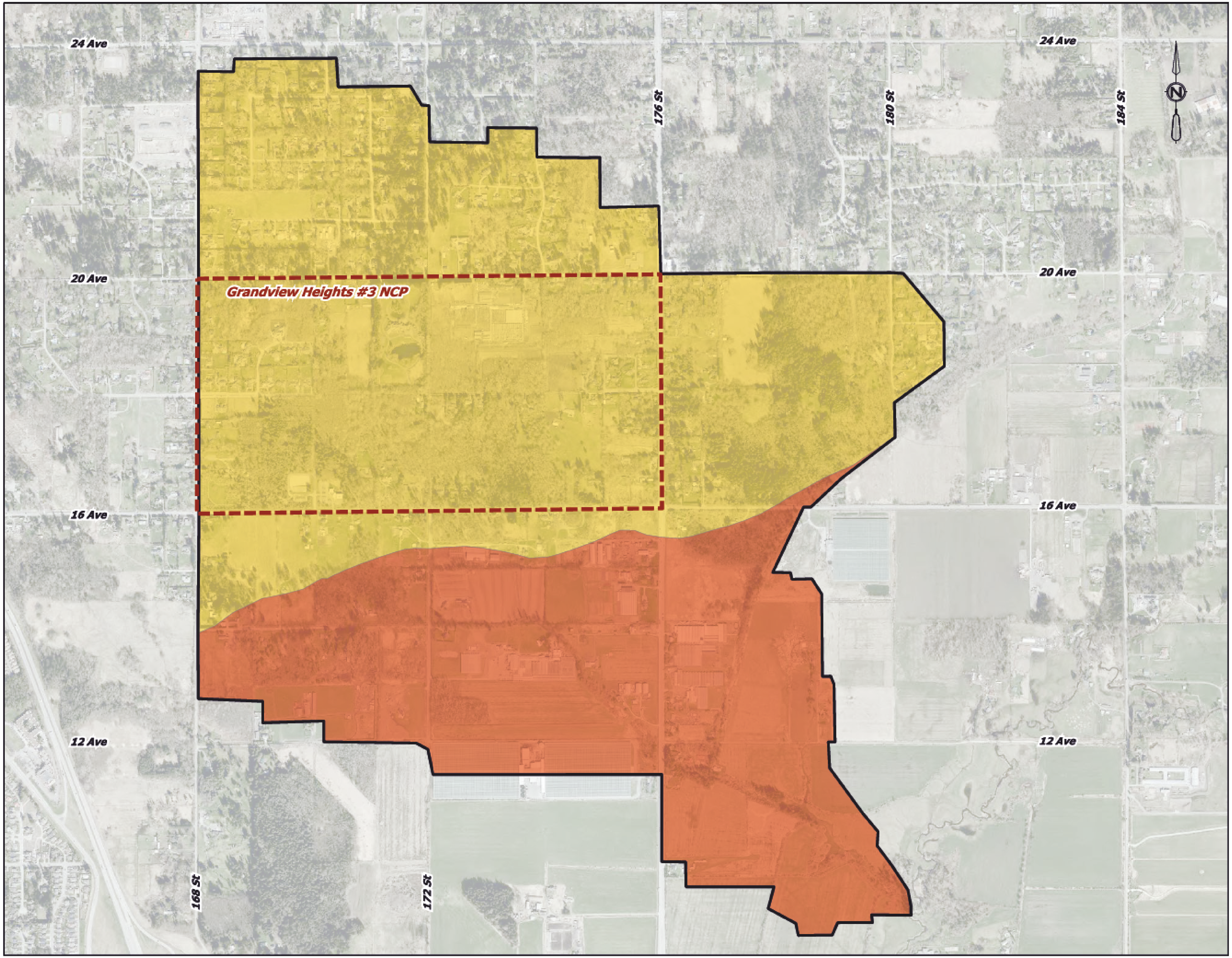
AQUIFERS

DRAWING NUMBER	REV. NO.	SHEET
MAP 4-8		



LEGEND

- Moderate Infiltration Potential
- Low Infiltration Potential

SCALE:	AS SHOWN		
PROJECT NO.	2017-2991	INITIAL	DATE
DRAWN		JT	17-06-23
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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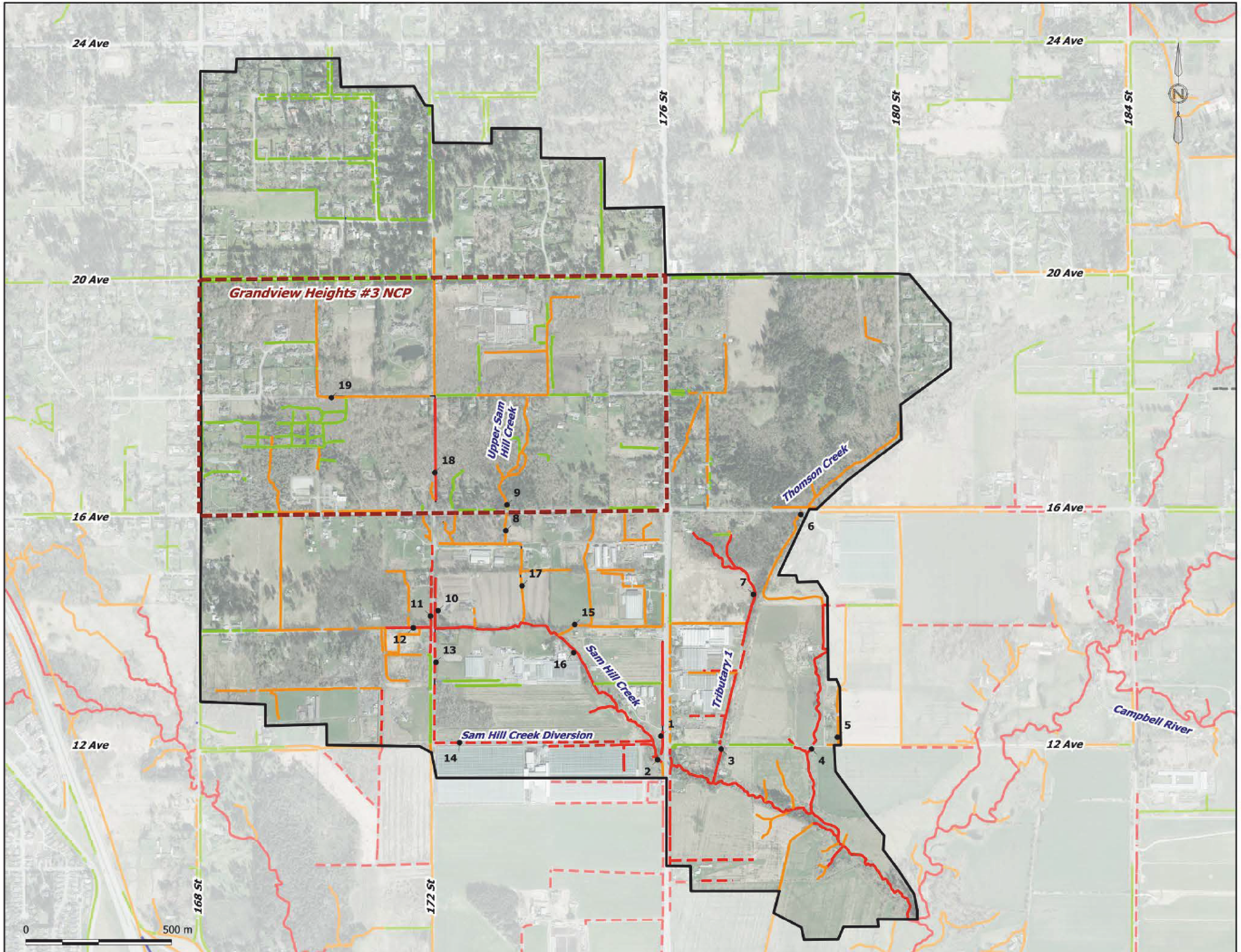
SAM HILL CREEK ISMP

INFILTRATION POTENTIAL

DRAWING NUMBER	REV. NO.	SHEET
MAP 4-9		



Map File: C:\Users\finneye\Desktop\map_Surrey_SamHill_20190503.map

LEGEND

ISMP Study Area
Grandview Heights #3 NCP

Watercourse Classification

A
AO
B
C
UN

Aquatic Habitat Assessment Site
12 Assessment ID

SCALE:	AS SHOWN		
PROJECT NO.	2017-2991	INITIAL	DATE
DRAWN		EF	10-07-18
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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SAM HILL CREEK ISMP

CURRENT STREAM CLASSIFICATION (JULY 2019)

DRAWING NUMBER	REV. NO.	SHEET
MAP 4-10		

5 Watershed Health Assessment

The Template for Integrated Stormwater Management Planning (Metro Vancouver, 2005) provides guidance on assessing the health of a watershed by using two physical characteristics: total impervious area and percent riparian forest integrity. Also, in principle the Benthic Index of Biotic Integrity (B-IBI), if available, can provide further information on watershed health from a biological perspective.

Total Impervious Area (TIA) provides an estimate of the fraction of paved and hard surface areas within a watershed. The more developed a watershed, the higher a percentage of impervious areas, such as roads, buildings and parking lots. These restrict the amount of land available to support natural infiltration and evapotranspiration of rainfall volumes. The result is a significant change to a watershed's hydrology compared to natural, undeveloped conditions, which often results in changes to stream hydrology (higher high flows, lower base flows) and has been correlated to detrimental stream health and the ability of such streams to provide suitable fish habitat.

TIA calculations assume that impervious surfaces do not provide any infiltration, which is not necessarily the case if source controls are implemented. As such, a common supplement to TIA is the Effective Impervious Area (EIA), which assumes the disconnection of a portion of impervious surfaces from watercourses. Source controls can effectively lower the TIA of a watershed, allowing for improved watershed health. EIA refers to this lowered value of impervious area and is an important consideration when considering long-term watershed health planning. However, estimation of EIA is a somewhat subjective process, based on interpretation of conditions within developed areas.

Riparian Forest Integrity (RFI) describes the fraction of riparian forest that remains intact within a 60 m buffer zone from watercourses within the watershed (30 m on either side of the stream). It is well understood that intact natural vegetation within this corridor support stream health by providing shade, supporting nutrient cycling, stabilizing erodible banks, promoting hydrologic processes such as interception and infiltration and supporting terrestrial biodiversity. Currently, property development within these corridors is generally regulated through provincial regulations and/or municipal bylaws, though this is not always the case.

5.1 IMPERVIOUS AREA ASSESSMENT

We developed an estimate of the TIA by first delineating sub-catchments for the study area based on an analysis of orthophotos, contours, and road crossings to confirm the boundaries using the available LiDAR data. The TIA of our sub-catchments was determined using land use mapping from the City overlaid with our sub-catchment areas. The imperviousness associated with each land use was transferred to our sub-catchments using an area-weighting method.

We have distinguished between four different land use types as listed in Table 5-1.

Table 5-1
Imperviousness by Land Use

Land Use	Imperviousness	Source
Park (Redwoods & Darts Hill Garden)	10%	Project Design Criteria
Agricultural	20%	2016 Surrey Design Criteria: 20% for Agricultural
Residential (lots > 1 ha)	20%	Project Design Criteria
Residential (lots < 1 ha)	50%	2016 Surrey Design Criteria: 50% for Residential

We have expanded on the definition of residential land use types as outlined in the City's Design Criteria Manual (DCM) to reflect the differences between residential land uses within the study area. For large residential lots greater than 1 ha, we have used an imperviousness of 20% rather than 50% as it is unlikely that impervious areas on these large lots would cover more than 20% of the total area.

We have also used an imperviousness of 10% for parks within the study area rather than the recommended 20% as outlined in the DCM. Based on our analysis of orthophotos of Redwood Park and Darts Hill Garden Park in the study area, we believe this is a realistic assessment due to the lack of any significant structures or paved areas visible.

Values for EIA were assigned for each land use classification. Map 5-1 provides an overview of the land use within our study area. The TIA and EIA land use values utilized in the assessment are presented in Table 5-2.

Table 5-2
Imperviousness by Land Use

Land Use	TIA	EIA
Park (Redwood & Darts Hill Garden)	10%	10%
Agricultural	20%	10%
Residential (lots > 1 ha)	20%	10%
Residential (lots < 1 ha)	50%	40%

Based on this approach, we calculated the Total Impervious Area of the watershed as 25.8%, and the Effective Impervious Area of the watershed as 16.9%.

5.2 RIPARIAN FOREST INTEGRITY ASSESSMENT

Percent Riparian Forest Integrity (RFI) is a key factor used in measuring overall watershed health. Under natural conditions, a riparian buffer would be present along either side of a watercourse. This buffer supports riparian functions that contribute to terrestrial and aquatic habitats.

We conducted an RFI analysis on the major watercourses in the study area using a total buffer width of 60 m. We delineated the in-tact forest areas based on the orthophotos and calculated the percentage of area along these corridors that still has forest intact. We included all of the drainage channels within the study area that are designated as 'creeks' within the City's database. Recognizing that there are also several ditches and linear channels which contribute to the riparian network, we also included all channels that were classified as A, A(O), or B. This represents all the watercourses and channels with either support fish directly, or contribute a significant source of food, nutrient, and cool water supplies to downstream fish populations. Our RFI assessment reflects the recommended stream reclassifications noted in Section 4.3.1.4.

In addition to calculating a single RFI value for the entire watershed, we recognize that the low-lying areas in the Little Campbell River floodplain may not be forested under natural conditions. Further, we recognize that there are limited opportunities for the City to enforce riparian conservation measures within the ALR. Based on this, we also calculated values for the portions of the watershed within the agricultural and non-agricultural areas separately:

- Zone 1: The area north of 16 Avenue that is predominantly large-lot residential
- Zone 2: The transitional area between 16 Avenue and 12 Avenue
- Zone 3: The agricultural lowland area south of 12 Avenue

The results of the analysis are presented in Table 5-3 and Map 5-2.

Table 5-3
Riparian Forest Integrity Assessment Results

	Riparian Area (ha)	Intact Forested Area (ha)	RFI
Zone 1	23.8	17.5	73.4%
Zone 2	64.5	24.9	38.6%
Zone 3	19.4	6.2	31.9%
All Zones	107.7	48.5	45.1%

The results indicate that the RFI decreases in the transition from the upland areas in the northern portion of the watershed to the lowland areas in the southern portion of the watershed.

The RFI in Zone 2 and Zone 3 is relatively low. However, in lowland areas that are prone to flooding, undisturbed riparian areas may be dominated by low-lying vegetation such as shrubs or grasses rather than treed forests. The lack of forest in these areas yields a low RFI value, however, the results may not necessarily indicate a severely degraded riparian environment.

Further, we note that Zone 2 and Zone 3 fall within the ALR. However, Zone 1 is located to the north of 16 Avenue and is entirely outside of the ALR. As such, there is greater potential for the City to protect the existing riparian forests which are still approximately 70% intact in this area.

5.3 BENTHIC INVERTEBRATE COMMUNITIES

The ISMP Template (Metro Vancouver, 2005) suggests that monitoring of the benthic invertebrate community within a given watershed can be used to add further detail to watershed health assessments.

The establishment of a Benthic Invertebrate Index of Biotic Integrity (B-IBI) score for a watershed can be used to assess the effectiveness of watershed planning. The B-IBI score determined through monitoring can be compared with a theoretical B-IBI score based on RFI and TIA. The comparison provides an indication of whether the watershed is performing either better or worse than would be expected given the RFI and TIA. B-IBI can also be monitored from year to year as an indicator to track the relative change in stream health. We note that the City of Surrey has a B-IBI monitoring program in place with over 40 sampling sites throughout the City. Sampling is generally conducted once a year. However, there is no B-IBI data available within the Sam Hill Creek ISMP study area. We note that the City has provided sampling data at two locations along Fergus Creek, as well as two locations along Little Campbell River. While these are not within the Sam Hill Creek ISMP study area, they are still useful for comparison purposes.

5.4 WATERSHED HEALTH

The Watershed Health Tracking System (WHTS) methodology outlined in the ISMP Template (Metro Vancouver, 2005) provides a qualitative indicator of watershed health. A fully healthy watershed would have very high (>90%) RFI, and very low (<5%) EIA, and therefore would plot in the upper left-hand corner of the WHTS template figure. As RFI decreases and EIA increases, the watershed health degrades and the plotting position moves toward the bottom right-hand corner of the figure.

We plotted the RFI and EIA results for the Sam Hill Creek watershed on the Watershed Health Tracking System (WHTS) as presented in Figure 5-1.

Based on the results for the entire watershed, the estimated EIA is 16.9%, and the estimated RFI is 45%. However, as noted, we also considered the portion of the watershed north of 16 Avenue (i.e. outside the ALR) separately. Based on the results of the study area to the north of 16 Avenue, the estimated EIA is 22.1%, and the estimated RFI is 73.4%. The results for this portion of the study area plot closer to the upper left corner of the figure, indicating a healthier watershed. Recognizing that this area is beyond the ALR, there is a greater opportunity for the City to protect the existing habitat.

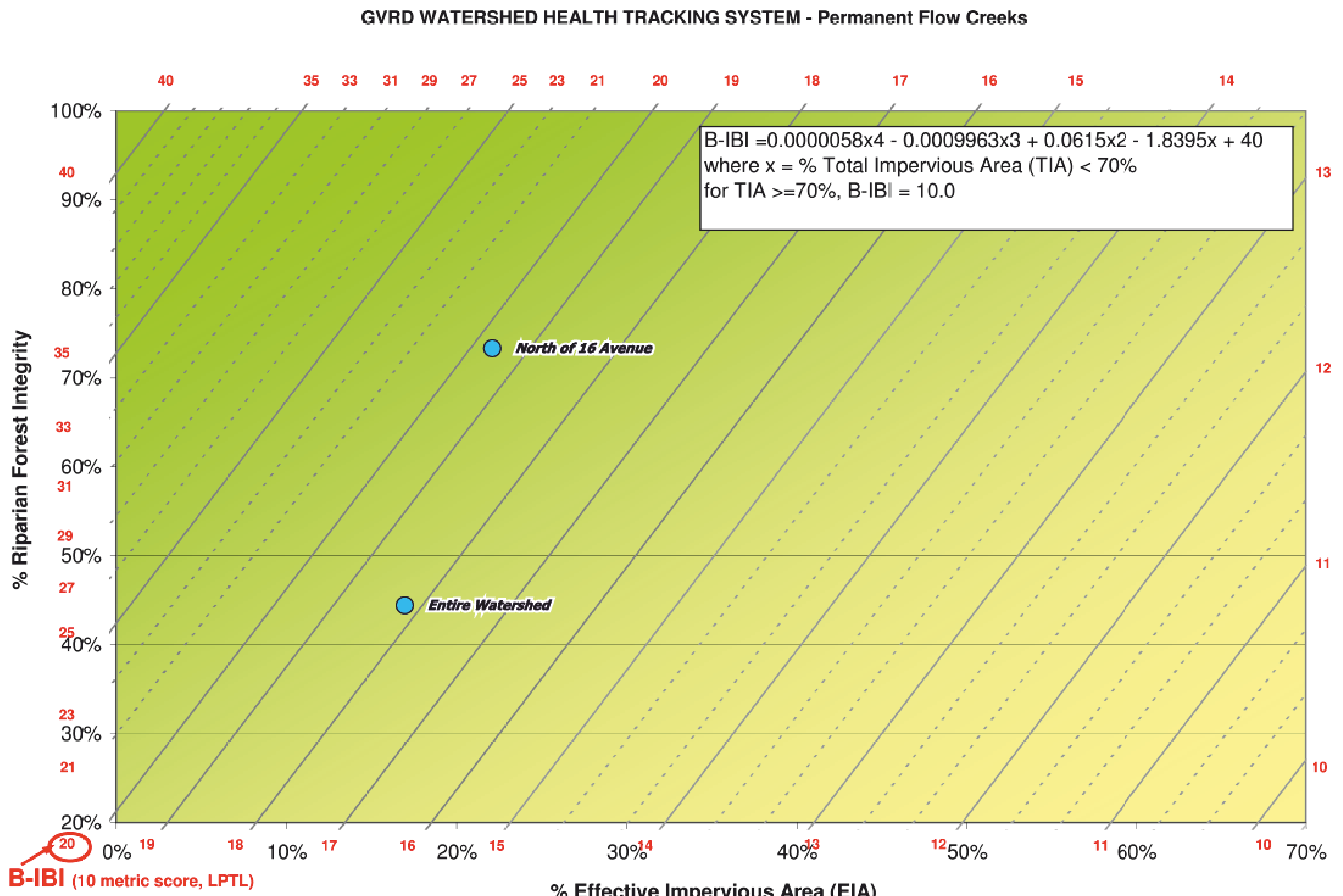
Based on the methodology of the WHTS, the B-IBI scores at the lower end of Sam Hill Creek (i.e. considering the entire watershed) would be expected to have a score in the range of 18 to 19. Upstream of 16 Avenue, the B-IBI score would be expected to be in the range of 19 to 20.

For comparison, Table 5-4 summarizes measured B-IBI scores from nearby Fergus Creek and Little Campbell River watersheds.

Table 5-4
B-IBI Scores from Comparison Watersheds

Watershed	2017		2018	
	Site 1	Site 2	Site 1	Site 2
Fergus Creek	14	15.33	14	15.33
Little Campbell River	19.33	24	18.67	34

Comparing the calculated B-IBI values for Sam Hill Creek to the measured values of Fergus Creek and Little Campbell River, it appears that the Sam Hill Creek scores sit between the two – higher than Fergus Creek, but lower than Little Campbell River.



Source: Kerr Wood Leidal Associates Ltd. 2005

LEGEND

SCALE:	AS SHOWN		
PROJECT NO.	2017-2991	INITIAL	DATE
DRAWN		JT	17-06-23
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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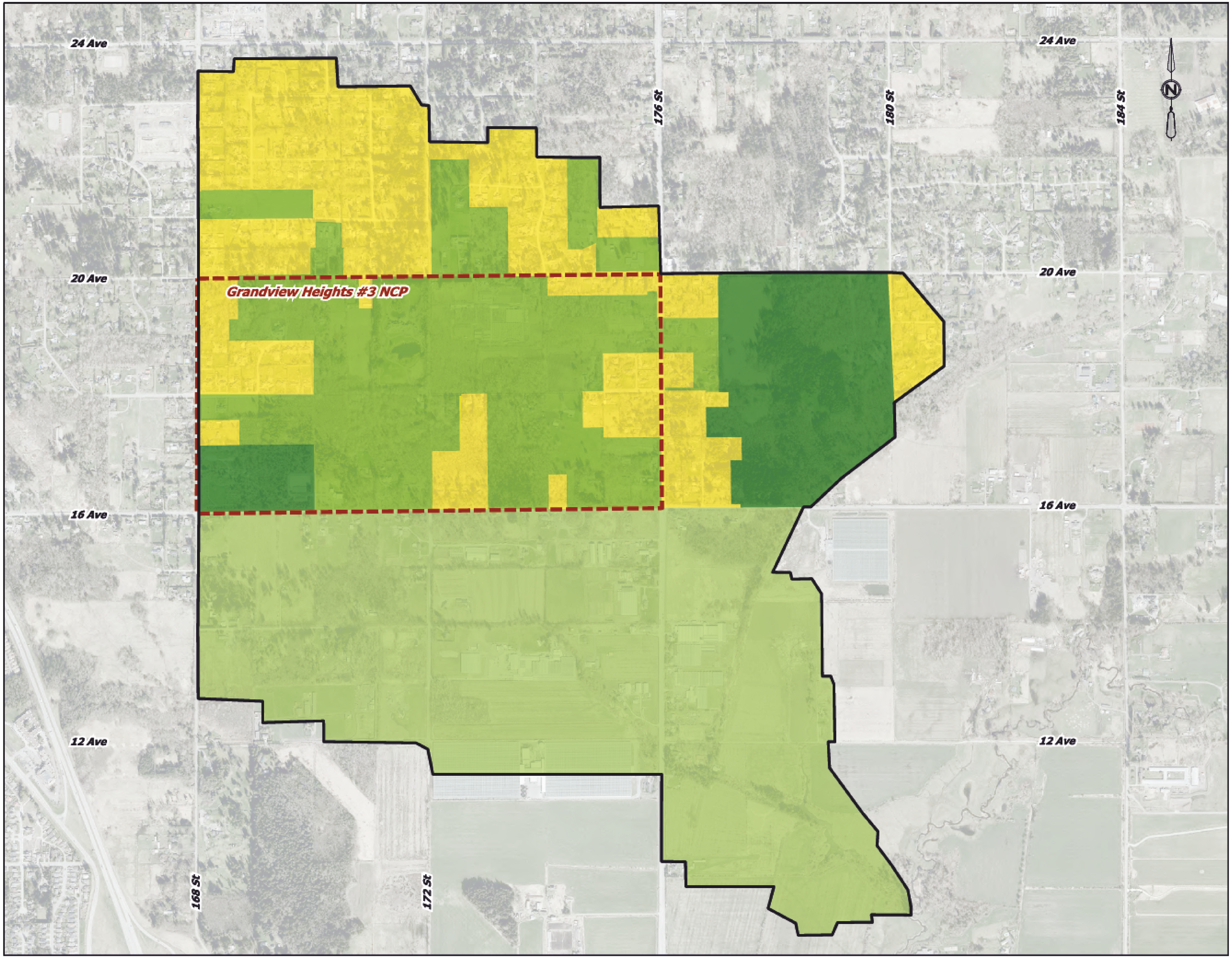
SAM HILL CREEK ISMP

GVRD
WATERSHED HEALTH ASSESSMENT

DRAWING NUMBER	REV. NO.	SHEET
FIGURE 5-1		



LEGEND

ISMP Study Area
Grandview Heights #3 NCP
Land Use
One Acre Residential Zone (<1ha)
One Acre Residential Zone (>1ha)
Park
Agricultural

SCALE:	AS SHOWN		
PROJECT NO.	2017-2991	INITIAL	DATE
DRAWN		JT	17-06-23
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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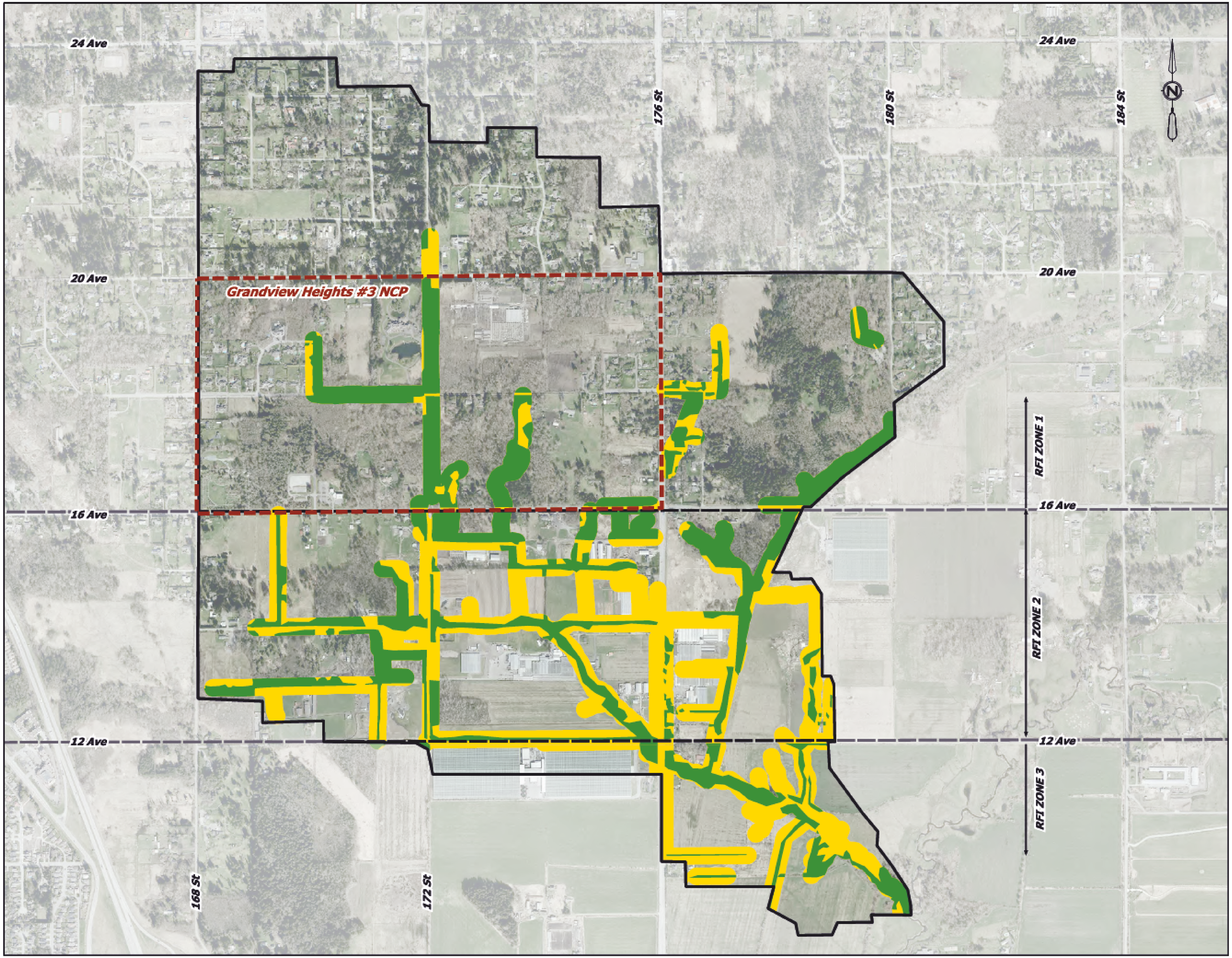
SAM HILL CREEK ISMP

EXISTING LAND USE

DRAWING NUMBER	REV. NO.	SHEET
MAP 5-1		

Map File: C:\Users\fnneye\Desktop\map_Surrey_SamHill_20190118.map



LEGEND

ISMP Study Area
Grandview Heights #3 NCP

Open Channel

Riparian Buffer

Forest Intact
Forest Not Intact

SCALE:	AS SHOWN		
PROJECT NO.	2017-2991	INITIAL	DATE
DRAWN		JT	17-06-23
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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SAM HILL CREEK ISMP

RIPARIAN FOREST INTEGRITY

DRAWING NUMBER	REV. NO.	SHEET
MAP 5-2		

Map File: C:\Users\fmneye\Desktop\map_Surrey_SamHill_20190118.map

6 Riparian Setbacks

Riparian zones are the areas that surround watercourses and wetlands. These 'riparian buffer' areas are intermittently wetted during rainfall events as water levels rise and directly support aquatic habitat by providing nutrient inputs, woody debris, and resisting bank erosion. Beyond this region of direct watercourse influence, "riparian corridors" provide additional benefits. Vegetation within these corridors provides shade, helping to regulate water temperatures, and supports terrestrial biodiversity while providing wildlife corridors. Where watercourses are in ravines, the "riparian area" that provides ecological benefits can extend beyond the top of the ravine banks.

The preservation and reinstatement of riparian areas is critical in protecting the health of watercourses and the watershed at large. This protection is most often provided by ensuring a certain setback is maintained between the high-water level of a stream and any existing or proposed development. Part 7A of the City's Zoning Bylaw for Streamside Protection (Part 7A) establishes setback limits according to watercourse classification and is consistent with the widths outlined in the Land Development Guidelines for the Protection of Aquatic Habitat (DFO, 1993). Table 6-1 presents the recommended setbacks outlined in Part 7A.

Table 6-1
City of Surrey Streamside Protection Bylaw (Part 7A of Zoning Bylaw) – Riparian Setback Recommendations

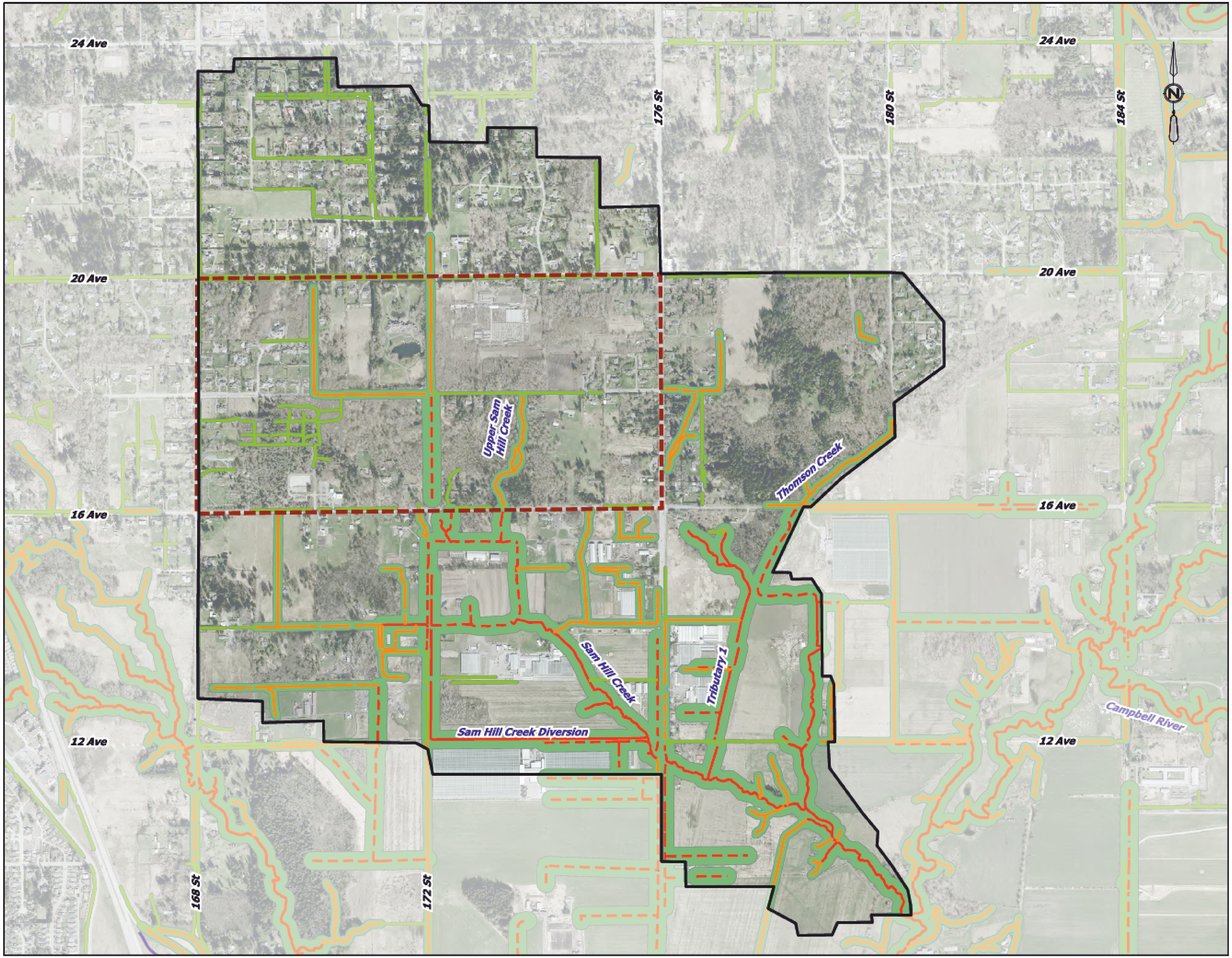
Watercourse Classification	Riparian Setback
A, A(O), ponds and lakes	30 m
B, wetlands	15 m
C	5 m

We note that there may be additional criteria for determining setbacks as described in the City's bylaws. The reader should confirm the required riparian setback for a given site by reviewing all applicable guidelines and bylaws.

The recommended riparian setbacks from Part 7A, and from the Provincial Land Development Guidelines, are measured from the top of bank. As such, the total required leave strip width for fish bearing watercourses under the riparian setback guidelines would be 60 m (30 m each side) plus the main channel width.

While the watercourse centerline data is readily available from the City of Surrey, the high-water mark has not been delineated along the length of the watercourses. Accurate high-water mark delineation would require a significant amount of field survey throughout the study area, which is beyond the scope of the current assignment. For the purposes of the current riparian setback mapping, we have assumed a channel width of 4 m for Class A and Class A(O) watercourses, a channel width of 2 m for Class B watercourses, and a channel width of 1 m for Class C watercourses. We note that the riparian setback mapping is based on the recommended watercourse classifications as described in Section 3. Any future development is required to meet Ecosystem Development Permit requirements.

Map 6-1 shows the riparian setbacks for watercourses throughout the study area based on the guidelines presented in the BCS.



Map File: C:\Users\fnneye\Desktop\map_Surrey_SamHill_20190118.map

LEGEND

ISMP Study Area
Grandview Heights #3 NCP

Watercourse Classification

- A
- AO
- B
- C
- UN

Riparian Setback

SCALE:	AS SHOWN		
PROJECT NO.	2017-2991	INITIAL	DATE
DRAWN		JT	17-11-10
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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SAM HILL CREEK ISMP

RIPARIAN SETBACKS

DRAWING NUMBER	REV. NO.	SHEET
MAP 6-1		

7 At-Risk Areas

Development is expected to occur within the Sam Hill Creek Watershed in these general locations:

- Between 168 Street and 176 Street, and between 16 Avenue and 20 Avenue, redevelopment will occur as per the Grandview Heights #3 NCP.
- North of 20 Avenue, future redevelopment will occur under Grandview Heights #5 NCP (NCP has not yet been developed).

We also note that there is potential for redevelopment along the east side of 176 Street between 16 Avenue and 18 Avenue in the future.

The remaining portions of the Sam Hill Creek study area include Redwood Park, located north of 16 Avenue to the east of 176 Street, and agricultural lands south of 16 Avenue. Redevelopment is not expected to occur in either of these areas within the current planning horizon.

7.1 AT-RISK ENVIRONMENTAL HUBS AND CORRIDORS

Based on the City's BCS, there is only one existing GIN component that is located within the footprint of the future redevelopments noted above. This is corridor C3, which has been recommended for relocation as noted in Section 4 and as detailed in the "Grandview Heights #3 NCP Environmental Study."

The other existing GIN components within the Sam Hill Creek ISMP study area include Redwood Park (H1), and corridors C1 and C2 along Sam Hill Creek and Thomson Creek, respectively. All three of these GIN components are located in areas where future redevelopment is not expected to occur.

As outlined in the BCS, these three GIN components are all considered to be at low risk of redevelopment.

In addition to the City's existing GIN, we have also identified three proposed corridors and two proposed sites. Proposed sites S1 and S2, as well as proposed corridors C4 and C5, are all located in areas where redevelopment is not expected to occur.

7.2 IMPACTS OF PLANNED DEVELOPMENT

7.2.1 Grandview Heights #3 NCP

The Grandview Heights #3 NCP covers the area between 168 Street and 176 Street, and 16 Avenue and 20 Avenue. Based on the draft land use concept for the Grandview Heights #3 NCP, the most predominant land uses within this area include Urban Single Family, Semi-Detached Residential, Multiple Cluster Residential, Low Density Multiple Residential, and Medium Density Multiple Residential. The NCP also includes some relatively small pockets of Commercial and Institutional, with two future schools.

Proposed GIN site S3 is located near the middle of the Grandview Heights #3 NCP area, just north of 16 Avenue. Site S3 largely coincides with a number of green land use designations, included a future park, the riparian areas along Sam Hill Creek and the watercourse that follows the 172 Street alignment, as well as Green Space Transfer Areas within the Multiple Residential Cluster areas. As such, a significant portion of proposed Site S3 should be protected from future redevelopment. However, the northern portions of site S3 will be impacted by a proposed road, as well as Semi-Detached Residential Development.

As outlined in the Grandview Heights #3 NCP Environmental Study, proposed GIN corridor C7 is a relocation of the existing corridor along 16 Avenue. The City's preferred alignment for this relocated corridor coincides with existing park space, future parks, riparian areas, and green space transfer areas. As such, it should largely be protected from future redevelopment.

7.2.2 Grandview Heights #5 NCP

The portion of the Sam Hill Creek ISMP study area located north of 20 Avenue falls within the Grandview Heights #5 NCP area. While this NCP has not yet been developed, the City has indicated that increased urbanization is expected to occur.

There are no existing or proposed Green Infrastructure Network components within this portion of the study area.

7.2.3 Redevelopment East of 176 Street

The existing lots immediately east of 176 Street between 16 Avenue and 18 Avenue could potentially be redeveloped in the future. These lots are currently zoned as One Acre Residential.

Based on the City's BCS, corridor C3 currently runs through this area and connects to Redwood Park. As discussed, this corridor is being relocated further north to better align with the City's environmental and planning objectives. Regardless of the exact location of the corridor between 176 Street and Redwood Park, it will likely cross through this area of potential redevelopment. It will be critical to protect the ultimate corridor alignment at this location to maintain connectivity between Redwood Park and the rest of the GIN further to the west.

8 Hydrologic / Hydraulic Modelling

8.1 MODEL APPROACH

We created a hydraulic and hydrologic model of the existing drainage system within the study area using PCSWMM version 5.1.011. The model represents major open channels, culverts, and piped storm systems and excludes some minor pipes, driveway culverts and service connections. This level of investigation is typical for ISMPs where only the main conveyance system is analyzed. The study area was divided into 34 subcatchments with an average area of approximately 15 ha and ranging from 4 ha to 40 ha in area. Map 8-1 provides an overview of the existing conditions model.

8.2 BASE MODEL ASSEMBLY

8.2.1 Data Collection

Our model is based on City-supplied data regarding culverts, pipes, and watercourses. We conducted a field investigation on May 9, 2017 to fill gaps in the data and confirm key information such as culvert diameter, material, inlet geometry, outlet geometry, and watercourse information such as channel dimensions. Details from our investigation can be found in Appendix C.

8.2.2 Modelled Sub-Catchments

We developed sub-catchments for the study area and estimated imperviousness based on an analysis of orthophotos, contours, and road crossings and confirmed the boundaries using the available LiDAR data.

8.2.3 Hydrologic / Hydraulic Modelling Parameters

The key hydrologic modelling parameters include Horton infiltration rates, average catchment slopes, Manning's roughness coefficients for overland flow, and depression storage depths. Our initial estimates for these parameters were based on interpretation of air photos, LiDAR data, previous hydrologic models within the study area, available background reports, and information gathered during site visits. Table 8-1 summarizes the initial hydrologic parameters used in the model.

Table 8-1
Hydrologic Model Parameters

Horton Infiltration Parameters	
Maximum Infiltration Rate (mm/hr)	10.0
Minimum Infiltration Rate (mm/hr)	4.0
Decay Constant (hr^{-1})	4.0
Drying Time (days)	7.0

Manning's Roughness Coefficient, n, for Overland Flow	
Impervious Surface (overland flow)	0.020
Pervious Surface (overland flow)	0.400
Depression Storage	
Impervious Surface (mm)	3.0
Pervious Surface (mm)	10.0

Table 8-2 presents the hydraulic parameters assigned to the conduits within the model.

Table 8-2
Hydraulic Model Properties

Manning's Roughness Coefficient, n, for Conduit Flow	
Plastic and Concrete	0.013
CSP	0.024
Ditches / Watercourses	0.050
Street	0.018
Culvert Entrance Loss	
Concrete Box/Pipe	
Projecting	0.5
Headwall/Wingwall	0.4
CSP and PVC	
Projecting	0.9
Mitred	0.7
Headwall	0.5
Culvert Exit Loss	**1.0**

The Manning's roughness values are based on pipe material data as indicated in the City's GIS database and confirmed by field observations.

Entrance and exit loss coefficients are a function of inlet and outlet conditions of the culvert (headwall, projecting, mitred to slope, etc.) and were assigned based on field observations.

8.2.4 Rainfall Data

To assess the existing drainage system for deficiencies we used Intensity Duration Frequency (IDF) data provided in the DCM (2016 version) for the White Rock STP rainfall gauge. The IDF curve is based on a period of record of 44 years. We note that the data supplied by the City in the DCM has different values (typically higher rainfall intensities) and a longer period of record than the IDF curve available from Environment Canada for the same gauge.

Table 8-3 shows the Coefficient A and Exponent B values from the White Rock STP for the 5-year and 100-year return periods as these are the return periods used for designing the minor and major storm systems, respectively, as described in the DCM.

Table 8-3
IDF Data for White Rock STP IDF Curve

	5-Year Return Period	100-Year Return Period
Coefficient A	17.026	31.184
Exponent B	-0.529	-0.561

We used this information to create All-Duration Storms (ADS) for the 5-year and 100-year return period storms for use in our models. The ADS is an effective screening tool that can be used to efficiently identify problem areas within the storm network. The ADS includes all durations on an IDF curve and therefore allows for the inclusion of the total runoff depth experienced with a 24-hour duration storm and also incorporates runoff responses for shorter-duration storms.

We divided the drainage system into sub-catchments with an average area of approximately 15 ha. This is an appropriate level of detail for a planning level study. However, these coarse catchments can potentially skew the predicted runoff response by overestimating peak flows. To account for this, we buffered the runoff response from the catchments by using a minimum middle time step of 50 minutes. This attenuates the peak of the ADS slightly, providing a reasonably reliable hydrologic response. This time step is consistent with previous ISMPs that Associated Engineering has completed of similar catchment sizes. The ADS design storms for the 5-year and 100-year return periods are shown in Figure 8-1. The design rainfall events are also included in tabular form in Appendix D.

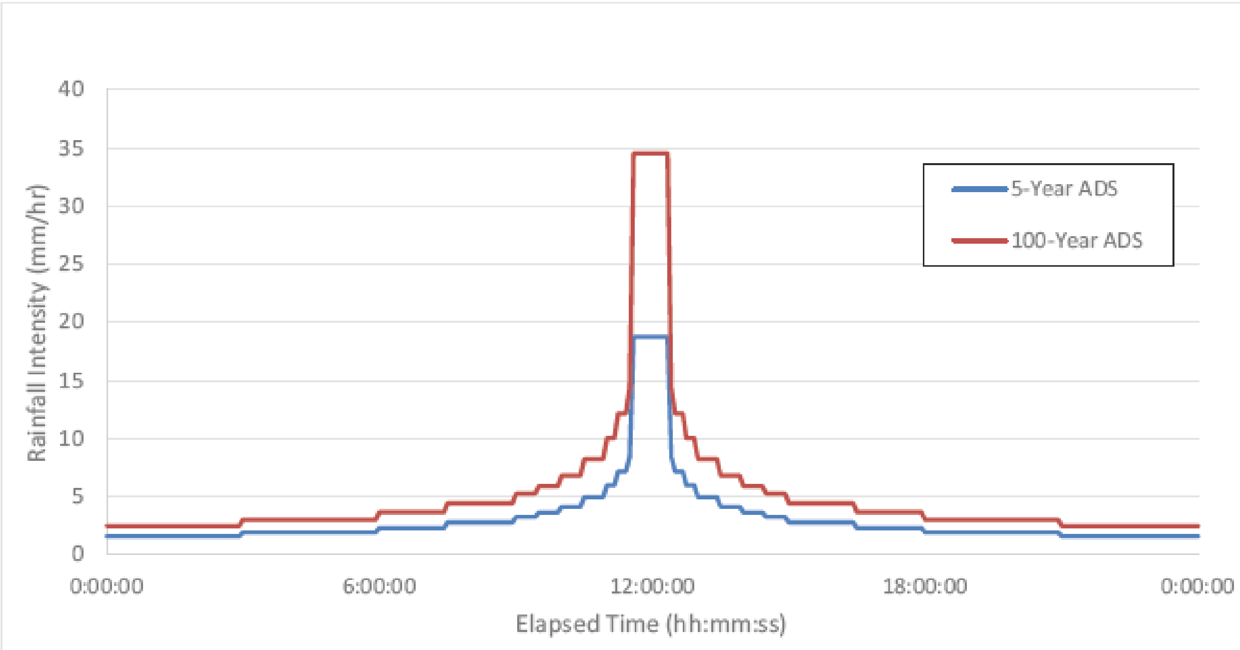


Figure 8-1
ADS Design Storms

8.2.5 Boundary Conditions

Recognizing that the focus of the current study is to assess future development north of the agricultural lands, we have modelled the drainage network with a free outfall into Little Campbell River. Future condition modelling focusses on peak flow rates generated within the study area and the measures required to limit increases in peak flow rates to acceptable levels.

8.3 MODEL CALIBRATION

We calibrated our model using recorded flow data to evaluate the existing condition. As part of the City's "Adaptive Management Framework, Hydrometric Monitoring Program Summary, South-East Region, November 2015 – January 2017" Draft Report (April 2017), flow data was collected on Sam Hill Creek at the inlet of the 2400 mm x 1200 mm concrete box culvert located immediately east of 172 Street at 14 Avenue.

The observed flow data was recorded at 5-minute intervals for the period between October 30, 2015 and January 18, 2017. We reviewed the available flow data and selected three events to use for calibrating the model. These include two of the largest events on record, with peak flows of 643 L/s and 538 L/s, as well as one moderate event with a peak flow of 186 L/s.

The observed, calibration flow rates on Sam Hill Creek, along with the recorded rainfall data from the White Rock STP gauge, are shown on Figure 8-2, Figure 8-3, and Figure 8-4 below.

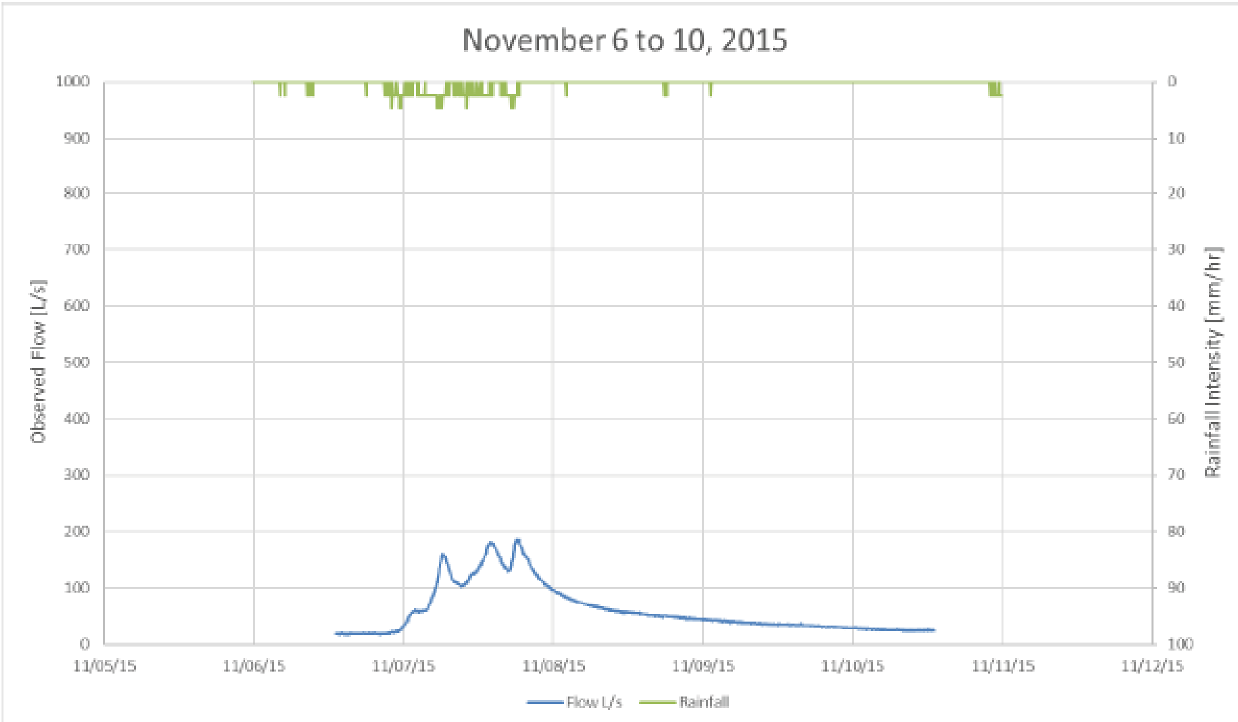


Figure 8-2
November 2015 Calibration Event

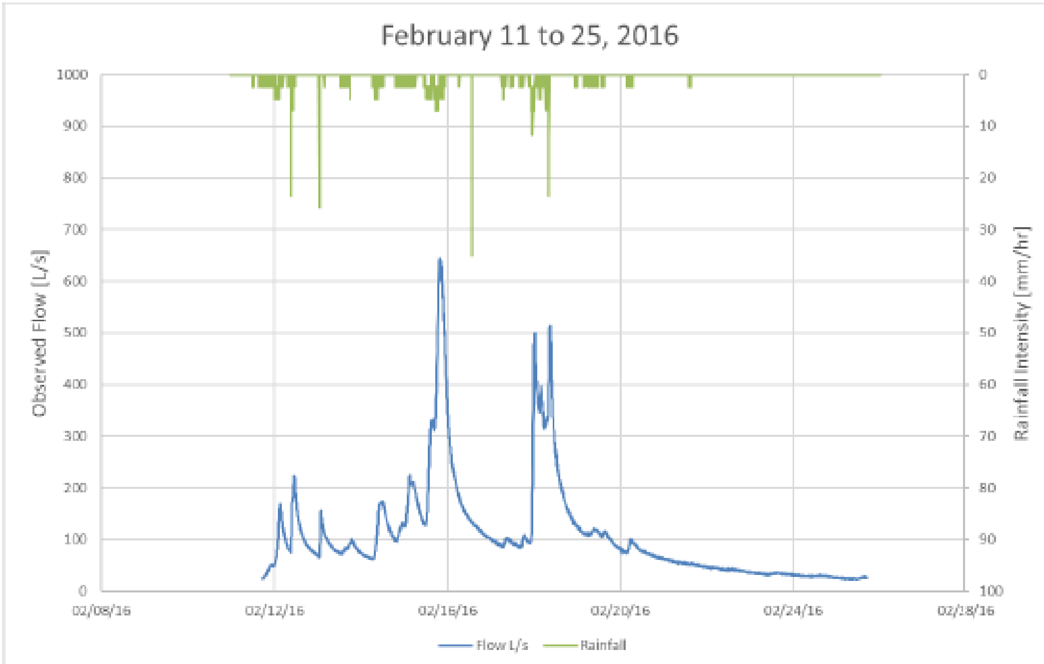


Figure 8-3
February 2016 Calibration Event

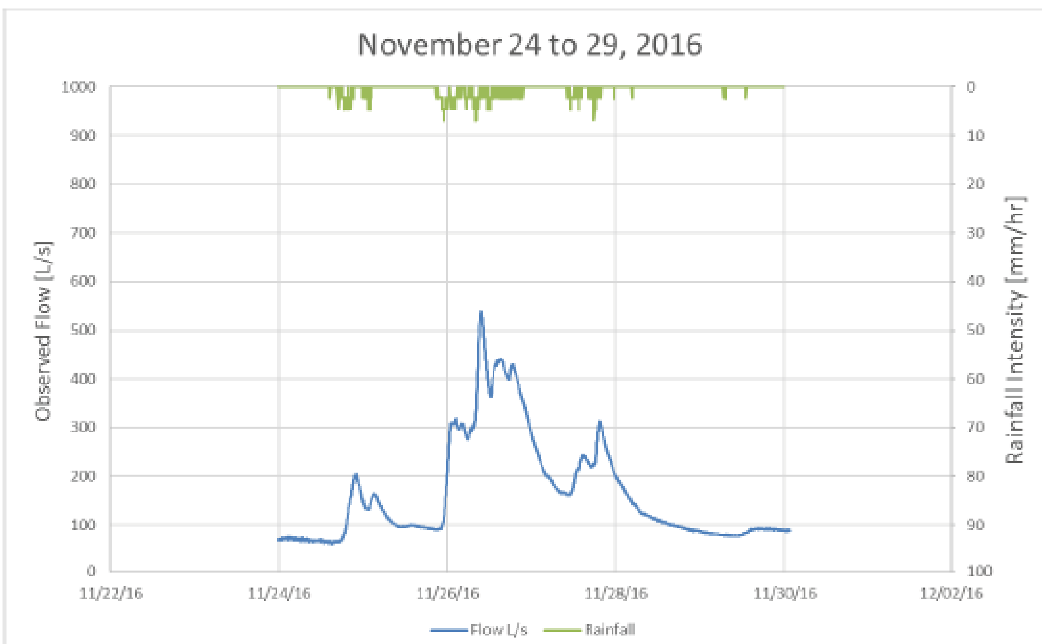


Figure 8-4
November 2016 Calibration Event

We also plotted the observed rainfall for these three calibration events on the rainfall intensity duration frequency curves for the White Rock STP rain gauge, as shown on Figure 8-5.

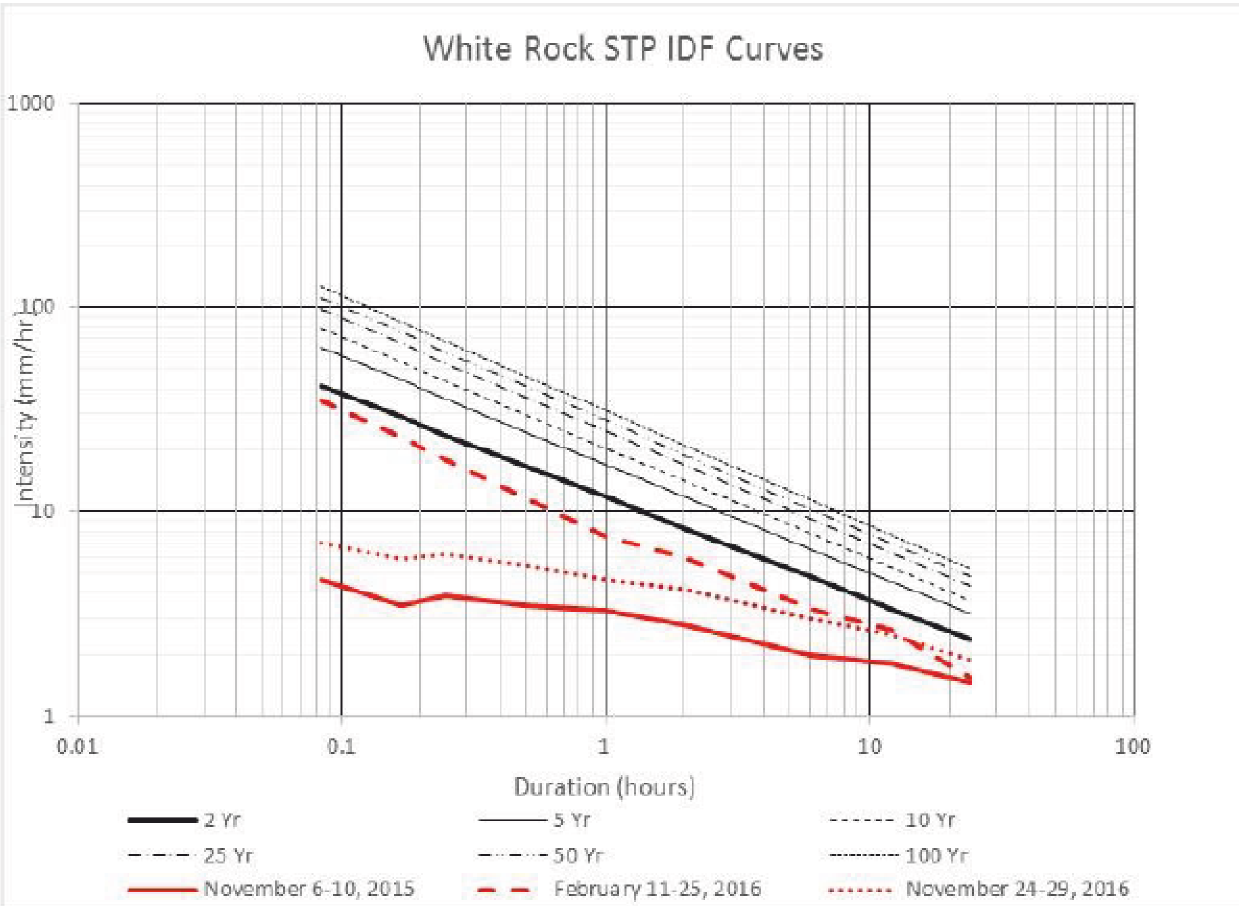


Figure 8-5
Calibration Events - Rainfall Intensity

As illustrated by Figure 8-5, all three observed rainfall events have return periods less than two years, with the largest of the three being the February 2016 event.

Using the initial hydrologic parameters that we developed as part of the PCSWMM modelling in Stage 1, we simulated the rainfall events, and compared the model output against the recorded flow data at the inlet of the 2400 mm x 1200 mm concrete box culvert.

We found that the PCSWMM model was underestimating the total runoff volumes for all three events, while also overestimating the peak flow rates for all three events. To correct this, we adjusted several hydrologic parameters and reran the model simulations. We continued this iterative process of reviewing the model results against the observed flow data and adjusting the hydrologic parameters until the simulated results matched reasonably well with the observed flows. Figures 8-6, 8-7, and 8-8 show the modelled flow rates plotted on top of the observed flow data for the three calibration events.

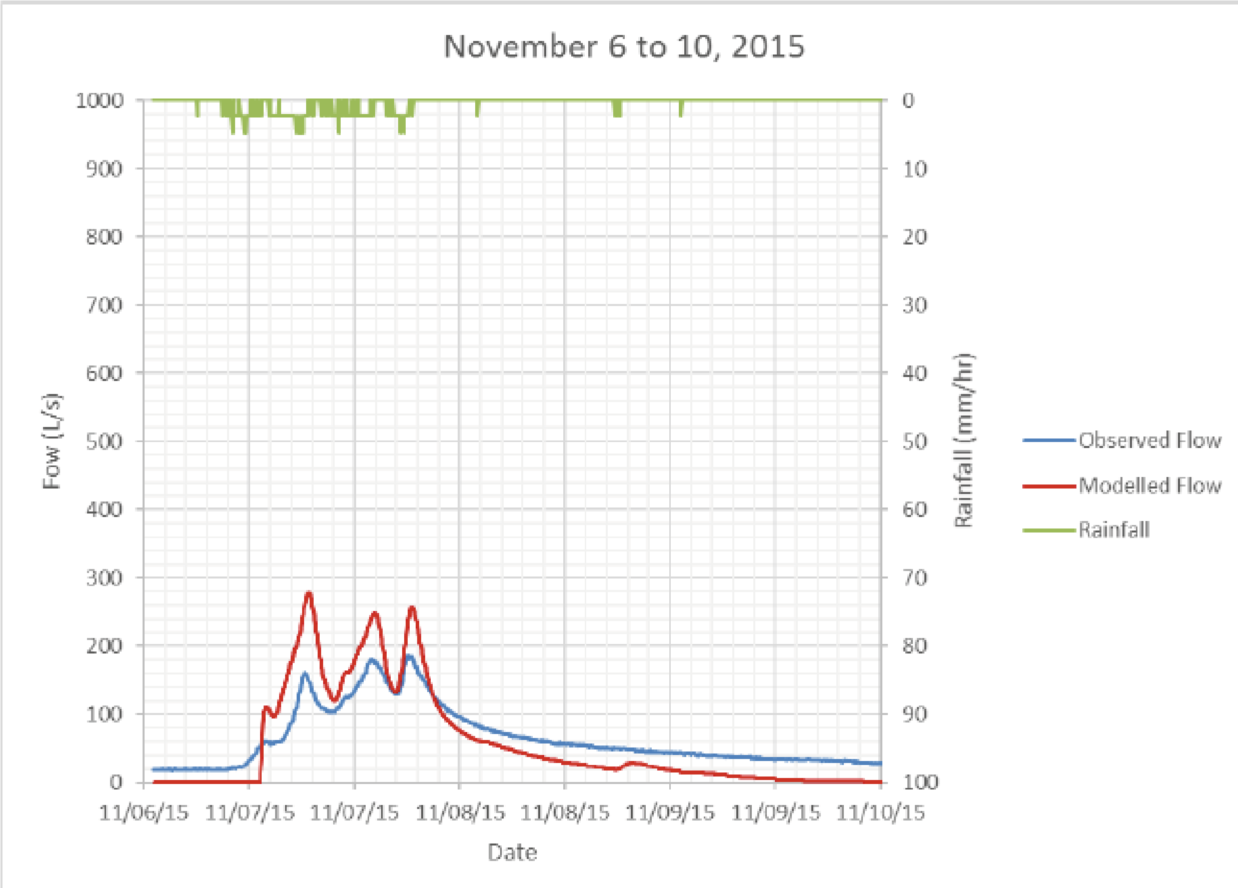


Figure 8-6
Calibration Results – November 2015

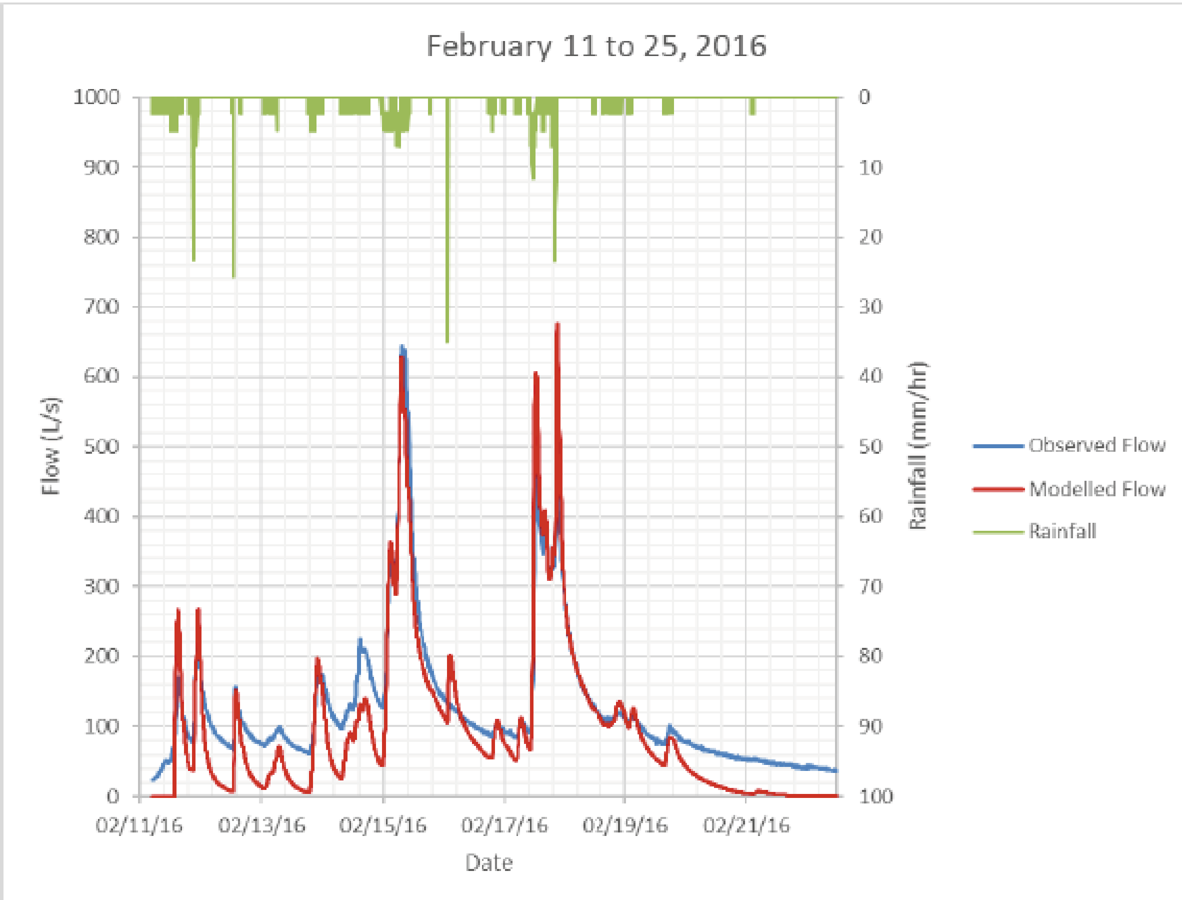


Figure 8-7
Calibration Results - February 2016

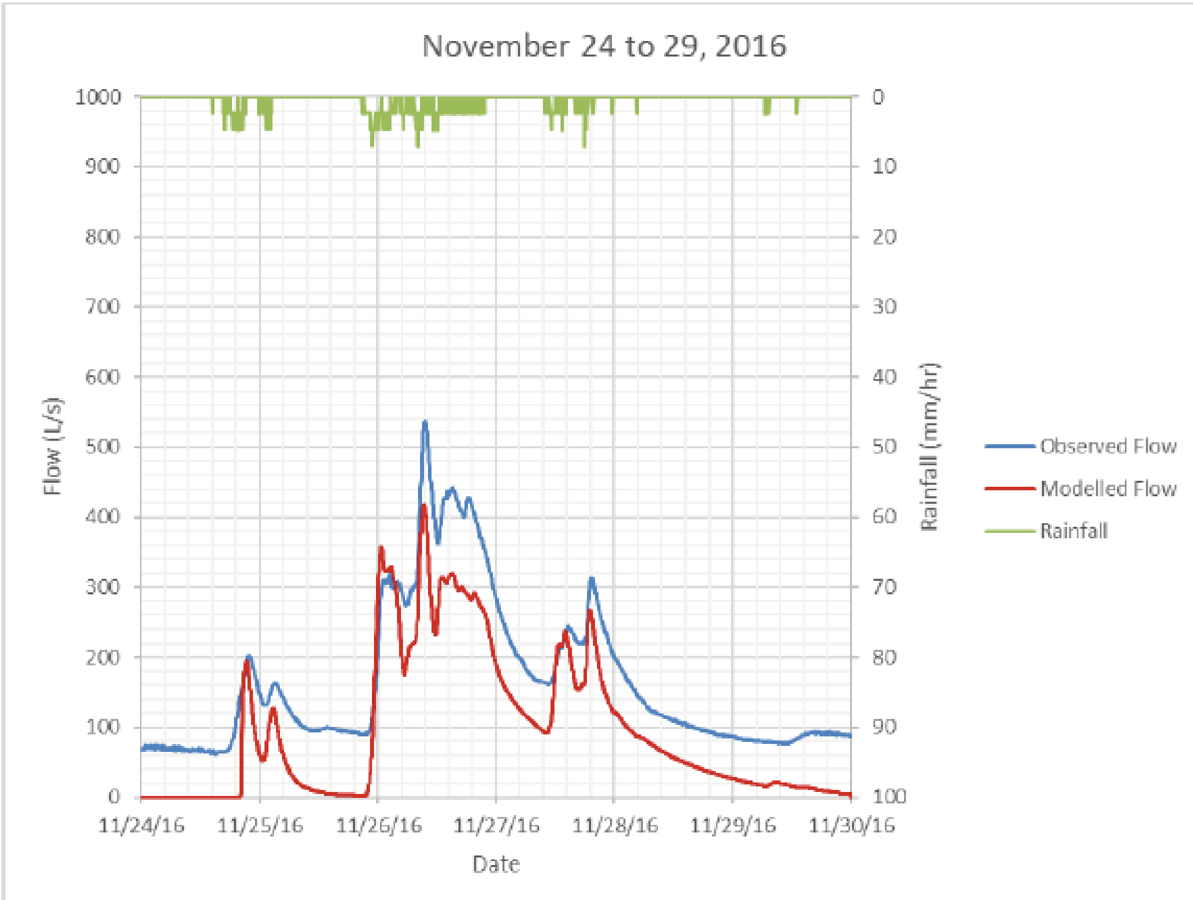


Figure 8-8
Calibration Results - November 2016

We understand that the November 24 to 29, 2016 calibration event was preceded by another significant rainfall event a few days earlier. The wet antecedent conditions may have contributed to elevated base flows during times of no rainfall observed during the calibration event. This could account for the 70 to 100 L/s flows that followed the peaks in the observed flow hydrograph presented in Figure 8-8. Despite the elevated base flows, we note that the modelled and observed peak flows are reasonably consistent.

As indicated by the calibration results, the modelled flow data matches reasonably well with the observed data for all three events. In particular, the model output shows a strong correlation with the recorded flow data for the February 2016 event, which was the most significant rainfall event on record from the available data.

Table 8-4 summarizes the hydrologic parameters based on our model calibration.

Table 8-4
Hydrologic Model Parameters Based on Calibration

	Initial Value	Calibrated Value
Maximum Infiltration Rate	10 mm/hr	4 mm/hr
Minimum Infiltration Rate	4 mm/hr	0.3 mm/hr
Decay Constant	4 hr^{-1}	4 hr^{-1}
Drying Time	7 days	7 days
Flow Length	Varies	× 20
Manning's "n" Impervious	0.020	0.020
Manning's "n" Pervious	0.400	0.800
Percent Impervious	Varies	÷ 1.2
Catchment Slope	Varies	÷ 1.2
Depression Storage Depth Impervious	3 mm	3 mm
Depression Storage Depth Pervious	10 mm	10 mm

8.4 CLIMATE CHANGE

As outlined in the "Development of Future IDF Statistics for the City of Surrey Final Report" (Dillon, 2015), rainfall intensities are expected to increase between 35% and 96% for the 2050's scenario.

In the future development scenario where climate change is included, we have applied an increase of 35% to each discrete point on the ADS hyetograph derived from the City's current IDF data. This corresponds to the lower band increase in intensities based on the 2015 Dillon report, and represents the minimum percent increase that should be considered when evaluating the potential impacts of climate change to the 2050's based on the available data. We recognize that the primary objective of considering climate change within the Sam Hill Creek ISMP is to identify areas that may be most susceptible to increased rainfall intensities. As a result, we have not used the adjusted hyetograph for determining upgrades.

Figure 8-9 presents a comparison of the ADS design storm with and without the 35% increase to account for climate change to the 2050's.

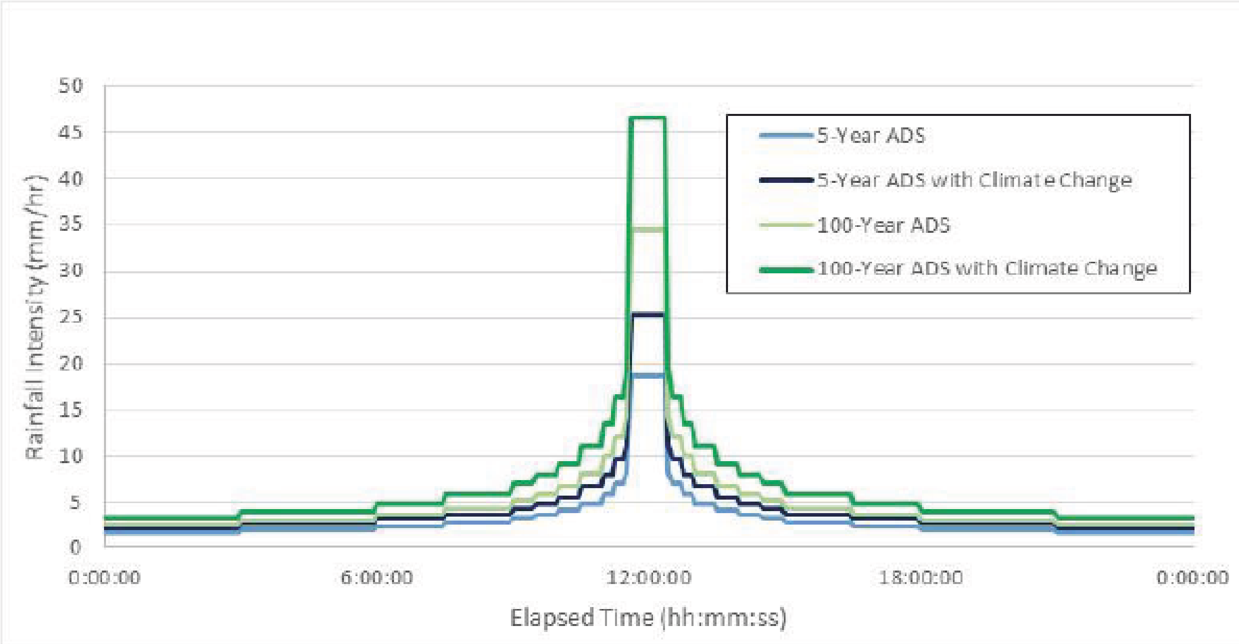


Figure 8-9
ADS Design Storms

8.5 LAND USE CHANGES

As noted, this ISMP is being completed in parallel with the Grandview Heights #3 NCP, which extends from 168 Street to 176 Street, and from 16 Avenue to 20 Avenue. Under existing conditions, this entire area is currently zoned as One Acre Residential, with the exception of Darts Hill Garden in the southwest corner. However, under the Grandview Heights #3 NCP, this area is going to be redeveloped with a variety of land uses. Table 8-5 summarizes the various land uses within the Grandview Heights #3 NCP, as well as the percent impervious values that we have modelled for each land use.

Table 8-5
Grandview Heights #3 NCP Land Uses

Land Use	Percent Impervious
Commercial	90%
School	80%
Institutional	80%
Low Density Multiple Residential	65%
Medium Density Multiple Residential	70%

Land Use	Percent Impervious
Multiple Residential Cluster	65%
Park	10%
Semi Detached Residential	80%
Urban Single Family	80%

North of 20 Avenue, future development is expected to occur as part of the Grandview Heights #5 NCP. While the Neighbourhood Community Plan for the Grandview Heights #5 area has not yet been developed, the City has indicated that increased urbanization is expected to occur. We have assumed that the area north of 20 Avenue will be developed as RF-12 (Single Family Residential (12) Zoning) as based on the Grandview Heights General Land Use Plan (GLUP). In accordance with the City's Design Criteria Manual, we have assumed that the percent impervious for this area will be 80%.

The existing lots immediately east of 176 Street between 16 Avenue and 18 Avenue may be redeveloped in the future. For these lots, we have assumed a percent impervious value of 70%.

Map 8-3 shows the land use under future development conditions.

8.6 MODEL RESULTS

We used different approaches for sizing potential storm sewer and culvert upgrades. For storm sewers, our approach was to introduce stormwater storage to attenuate peak flows on a widespread scale and then investigate upgrades for specific areas. We took this approach to be consistent with the City's criteria of attenuating peak flows to limit increases resulting from new development as described in the City of Surrey's DCM.

For developing culvert upgrade recommendations, our model does not include any stormwater detention. Since stormwater detention is sized to accommodate the 5-year return period design event, we have assumed there would be no attenuation at the 100-year return period event for investigating culvert upgrades. This is a conservative approach and the sizes recommended could potentially be reduced by the inclusion of appropriately sized stormwater detention in new development.

Culverts have been analyzed using a 100-year return period design event while storm sewers have been analyzed using the 5-year return period design event. We note that, at the direction of the City, the recommended drainage upgrades are based on the current rainfall data (i.e. not adjusted to account for climate change impacts).

8.6.1 Storage Requirements

The City's DCM outlines design criteria and servicing objectives for new developments. One of the objectives is to provide runoff control to reduce the impacts of increased imperviousness typical with new development. The DCM requires a new development to protect receiving waters from increased erosion by providing mitigation to meet the more stringent of the two following criteria:

- Control the 5-year post development flow to 50% of the 2-year post development rate; or
- Control the 5-year post development flow to the 5-year pre-development flow rate

Recognizing that the City's design criteria is to control the 5-year return period event, future development may affect flows exceeding this return period. The City should ensure that they have ROWs in place for all the watercourse and major flow path routes to ensure these areas can be maintained.

Table 8-6 shows the estimated storage volume requirements for the various criteria.

Our analysis shows that storage facilities sized to match the 5-year return period post-development flow to 50% of the 2-year return period post-development flow tends to be the most conservative criterion.

The DCM states storage ponds should have catchments no smaller than 20 ha. This approach works well for most areas of GHNCP #3 except for the southeast quadrant, where there are multiple channels with tributary areas less than 20 ha in area. In this area, flow controls would be used to maintain base flows to the existing channels while diverting the peak flows to a consolidated pond location. This is reflected in our model by directing the 5-year return period peak flows from catchments S07 and S32 to Storage Pond 6. This pond is sized to accommodate this increased drainage area, but the maximum discharge would still be limited to 50% of the 2-year return period peak flow of sub-catchment S26.

Based on a high-level assessment of the conceptual land use plans for GHNCP#3 and LiDAR data, it appears to be possible to route flows down the 172 Street and 174 Street ROWs and along the 16 Avenue ROW to Storage Pond 6. Existing piping along 16 Avenue may need to be replaced to accommodate the flow reroute as well as maintaining base flows to the existing channels.

The storage volumes calculated are based on an assumed grouping of catchments as described in Table 8-6. The catchment grouping was based on the existing infrastructure as well as available land use plans. Finalized land use plans could impact the storage volume and ultimate pond location.

In addition, BMP implementation may have an effect on required storage volume by reducing the total volume required. However, BMPs are typically intended to address rainfall arising from low-intensity, frequent storms, and may be overwhelmed in a significant storm event. An extreme storm event may also be preceded by a period of significant precipitation. In this case, the ground may be saturated, and the volume reduction benefit realized through infiltration-based BMPs may be limited. We have assumed that the BMPs will provide no volume reduction benefit for our modelling.

Table 8-6
Potential Stormwater Storage Facilities

Storage Location	Sub-Catchments	Total Catchment Area [ha]	Uncontrolled 5-year Post-Development Flow [m³/s]	Criteria 1: Control 5-year Post-Development Flow to 50% of 2-year Post-Development Flow*				Criteria 2: Control 5-year Post-Development Flow to 5-year Pre-Development Flow			
				Maximum Design Outflow [m³/s]	Allowable Release Rate [L/s/ha]	Required Storage Volume [m³]	Storage Volume per unit area [m³/ha]	Maximum Design Outflow [m³/s]	Allowable Release Rate [L/s/ha]	Required Storage Volume [m³]	Storage Volume per unit area [m³/ha]
1	S14, S13, S12, S11 and S10	42	0.805	**0.3325**	**7.9**	**12,391**	**295**	0.651	**15.5**	5,177	123
2	S34, S33 and S08	47	1.168	**0.314**	**6.7**	**13,362**	**287**	0.505	**10.9**	8,752	188
3	S31 and S06	32	0.552	**0.1705**	**5.3**	**4,222**	**131**	0.284	**8.8**	2,135	66
4	S29, S28_2 and S28_1	32	0.703	**0.242**	**7.7**	**9,104**	**288**	0.388	**12.3**	5,822	184
5	S09 and S27	32***	0.689	**0.247**	**7.7**	**10,595**	**331**	0.461	**14.4**	4,010	125
6	S26, S07, S32	32	0.766	**0.127**	**4.0**	**10,644**	**336**	0.200	**6.3**	7,204	228
				Average	**6.6**		**278**	Average	**11.4**		152

*Note that Criteria 1 governs (**bolded**).
**Maximum outflow at Storage Location 6 is sized based on subcatchment S26 only. Storage is based on combined runoff from S26, S07, and S32.
***There is a flow split upstream of Pond 5 (at Culvert 2) where some flow continues east along 18 Avenue and some flows south along 172 Street. The amount of flow splitting varies during the design event. The total catchment area potentially draining to this area is 72 ha, however, 32 ha from S09 and S27 is directly connected to the channel along 18 Avenue.

8.6.2 Storm Sewers

The City's design criteria require the storm sewer network to convey the 5-year return period storm event. We evaluated the existing storm sewer using this criterion. We then re-ran the model using the future land use conditions in addition to detention storage. We used this model to identify locations where the storm sewer still had capacity issues. Understanding that upgrading an upstream chokepoint could potentially cause downstream capacity issues, we used an iterative process of re-running potential upgrades to develop a set of recommended sewer improvements. Table 8-7 and Map 8-4 summarize these locations.

Table 8-7
Storm Sewer Upgrades

Storm Sewer Reference Location	Modelled Pipe	Length [m]	Existing Pipe	Proposed Pipe
A 172 Street north of 20 Avenue	P107*	48	450 mm dia Conc.	750 mm dia Conc.
	P108*	15	450 mm dia Conc.	750 mm dia Conc.
	P109*	15	450 mm dia Conc.	750 mm dia Conc.
B 20 Avenue west of 176 Street	P509_1	191	525 mm dia Conc.	675 mm dia Conc.
	P509_2	135	525 mm dia Conc.	900 mm dia Conc.
	P508	53	450 mm dia Conc.	900 mm dia Conc.
	P507	13	525 mm dia Conc.	900 mm dia Conc.

* Sized to 100-year return period design event.

The recommended storm sewer upgrades were developed using a model that included storage ponds so that the storm sewer upgrades could be developed assuming that peak flows were being attenuated. Storm sewers were then analyzed for their ability to convey peak flows without surcharging. If a sewer surcharged, it was upsized, and the model rerun until the it no longer surcharged in the future condition.

20 Avenue West of 176 Street (Location B)

The model results indicate that the existing storm sewer along 20 Avenue which flows east to 176 Street is undersized (Location B in Table 8-7). The pipe surcharges during the 5-year event, with the Hydraulic Grade Line (HGL) exceeding the ground elevation. The length of undersized storm sewer is approximately 410 m, with existing diameters varying between 450 mm and 525 mm. The sewer is quite flat along 20 Avenue, ranging between 0.3 and 0.4% towards the intersection with 176 Street. To provide sufficient conveyance capacity, we recommend increasing the pipe diameter for this sewer.

176 Street South of 20 Avenue

Based on the model results, the existing storm sewer that runs south along 176 Street from 20 Avenue to just north of 14 Avenue has sufficient capacity to convey the 5-year flows. This storm sewer is surcharged near the downstream end where it discharges into an open channel; however, the elevated water level at this location is due to the limited capacity of the downstream channel rather than the capacity of the storm sewer itself.

176 Street South of 16 Avenue (East Side of Road)

South of 16 Avenue, there is a 600 mm / 675 mm diameter concrete storm sewer which drains south along the east side of 176 Street for approximately 120 m before connecting to the main storm sewer under 176 Street. This parallel pipe conveys runoff from the area north of 16 Avenue and east of 176 Street. Based on the model results, this pipe has sufficient capacity for the 5-year event in both the existing and future condition. We note that potential redevelopment east of 176 Street could increase peak flows through this sewer. However, maintaining the allowable release rate will reduce the impacts to downstream areas during the minor design event. For major events, downstream culverts have been upgraded or assessed to convey the 100-year return period design event.

18 Avenue East to 176 Street

Along 18 Avenue, there is approximately 192 m of existing 450 mm PVC storm sewer that ties into the 176 Street system. This storm sewer meets the design criteria in the future scenario with detention ponds.

172 Street at 21 Avenue (Location A)

At the intersection of 172 Street and 21 Avenue (Location A in Table 8-7), there are two short segments of 450 mm diameter concrete storm sewer. The portion of pipe that flows in from the west appears to have sufficient capacity. However, it is backwatered by the downstream pipe along 172 Street, and surcharges to ground. The portion of pipe that flows south along 172 Street has sufficient capacity upstream of the confluence with flows from the west; however, as noted, the pipe immediately downstream of 21 Avenue surcharges. These pipes appear to function as a part of the major drainage system as they are just downstream from Culvert 4 and we have sized upgrades using the 100-year return period design event.

172 Street Crossing 16 Avenue

Further south along 172 Street, there is an existing 600 mm / 750 mm diameter concrete storm sewer that starts at 16 Avenue and flows south for approximately 260 m. This system appears to have sufficient capacity for the existing 5-year event under existing conditions however it surcharges in the future condition if development occurs, but detention ponds are not constructed. This sewer meets design criteria when detention ponds are implemented.

16 Avenue East to Culvert 10 (Crossing 172 Street)

Just west of this system, there is a 600 mm diameter concrete storm sewer which flows east along 16 Avenue and ties into Culvert 10; this 600 mm diameter storm sewer has sufficient capacity to convey the 5-year flows. Culvert 10 discharges into an open channel which flows southeast and drains into the storm sewer along 172 Street. There is a 600 mm diameter concrete pipe at this location where the flows connect into the storm sewer; this 600 mm inlet has sufficient capacity of the 5-year event.

16 Avenue East of 172 Street

Just east of 172 Street, there is a 750 mm diameter concrete storm sewer which flows east for approximately 50 m along 16 Avenue, and then discharges south into Upper Sam Hill Creek. This 750 mm storm sewer has sufficient capacity for the 5-year event.

Crossing 16 Avenue 240 m West of 176 Street

Further east along 16 Avenue, there is a small diameter storm sewer system which captures flows from north of 16 Avenue and conveys them to a 400 mm diameter concrete outlet that discharges to the south approximately 240 m west of 176 Street. This 400 mm diameter crossing appears to have sufficient capacity for the existing condition 5-year event but surcharges in the future event. We note that there are sections of 16 Avenue where the ditch is infilled between 176 Street and 172 Street. Storage Location 6 would be located near here to provide attenuation for sub-catchments S26, S32, and S07.

We note that the storm sewer upgrades were developed using a model that does not include BMPs. BMPs would have an attenuating effect on peak flows and may reduce the total volume of the design storm event. However, BMPs are typically designed to address frequent rainfall events, so it is likely that they would be overwhelmed during the minor system design storm event. In addition, BMP implementation may not be consistent throughout the watershed over time. By not including the BMPs in this model, the storm sewer upgrades are conservative.

There is an additional, parallel storm sewer along 176 Street from 20 Avenue to 16 Avenue along the east side of the road. There appears to be a missing GIS link in the sewer just north of 16 Avenue. However, we believe this storm sewer ties in to the sewer on the east side of 176 Street south of 16 Avenue which ultimately drains into the main 600 mm diameter sewer running down the west side of the road. Since the existing sewer has capacity for the existing and future condition, we have assumed this additional sewer is for road drainage only and have not included it in our model.

8.6.3 Culverts

We determined the risk by assessing the limiting property or road crest elevation near the culvert inlet and comparing the peak Hydraulic Grade Line (HGL) during the design event with this value. Where there was less than 150 mm freeboard, we assessed the culvert to determine the cause and if a culvert upgrade was required. Where required, we upgraded the culvert and reran the model to observe if the upgrade had caused downstream capacity issues. If it had, we upgraded the downstream culvert accordingly and continued this iterative process to confirm all capacity issues were addressed.

Applying our minimum freeboard criterion to the future model has highlighted issues with culverts 2, 3, 4, 5, 7, 11, and 13. Hydraulic results for all analyzed culverts are provided in Table 8-8 and Table 8-9 and recommended upgrades are described in Table 8-10. See Map 8-5 for locations.

Table 8-8 shows the results of the 5-year design storm. We note that the future scenario with upgrades model also includes storage ponds as they are intended to improve hydraulic functioning during the 5-year return period design event. However, these results are shown for information. Culvert sizing analysis was conducted using the 100-year return period design event model.

Table 8-10
Recommended Culvert Upgrades

Culvert Reference Location	Location Description	Existing Pipe	Proposed Pipe	Future Development, 100-year ADS (with upgrades)		
				Peak Flow [m³/s]	HGL [m]	Freeboard [m]
C2*	Crossing 18 Ave. along 172 St.	600 mm dia Conc.	1500 mm dia Conc.	2.838	72.72	0.18
C3*	Crossing 20 Ave. along 172 St.	600 mm dia Conc.	1500 mm dia Conc.	1.705	90.53	0.37
C4	Crossing 171 St. at 21 Ave.	450 mm dia Conc.	750 mm dia Conc.	0.547	98.91	0.19
C5	Crossing 12 Ave. at 17800 Block	600 mm dia Conc.	675 mm dia Conc.	0.625	11.49	0.21
C7	Crossing 12 Ave. at 17900 Block	300 mm dia Conc.	375 mm dia Conc.	0.159	12.34	0.46
C11*	Crossing 170 St. on 16 Ave.	450 mm dia Conc.	750 mm dia Conc.	0.381	42.45	0.25
C13*	Crossing 18 Ave. along 172 St. ROW	600 mm dia Conc.	1500 mm dia Conc.	2.366	72.61	0.19

* Within the boundaries of NCP#3 drainage capacity issues will be managed by future developers as the NCP is realized. As a result, the City should not need to address culvert upgrades as separate issues.

We note that most culverts show peak flows increasing from the "Future Development Without Upgrades" to the "Future Development With Upgrades" scenarios (Culverts 1, 2, 3, 7, 9, 10, 13, 14). The main criterion for determining culvert upgrades was surcharging risk and maintaining adequate freeboard to spill elevations. For some culverts, even though the peak flow and HGL increases significantly, the margin of freeboard may still be greater than 150 mm. This is consistent with the City's preferred approach of utilizing available online storage in ditches to reduce pipe upgrade sizes.

Culvert 2 is recommended to be upgraded as the current culvert surcharges during the design event with some flow being diverted along 18 Avenue. Once the culvert is upgraded to meet the freeboard criterion, the culvert capacity is increased enough to reduce the flow rate being diverted along the ditch and increase flow through the culvert. This is reflected in the peak flow experienced during the design event as shown in Table 8-9.

Table 8-8
Model Results – 5-Year ADS

Location ID	Conduit ID	Existing Pipe	Upgraded Pipe	Road Crossing	Limiting Elevation [m]	Existing Development		Future Development Without Upgrades		Future Development with Upgrades and Ponds	
						Peak Flow [m³/s]	Peak HGL [m]	Peak Flow [m³/s]	Peak HGL [m]	Peak Flow [m³/s]	Peak HGL [m]
1	P101	1800x1200 Conc Box Culvert		176 St	13.6	3.56	10.87	4.88	11.18	1.93	10.48
2	P105	600 Conc Culvert	1500 Conc Culvert	18 Ave	72.9	0.48	72.22	0.80	72.66	0.45	72.06
3	P106	600 Conc Culvert	1500 Conc Culvert	20 Ave	90.9	0.55	90.27	0.68	90.52	0.28	89.72
4	P110	450 Conc Culvert	750 Conc Culvert	171 St	99.1	0.16	98.69	0.23	98.87	0.27	98.71
5	P201	600 Conc Culvert	675 Conc Culvert	12 Ave	11.7	0.31	11.17	0.31	11.17	0.31	11.14
6	P202	750 Conc Culvert		16 Ave	19.7	0.18	19.03	0.18	19.03	0.18	19.03
7	P251	300 Conc Culvert	375 Conc Culvert	12 Ave	12.8	0.08	12.16	0.08	12.16	0.08	12.06
8	P301	1400x950 CSP Arch Culvert		12 Ave	14.1	0.21	13.35	0.21	13.35	0.21	13.35
9	P401	750 Conc Culvert		172 St	18.4	0.24	18.22	0.29	18.51	0.27	18.06
10	P603	600 Conc Culvert		16 Ave	37.7	0.28	36.64	0.53	36.75	0.14	36.57
11	P605	450-525 Conc Culvert	750 Conc Culvert	170 St	42.7	0.13	42.33	0.18	42.39	0.18	42.33
12	P701	900 Conc Culvert		16 Ave	35.2	0.16	32.07	0.28	32.16	0	31.87
13	P901	600 Conc Culvert	1500 Conc Culvert	18 Ave	72.8	0.51	72.25	0.83	72.88	0.26	71.97
14	P401a	2400 x 1200 Conc Box Culvert		Driveway	18.1	1.45	17.81	2.16	18.01	0.92	17.62

Table 8-9
Model Results – 100-Year ADS

Location ID	Conduit ID	Existing Pipe	Upgraded Pipe	Road Crossing	Limiting Elevation [m]	Existing Development		Future Development Without Upgrades		Future Development with Upgrades and No Ponds	
						Peak Flow [m³/s]	Peak HGL [m]	Peak Flow [m³/s]	Peak HGL [m]	Peak Flow [m³/s]	Peak HGL [m]
1	P101	1800x1200 Conc Box Culvert		176 St	13.6	6.04	11.47	7.30	11.87	7.63	12.00
2	P105	600 Conc Culvert	1500 Conc Culvert	18 Ave	72.9	0.78	72.60	1.35	74.27	2.84	72.72
3	P106	600 Conc Culvert	1500 Conc Culvert	20 Ave	90.9	0.72	90.62	0.86	90.96	1.70	90.53
4	P110	450 Conc Culvert	750 Conc Culvert	171 St	99.1	0.26	99.07	0.28	100.33	0.55	98.91
5	P201	600 Conc Culvert	675 Conc Culvert	12 Ave	11.7	0.58	11.65	0.58	11.65	0.63	11.49
6	P202	750 Conc Culvert		16 Ave	19.7	0.37	19.22	0.37	19.22	0.37	19.22
7	P251	300 Conc Culvert	375 Conc Culvert	12 Ave	12.8	0.14	12.69	0.14	12.69	0.16	12.34
8	P301	1400x950 CSP Arch Culvert		12 Ave	14.1	0.45	13.51	0.45	13.51	0.45	13.51
9	P401	750 Conc Culvert		172 St	18.4	0.48	18.76	0.37	19.27	0.69	19.76
10	P603	600 Conc Culvert		16 Ave	37.7	0.58	36.77	0.94	36.97	1.01	37.33
11	P605	450-525 Conc Culvert	750 Conc Culvert	170 St	42.7	0.26	42.70	0.33	43.06	0.38	42.45
12	P701	900 Conc Culvert		16 Ave	35.2	0.32	32.19	0.57	32.33	0.57	32.33
13	P901	600 Conc Culvert	1500 Conc Culvert	18 Ave	72.8	0.80	72.79	1.32	74.36	2.37	72.61
14	P401a	2400 x 1200 Conc Box Culvert		Driveway	18.1	2.43	18.07	3.11	18.23	3.65	18.35

Culvert 4 is recommended to be upgraded as the culvert appears to restrict the flow and surcharge excessively upstream during the 100-year design event. Upsizing this culvert would reduce the flooding risk of nearby properties. During the 5-year event, flows are increased as this culvert is upstream of the proposed storage pond. Flow rates increase in the “upgrade” scenario due to the removal of a bottleneck by the upgraded storm sewer pipes (Location A) downstream. In the existing and future scenarios, this bottleneck backwaters Culvert 4, reducing the peak flow.

Culverts 5 and 7 are located within the southern ALR zone of the study area and both cross 12 Avenue. These culverts appear undersized during the design event with only a marginal freeboard. We recommend these culverts be upgraded. We note that the flow rates for these culverts increases slightly in the upgraded scenario – likely because of the increased culvert capacity and reduced online storage.

Culverts 3, 11, and 13 would benefit from being upgraded as these culverts surcharge excessively during the design event presenting a flooding risk. However, all of these culverts are located within the Grandview Heights NCP #3 area. We understand that these will be upgraded as part of the GHNCP #3 redevelopment.

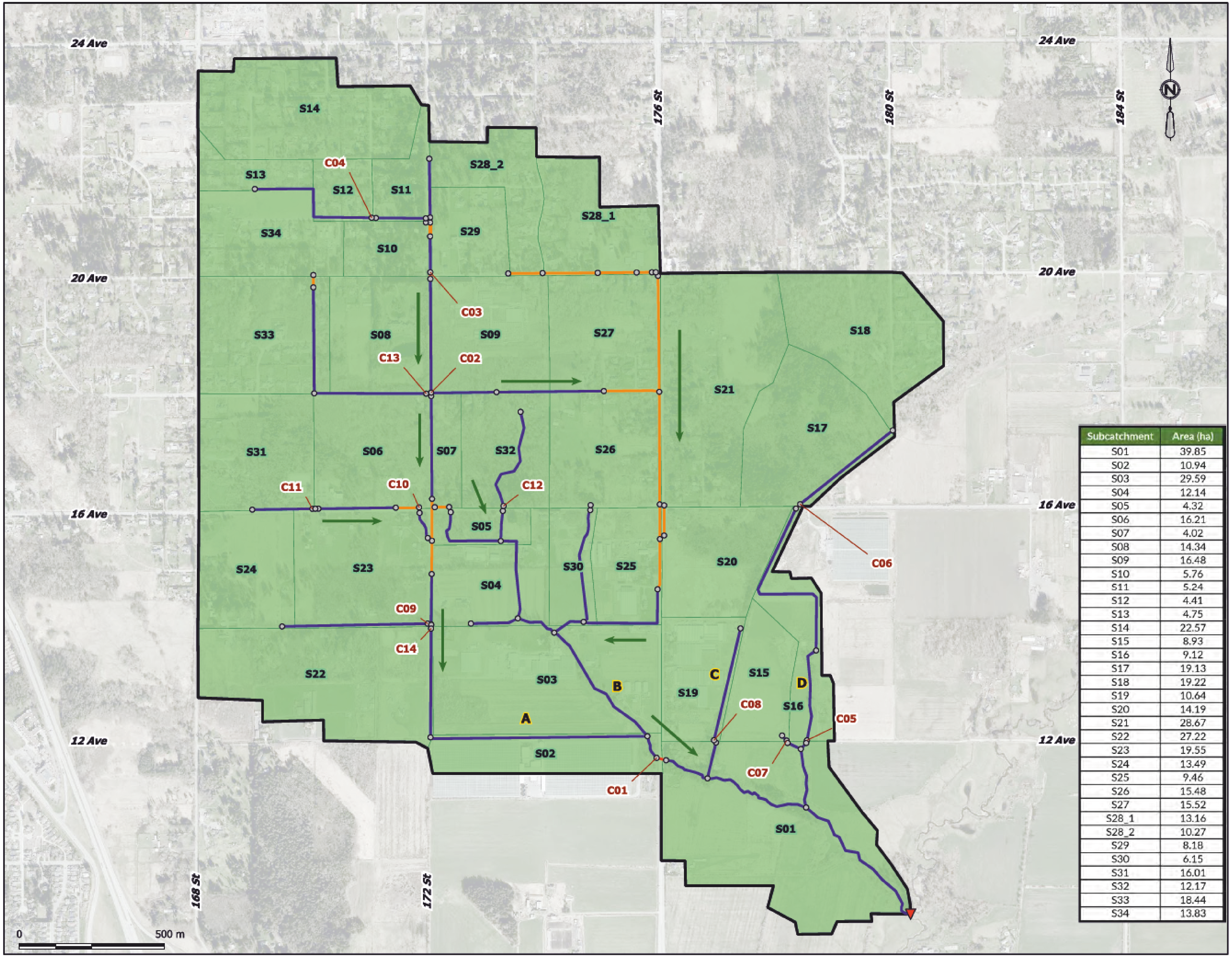
Peak HGLs at Culvert 9 suggest that flooding could be an issue during the design event. However, this culvert is located just upstream from a flow measurement weir located at 14 Avenue and 172 Street. As a result, this culvert surcharges due to the downstream influence of the weir – upgrading the culvert would not improve the hydraulic condition. We further note that the reduced flow rate observed in the future scenario without upgrades over existing stems from the influence of the heightened water level over the weir backwatering the culvert.

Also influenced by the weir at 14 Avenue and 172 Street, Culvert 14 has a peak HGL that is higher than the adjacent ground in the property immediately to the east of the inlet. However, the head-losses through the culvert are small and the downstream channel appears to have sufficient capacity for the design event. Our field reconnaissance suggests that there may be a hydraulic connection to the east during high flows and there is a poorly defined channel running east along 14 Avenue which eventually joins Sam Hill Creek. We recommend re-establishing this connection to the east with a properly designed high-flow connection to the channel. Alternatively, the City could construct a berm to contain flows near the weir. See Map 8-5 for culvert upgrade locations.

We note that Culverts 2, 3, and 13 are located downstream of proposed storage ponds. The upgrades recommended in Table 8-9 for these culverts may be conservatively high because no storage ponds were included in the model used to size them. Including storage ponds would attenuate the peak flows and lower the demand on the culvert capacity and a smaller culvert may be adequate. This a conservative assumption, however, it is valid since the storage ponds have been sized to the 5-year return period event and attenuation during the 100-year culvert design storm event may be limited.

Similarly, BMPs have not been included in the 100-year return period culvert sizing models as they would likely have little effect on peak flow attenuation during an extreme event.

The culvert upgrades recommended are based on the existing road network but with redeveloped land use. This is appropriate for a planning-level study. In the GHNCP#3 area, the road network will likely be altered as the land uses are finalized and designs are developed. As a result, the proposed upgrades may be superseded by upgrades developed by future designers.



Subcatchment	Area (ha)
S01	39.85
S02	10.94
S03	29.59
S04	12.14
S05	4.32
S06	16.21
S07	4.02
S08	14.34
S09	16.48
S10	5.76
S11	5.24
S12	4.41
S13	4.75
S14	22.57
S15	8.93
S16	9.12
S17	19.13
S18	19.22
S19	10.64
S20	14.19
S21	28.67
S22	27.22
S23	19.55
S24	13.49
S25	9.46
S26	15.48
S27	15.52
S28_1	13.16
S28_2	10.27
S29	8.18
S30	6.15
S31	16.01
S32	12.17
S33	18.44
S34	13.83

LEGEND

- Catchment Area
- Open Channel
- Storm Sewer
- Culvert
- Node
- Outfall
- C01 — Culvert Label
- A — EPS Reporting Location
- S01 — Subcatchments
- Flow Direction

SCALE:	AS SHOWN		
PROJECT NO.	2017-2991	INITIAL	DATE
DRAWN		EF	18-09-21
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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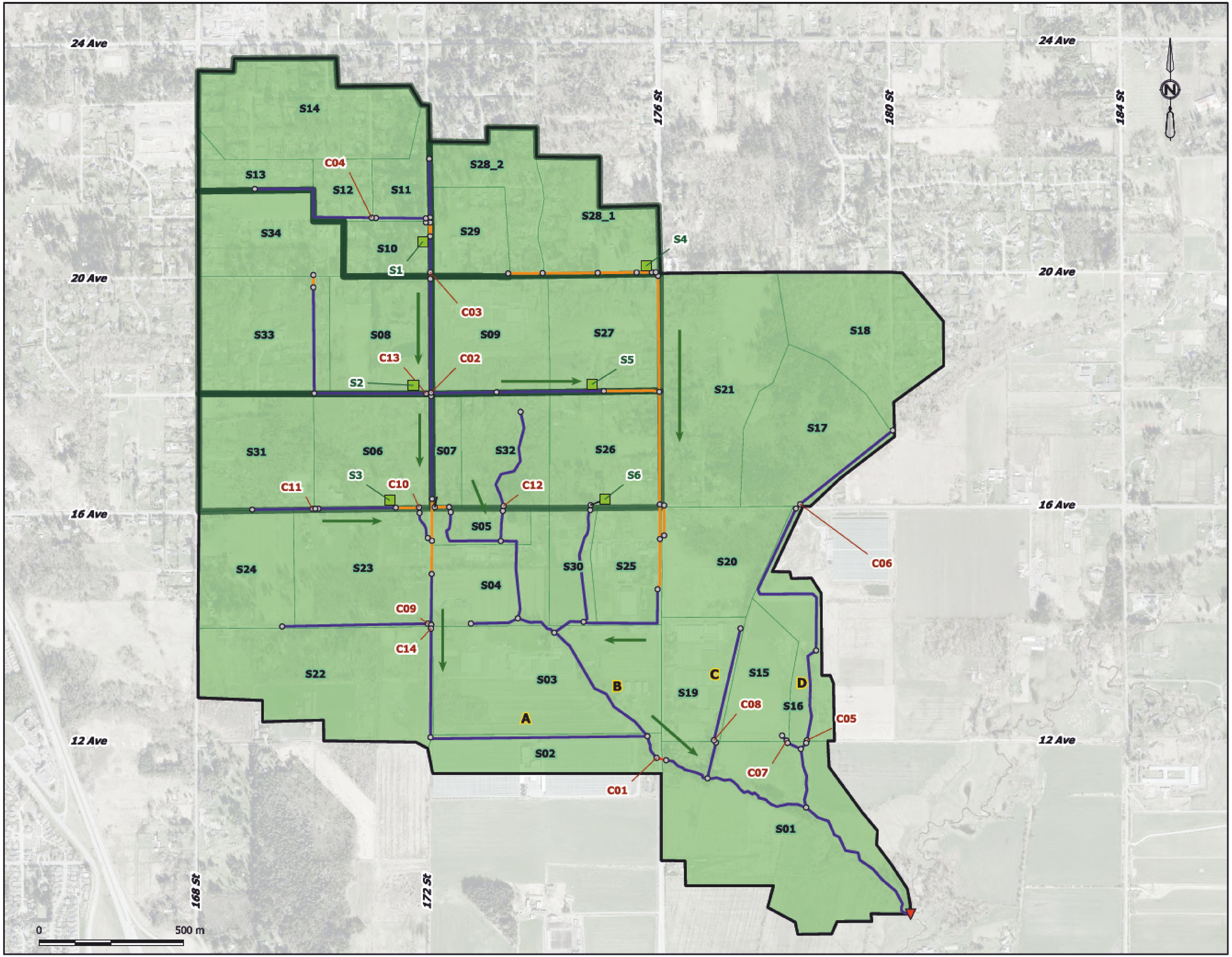
EXISTING PCSWMM MODEL

DRAWING NUMBER	REV. NO.	SHEET
MAP 8-1		



LEGEND

- Catchment Area
- Pond Catchment
- Open Channel
- Storm Sewer
- Culvert
- Node
- Outfall
- S1 Storage Location
- C01 Culvert Label
- A EPS Reporting Location
- S01 Subcatchments
- Flow Direction

SCALE:	AS SHOWN		
PROJECT NO.	2017-2991	INITIAL	DATE
DRAWN		EF	18-09-21
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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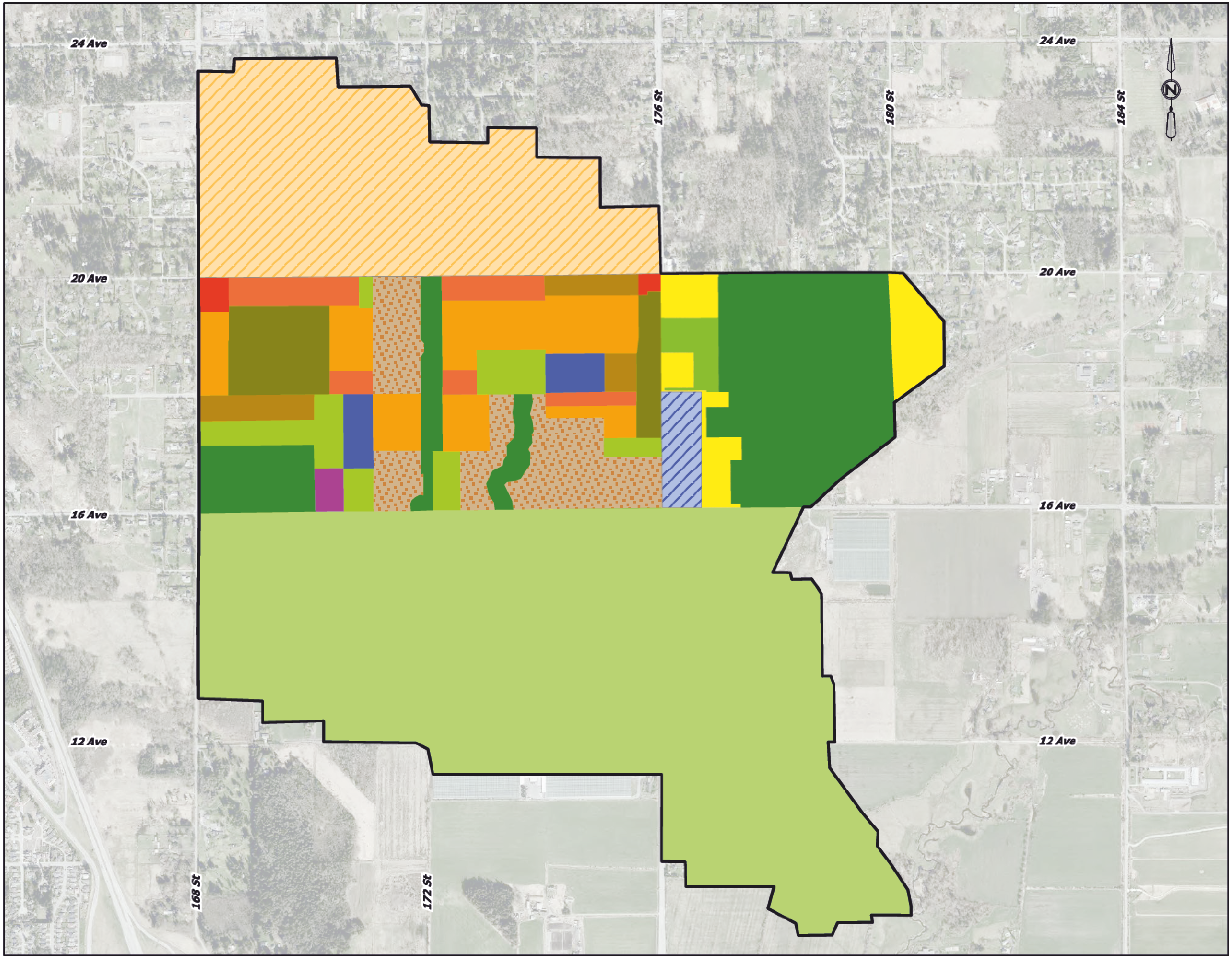
FUTURE PCSWMM MODEL

DRAWING NUMBER	REV. NO.	SHEET
MAP 8-2		



Map File: C:\Users\fmneye\Desktop\map_Surrey_SamHill_20190118.map

LEGEND

ISMP Study Area

Land Use

- RF-12 (GH#5NCP)
- Development
- Commercial
- Future School
- Institutional
- Low Density Multiple Residential
- Med Density Multiple Residential
- Multiple Residential Cluster
- Semi-Detached Residential
- Urban Single Family
- Riparian Area
- Existing Park
- Future Park
- Agricultural
- One Acre Residential Zone (<1ha)
- One Acre Residential Zone (>1ha)

SCALE:	AS SHOWN		
PROJECT NO.	2017-2991	INITIAL	DATE
DRAWN		JT	17-11-10
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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0 500 m

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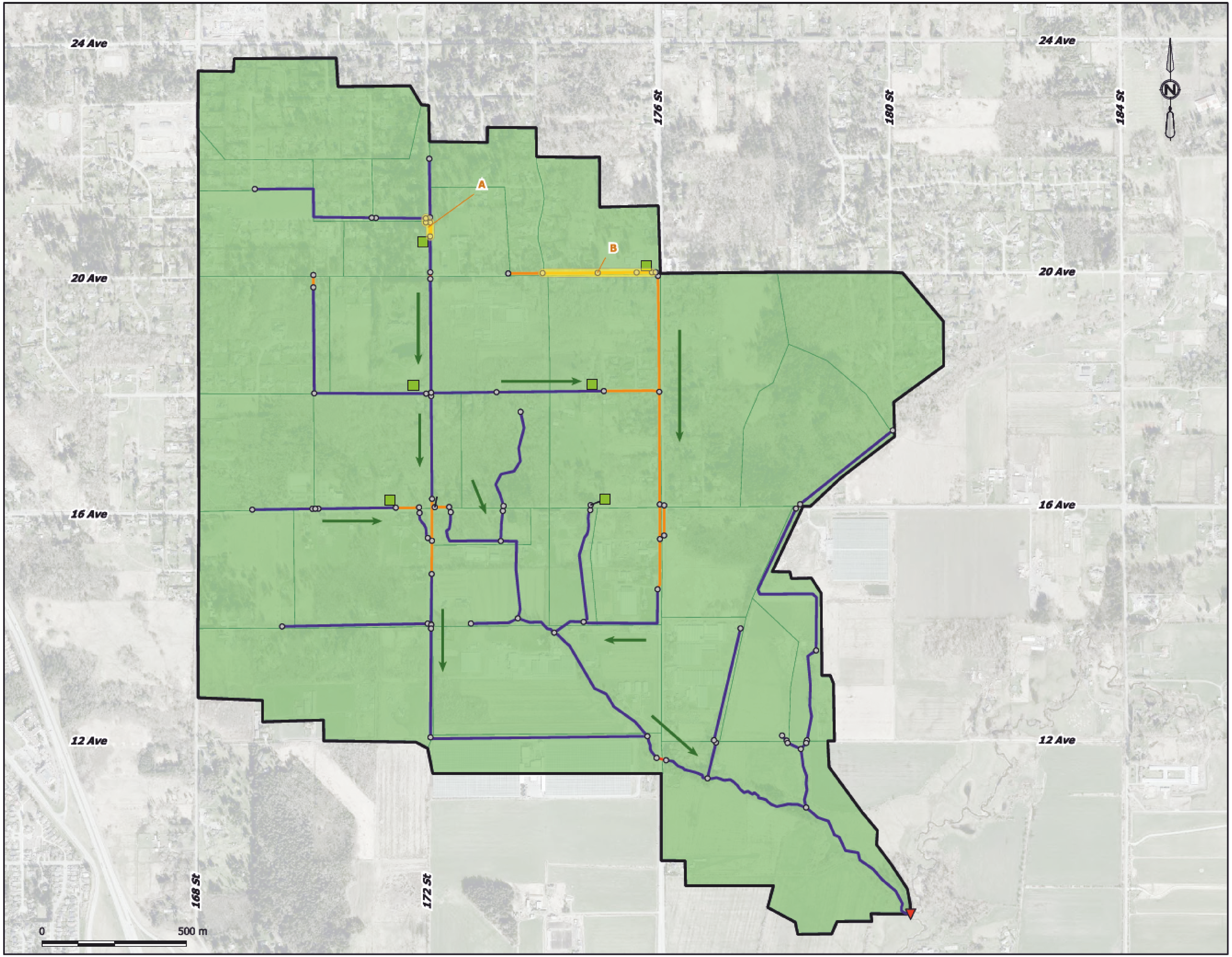
MODELLED LAND USE

DRAWING NUMBER	REV. NO.	SHEET
MAP 8-3		



LEGEND

- Catchment Area
- Open Channel
- Storm Sewer
- Culvert
- Node
- Outfall
- Flow Direction

SCALE:	AS SHOWN		
PROJECT NO.	2017-2991	INITIAL	DATE
DRAWN		EF	18-09-21
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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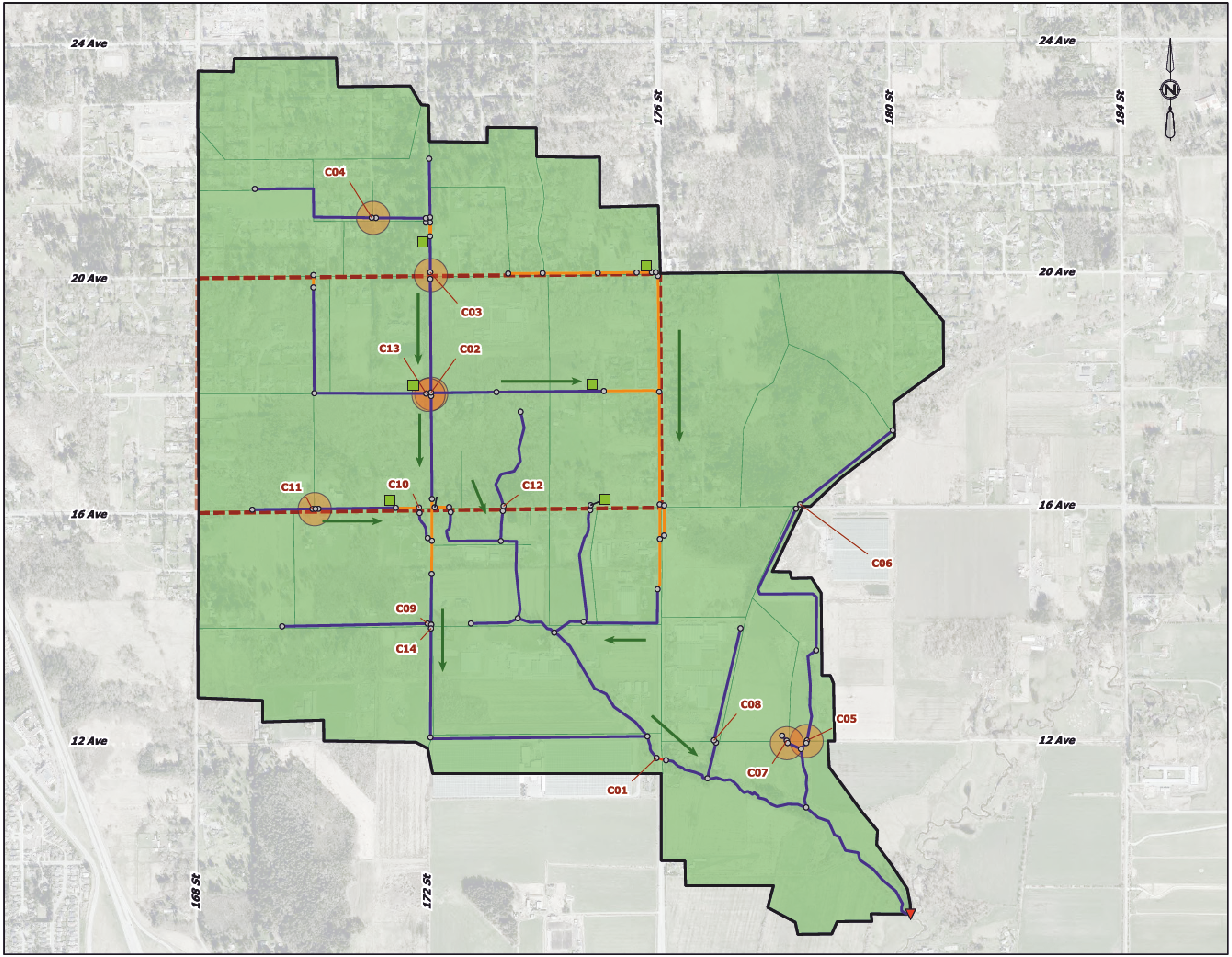
STORM SEWER UPGRADES

DRAWING NUMBER	REV. NO.	SHEET
MAP 8-4		



LEGEND

	Catchment Area
	Open Channel
	Storm Sewer
	Culvert
	Grandview Heights NCP #3
	Node
	Outfall
	Culvert Upgrades
C01	Culvert Label
	Flow Direction

SCALE:	AS SHOWN		
PROJECT NO.	2017-2991	INITIAL	DATE
DRAWN		EF	18-09-21
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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SAM HILL CREEK ISMP

CULVERT UPGRADES

DRAWING NUMBER	REV. NO.	SHEET
MAP 8-5		

9 Assessment of Potential Impacts

We ran several four-year continuous simulations of the drainage network to compare the existing and future conditions in the watershed. This allows us to analyze the potential impacts of development in the Sam Hill Creek study area, with and without mitigative measures such as Low-Impact Developments (LIDs) and Best-Management Practices (BMPs). We used the Water Balance Model (WBM) to evaluate the effectiveness of the potential Best Management Strategies for the study area.

The purpose of the simulation is to assess the impact of development on the hydrologic regime in natural watercourses. This provides an indication of changes in flow-duration characteristics following development, which can indicate locations where accelerated stream erosion may arise. Accelerated erosion poses a risk for developments situated near the edges of ravines, can detrimentally affect aquatic habitat, and can cause sediment accumulation that leads to reduced channel capacity and possible flooding in lowland reaches.

9.1 EXTENDED PERIOD SIMULATION

To assess the impact of development on the hydrologic regime in natural watercourses we completed Extended Period Simulation (EPS) modelling for two scenarios based on the:

(1) Existing land uses
(2) Future land uses

The first scenario was based on existing land use, while the second scenario is based on future land uses. The modifications to the land use under future development conditions are the same as those used for the event-based models, as discussed in Section 8.

9.1.1 Rainfall Data

We used rainfall data spanning from January 1, 2013 to December 31, 2016 from the White Rock STP rain gauge, as shown in Figure 9-1.

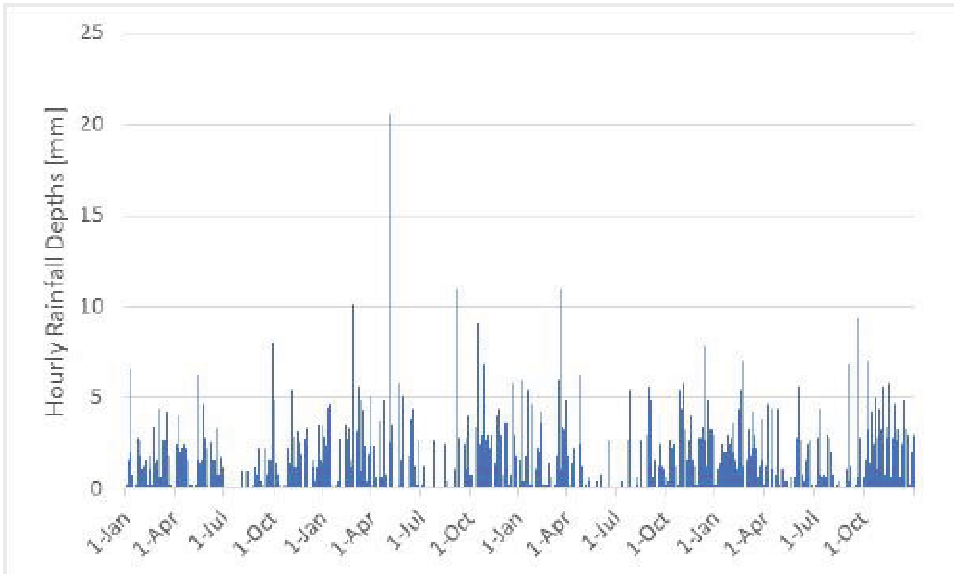


Figure 9-1
White Rock STP Rainfall Data 2013 - 2016

The Canadian Climate Normals data for White Rock STP indicates an average annual rainfall of 1108 mm. The period selected for the EPS simulation has an average annual rainfall of 1201 mm, representing a slightly higher than average, yet representative, amount of annual rainfall.

9.2 POTENTIAL IMPACTS OF DEVELOPMENT

9.2.1 Hydrologic Impacts

The EPS modelling is based on actual recorded rainfall data over an extended period, not on synthetic design events. As such, it is representative of the typical rainfall events that occur within the study area, and therefore provides quantitative insight into the study area's response to development, absent any mitigation measures such as source controls or BMPs.

We used EPS modelling to assess two fundamental scenarios, the existing and future, unmitigated scenarios (Scenarios 1 and 2). The key hydrologic results from these two EPS models are summarized in Table 9-1.

Table 9-1
Hydrologic Results from Extended Period Simulation of Entire Model

	Existing Development	Future Development	Change
Impervious Percent (%)	23.1%	43.2%	+86.3%
Runoff Volume (10^3 m^3)	7,634	11,360	+48.9%
Total Infiltration (mm)	111,181	81,677	-26.5%

The increased impervious area associated with the future development condition results in an increase in the total runoff volume. This is also consistent with the results from the event-based modelling described in Section 8, which demonstrated increases in the peak flow rates under future development conditions. The increase in impervious area within the study area also reduces the total infiltration, as there is an increase in hard surfaces which cannot accommodate infiltration.

We created flow-duration-exceedance curves at four locations:

- Sam Hill Creek Diversion, along 12 Avenue between 172 Street and 176 Street
- Sam Hill Creek, between 14 Avenue and 12 Avenue
- Tributary 1, north of 12 Avenue
- Thomson Creek, north of 12 Avenue

The curves are presented in Figure 9-2, and the reporting location for each curve is identified on Map 9-1. These curves represent the fraction of the total simulation time that a particular flow rate is exceeded in each watercourse.

Under future development conditions, both Sam Hill Creek (Point B) and the Sam Hill Creek Diversion (Point A) are subject to significant increases in the occurrence of high flows. This increase in the occurrence of high flows is consistent with the fact that there is a significant amount of redevelopment and urbanization that is expected to occur within the Grandview Heights #3 NCP area, as well as future development north of 20 Avenue.

Conversely, both Tributary 1 and Thomson Creek show no changes in the occurrence of high flows under future development conditions. Under future conditions, there are no anticipated changes in land use within the areas that contribute runoff to these watercourses.

9.2.2 Erosion Potential

Greater runoff volumes and increased frequency of high flows originating from sub-catchments can translate into accelerated erosion rates in natural watercourses.

The indicators of increased erosion potential in a natural watercourse are the tractive force and stream impulse. Tractive force is the shear force acting on the stream bed, caused by flowing water concentrated in the watercourse. When the tractive force exceeds the threshold of movement of the bed material, erosion occurs. Stream impulse is a parameter that describes the energy of a given watercourse and is a function of the tractive force and the wetted perimeter over time.

Using the results from our EPS, we calculated the increase in both maximum tractive force and stream impulse. The reporting locations are the same as those used for the flow exceedance curves, as shown on Map 9-1. The results of the maximum tractive force and total stream impulse evaluation are presented in Table 9-2.

Table 9-2
Maximum Tractive Force and Total Stream Impulse

Point ID (Map 6-1)	Watercourse	Maximum Tractive Force (N/m^2)			Total Stream Impulse (kNh/m)		
		Existing	Future	Increase	Existing	Future	Increase
A	Sam Hill Creek Diversion	34.2	43.8	+25%	180	252	+40%
B	Sam Hill Creek	28.5	35.7	+25%	262	370	+41%
C	Tributary 1	6.1	6.1	-	27	27	-
D	Thomson Creek	14.9	14.9	-	63	63	-

The maximum tractive force and total stream impulse experience notable increases under future development condition both on the Sam Hill Creek Diversion, and on Sam Hill Creek. As noted above with respect to the flow-duration-exceedance curves, the increases are consistent with the increased urbanization and impervious cover within these portions of the watershed.

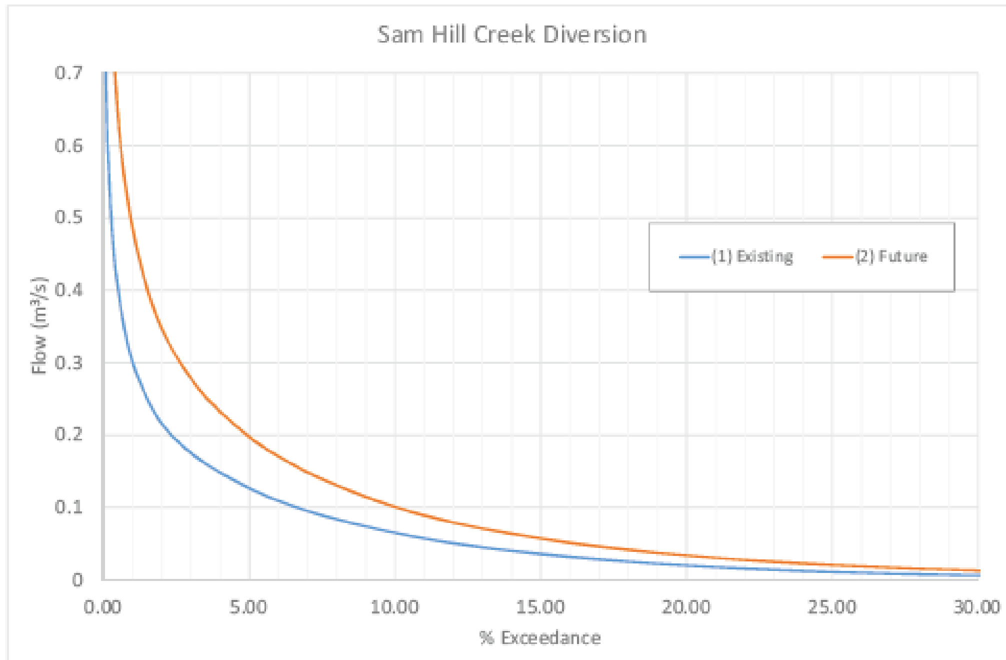
The EPS results indicate that there will be no increases in erosion activity on Tributary 1 or Thomson Creek, as no future development is expected to occur within the tributary areas that drain to these watercourses.

As noted above, erosion occurs when the tractive force exceeds a watercourse's critical tractive force (the threshold of the bed material to resist movement). Without detailed information about the streambed composition and particle size distribution within each watercourse, it is difficult to comment on the actual erosion potential. We would generally only calculate stream impulse for periods where the tractive force exceeds the critical tractive force. However, given the uncertainty regarding the streambed composition, we have calculated stream impulse for each time step in the extended period simulation.

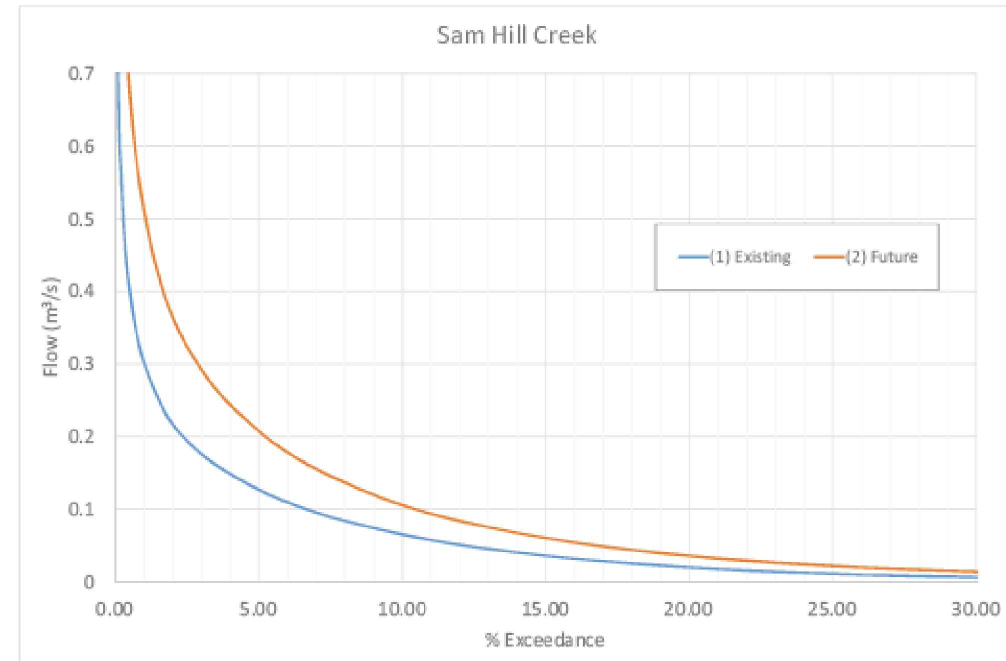
If the watercourses are already near the threshold where average tractive forces would exceed the natural resistance to movement under existing conditions, then the increases noted above could result in the onset of erosion problems. However, if the watercourses are well below that threshold under existing conditions, then the increases noted above may not result in significant erosion problems.

The City's ongoing ravine assessment program has not identified any significant instability sites within the Sam Hill Creek ISMP study area. While the 2011 report noted a medium-risk location along Thomson Creek at 12 Avenue where the culvert was observed to be largely blocked at the inlet, subsequent assessments reclassified the site as low-risk. Based on our review of the data, no significant instability sites have been identified within the Sam Hill Creek ISMP study area.

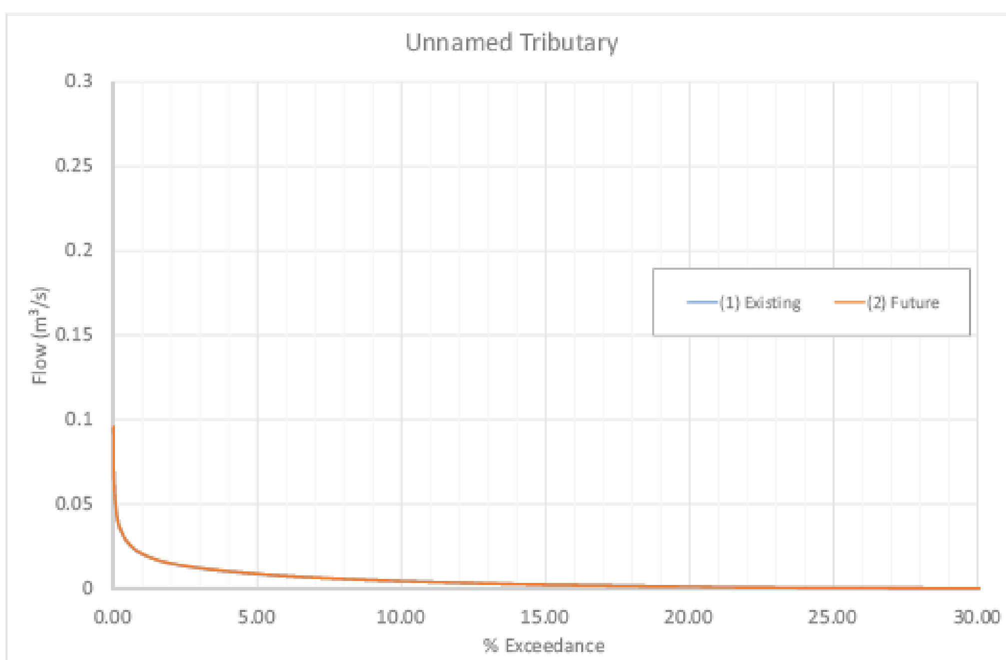
Figure 9-2
Flow Duration Exceedance Curves for Study Area Watercourses



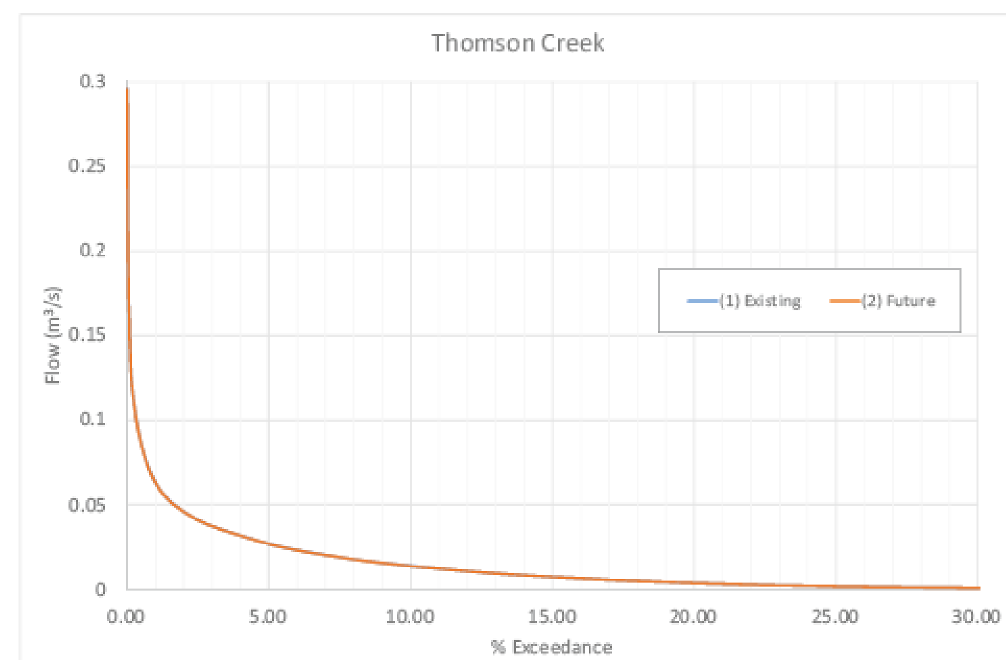
(A)



(B)



(C)



(D)

Regardless of the accuracy of absolute values, the extended period simulation results indicate that future development will have a significant impact on the erosion potential for both Sam Hill Creek Diversion, and Sam Hill Creek. BMPs and LIDs can be implemented to help mitigate this impact. The next section discusses the use of Water Balance Modelling (WBM) to assess the effect these measures can have in reducing impacts to natural watercourses.

9.3 WATER BALANCE MODELLING

The Water Balance Model is a web-based tool that allows the user to determine hydrologic benefits of applied source controls. The user enters soil information, details on land use type, surface conditions and source control details, and the model outputs volume, flow, infiltration, losses and discharge under an extended period simulation. We used rainfall data based on records from the White Rock STP station from 1965 to 1990.

Based on the current draft land use concept, the most predominant land uses within the Grandview Heights #3 NCP area include Urban Single Family, Semi-Detached Residential, Multiple Cluster Residential, Low Density Multiple Residential, and Medium Density Multiple Residential. Based on discussions with the City, we understand that the area north of the Grandview Heights #3 NCP area is expected to be developed as Single Family Residential (RF-12).

Based on the City's Design Criteria Manual, these various residential land uses generally fall into two classes of percent impervious values: the various multiple residential land uses (RM) have a recommended percent impervious value of 65%, while the various single family residential land uses (RF) have a recommended percent impervious value of 80%.

Recognizing that the majority of the residential land uses fall into these two general categories, we developed WBM scenarios to assess RF areas and RM areas. Based on our review of the City's Zoning bylaw, the RM lots typically have an average size of 2000 m^2, while the RF lots typically have a lot size of 320 m^2.

Single Family Residential

For the Single Family Residential lots, we modelled the following scenarios:

- Existing development as One Acre Residential < 1 ha (41.7% impervious)
- Existing development as One Acre Residential > 1 ha (16.7% impervious)
- Future development at Single Family Residential, no BMPs (80% impervious)
- Future development as Single Family Residential, % Impervious Limited
- Future development as Single Family Residential, with BMPs

The two existing development scenarios reflect the current conditions within the watershed and use percent impervious values that are consistent with our PCSWMM modelling. See Section 8.3 (Table 8-4) for more information on how the imperviousness values were developed.

The first future development scenario reflects a future development condition, with an 80% impervious value consistent with the City's Design Criteria Manual for RF-12.

We then modelled two potential improvement scenarios under future conditions. The first reflects a scenario where development proceeds in accordance with the City's Zoning Bylaws. While the City's Design Criteria Manual recommends a value of 80% impervious, the Zoning Bylaw limits the percent impervious to 50%. This improvement scenario reflects a situation where the percent impervious limits in the Zoning Bylaw are strictly enforced.

The second improvement scenario reflects an 80% impervious value, with absorbent landscaping applied over the entire pervious area (20% of the total lot footprint), and pervious paving applied over 25% of the impervious area (20% of the total lot footprint).

The Water Balance Model results are presented in Figure 9-3. Detailed model output results are provided in Appendix E.

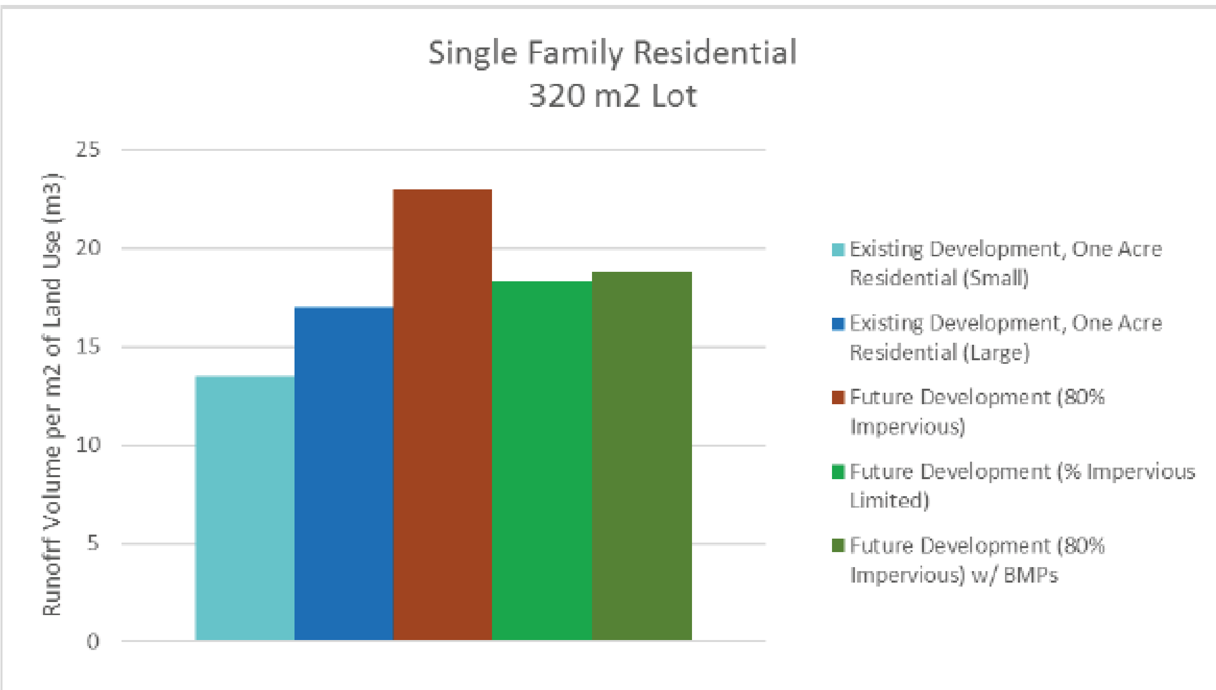


Figure 9-3
Water Balance Model Results - Single Family Residential

Multiple Residential (RM)

For the Multiple Residential lots, we modelled the following scenarios:

- Existing development as One Acre Residential < 1 ha (41.7% impervious)
- Existing development as One Acre Residential > 1 ha (16.7% impervious)
- Future development at Multiple Residential, no BMPs (65% impervious)
- Future development as Multiple Residential, % Impervious Limited
- Future development as Multiple Residential, with BMPs

The two existing development scenarios reflect the current conditions within the watershed and use percent impervious values that are consistent with our PCSWMM modelling.

The first future development scenario reflects a future development condition, with a 65% impervious value consistent with the City's Design Criteria Manual for RF.

We then modelled two potential improvement scenarios under future conditions. The first reflects a scenario where development proceeds in accordance with the City's Zoning Bylaws. While the City's Design Criteria Manual recommends a value of 65% impervious, the Zoning Bylaw limits the percent impervious to 45%. This improvement scenario reflects a situation where the percent impervious limits in the Zoning Bylaw are strictly enforced.

The second improvement scenario reflects a 65% impervious value, with absorbent landscaping applied over half of the pervious area (17.5% of the total lot footprint), and pervious paving applied over approximately 27% of the impervious area (17.5% of the total lot footprint).

The Water Balance Model results are presented in Figure 9-4. Detailed model output results are provided in Appendix E.

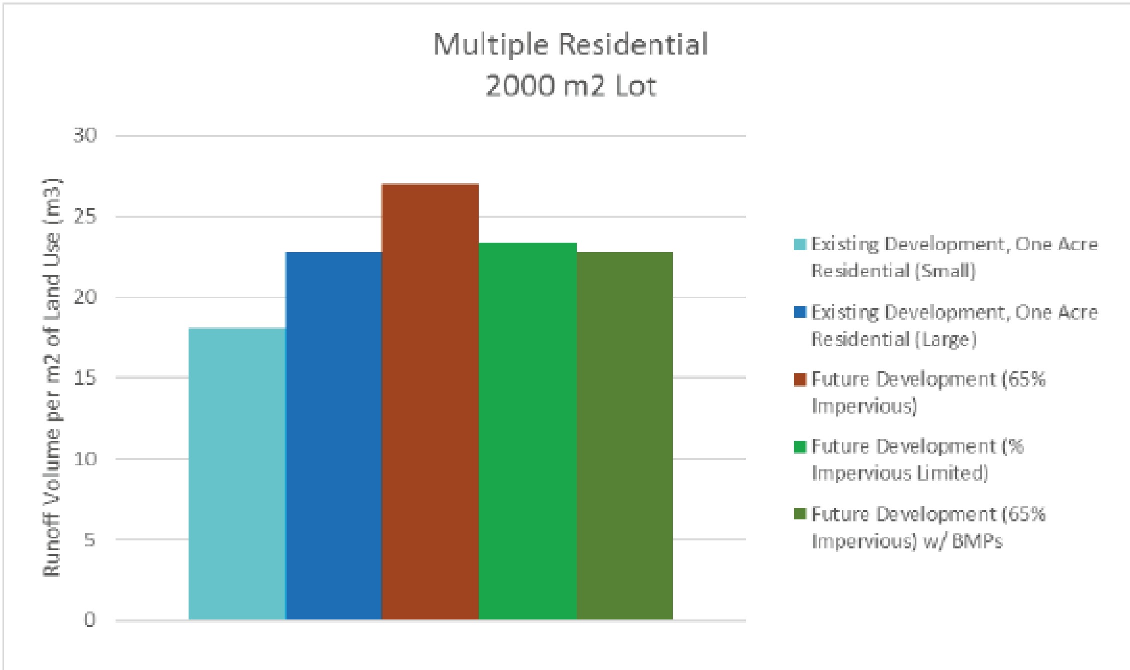


Figure 9-4
Water Balance Model Results - Multiple Residential

The results indicate that, for both the Single Family Residential and Multiple Residential land uses, there will be an increase in the runoff volume compared to existing development (One Acre Residential) conditions. This increase in runoff volume reflects the increase in impervious coverage from existing conditions to 65% for Multiple Residential and 80% for Single Family Residential land uses.

The results also indicate that, if the impervious cover can be limited under future conditions to match the restrictions outlined in the City's Zoning Bylaw, the runoff volumes will also be limited. Alternatively, applying BMPs would also help to limit the increase in stormwater runoff under future development conditions.

We note that the Single Family Residential and Multiple Residential scenarios are based on lots of different sizes and shapes. Accordingly, the results of changes to runoff should be compared within each scenario as shown in Figures 9-3 and 9-4. The important trend to note is the relative shifts in runoff generation as imperviousness and the implementation of BMPs are modified as applied to each lot type.

9.4 EXTENDED PERIOD SIMULATION WITH MITIGATIVE MEASURES

In order to develop the flow-duration-exceedance curve for the study area with BMPs implemented, we used the WBM to determine the reduction in runoff coefficient for typical land uses. The reduction was based on specific BMP scenarios for each land use as discussed in Section 9.3. Table 9-3 outlines the results. We note that BMPs were only applied to Multiple Residential and Single Family Residential lot types. Our analysis did not include any BMP implementation in road ROWs or other land uses.

Table 9-3
Water Balance Modelling Results

Land Use	Base Runoff Coefficient	Modified Runoff Coefficient	Percentage Change
Single Family Residential	0.645	0.527	-18.3%
Multi-Family Residential	0.757	0.639	-15.6%

In general, a decrease in imperviousness will result in a decrease in runoff coefficient, however the relationship is not necessarily linear. PCSWMM reports a sub-catchment's runoff coefficient based on several parameters, including imperviousness. As a result, the runoff coefficient cannot be modified directly. Instead, we tested several sub-catchment imperviousness values in order to arrive at a runoff coefficient that is similar to the desired value found in Table 9-3 for the two different land use values with BMPs applied. We did this by incrementally changing the imperviousness of test sub-catchments that have predominantly single family residential or multi-family residential land uses and checking the calculated runoff coefficient. Using this method to 'calibrate' our model, we found that to observe the percentage change to runoff coefficients outlined in Table 9-3, we needed to reduce the imperviousness of single family and multi-family land uses by 22.5% and 18.2% respectively. This achieved reductions in runoff coefficient of 18.4% and 16.1% for single family and multi-family land uses respectively. We note that this closely matches with the targeted reductions of 18.3% and 15.6% as described in Table 9-3.

Multi-family residential land uses have similar characteristics to commercial or institutional land uses in terms of runoff coefficient and imperviousness. In addition, future commercial and institutional land uses make up a very small portion of our study area. For these reasons, we have treated multi-family residential, commercial, and institutional land uses as the same and applied a common percent reduction to their imperviousness values.

Using an area weighting method, we adjusted the imperviousness values in our model for each land use and reran the EPS simulation to calculate the flow exceedance curves for the scenarios that include variations of BMP implementation according to the following configurations:

- (3) Future land uses with standard BMPs applied.
- (4) Future land uses with standard BMPs as well as stormwater storage ponds.
- (5) Future land uses with maximum BMPs as well as stormwater storage ponds.
- (6) Future land uses with maximum BMPs, stormwater storage ponds, and low flow bypasses.

Scenarios (3) and (4) represent BMP implementation as described in Section 9.3 with and without detention ponds. Scenarios (5) and (6) reflect a level of BMP implementation representing a theoretical maximum for volume reduction of runoff that would be very difficult to implement. This scenario assumes a level of BMP implementation sufficient to limit an imperviousness increase of only 25% over existing conditions. Scenario (6) also includes low flow bypasses so that low-intensity, frequent events bypass detention ponds and peak flows are not attenuated. The "Maximum" BMP implementation levels are also included.

Flow exceedance curves for all scenarios are presented in Figure 9-5.

Section 9.2.2 highlights the increased erosion potential in local watercourses as a result of development. We have assessed the ability of BMPs to lessen the erosion potential in the future condition in several scenarios. Table 9-4 and Table 9-5 show the results for Scenarios 3 through 6. We note that locations C and D showed no increase as no re-development is expected in this area. As a result, we have not included the analysis in further discussion.

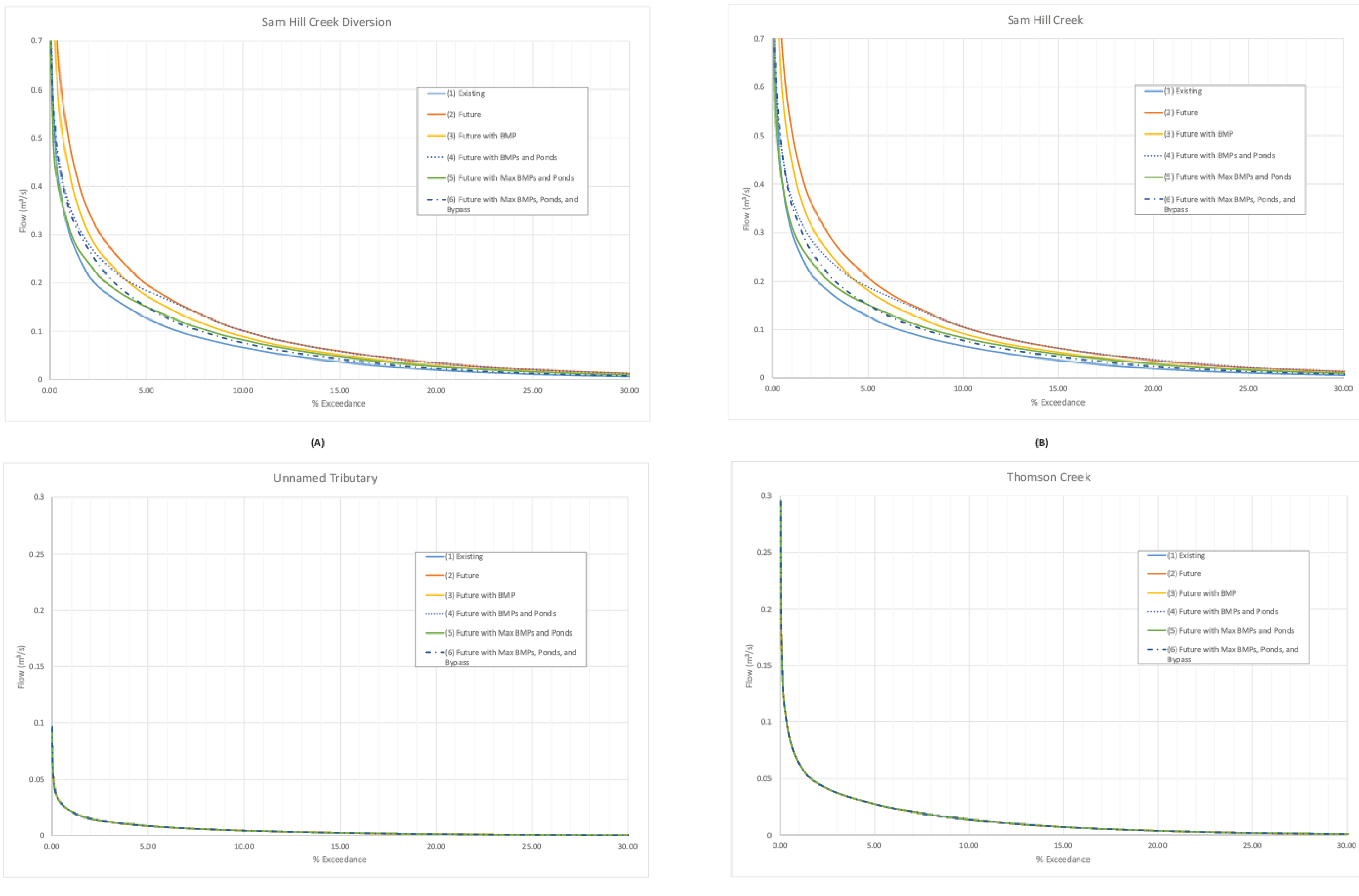
Table 9-4
Maximum Tractive Force Results

Scenario	Maximum Tractive Force (N/m^2) and Percent Change from Existing			
	Sam Hill Creek Diversion		Sam Hill Creek	
	A		B	
(1) Existing	34.2		28.5	
(2) Future	43.8	28%	35.7	25%
(3) Future with BMP	40.7	19%	33.2	16%
(4) Future with BMPs and Ponds	30.2	-12%	24.6	-14%
(5) Future with Max BMPs and Ponds	27.8	-19%	23.2	-19%
(6) Future with Max BMPs Ponds, and Bypass	29.3	-14%	24.4	-14%

Table 9-5
Total Stream Impulse Results

Scenario	Total Stream Impulse (kNh/m) and Percent Change from Existing			
	Sam Hill Creek Diversion		Sam Hill Creek	
	A		B	
(1) Existing	180		262	
(2) Future	252	40%	370	41%
(3) Future with BMP	227	26%	333	27%
(4) Future with BMPs and Ponds	235	31%	346	32%

Figure 9-5
Flow Duration Exceedance Curves for Study Area Watercourses



Scenario	Total Stream Impulse (kNh/m) and Percent Change from Existing			
	Sam Hill Creek Diversion		Sam Hill Creek	
	A		B	
(5) Future with Max BMPs and Ponds	205	14%	301	15%
(6) Future with Max BMPs Ponds, and Bypass	198	11%	291	11%

As discussed, the results show that development will have a significant impact on the Sam Hill Creek watershed watercourses.

In Scenario 3, the addition of BMPs reduces the total stream impulse and maximum tractive force. The flow exceedance curve shows that the BMPs are effective in reducing the total volume of runoff and tend to shift the curve back towards the existing condition at all flows. However, the effect of BMPs is not enough to shift the curve back to the existing condition.

In Scenario 4, the effect of storage ponds has also been considered. These ponds are designed to attenuate the peak flows, and this is reflected in the flow exceedance curves being returned to the existing condition at the upper end. However, by attenuating the peak rainfall event, the excess water is stored and released at a lower rate for a longer period of time. This results in increased flow exceedance at lower flow rates when compared to existing. While maximum tractive force is reduced below the existing level, the extended lower flow condition increases the total stream impulse experienced over existing. We note that the effect of the BMPs on potentially reducing required pond size was not investigated. This is because the ponds are designed to the 5-year return period event when most BMPs would be surcharging or overwhelmed and any attenuation or volume reduction benefit would likely be small.

In order to reduce the level of flow exceedances and total stream impulse, the volume of water must be reduced. As a sensitivity check, Scenario 5 introduces a much higher level of BMP implementation intended to simulate a significant reduction in EIA. In this scenario, we limited the increase in EIA to only 25% of the increase in TIA between existing and future scenarios. These measures shift the flow exceedance curves closer to existing and reduce the total stream impulse further than in Scenario 4, although it is still higher than existing. While these are positive results, we note that this level of BMP implementation may be unrealistic.

Scenario 6 explores installing a bypass for low flows at the ponds. In this scenario, low flows, (up to one-third of the allowable maximum discharge), are diverted around the pond. In this way, low flows are not attenuated, and the flow exceedance curve moves closer to existing levels at the lower end of the curve. Total stream impulse is reduced further but is still higher than existing.

We note that even without changes to the imperviousness or runoff coefficients, introducing storage ponds will change the hydraulic response of the system. This is demonstrated by comparing the results of Scenario 4 with the results of Scenario 3. Attenuating peak flows will reduce the upper end of the flow exceedance curve while increasing the lower end. As stream impulse is a function of flow and time, a lower flow for a longer time may result in an overall increase to total stream impulse. This is consistent with our modelling results. Scenario 6 is intended to address this point. If low flows are allowed to bypass the detention ponds, peak flows pass through the downstream watercourses in less time than a lower flow rate sustained for a longer period of time. This has a cumulative effect and lowers the summed total stream impulse experienced in the watercourse.

As noted, the values presented here are based on the total stream impulse. This includes hydraulic results for the entire flow spectrum, including the lowest end. Depending on the details of the particle size distribution for the existing watercourses, the lower end of the spectrum may or may not be critical. If the existing streambed material is fine grained, then increases in stream impulse at the lower end of the spectrum may be an issue. Conversely, if the existing streambed consists of coarse gravels, increases in stream impulse at the lower end of the spectrum may not be of concern.

Determining the critical tractive force requires detailed information on the existing streambed composition. It is also dependent on the geometry of the channel, including the base width, the side slopes, the Manning's roughness, and the overall channel slope. These parameters are site specific and will vary over the length of a channel. As such, it is beyond the scope of this ISMP to complete an in-depth investigation into the critical tractive force.

The results of our modelling show that the proposed storage ponds are effective at attenuating flows for the 5-year return period. This is demonstrated through the event-based modelling results, as well as the continuous simulation results which show a reduction in the maximum tractive force. By applying the recommended BMPs, the negative hydrologic impacts of future development can be reduced, although they cannot be mitigated entirely. The only way to maintain the existing hydrologic and hydraulic response of the watershed under future development conditions would be to introduce enough BMPs that there is no increase in the Effective Impervious Area, despite the increase in Total Impervious Area.

9.5 LOW-IMPACT DEVELOPMENTS AND BEST MANAGEMENT PRACTICES

In this section, we develop a list of Low Impact Developments (LIDs) and Best Management Practices (BMPs) that appear feasible for the Sam Hill Creek ISMP study area based on proposed land use. We discuss the unique aspects of each land use type and highlight the various techniques that can potentially be used to manage runoff.

Anticipated land use changes in the study area will likely lead to higher overall imperviousness. Our analysis shows that higher imperviousness due to changing land use will result in higher runoff volumes and peak flows than are currently experienced. We also expect that stormwater quality will degrade. To help mitigate some of these effects, LIDs and BMPs should be implemented.

9.5.1 Future Development

As noted, future redevelopment is expected to change the land use between 168 Street and 176 Street, and between 16 Avenue and 20 Avenue, redevelopment will occur as per the Grandview Heights #3 NCP.

North of 20 Avenue, future redevelopment will occur under Grandview Heights #5 NCP (NCP has not yet been developed). We also note that there is potential for redevelopment along the east side of 176 Street between 16 Avenue and 18 Avenue in the future.

9.5.2 Stormwater Management Approach

The City has developed a number of documents that outline environmental, socio-economic and stormwater management goals and objectives, including the City's Sustainability Charter (2008), Official Community Plan (2013), Biodiversity Conservation Strategy (2014), and Shade Tree Management Plan (2012).

Enhancement of watershed health simultaneously supports many of the City's sustainability initiatives. Some examples of the relationship between environmental, stormwater management and community enhancements include the following:

- Creating an enjoyable streetscape for the community allows the use of absorbent soils and vegetation that attenuates runoff and may also reduce the loading to the City's storm system.
- Enhancement of the City's tree canopy to achieve the goals outlined in the Shade Tree Management Plan provides interception and evapotranspiration of small, frequent rainfall events, reducing the volume of water translated into direct runoff.
- Reducing the impact of peak flows in watercourses through peak flow diversions and fish-friendly flow control structures can slow the rate of bank erosion and allows riparian vegetation to develop, which ultimately provides improved terrestrial habitat and wildlife corridors.

While the focus of this section is on stormwater management BMPs and LIDs, the benefits to aquatic habitat, terrestrial biodiversity, the City's tree canopy goals, and socio-economic benefits such as increased green space are inherently linked. The list of potential LIDs and BMPs is presented below. In subsequent sections, the various LIDs and BMPs are arranged by land use within the study area.

- Absorbent Landscaping and Growing Media
- Disconnect Impervious Areas
- Pervious Pavement
- Limit On-Lot Effective Impervious Coverage
- Underground Storage
- Infiltration Trench
- Bioswales
- Green Roof
- Rain Garden
- Water Quality Devices

9.5.3 Residential Land Uses

Urban Single Family (10-12 UPA)
This land use type is not explicitly defined in the City's Zoning Bylaw or the Design Criteria Manual (DCM). However, there are two residential zoning types that meet the proposed dwelling density of 10 to 12 Units Per Acre (UPA): RF-12 and RF-12C. Both of these lot types have a maximum lot coverage of 50%, except where a coach house has been built in RF-12C lots, the maximum is 59%. Lot coverage is a measurement of the combined areas of all buildings, outdoor covered areas, and structures on a lot.

Recognizing that, in practice, the percentage of hard surfaces typically exceeds the limits that are specified in the Zoning Bylaw, the DCM provides a recommended value of 80% for lot imperviousness for RF-12 lots. We have used this value for our modelling analysis.

Urban Single Family lots figure prominently in future changes to land uses. Much of NCP #5 and large portions of NCP #3 will be designated with this lot type.

Semi-Detached Residential (12-14 UPA)
The City's Zoning Bylaw describes RF-SD as having a maximum of 15 UPA. However, the NCP may prescribe a slightly lower density of dwellings (12-14 UPA). The maximum lot coverage of this lot type is 60% in the Zoning Bylaw with a maximum imperviousness for modelling purposes indicated in the DCM at 80%.

Lots zoned as RF-SD are limited to certain areas along collector roads in NCP #3. It is not anticipated these lot types will be used elsewhere. However, for our modelling purposes, Semi-Detached Residential and Urban Single Family lots are equivalent.

Multiple Residential Cluster (15 UPA)
The City's Zoning Bylaw describes that the intended use of this zoning (RC) is to take advantage of large lots which may have unique features such as watercourses, mature vegetation, or ravines that are worthy of preservation. This land use has been assigned to various areas within NCP #3 which tend to contain such features, including proposed additions to the GIN.

There are three types of RC lots, with a maximum lot coverage of 50%, 70%, and 80%. It is also possible to have a combination of those three lots with a permissible lot coverage between 50% and 80%. The imperviousness of this type of lot has not been specified in the DCM. We have assumed a value of 65% for modelling purposes.

Low Density Multiple Residential (15-20 UPA)
The City's Zoning Bylaw does not specify low density multiple residential lot types. However, the UPA constraints identified in NCP #3 for this land use are consistent with RM-15. The City's Zoning Bylaw specifies a maximum lot coverage of 45% for RM-15. The DCM indicates an imperviousness of 65% should be used for analysis for RM-15 lots and we have assumed this value for our purposes.

Medium Density Multiple Residential (20-25 UPA)

The Zoning Bylaw does not specify a particular zoning type for Medium Density Multiple Residential. However, we have assumed a value of 70% imperviousness to reflect the increase in density over Lower Density Multiple Residential.

Potential Redevelopment

We understand that the existing lots immediately east of 176 Street between 16 Avenue and 18 Avenue may be redeveloped in the future. We have assumed this lot type is equivalent to Medium Density Multiple Residential with an impervious value of 70% for these lots.

9.5.3.1 Potential BMPs and LIDs for Residential Land Uses

Absorbent Landscaping and Growing Media

Absorbent landscaping acts like a sponge that retains rainfall, stores it temporarily, and then slowly releases it. Its primary purpose is to mimic the hydrologic function of undeveloped land on a developed site. It tends to have only a limited capacity and will saturate and lose functionality during large rainfall events. Regardless, it is an appropriate measure to manage stormwater at the source, and is particularly effective for small, frequent rainfall events. Additionally, the filtration mechanism of the soil layer provides water quality benefits.

Absorbent landscapes typically consist of a layer of absorbent soil with vegetation such as shrubs and trees. The vegetation provides an additional function of supporting interception and evapotranspiration. Absorbent landscapes receive direct rainfall and runoff from small impervious surfaces (such as driveways, paths and patios).

Absorbent landscapes are easily applied (relative to other source controls) to existing residential lots and provide aesthetic benefits for the community and individual homeowners. Vegetation can be selected such that it also supports backyard biodiversity and the increased presence of native plants. Required maintenance includes typical gardening activities such as weeding and replacing dead plants, as well as watering during extended dry periods. As well, an overflow should be considered, and should be inspected monthly and debris removed.

For the purpose of effective stormwater management, the depth of absorbent soils should be a minimum of 450 mm, and be comprised of soils with high organic content, such as sandy loam.

Disconnect Impervious Areas

In conventional drainage systems, impervious surfaces such as roads, driveways, parking lots, and roofs are connected directly into a conveyance system or receiving watercourse. Runoff from these impervious surfaces moves very rapidly and mobilizes and transports sediment and other pollutants. The result is very flashy flows with low times of concentration, high peak flow rates, large runoff volumes, and high pollutant mobility. These negative hydrologic impacts can be mitigated by disconnecting impervious areas from each other and the downstream pipe networks.

Disconnection can also include parking lots, roads, and other impervious surfaces; runoff can be directed to vegetated/pervious surfaces prior to arriving at a conventional drainage system. This approach will promote infiltration (subject to local soil conditions), evapotranspiration, and overland filtering. Even where runoff volumes are not significantly reduced, slowing of runoff provides downstream benefits in receiving streams, and is closer to a natural hydrologic regime.

The location, capacity, and soil conditions of each vegetated receiving area should be given careful consideration to ensure that directing impervious area runoff to pervious surfaces does not result in potential flooding or erosion.

Disconnecting impervious areas has good potential in medium and low density residential developments since there are generally green spaces available to receive runoff.

Pervious Pavement

Pervious pavement provides an alternate configuration for otherwise impermeable surfaces, such as driveways, walkways and patios. It consists of a paving system that allows rainfall to percolate into an underlying subgrade reservoir. If sufficient infiltration capacity exists in the subgrade or underlying soils, the water will be infiltrated. Otherwise, it can be discharged to the storm network through an underdrain.

Metro Vancouver's Stormwater Source Control Guidelines (2012) suggests that pervious pavement can receive runoff from other impermeable areas, provided sediment loads are not excessively high. Pervious pavement can provide a reduction in peak flows and runoff volume, as well as some contaminant removal, and in certain areas assists in rehabilitating baseflows to natural watercourses via groundwater recharge.

Pervious pavement typically consists of five layers including the surface (porous asphalt / concrete, concrete / plastic grid pavers, concrete pavers installed with gapped joints), an aggregate bedding, open graded base, open graded sub base, and subsoil. Additionally, the use of a geotextile to prevent migration of fines into the base drainage courses is recommended. For areas that have been identified as having low infiltration potential, a partial-infiltration configuration that includes an underdrain may be required.

On residential lots, pervious pavement provides excellent mitigation to the effects of driveway expansions, new walkways, porches and patios. Due to the relatively complicated nature of construction, however, home owners may be hesitant to install pervious pavement for these types of projects. Supplemental support and encouragement from the City will likely be necessary to maximize the implementation of pervious pavements within the study area.

Limit On-Lot Effective Impervious Coverage

Impervious areas are any surface that water cannot penetrate and include areas such as parking lots, pathways, driveways, roads, and rooftops. In hydrologic terms, impervious surfaces prevent infiltration, generate increased runoff volumes and peak flow rates, facilitate mobilization of accumulated sediment, transport non-point source pollutants, and increase the potential for erosion and water quality problems in receiving watercourses.

The majority of the other stormwater management BMPs discussed in this report aim to reduce the negative hydrologic effects of runoff from impervious surfaces. Their function can be heightened by reducing the percent impervious values of contributing developments. We recommend that impervious surface reduction be considered at the planning stage of site development and re-development.

We note that lots which are currently undeveloped present the best opportunity to implement limits on impervious areas during future development.

Underground Storage

Future development within the study area is expected to increase the proportion of impervious cover and land consumption. As a result, large scale surface detention and treatment systems may not be viable. As an alternative, storage can be provided by underground systems. In commercial, industrial, and high density residential areas, detention storage can be provided as tanks located under parking or working areas and in urban residential areas within lawns or under driveways, preferably at the low point of each site.

These systems could be designed to provide both peak flow attenuation and volume reduction functions. To provide attenuation, storage units should be sized and configured with sufficient volume to retain a significant portion of the runoff for an extended period of time. They would require a flow control feature at the outlet to limit release rates. Water would be temporarily stored, and released at a slower rate, which would better mimic the slow percolation and concentration rates of the organic surficial soils and vegetation present under natural conditions. These units would require a bypass system, either external to the unit or an internal overflow, to ensure large design storms exceeding the unit capacity can be conveyed to the downstream system.

To provide a volume reduction function, these units can be hydraulically connected to the underlying soils to promote infiltration. We note that infiltration based facilities could be employed within the northern parts of the study area (above 16 Avenue) of the study area. These areas have been identified as having moderate infiltration potential.

Infiltration Trench

Similar to the concepts discussed for underground storage, infiltration trenches can be designed to infiltrate runoff in an effort to reduce the overall volume of water entering the storm system. The simplicity of infiltration trenches is suitable for installation in small scale residential developments or by individual homeowners. However, if contaminants are present in the runoff, the water may need a form of pre-treatment to avoid contaminating groundwater.

The trench is constructed by excavating to the desired depth and shape then lining the trench with a non-woven geotextile. The excavation is backfilled with drain rock. The surface layer could be topsoil to allow for evaporation, or paved. Runoff is directed to the drain rock where it can infiltrate into the ground. In areas of poor infiltration, an overflow can be installed and connected to the storm system. The design and construction should follow the direction provided in the DCM.

9.5.4 Commercial Land Use

Under the City's Zoning Bylaw, Commercial land use type lots can have varying amounts of lot coverage based on classification ranging from 50% to 85%. However, the DCM prescribes an imperviousness value of 90% for all commercial land uses.

Commercially zoned lots have only been designated in two areas of NCP #3, totalling about 1 ha of developed land. While the total lot coverage value is unknown, we have assumed a value of 90% imperviousness for these areas for the purposes of modelling future land use.

9.5.4.1 Potential BMPs and LIDs for Commercial Land Uses

Bioswales

Bioswales are shallow open channels that capture and convey stormwater runoff. They are typically comprised of a vegetated topsoil layer; a drain rock layer and a subgrade drain. In locations where stormwater treatment is a concern, as with commercial developments, bioswales provide stormwater treatment by assisting in the removal of Total Suspended Solids (TSS), heavy metals and some hydrocarbons. Perched lawn basins (meaning the rim is raised above the surrounding ground surface) allow for attenuation and treatment of stormwater while also providing an overflow for significant rainfall events.

Compared to a traditional piped drainage network, bioswales can significantly attenuate runoff received from impervious surfaces due to the relatively high roughness of the surface layer, and the effect of temporary subsurface storage in the drain rock layer and promotion of shallow infiltration.

Bioswales can be implemented along the edges of parking lots and provide benefits to stormwater quality while lessening the strain on the City's piped drainage network.

Green Roof

A green roof is an amended conventional roof that incorporates features such as planter boxes that support living vegetation. For the purposes of stormwater management, soil depth is typically 300 mm or less. Green roofs operate similar to absorbent landscaping as discussed above by soaking up and temporarily retaining direct rainfall.

Buildings located on commercial lots tend to occupy a significant fraction of the total lot area and often have flat roofs. This makes the implementation of green roofs practical for these developments.

Various studies have highlighted that green roofs provide extra insulation reducing heat transfer as well as improving the longevity of the roof structure by helping to protect the membrane from extreme temperature fluctuations (Metro Vancouver, 2012). With proper communication of these benefits, property managers may be more inclined to support the inclusion of green roofs on their lots.

Rain Gardens

Rain gardens are aesthetically pleasing landscape features designed to capture, detain, treat and infiltrate stormwater runoff. Rain gardens typically consist of 450 mm of absorbent topsoil supporting trees, shrubs and groundcover, overlying a drain rock reservoir. The soil and vegetative layers provide attenuation and treatment of water as it percolates and collects in the drain rock reservoir. If infiltration capacity in the drain rock reservoir is sufficient, the water will infiltrate. Otherwise, the water is directed into the storm drainage network either through an overflow catch basin at the surface or through a subdrain located in the drain rock layer.

Within commercial areas, rain gardens can provide a pleasant aesthetic feature while collecting and treating the majority of direct runoff developed from impervious surfaces such as parking lots or rooftops.

Water Quality Treatment Devices

Propriety water quality devices are becoming common and are available from a variety of vendors. The most common devices separate sediment and oils from the water stream through settling chambers, inverted weirs, swirl chambers, and submerged outlets. There are also more advanced units which incorporate absorbent materials and filters; some devices are also available with chemical agents to promote coagulation and settling of fine particles.

In general, these devices are most effective when applied to areas where pollutants are mobilized and concentrated at a single point, such as parking lots, soil or sediment stockpiles, and vehicle maintenance locations.

They can also be provided as spill traps to reduce the spread of accidental pollutant releases and facilitate emergency cleanup and response. As with all BMPs, water quality devices can be used in conjunction with other features. In particular, they can help protect other BMPs, such as infiltration systems and vegetated features, from excessive loadings that could degrade their performance.

Underground Storage

Underground storage units could potentially be implemented within the commercial lots of NCP #3, however, the small scale of these lots may make this impractical.

Underground storage can potentially provide peak flow attenuation, as well as volume reduction. For details regarding underground storage, refer to Section 9.5.3.1.

9.5.5 Institutional and School Land Uses

Institutional and school land uses make up a relatively small area of the proposed land use changes in the study area (about 5.5 ha within NCP #3). There is no specific school zoning type within the Zoning Bylaw, however, there is an Institutional Zone (PI). The maximum lot coverage for this land use is 40%. However, in the DCM, the recommended imperviousness value for both institutional and school land uses is 80%.

9.5.5.1 Potential BMPs and LIDs for Institutional and School Land Uses

Generally, schools and institutional areas could implement BMPs and LIDs in a similar manner to commercial land uses as discussed in Section 9.5.4.1. In addition, despite the high imperviousness of these land uses, schools frequently have large pervious areas such as fields or landscaping that could potentially be utilized as a BMP.

9.5.6 Roadways

Private land redevelopment faces practical limitations on the source controls that can feasibly be implemented. While source controls provide excellent community benefits, lot owners may not be willing to commit the effort into proper design that would translate to real benefits for the City. Considering this, City road rights-of-way (ROW) have significant opportunities for the implementation of BMPs because they are linear, and within the City's control. Enhancing roadways through 'green-street' type developments not only provides stormwater management benefits, but also supports the City's goals of providing aesthetically pleasing communities.

Below we outline a list of potential BMPs that can be implemented on road rights-of-way that support stormwater management while enhancing community aesthetics. The BMPs discussed in this section are best-suited to local/collector and arterial roads.

9.5.6.1 Potential BMPs and LIDs for Roadway Land Uses

Bioswales
The hydrologic benefits and typical structure of bioswales was discussed in Section 9.5.4.1.

Runoff from travelled lanes and parking areas can be directed to bioswales, rather than being immediately discharged into the storm drainage network. This provides for treatment of TSS, heavy metals and hydrocarbons, reducing the direct loading on the storm drainage network.

Pervious Pavement
The hydrologic benefits and typical structure of pervious pavements were discussed in Section 9.5.3.1.

While pervious pavement should not be implemented in high-traffic areas due to potential structural concerns and ponding, sidewalks and parking lanes can utilize pervious pavement to attenuate runoff and promote shallow infiltration to the underlying soil. However, we understand that the City has not had positive experiences in the past with the implementation of pervious pavement in road ROWs.

Rain Gardens
The hydrologic benefits and typical structure of rain gardens were discussed in Section 9.5.4.1.

Runoff from travelled lanes and parking lanes can be directed to rain gardens to provide treatment and runoff attenuation. Rain gardens can be placed at the downstream ends of bioswales to provide maximum treatment efficiency and runoff reduction. Rain gardens may be linear features or incorporated into curb bulges.

Absorbent Landscaping and Street Trees

The hydrologic benefits and structure of absorbent landscaping are discussed in Section 9.5.3.1.

Absorbent landscaping can be employed in combination with street trees to support the City's ultimate tree canopy goals as well as the City's goal to provide aesthetically pleasing communities. Absorbent landscaping in a roadway context is best suited to the inclusion of street trees to maximize the hydrologic benefits. Trees can consist of coniferous or deciduous trees and are most beneficial if they possess high leaf densities. Coniferous trees are preferred over deciduous trees, as leaf litter can restrict the absorption of the underlying soil, and their retention of foliage through the winter rainy season promotes maximum interception.

For maximum effectiveness, the growing medium should have a minimum depth of 450 mm. Analysis of the feasibility of street trees must consider implications to the surrounding pavement structures, as tree roots can damage concrete sidewalks and paved roads, although this effect can be mitigated by the use of structural soils.

Structural Soils

Structural soils are soil media that can be compacted to meet pavement design and installation requirements while permitting adequate root growth. It is generally composed of gap-graded crushed stone, clay loam and a hydrogel stabilizing agent to bind the mixture together. It provides a root-penetrable, high strength pavement system that shifts design away from individual tree pits (Bassuk, Grabosky, Trowbridge, and Urban, 1996).

Structural soil can be located under the sidewalks adjacent to most arterial and local roads. By allowing roots to cover a greater area without damaging pavement structure, structural soil can reduce some of the drawbacks of street trees.

9.5.7 Green Space Land uses

There is currently a significant amount of green space throughout the study area, mainly found in a few parks or conservation areas as well as on the low density residential lots. This is reflected by the high Riparian Forest Integrity value of 73.4% for the regions of the study area north of the ALR (16 Avenue).

Significant green spaces found in the study area include:

- Dart Hill Garden Park
- Redwood Park

Future development plans show that many areas of the residential areas will be densified with several additional small parks or green spaces along riparian corridors proposed. These proposed land use changes are in agreement with the objective to preserve existing green space and undeveloped lands.

The BCS has identified hubs, sites, and corridors in the study area for environmental protection to maintain and enhance the aquatic and terrestrial value of the existing GIN. We have proposed the addition of several other environmental features into the GIN as well as specific enhancement projects as outlined in Section 4.

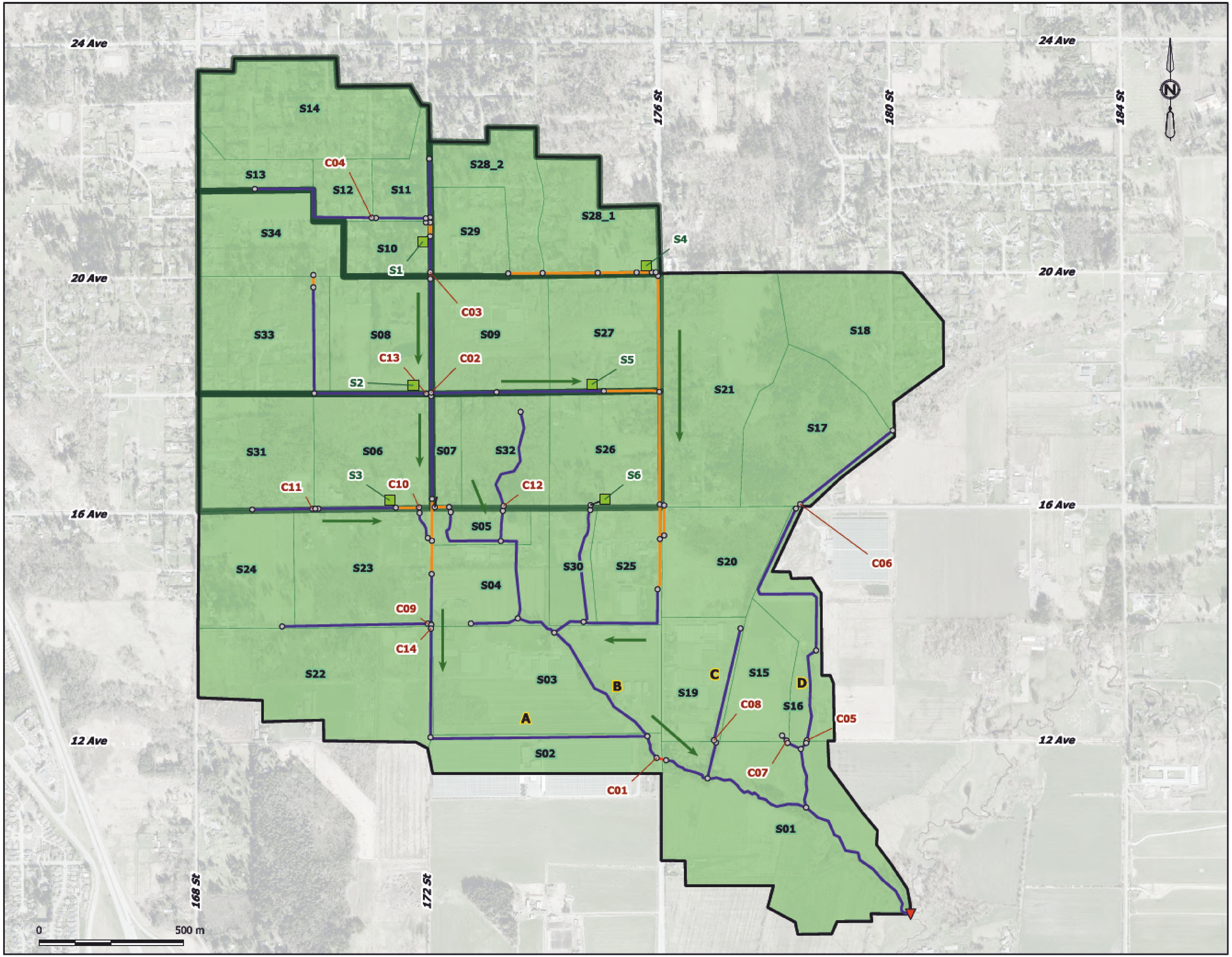
9.5.7.1 Potential BMPs and LIDs for Green Space Land Uses

The preservation of green spaces has inherent benefits to stormwater management of the study area and is itself a type of BMP. No further BMPs or LIDs would be needed to help achieve stormwater management objectives.

9.5.8 Agricultural Land Reserve

There are large portions of the study area which are contained within the ALR; generally, the region south of 16 Avenue. We note that the operation and management of land within the ALR is protected under the Farm Practices Protection (Right to Farm) Act. As such, there is little to no opportunity for municipalities to enforce stormwater management LIDs and BMPs on agricultural lands.

In general, stormwater management within the City's agricultural areas is covered under the lowland drainage studies, which are distinct from the various ISMPs within the upland areas.



Map File: C:\Users\fnneye\Desktop\map_Surrey_SamHill_20190118.map

LEGEND

Catchment Area
Pond Catchment
Open Channel
Storm Sewer
Culvert
Node
Outfall
S1 Storage Location
C01 Culvert Label
A EPS Reporting Location
S01 Subcatchments
Flow Direction

SCALE:	AS SHOWN		
PROJECT NO.	2017-2991	INITIAL	DATE
DRAWN		EF	18-09-21
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

Associated Engineering GLOBAL PERSPECTIVE. LOCAL FOCUS.

CITY OF SURREY the future lives here.

SAM HILL CREEK ISMP

EPS REPORTING LOCATIONS

DRAWING NUMBER	REV. NO.	SHEET
MAP 9-1		

10 Recommended Drainage Upgrades

10.1 LOCATION SPECIFIC IMPROVEMENTS

We have completed hydraulic modelling based on future conditions and performed an environmental assessment of the study area. We analyzed the results and have determined a number of location specific drainage upgrades and environmental improvement projects. These projects address a range of issues including barriers to fish passage, undersized culverts, or proposed storage ponds. See Table 10-1 for a complete list of projects and Map 10-1 for locations.

Table 10-1
Recommended Drainage Upgrades and Environmental Improvements

Location Reference	Reason for Project	Description/Action	Cost
1	Barrier to fish passage	Stepped concrete barriers should be replaced with stepped pools 0.3 m in height with each step (350 m)	$150,000
2	Long sewer	260 m of sewer should be daylighted and returned to open channel	$250,000
3	Blocked culvert	Clear debris from culvert	$10,000
4	Fish passage	Re-establish hydraulic connection between the Sam Hill Creek Diversion and the watercourse to the east.	$50,000
5	Vegetation	Re-plant native vegetation in riparian areas and establish setbacks	$70,000
S1	Detention Storage	Implement 12,391 m^3 stormwater storage.	$5,810,000***
S2	Detention Storage	Implement 13,362 m^3 stormwater storage.	$6,260,000***
S3	Detention Storage	Implement 4,222 m^3 stormwater storage.	$1,980,000***
S4	Detention Storage	Implement 9,104m^3 stormwater storage.	$4,270,000***
S5	Detention Storage	Implement 10,595 m^3 stormwater storage.	$4,970,000***
S6	Detention Storage	Implement 10,644 m^3 stormwater storage.	$4,990,000***
A	Storm Sewer Upgrade	Replace existing sewer with upgraded pipe. See Table 9-9.	$105,000**
B	Storm Sewer Upgrade	Replace existing sewer with upgraded pipe. See Table 9-9.	$385,000**
C02*	Culvert	Upgrade culvert to 1200 mm dia.	$80,000**
C03*	Culvert	Upgrade culvert to 1500 mm dia.	$90,000**

Location Reference	Reason for Project	Description/Action	Cost
C04	Culvert	Upgrade culvert to 750 mm dia.	$80,000**
C05	Culvert	Upgrade culvert to 675 mm dia.	$55,000**
C07	Culvert	Upgrade culvert to 375 mm dia.	$50,000**
C11*	Culvert	Upgrade culvert to 750 mm dia.	$65,000**
C13*	Culvert	Upgrade culvert to 1500 mm dia.	$90,000**

* Within NCP#3. Drainage changes recommended here are likely to be revisited as significant changes to the stormwater network are expected as the NCP is implemented.

** Based on similar projects in the City's 10-year Servicing Plan

*** Based on similar projects in the Redwood Heights NCP as supplied by the City.

We note that several additional environmental improvements were listed in Section 4. These are located either on private property or are within the jurisdiction of the Ministry of Transportation. While still valid, these recommendations have not been included in the summary list of Table 10-1 for the City to address as they are outside of the City's property.

Upgrades to the drainage system were developed with the following conditions and assumptions. Rationales for the assumption can be found in Section 8.

- Detention storage volumes were developed using the 5-year return period design storm applied to the future land use condition with no BMP implementation and maximum allowable outflow equal to 50% of the 2-year post-development peak flow rate.
- Storm sewer upgrades were assessed using the 5-year return period design storm applied to the future land use condition and included storage ponds but assumed no BMP implementation.
- Culvert upgrades were determined using the 100-year return period design storm applied to the future land use condition with no storage ponds or BMPs included.

Detailed detention pond costs are shown in Table 10-2.

Table 10-2
Detailed Detention Pond Costs

Storage Pond	Pond Size [m³]	Pond Area [m²][1]	Required Lot Size [m²][2]	Volume Cost[3]	Land Cost[4]	Landscaping Cost[5]	Total Cost (Rounded)
1	12391	6196	7744	$495,640	$5,214,765	$96,805	$5,810,000
2	13362	6681	8351	$534,480	$5,623,411	$104,391	$6,260,000
3	4222	2111	2639	$168,880	$1,776,833	$32,984	$1,980,000
4	9104	4552	5690	$364,160	$3,831,427	$71,125	$4,270,000
5	10595	5298	6622	$423,800	$4,458,916	$82,773	$4,970,000
6	10644	5322	6653	$425,760	$4,479,538	$83,156	$4,990,000

[1] Assuming a maximum depth of 2 m.

[2] Lot size is 25% larger than pond area.

[3] Volume cost is $40/m³.

[4] Land Cost is $2,725,000/ac.

[5] Landscaping is applied to 25% of required lot size at $50/m².

10.2 RECOMMENDED BMPS

In addition to these specific projects, we have developed a strategy of BMP and LID implementation that is applicable to areas expecting new development or re-development. This strategy builds from the information presented in Section 9 developed to describe the candidate BMPs. This strategy will be implemented as new or existing developments are built. BMPs should be implemented to mitigate the potential hydrologic impacts of development within the study area.

Except for some parks and green spaces, future land uses will generally see densification of areas north of 16 Avenue. Many currently zoned one-acre residential lots will be rezoned as a mixture of higher density single family residential, multi-family residential, and limited amounts of institutional and commercial zoning. South of 16 Avenue, land use will remain zoned for agricultural purposes as part of the Agricultural Land Reserve (ALR). We note that the operation and management of land within the ALR is protected under the Farm Practices Protection (Right to Farm) Act. As such, there is little to no opportunity for municipalities to enforce stormwater management LIDs and BMPs on agricultural lands.

As noted in Section 4, infiltration of the top layer of soil is generally good in the upland area (north of 16 Avenue). However, this layer is quite shallow (20 to 80 cm). As a result, the application of BMPs will focus on attenuating peak flows and improving water quality rather than reducing runoff volumes.

Table 10-3 summarizes the recommended BMP performance targets.

Table 10-3
Recommended BMP and Detention Pond Performance Targets

	Single Family (Urban Single Family, Semi-Detached Residential)	Multi-Family Residential (Multiple Residential Cluster, Low-Density Multiple Residential, Medium Density Residential, and Townhouse Residential)	Commercial, Institutional, and School Land Uses	Road Rights-of-Way
BMP Rainfall Capture Target*	72% of the 2-year return period event (38.3 mm)			
BMP Maximum Allowable Release Rate*	0.25 L/s/ha			
5-year Stormwater Storage**	278 m³/ha			
5-year Maximum Allowable Release Rate***	6.6 L/s/ha			

* As recommended in the Metro Vancouver Stormwater Source Control Design Guidelines.

** Criteria is to control the 5-year post development flow to 50% of the 2-year return period post-development flow. Value presented is based on an average of calculated storage volumes for each subcatchment.

*** Average maximum release rate of proposed detention ponds (see Table 8-6).

The following BMPs are proposed for each category of land uses.

10.2.1 Residential Land Uses

Single Family Land Uses

This category of land use is assumed to contain Urban Single Family, and Semi-Detached Residential (RF-SD). Land use for Urban Single Family is not explicitly defined in the City's Zoning Bylaw or the DCM. However, there are two residential zoning types that meet the proposed dwelling density of 10 to 12 Units Per Acre (UPA): RF-12 and RF-12C. Both of these lot types have a maximum lot coverage of 50%, except where a coach house has been built in RF-12C lots, the maximum is 59%. RF-SD has a maximum lot coverage of 60% in the Zoning Bylaw. Lot coverage is a measurement of the combined areas of all buildings, outdoor covered areas, and structures on a lot. Recognizing that, in practice, imperviousness exceeds the regulated value, imperviousness is specified as 80% for these lot types.

We recommend all impervious areas be hydraulically disconnected from the downstream conveyance system or receiving watercourses for Urban Residential lots.

Pervious Paving

Recognizing the limited amount of available pervious area, we recommend that absorbent landscaping should be applied to the entire pervious area on Urban Residential lots (20% of the total lot area). Pervious pavement should also be applied to the extent possible; we recommend that at least 25% of the total impervious area be pervious pavement.

Some lots may present an opportunity to implement underground storage and lots in the northern part of the study area may be in areas with infiltration potential. These facilities should be designed to attenuate the peak design flows in accordance with the DCM with analysis to support infiltrating some of the runoff.

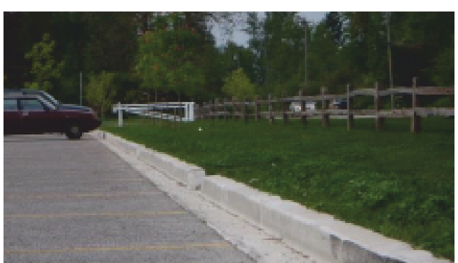
Infiltration trenches can also be implemented in the northern parts of the study area and designed in accordance with the DCM. Design should be in accordance with the DCM. Site specific investigation should be conducted before implementing any infiltration-based facilities.

Multi-Family Land Uses

Porous Pavement

There are four types of multi-family land uses specified in future land uses in the study area: Multiple Residential Cluster (RC), Low density Multiple Residential, Medium Density Residential, and Townhouse Residential. The specific zone definition is not available for these lot types and so we have assumed impervious values ranging from 65% to 70% for these lots.

Impervious areas should be limited as much as possible at the planning phase of new developments. Additionally, as with Single Family land uses, all impervious areas should be disconnected em or receiving watercourses for Multi-Family lots.



Porous Pavement

Recognizing the limited amount of available pervious area, we recommend that absorbent landscaping should be applied to at least half of the pervious area on Multi-Family lots (17.5% of the total lot area). Pervious pavement should also be applied to the extent possible; we recommend that at least 27% of the total impervious area be pervious pavement. As outlined in the DCM, subdrains should be considered where subgrades have low infiltration rates (<0.5 mm./hr).

Some lots may present an opportunity to implement underground storage. These facilities should be designed to attenuate the peak design flows in accordance with the

DCM. We note that while it may be possible to infiltrate stored water in the northern parts of the study area, most multi-family lots will be located between 24 Avenue and 16 Avenue in areas where the infiltration potential may be limited. Site specific investigation should be conducted before implementing any infiltration-based facilities.

10.2.2 Commercial Land Uses

Under the City's Zoning Bylaw, Commercial land use type lots can have varying amounts of lot coverage based on classification ranging from 50% to 85%. However, the DCM prescribes an imperviousness value of 90% for all commercial land uses.

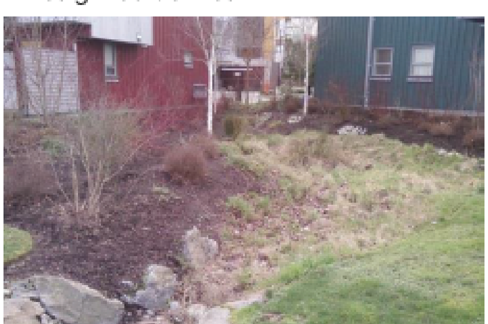
Commercially zoned lots have only been designated in two areas of NCP #3, totalling about 1 ha of developed land. While the total lot coverage value is unknown, we have assumed a value of 90% imperviousness for these areas for the purposes of modelling future land use.

Rain garden adjacent to parking lot.

In Section 9, we identified a number of potential BMPs that can be applied on Commercial lots. These include bioswales, green roofs, rain gardens, water quality devices, and underground storage facilities.

We recommend implementing bioswales along the edges of parking lots, while rain gardens can be located to receive runoff from parking lots and/or rooftops. Based on the Metro Vancouver Stormwater Source Control Design Guidelines (2012), bioswales and rain gardens should both be sized to at least 5% of the impervious area they service. This represents a 20:1 ratio of impervious area to bioswale/rain garden footprint. The guidelines provide additional recommendations regarding the detailed design and application of these BMPs.

Where buildings have flat roofs and occupy a large fraction of the total lot area, we recommend that green roofs be implemented. The potential size of green roof is limited by the roof area that is available. The standard range for green roof soil depths is 150 mm to 600 mm, as noted in the Stormwater Source Control Design Guidelines.



Rain garden adjacent to buildings.

As an alternative to these more natural BMPs, structural treatment devices can be implemented to remove total suspended solids (TSS) prior to discharging flows from the site. There are a number of proprietary treatment devices available from a variety of vendors. These units are typically sized based on a treatment flow rate, and a representative particle size distribution for the site (or average particle size). We recommend that structural treatment devices be sized to accommodate site runoff from 72% of the 2-year, 24-hour rainfall event. Further design guidance is provided in the DCM.

There may be potential for infiltration facilities in the north part of the study area, where business centre development is expected to occur (along 20 Avenue). As such, these lots present a potential opportunity to apply underground storage and infiltration facilities. These underground storage facilities would be aimed at capturing and infiltrating runoff from the more frequent, low-intensity rainfall events.

10.2.3 Institutional and School Land Uses

Institutional and School Land uses make up a relatively small area of the study area (approximately 5.5 ha in NCP #3). The Zoning Bylaw describes Institutional Zones as having a maximum lot coverage of 40% while the DCM describes them as having an imperviousness of 80%.

Given the similarity to Commercial land uses, BMPs can be applied in a similar manner as described in Section 10.2.2. However, as the zoned lots are located on land that is further south and less likely to have favourable infiltration characteristics, infiltration based BMPs are not recommended without site investigation into the local hydrogeological conditions.

10.2.4 Road Rights-of-Way

Road rights-of-way (ROWs), being linear and publicly owned, provide an opportunity for implementing BMPs on a widespread scale. Further, since the City already has funding committed to road projects, these projects present an opportunity to incorporate BMP measures in a cost-effective manner. Rather than planning and funding Stormwater LID projects in isolation, existing road projects can be modified to achieve LID goals.

Structural Treatment Device

There are a variety of road classifications within the study area, including local, collector, and arterial. Highway 15, which runs north-south through the study area, falls under the jurisdiction of the Ministry of Transportation and Infrastructure. There is also a proposed collector road extension along the existing collector road of 172 Street from 16 Avenue to 21 Avenue.

Within the study area, arterial roads either have 30 m or 37 m wide ROWs. In the City's standard drawings, these road cross sections show each side of the road typically has a 3.2 m wide utility strip, as well as a 3.8 m wide boulevard down the middle. Collector roads in the area tend to have 24 m wide ROWs, with utility strips along each side 3.2 m wide.

Road ROWs can incorporate a variety of BMPs, including:

- Bioswales
- Rain gardens

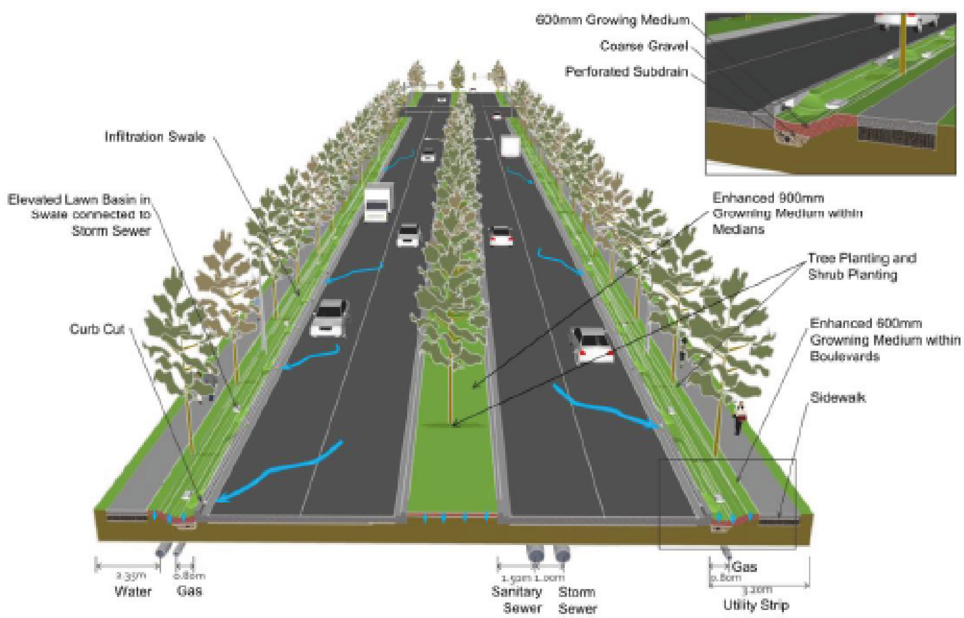
- Absorbent landscaping and street trees
- Structural soils

Figure 10-1 illustrates the potential configuration of BMPs to provide hydrologic benefits across the study area. The City's DCM provides design guidance on implementing some of these BMPs in road ROWs.

A review of the aerial photography of the study area reveals that few of the road ROWs are built to reflect the standard cross section. The paved surfaces are narrower than typical drawing specifies and there are generally vegetated areas along the road edges. There are few boulevards down the middle of existing arterial roads. This presents an opportunity during re-development as this portion of the ROW can be improved to provide hydrological benefit.

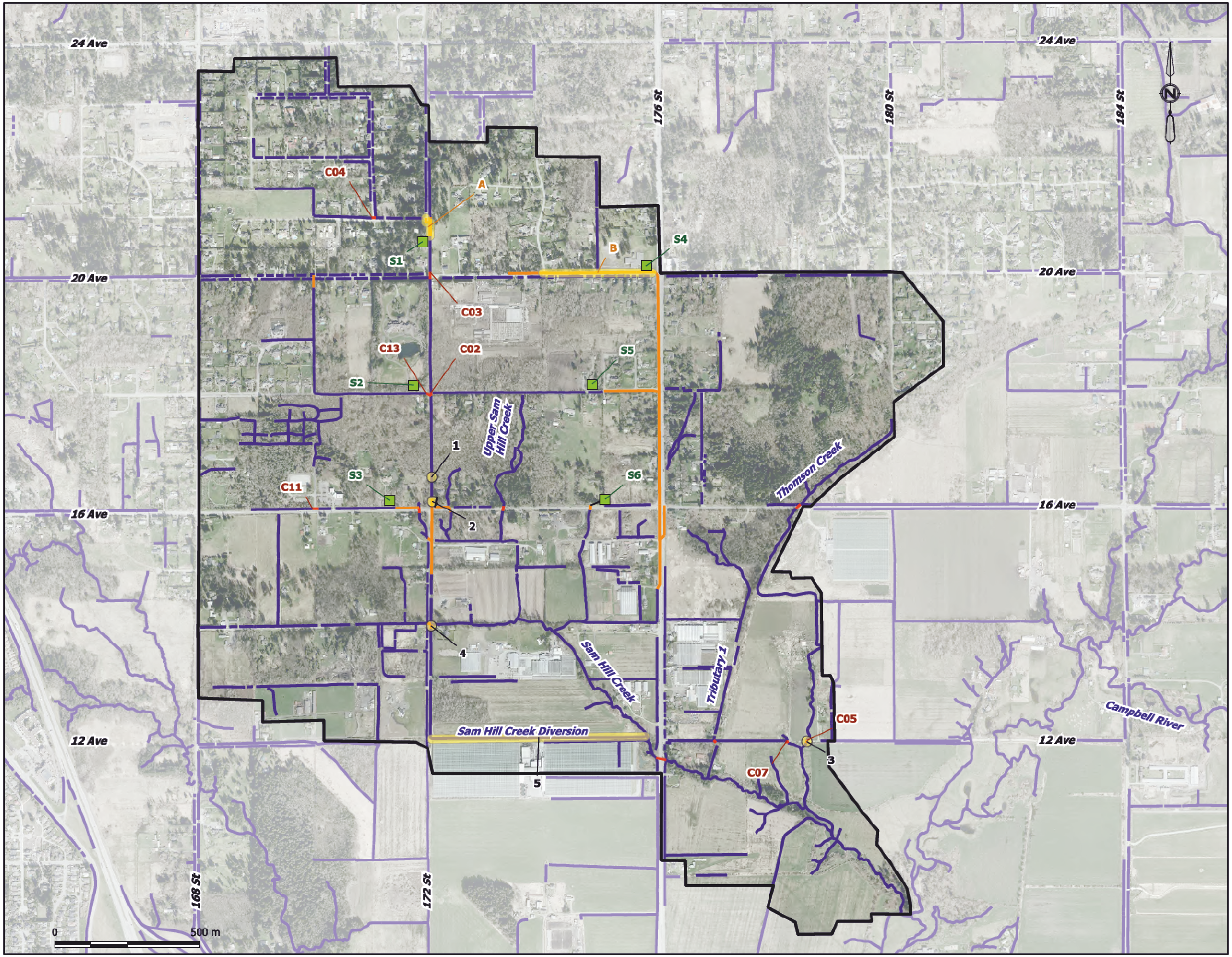
Given the challenges in estimating the potential extent of various BMP applications within road rights-of-way, we did not explicitly calculate the impact of road right-of-way source controls. As noted, our analysis focused on applying various BMPs for different land uses. Nevertheless, road right-of-way BMPs will provide a hydrologic benefit, and we recommend these measures be implemented wherever possible. We note that the City has indicated that pervious pavement has not been implemented with success in roadway ROWs. For this reason, we have omitted this BMP in favour of other types of BMPs as listed above.

Local and Collector Roads



Arterial Roads

Figure 10-1
Road Right-of-Way Source Control / BMP Configurations



LEGEND

- Storage Facilities
- Storm Sewer
- Culvert
- Watercourse
- 01 Environmental Improvement
- S01 Storage Facilities ID
- A Storm Sewer Location ID
- C01 Culvert Labels
- Upgrade or Improvement

SCALE:	AS SHOWN		
PROJECT NO.	2017-2991	INITIAL	DATE
DRAWN		EF	18-09-21
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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SAM HILL CREEK ISMP

DRAINAGE AND ENVIRONMENTAL UPGRADES

DRAWING NUMBER	REV. NO.	SHEET
MAP 10-1		

11 Implementation Strategies

11.1 FUNDING STRATEGIES

A variety of funding sources are available to support the implementation, operation and maintenance of the stormwater management components recommended within the Sam Hill Creek ISMP.

Individual land owners are responsible for funding and implementing source controls and BMPs specific to their own properties. Offsite upgrades to City-controlled infrastructure directly related to development activities will also be chargeable to the subject property owner / developer in the form of Development Cost Charges (DCCs). These are governed by the Surrey Development Cost Charge By-law No. 19478 (2018). DCCs are paid to the City by proponents who obtain approval for lot subdivision or a building permit to develop or alter buildings. For properties zoned as Single Family Residential, DCCs are determined on a per-lot basis; for all remaining land uses within the City, DCCs are determined based on parcels.

For infrastructure upgrades on City owned property, the Capital Construction Program allocates funds for infrastructure projects throughout the City and includes drainage, sewer, water and roads projects that maintain and renew existing City infrastructure or support growth and development. Based on the 2017 Capital Construction Program overview, of the total $129 million Capital Construction Program budget, $17.9 million is allocated to drainage projects.

These projects stem from the relevant 10-Year Servicing Plan, the most recent of which was published for the 2018 to 2027 timeframe. The 10-Year Servicing Plan lists the approved projects as well as their expected cost, priority, and categorization in terms of 'growth' or 'non-growth' type expenditures. 'Growth' and 'non-growth' refer to the reason for the project, i.e. if it supports an expansion of existing services to support new populations, or if it is intended to maintain existing services. We note that development-driven upgrades servicing catchments greater than 20 hectares are eligible to be funding from DCCs, while those for service areas smaller than 20 hectares must be directly funded by development proponents.

We also note that the funding allocated for roads ($44.4 million) represents a significant portion (34%) of the City's funding for the Capital Construction Program. As a result, there is significant potential to implement stormwater BMPs through road projects; we encourage the City to include the implementation of source controls along local, collector and arterial road renewal projects where applicable. This will provide a substantial benefit to watershed health and be much more cost-effective than stand-alone stormwater management projects in locations where roads are not otherwise being improved.

11.2 ENFORCEMENT STRATEGY

Managing rain where it falls is referred to as "source-control" and this is a critical part of any framework intended to improve watershed health. This means that individual property owners must participate in the management of stormwater. However, it can be difficult to enforce stormwater management priorities at this fine of scale. The City is aware of the difficulties in enforcing policies regarding stormwater management and has developed a number of tools to do so including:

- City of Surrey Engineering Design Criteria Manual – Section 5 Storm Drainage System
- City of Surrey Zoning Bylaw, 1993, No. 12000
- City of Surrey Drainage Parcel Tax Bylaw, 2001, No. 14593
- City of Surrey Stormwater Drainage Regulation and Charges Bylaw, 2008, No. 16610
- City of Surrey Erosion and Sediment Control Bylaw, 2006, No. 16138
- City of Surrey Supplementary Master Municipal Construction Documents, 2016
- City of Surrey Official Community Plan Bylaw, 2013, No. 18020 - Streamside Development Permit Areas
- City of Surrey Invasive Species Management Plan

We understand the City is continually reviewing these documents with a view to improve the management of stormwater within the City.

11.3 MONITORING STRATEGY

As part of the Integrated Liquid Waste Resource Management Plan Metro Vancouver published the Monitoring and Adaptive Management Framework for Stormwater (AMF). This document outlines a framework for establishing a baseline understanding of watershed health and tracking changes to it over time. The City of Surrey has adopted this framework within its watersheds to track the success of implementing stormwater management goals and targets, such as those set out in ISMPs.

The AMF recommends monitoring indicators of watershed health for both high (>1%), low gradient (<1%) and piped systems. These include water quality indicators, flow monitoring, and benthic invertebrate monitoring (high gradient systems only). The Sam Hill Creek watershed has systems that fall within each of these categories.

The City has established a water quality monitoring site on Sam Hill Creek south of 16 Avenue in the low gradient reaches of the creek, at the intersection of 172 Street and 14 Avenue. We understand that there is no benthic invertebrate testing data available for this location (See Section 5.3). This is also the location of a flow monitoring station.

We recommend that monitoring efforts be expanded within the watershed. The single monitoring station currently on Sam Hill Creek receives runoff from a significant portion of the watershed (approximately 150 ha), however, a similarly sized area of the watershed is being diverted down the Sam Hill Creek Diversion. In this location, water is flowing over the weir and continuing south along Sam Hill Creek Diversion. This area will receive runoff from areas that are expected to be redeveloped in the future. Until the hydraulic connection between the diversion and Sam Hill Creek is restored (See Section 10), monitoring Sam Hill Creek Diversion would be helpful to measure the success of implementing stormwater controls during future development.

We also recommend that benthic invertebrates health be measured using the B-IBI in accordance with Metro Vancouver's AMF within the watershed. As a low-gradient watercourse, the AMF suggests monitoring water quality parameters and flows. Water quality sampling would be conducted seasonally, during the wet season between November and December, and during the dry season, between July and August. While benthic invertebrate sampling is suggested only for higher gradient streams, the monitoring location selected by the City is at the transition of Sam Hill Creek from a higher gradient (>1%) to a lower gradient (<%) system. Sampling in accordance with the AMF, taking care to highlight the species richness rather than only absolute counts, would be beneficial to understanding the effect of watershed health improvement efforts.

Closure

This report was prepared for the City of Surrey to provide a Final Integrated Stormwater Management Plan for the Sam Hill Creek watershed.

The services provided by Associated Engineering (B.C.) Ltd. in the preparation of this report were conducted in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions. No other warranty expressed or implied is made.

Respectfully submitted,
Associated Engineering (B.C.) Ltd.

2019-09-12

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REPORT

Appendix A – Grandview Heights #3 NCP Environmental Study

Associated Engineering — GLOBAL PERSPECTIVE. LOCAL FOCUS.

Date:	January 17, 2018	**File:**	2017-2991.00.E.04.00
To:	City of Surrey c/o Jeannie Lee, M.A.Sc., P.Eng.		
From:	Stacy Boczulak and Chris Hegele		
Project:	Sam Hill ISMP		
Subject:	Grandview Heights #3 NCP Environmental Study		

MEMO REPORT

1 INTRODUCTION

Associated Engineering (Associated) was retained by the City of Surrey (the City) to complete an Integrated Stormwater Management Plan (Stage 1 ISMP) with an Environmental Study component. The Environmental Study will influence the future development of a land use plan for the Grandview Heights Neighbourhood Concept Plan (NCP) Area #3. The Stage 1 ISMP document has been submitted to the City and broadly outlines the existing environmental conditions of the ISMP area (Associated 2017); however, the land use planning process requires further recommendations regarding the conservation and/or enhancement of identified and known key environmental features specific to the NCP. A large volume of environmental information has been previously assembled for the City, including detailed environmental information within the NCP Area # 3. To assist advancement the NCP process, this memo report will:

- Compile additional detailed environment information specific to the NCP Area #3 available in previous reports, and update based on recent knowledge gained during the Sam Hill Creek ISMP. Environmental information to be provided will include:
  - Watercourses, watercourse classifications, and recommended setbacks;
  - Vegetation resources, wildlife resources and wildlife habitat values (including species at risk (SAR);
  - Terrestrial Ecosystem Mapping (TEM) with rankings of vegetation values and presence of significant trees;
  - Wildlife habitat suitability mapping;
  - the Green Infrastructure Network (GIN) (i.e. hubs, sites and corridors);
  - Description of soils and terrain; and
  - Terrain mapping.
- Provide conservation recommendations and enhancement opportunities available within NCP Area #3 including proposed GIN protection.

2 METHODS

2.1 Characterization of the Existing Environment

2.1.1 Background Information Review

Associated compiled and reviewed the following information sources to characterize existing environmental conditions within NCP Area # 3:

- Habitat Wizard database (MOE 2017a);
- Fisheries Information Summary System database (MOE 2017b);
- BC Conservation Data Centre Species and Ecosystem Explorer database and associated reports (MOE 2017c);
- Species at Risk Public Registry (Government of Canada 2017);
- City of Surrey's Biodiversity Conservation Strategy (BCS; Diamondhead 2014);
- Grandview Heights Environmental Assessment and Tree Survey (Madrone 2008 and associated raw data);
- General Environmental Review for the Grandview Heights Plan Area, Surrey BC (Envirowest 2005);

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- City of Surrey's Watercourse Classification Map (CoS 2011);
- City of Surrey's Online Mapping System (COSMOS; CoS 2017a);
- Published Soil Survey and Soil Management Reports (Luttmerding 1984, Bertrand et al. 1991); and
- Other relevant consultant and government reports and journals.

2.1.2 Field Investigation

In addition to the above information sources, Associated conducted field assessments on May 9, 2017 and October 5, 2017 of the NCP # 3 Study area to validate available information regarding vegetation resources, fish and wildlife resources and the potential for species-at-risk presence and habitat use.

2.1.3 Data Analysis and Mapping

A large volume of environmental information has been previously assembled for the City, including information overlapping with NCP Area # 3. Background information and data collected during field assessment were compiled and summarized to characterize the existing environment in the NCP #3 area. We sourced existing mapped data across a wide suite of documents to create new map products as described below.

- Watercourse classification mapping based on the City's watercourse classification system (CoS 2011) and updated based on observations made during Associated's field assessment of select watercourses and the City's current classification system in Part 7a (Streamside Protection) of the City of Surrey's Zoning Bylaw (1993, 12000). Setbacks corresponding to the City's Zoning Bylaw (1993, 12000) were applied.
- Terrestrial Ecosystem Mapping (TEM) based on polygons developed by Madrone (2008) were adjusted and updated using recent areal photography and observations from Associated's field assessment. TEM polygon numbers correspond to Madrone's original study (Madrone 2008).
- Vegetation value mapping in Madrone (2008) was updated to reflect the updated TEM polygons and rankings were confirmed based on the field assessment. Vegetation values were calculated using a weighted average score for: the type of ecosystem, forest structural stage, riparian features and polygon size (Madrone 2008).
- Wildlife habitat suitability ranking was completed using the Biodiversity Conservation Strategy (BCS) habitat suitability ranking system (Diamondhead 2014) to assess each of the polygons in the updated TEM (described in previous bullet). The BCS system ranks terrestrial and aquatic habitats and then applies a modifier based on the size of the terrestrial habitat polygon or on the watercourse classification (Diamondhead 2014). The ranking methodology of the BCS was used as Madrone's (2008) wildlife suitability ranking was not completed for the majority of NCP Area #3, and the ranking system was not easily replicated.
- The City's existing terrain information was used to calculate slope percentages within NCP # 3. Additionally, The Steep Slope Development Permit Area polygon, provided by Surrey, was overlaid onto the terrain map to clearly distinguish areas containing hazardous terrain.

2.2 Recommendations

Recommendations for conservation and promoting connectivity within Surrey's existing Green Infrastructure Network (GIN) considered habitat composition and size, connectivity, habitat suitability, and species at risk potential.

Also provided are general recommendations for management and mitigation measures related to:

- Aquatic / instream habitat;
- Riparian habitat;
- High value vegetation and tree preservation areas; and
- High suitability habitat areas and species at risk.
- Invasive species.

Although it is unlikely that all of the recommendations can be followed, attempts should be made to incorporate as many recommendations as possible during the development of NCP Area #3. Although other guidelines may be applicable to specific development projects, the applicable recommendations presented here were based on the following environmental guidelines:

- Develop with Care 2014: Environmental Guidelines for Urban and Rural Land Development in British Columbia (MOE 2014);
- Guidelines for Raptor Conservation During Urban and Rural Land Development in British Columbia (MOE 2013);
- Land Development Guidelines for the Protection of Aquatic Habitat (DFO 1993);
- Standards and Best Practices for Instream Works (WLAP 2004);
- Best Management Practices Guidelines for Pacific Water Shrew (Craig et al. 2010)
- Part 7a (Streamside Protection) of the City's zoning by-law (1993, No. 12000);
- The City's Sensitive Ecosystems DPA#3 Guidelines (CoS n.d.);
- Environmental guidelines to help minimize disturbance and maintain ecosystem function (CoS PRC n.d., and Ward et al. n.d.); and
- The City's Tree Protection Bylaw (2006, No. 16100).

3 EXISTING CONDITIONS

3.1 Watercourses and Fish Habitat

Part 7a (Streamside Protection) of the City's Zoning Bylaw (1993, No. 12000) describes the classification system for watercourses, tributaries and ditches in each watershed within the City. The classification provides an overall fish habitat value rating based on potential fish presence, duration of water flow and water source and surrounding vegetation potential.

All watercourses within the City are classified as follows:

- Class A: inhabited by salmonids year-round or are potentially inhabited year-round with access enhancement;

- Class A/O: inhabited by salmonids, primarily during the overwintering period, or potentially inhabited with salmonids during the overwintering period with access enhancement and non-salmonid species generally present year round; or
- Class B: a significant source of food and nutrient value to downstream fish populations with no documented fish presence and no reasonable potential for fish presence.

The Class C watercourses are currently mapped on the City's Watercourse Classification Map (CoS 2011) and Online Mapping System (COSMOS; CoS 2017); however, Class C watercourses are man-made conveyance channels that do not have significant food and nutrient value and are not assigned a streamside setback under the City's Zoning Bylaw (2006, No. 16100). These watercourses are mapped as solid green lines (Figure 1).

Watercourse types and minimum streamside setbacks corresponding with stream classifications are summarized in Table 3-1.

Table 3-1
Minimum Distance from Top of Bank (i.e., Streamside Setback)

Stream Type	Description	Stream Classifications	
		A or A/O	B
All Stream Types (except as shown below)		30	20
Channelized	Stream that has been dyked, diverted or straightened carrying drainage flows from headwaters or significant sources of groundwater, and can include channels that divert irrigation from a stream and send overflow water back to a stream.	25	15
Ditches	Stream that is a constructed drainage channel, carrying water that does not originate from a headwater or significant source of groundwater.	10	7
Natural	Stream predominantly in its natural state that is not significantly altered by human activity.	30	15
Large Ravines	Stream with a narrow, steep-sided valley with a minimum of 60 m between the top of bank from either side of the stream.	15	15

Notes:
Class A streams are mapped as solid red lines
Class A/O streams are mapped as dashed red lines
Class B streams are mapped as solid yellow lines

Based on aerial photography, LIDAR interpretation, and site reconnaissance, there are 12 watercourses contained within NCP Area #3 including Upper Sam Hill Creek (Figure 1; Table 3-2). These watercourses drain south/southeast to Sam Hill Creek. Six of the watercourses are Class C (i.e. Watercourses 2, 6, 8, 10, 11, 12), five are Class B (i.e. Watercourses 1, 3, 4, 5, 9), and one is Class A/O (i.e. Watercourse 7). There are also numerous Class C roadside ditches along the perimeter of the NCP Area #3 (Figure 1).

Table 3-2
Watercourses within NCP Area #3

Watercourse #	Current Class	Recommended Class	Setback (m)	General Description
1	C	B	15	Linear, channelized stream, with scoured substrate, and relatively intact riparian corridor contributing significant food and nutrient supply to downstream fish habitat.
2	C	C	NA	Roadside ditch with insufficient flows to support fish populations and insignificant contribution of food and nutrient supply to downstream fish habitat.
3	C	B	15	Linear, channelized stream, with scoured substrate, contributing significant value as food and nutrient supply to downstream fish habitat.
4	C	B	15	Linear, channelized stream with depositional and scoured substrates, summer baseflows and mainly intact riparian corridor contributing significant value as food and nutrient supply to downstream fish habitat.
5	C	B	15	Linear, channelized stream with depositional and scoured substrates, summer baseflows and an intact riparian corridor. Watercourse has insufficient flows to support fish populations but provides significant value as food and nutrient supply to downstream fish habitat.
6	C	C	NA	Roadside ditch with insufficient flows to support fish populations and insignificant contribution of food and nutrient supply to downstream fish habitat
7	B	A/O	25	Linear, channelized stream through mainly intact riparian corridor. Sufficient flows to support fish populations during high flows, with access improvements. Historical occurrences of fish.

Watercourse #	Current Class	Recommended Class	Setback (m)	General Description
8	B	C	NA	Steep depression with no defined channel or substrate, or visible flow. Provides no food or nutrient supply to downstream fish habitat.
9	B	B	15	Natural stream with intact riparian area. Watercourse has insufficient flows to support fish populations but provides significant food and nutrient supply to downstream fish habitat.
10	B (some A)	C	NA	Shallow roadside ditch with insufficient flows to support fish populations and insignificant contribution of food and nutrient supply to downstream fish habitat.
11	B	C	NA	Shallow ditch (approximately 15 m long) leading to storm drain. No flows to support fish populations and insignificant value as food and nutrient supply to downstream fish habitat.
12	NA	C	NA	Network of relic agricultural drainage ditches with no flows to support fish populations and no contribution of food and nutrient supply to downstream fish habitat.

3.1.1 Class A/O Watercourses

Class A/O watercourses are inhabited or potentially inhabited by fish (primarily during the over-wintering period), if migration barriers are removed. These watercourses typically have a well-defined channel, suitable instream habitat and cover (e.g., deep pools, boulders, large woody debris, instream vegetation), intact riparian vegetation, and sufficient, sustained water flow and depth to support fish populations.

Watercourse 7 is a channelized stream currently classified as Class B ditch, but should be reclassified as a Class A/O channelized stream with a minimum 25 m streamside setback, since the watercourse currently provides good overwintering habitat and suitable flows to support fish populations during winter high flows, with access improvements. Fish use during the summer may be limited by low flows. The watercourse is a straight, high gradient (approximately 12%) channel with an average width of 1.2 m and average bankfull depth of 0.3 m (Photos 7 – 9). The watercourse has constructed concrete weir steps and pools along its length. Substrates are primarily cobbles and boulders. The riparian vegetation is mature and intact on the east bank with the 172 Street right of way on the west bank. Average wetted width and depth during the October field assessment was 0.9 m and 0.09 m. The watercourse flows through a culvert at 16th Avenue crossing, which is approximately 260 m long culvert and has a gradient of 9.8 % (CoS 2017) and acts as a fish passage barrier. Downstream of 16th Avenue the watercourse connects to Sam Hill Creek.

Coho salmon and cutthroat trout have previously been documented in the watercourse (MoE 2017a). Fish passage improvements such as daylighting sections of the culvert at 16th Avenue, regrading of the culvert to reduce gradient, and installing an open bottom culvert crossing could re-establish fish use in this watercourse upstream of 16th Avenue. In addition, removal of the concrete weirs and channel enhancements (e.g., log and boulder steps, and channel meanders) could improve access and fish use in this watercourse.

3.1.2 Class B Watercourses

Class B watercourses are not fish-bearing, but provide a significant food and/or nutrient source to downstream fish-bearing habitat. These watercourses typically have a relatively intact riparian corridor and a well-defined channel with scour and alluvial substrate indicative of substantial flows during at least the wetter times of the year (i.e., late fall to late spring). However, low water flow, duration of flow and/or extreme gradients (i.e., >20%) in these watercourses are limiting factors to support fish presence.

Watercourses 1, 3, 4, and 5 are currently classified as Class C ditches by the City but should be reclassified as Class B channelized streams with a minimum 15 m streamside setback. These watercourses are well-defined, linear channels with relatively intact riparian corridors. The channels have scoured substrates and undercut banks indicating substantial flows during high rainfall and the wet fall and winter seasons. These watercourses contribute food and nutrients to downstream fish-bearing habitat (i.e., Sam Hill Creek) but flows are not of sufficient volume or duration to support fish populations. Watercourses 1 and 3 were dry during the October field assessment but have an average channel width of 1.2 m and average bankfull depth of 0.3 m. Substrates include gravel, and cobble indicating substantial flow at wetter times of the year (Photos 10 – 14). Watercourse 4 has an average channel width of 2.0 m and bankfull depth of 0.4 m with fine substrates. During the October field assessment, average wetted width was 0.7 m and average wetted depth was 0.03 m (Photos 15 – 16). Watercourse 5 has an average channel width of 1.7 m and bankfull depth of 0.3 m with cobble and gravel substrate. During the October field assessment, this watercourse was dry at its north end near 20 Avenue but had an average wetted width of 0.5 m and average water depth of 0.05 m at the south end near 18 Avenue (Photos 17 – 18). There is also a natural barrier with a concrete weir built over top of it approximately 100 m upstream from 18 Avenue (Photo 19).

Watercourse 9 is a natural stream currently classified as a Class B ditch by the City. This watercourse has an average channel width of 1.4 m and bankfull depth of 0.6 m (Photos 20 - 21). During the May field assessment, average wetted width was 1.2 m and average wetted depth was 0.1 m. This watercourse is steep (approximately 15%), and is characterized by a step-pool morphology with fines and organic substrate. Canopy and instream cover (i.e., large woody debris) is abundant. Natural large woody debris jams and a steep gradient combine to create natural barriers (0.4 m to 1.0 m drops) to fish passage (Photos 21). This watercourse does not provide sufficient flow volume to support fish populations, but is a significant source of food and nutrient supply to downstream fish habitat (i.e., Upper Sam Hill Creek) and should remain a Class B natural stream with a minimum 15 m streamside setback.

3.1.3 Class C Watercourses

Class C watercourses are ditches that are non-fish bearing channels that have insignificant food and/or nutrient value. These watercourses are typically shallow, low gradient road-side ditches with no visible channel scour or alluvial substrate, limited flow, and limited riparian vegetation (typically mowed grasses).

Watercourses 2 and 6 are currently classified as Class C ditches by the City and should remain as such. Although these ditches drain to Class B watercourses, they are shallow, low gradient roadside ditches with little to no riparian vegetation and no scoured channel or alluvial substrate (Photos 22 - 24). Average channel width and bankfull depth of these ditches are 0.8 m and 0.2 m, respectively. Based on the lack of flow and habitat conditions, these watercourses are an insignificant source of food and nutrients to downstream fish habitat and should remain as currently classified (i.e., Class C ditches) with no minimum streamside setback.

Watercourse 8 is currently classified as a Class B natural stream by the City but should be reclassified as a Class C ditch. This watercourse is a low-lying area in a ravine that has no defined channel and no visible scour or depositional substrate (Photos 25 - 26). As such, this watercourse is an insignificant source of food and nutrients to downstream fish habitat and should therefore be reclassified to Class C ditch with no minimum streamside setback.

Watercourse 10 is currently classified as a Class B (with a small portion as Class A) ditch by the City but should be reclassified as a Class C ditch. This watercourse is a shallow, low gradient roadside ditch with no riparian vegetation and no alluvial substrate (Photos 27 and 28). Average channel width and bankfull depth of this ditch is 1.5 m and 0.7 m respectively. Based on the lack of flow and habitat conditions, this ditch is an insignificant source of food and nutrients to downstream fish habitat and should be reclassified as a Class C ditch with no minimum streamside setback.

Watercourse 11 is currently classified as a Class B ditch by the City but should be reclassified as a Class C ditch. This watercourse is a short (approximately 15 m), shallow, grassy swale leading to a storm drain (Photo 29). It has no defined channel and no scour substrate or evidence of substantial flow and as such, is an insignificant source of food and nutrients to downstream fish habitat. Therefore, this watercourse should be reclassified as a Class C ditch with no assigned minimum streamside setback.

Watercourse 12 is a network of relic, overgrown, agricultural drainage ditches located in a young stand of red alder (*Alnus rubra*) and thick understory of salmonberry (*Rubus spectabilis*), trailing blackberry (*Rubus ursinus*), and Himalayan blackberry (*Rubus armeniacus*). This network of linear channels is not mapped by the City and thus has no current classification. These channels are relatively deep and low gradient with no signs of scour or alluvial substrate (Photos 30 – 32). Average channel width and bankfull depth of these channels are 1.5 m and 0.9 m, respectively. These channels were dry during the October field assessment and, based on the overgrown channel bed and lack of substrate, the channels do not convey substantial flows at any time of the year to support fish populations or contribute significant food and nutrients to downstream fish habitat. In addition, this network of channels is not directly connected to Watercourse 4 or other downstream channels. As such, this network of relic channels should be classified as Class C ditches with no streamside setback required.

Several other Class C roadside ditches bordering the NCP Area #3, flowing along 18 Avenue, 176 Street, 16 Avenue, and 168 Street in the Study area consist of linear ditches, with uniform dimension with an average channel width of 1.8 m and average bankfull depth of 0.6 m (Photos 33 – 37). These drainages have a grassy bottom, lack a scoured channel, and were dry during the October field assessment. As such, these ditches do not contribute significant food and nutrient supply to downstream fish habitat and should therefore remain classified as Class C ditches with no minimum streamside setback.

3.2 Vegetation and Wildlife Habitat

A total of 35 TEM polygons were identified in the NCP Area #3. The polygons included four major vegetation classes in NCP Area #3:

- Forest;
- Riparian;
- Agricultural; and
- Suburban.

Only one area required updating (Polygon 0) from Madrone's Study (2005). The boundary of this polygon was updated due to land clearing of forest for agriculture.

Vegetation value and habitat suitability scores of polygons in the NCP Area #3 ranged from nil to very high.
The vegetation classes, value ranking and habitat suitability scores are described in detail below and summarized by individual TEM polygons in Table 3-3 and shown on Figures 2 and 3.

Table 3-3
Vegetation and Wildlife Habitat Summary

Polygon ID	Area (m^2)	Vegetation Class	Vegetation Value		Habitat Suitability		Description
			Rank*	Class	Rank*	Class	
0	101481	Agricultural and Suburban	5	Very Low	18	Very Low	Acreages with small fields
6	119586	Agricultural	4	Low	18	Very Low	Acreages with small fields
7	1412	Agricultural	5	Very Low	3	Very Low	Acreages with small fields
8	14785	Agricultural and Suburban	5	Very Low	6	Very Low	Acreages with small fields
9	7707	Forest	3	Moderate	16	Very Low	Forested groves around acreages

10	27513	Suburban	6	Nil	4.8	Very Low	Church and parking lot
11	14688	Agricultural and Suburban	5	Very Low	6	Very Low	Acreages with small fields
12	6954	Agricultural and Suburban	5	Very Low	6	Very Low	Acreages with small fields
13	13686	Forest	3	Moderate	14	Very Low	Forested groves around acreages
14	61562	Forest	2	Moderately High	67.5	Moderately High	Mixed forest and botanical garden
15	54349	Agricultural	5	Very Low	12	Very Low	Old field and lawn
16	1367	Forest	4	Low	8	Very Low	Tree stand
17	38479	Agricultural and Suburban	5	Very Low	12	Very Low	Acreages with small fields
18	11789	Agricultural and Suburban	5	Very Low	9	Very Low	Forested groves around acreages
19	30052	Forest	3	Moderate	72	Moderately High	Deciduous forest
20	144254	Forest	2	Moderately High	72	Moderately High	Undisturbed deciduous forest
21	19292	Forest	3	Moderate	65.25	Moderately High	Young deciduous forest
21	1789	Forest	3	Moderate	7.25	Very Low	Deciduous forest
22	4776	Forest	3	Moderate	32	Low	Mixed forest
23	51308	Suburban	4	Low	14.8	Very Low	Large landscaped property
24	60972	Agricultural and Suburban	5	Very Low	12	Very Low	New developments
25	18353	Forest	4	Low	19	Very Low	Recently disturbed deciduous forest
26	35110	Forest	3	Moderate	32	Low	Deciduous forest
27	94619	Agricultural	5	Very Low	12	Very Low	Cultivated field
29	10544	Forest	3	Moderate	72	Moderately High	Cedar hedges
30	12465	Forest	3	Moderate	72	Moderately High	Cedar hedges
31	131325	N/A (Industrial)	5	Very Low	7.2	Very Low	Nursery operation
32	21530	Forest	3	Moderate	72	Moderately High	Mixed forest

148	48750	N/A (Road)	6	Nil	0	Very Low	Roadways
170	19536	Forest	3	Moderate	72	Moderately High	Young deciduous forest
171	13831	Forest	3	Moderate	54	Moderate	Young deciduous forest
172	25284	Forest	2	Moderately High	72	Moderately High	Undisturbed mixed forest
173	47319	Forest	3	Moderate	67.5	Moderately High	Young deciduous forest
175	3488	Forest	3	Moderate	72	Moderately High	Undisturbed mixed forest
176	20337	Forest	2	Moderately High	72	Moderately High	Undisturbed mixed forest
1	N/A	Riparian Class A/O	N/A	N/A	105	Very High	25 m from watercourse 7
2	N/A	Riparian Class B	N/A	N/A	84	High	15 m from watercourses 3, 4, 5, 8, and 9.
3	N/A	Riparian Class C	N/A	N/A	77	Moderately High	Watercourse only

*For a description on how vegetation value and habitat suitability ranks are calculated, see Section 2.3.1. Vegetation value is based on Madrone's (2008) ranking system, and habitat suitability is based on Surrey's Biodiversity Conservation Strategy (Diamondhead 2014).

3.2.1 Forest

Forests in the NCP area are primarily second growth stands (Photos 1 and 2). They are structurally diverse, including both young and mature mixed forest. Dominant tree species include red alder, western red cedar (*Thuja plicata*), big leaf maple (*Acer macrophylum*), trembling aspen (*Populus tremuloides*), and black cottonwood (*Populus balsamifera* ssp. *Trichocarpa*) with lesser contributions of Douglas-fir (Pseudotsuga menziesii), Pacific dogwood (*Cornus nuttallii*), Pacific crab apple (*Malus fusca*), Douglas maple (*Acer glabrum*) and willow species (Salix spp.). The understory is mainly composed of salmonberry, vine maple (*Acer circinatum*), thimbleberry (*Rubus parviflorus*), with lesser amounts of bitter cherry (*Prunus emarginata*), oval-leaved blueberry (*Vaccinium ovalifolium*), red huckleberry (*Vaccinium parvifolium*) and elderberry (*Sambucus racemosa*). Forest floor cover consists of piggyback plant (*Tolmiea menziesii*), vanilla leaf (*Achlys triphylla*), lady fern (*Athyrium filix-femina*), sword fern (*Polystichum munitum*), Henderson's checker mallow (*Sidalcea hendersonii*) and stair step moss (*Hylocomium splendens*).

Forested habitat provides food resources (e.g., fruits and seeds), and/or hunting opportunities (i.e., predators), shelter, and nesting for bird species, and habitat supporting various smaller mammals. Larger forested areas provide shelter for larger mammals (e.g., deer). Birds may breed, forage or take refuge in forested habitats during seasonal use. Wildlife trees and coarse woody debris are important features for a range of wildlife living in forested habitat (Pojar 1991). Wildlife trees were observed within NCP Area #3. These trees provide forage for insectivorous bird species as well as nesting cavities for birds during the breeding season and additionally cover and refuge for small to medium sized mammals (e.g., bats).

In forested areas, vegetation values ranged from low to moderately high with most polygons given a moderate value (Figure 2; Table 3). Higher vegetation values corresponded with more mature forest and forest containing conifers (e.g. Polygon 172). Low vegetation values corresponded with isolated forests (e.g. Polygon 16).

Forested areas with good connectivity were rated as moderate-high habitat suitability with some smaller amounts of moderate habitat suitability. Isolated forested pieces were rated as having very low to low habitat suitability (Figure 3; Table 3).

3.2.2 Riparian

Riparian habitat is mainly intact within NCP Area #3 (Photos 7-11). Vegetation in riparian areas were similar to that described for the forests. The riparian forests were dominated by red alder, bigleaf maple, aspen and willows, with salmonberry, devil's club (*Oplopanax horridus*), horsetail (*Equisetum* spp.), and reed canary grass (*Phalaris arundinacea)* present in the understory. Riparian areas provide cover and food resources for mammals, nesting and foraging habitat for bird species, reptiles, amphibians and invertebrates.

The value of the vegetated areas overlapping these riparian areas range from very low (e.g. within Polygon 31) to moderately high (e.g. within Polygon 20) (Figure 2; Table 3). Habitat suitability of riparian areas does not consider the level of disturbance to vegetation and instead considers the habitat potential and the ability for the riparian vegetation to affect instream fish habitat value in the watercourse. Riparian areas associated with the Class A/O stream (i.e. Watercourse 7) are considered to have very high habitat suitability (Figure 3). Riparian areas associated with Class B streams (i.e. Watercourses 1, 3, 4, 5, 9) have high habitat suitability (Figure 3). Riparian areas associated with Class C streams (i.e. Watercourses 2, 6, 8, 10, 11, 12) are considered to have moderately high habitat suitability (Figure 3).

3.2.3 Agricultural

Agricultural areas include both actively cultivated and old unmanaged fields (Photo 3). Agricultural areas are often bordered by riparian habitats, associated with drainage ditches or channelized watercourses, remnant vegetated corridors, or urban development. Agricultural edge habitats are dominated by reed canary grass, red alder, Douglas maple, and Himalayan blackberry. Agricultural fields provide hunting opportunities for predator species (e.g., raptors) as they typically support small mammal populations and songbird use.

Agricultural areas have vegetation values and habitat suitability ranging from very low to low (Figure 2 and Figure 3; Table 3-3).

3.2.4 Suburban

Within suburban areas there are small farms and acreages along with large landscaped lots (Photo 6). Acreages often have forest species and lawn scattered throughout or along edges of properties. Landscaped lots contain lawns and planted native and ornamental species. Suburban areas/ man made structures and infrastructure also offer wildlife habitat for some birds, and lawn or treed areas are often used by small mammals. Predators such as raccoons, coyotes, or owls are also typical wildlife found utilizing suburban areas. There is one wetland/pond within Polygon 23 (Figure 3). This is an artificial/ landscaped pond with no riparian vegetation (i.e. surrounded by manicured lawn); however, it may provide amphibian habitat.

Purely suburban areas have vegetation values ranging from nil to low (Figure 2; Table 3), and very low habitat suitability (Figure 3; Table 3).

3.3 Species-at-Risk

No species at risk or their critical habitat have been identified within NCP Area #3. Six potential wildlife species-at-risk have known occurrences within 5 km of the NCP area including two red-listed species (MOE 2017c). A brief description of these species and their habitat is provided below.

Oregon forestsnail (red listed; *Allogona townsendiana*) is found in mixed-wood and deciduous forests typically dominated by bigleaf maple. Dense herbaceous vegetation is usually present with coarse woody debris (COSEWIC 2002). The habitat requirements of this snail are generally unknown although it has been associated with stinging nettle (Environment Canada 2016; Government of Canada 2017). Critical habitat for the species is located within 5 km of the NCP Area #3, within the Fergus Creek Hub (Environment Canada 2016). There is potential for this species to occur in suitable forested portions of NCP Area #3.

Pacific water shrew (red-listed; *Sorex bendirii*) habitat is typically within 50 m of a watercourse. The watercourses within NCP Area #3 have potential habitat for the species, in particular where there is habitat structural complexity and coarse woody debris (although there have also been captures in ditches) (Madrone 2008; Gov Canada 2017).

Trowbridge's shrew (blue-listed; *Sorex trowbridgii*) occupies forested habitat with significant ground litter, occurring on the fringe of riparian areas (Madrone 2008; Gov Canada 2017). This description applies to forested portions of NCP Area #3.

Northern red-legged frog (blue-listed; *Rana aurora*) spend most of their lives in moist forest habitats and use shallow waterbodies for breeding (Gov Canada 2017). Ponds in neighbouring areas may provide breeding habitat for the frog and the forest within NCP Area #3 may provide upland habitat to dispersing individuals. The species is known to migrate long distances from breeding habitats (Gov Canada 2017).

Painted turtle (blue-listed; *Chrysemys picta*) is typically found in shallow waters of ponds, lakes, sloughs, and slow moving stream reaches with abundant aquatic vegetation (Gov Canada 2017). As there is only one pond/wetland within the NCP Area #3 and it has low habitat suitability (i.e. the artificial pond on the suburban Polygon 23), it is unlikely that this species will be encountered.

American bittern (blue-listed; *Botaurus lentiginosus*) is a wading bird typically found in wetlands (Government of Canada 2017). Thus, it is unlikely that this species will be encountered within NCP Area #3.

A species recovery strategy has been developed for each of the two red-listed species (i.e. Oregon forestsnail and Pacific water shrew), and conservation and enhancement of their habitat is a priority for the species to (Environment Canada 2014, Environment Canada 2016).

3.4 Green Infrastructure Network

Hubs, sites, and corridors are necessary to support biodiversity. Hubs and sites act as core habitat areas that have ecological integrity (provide ecological services: nutrient cycling, diverse habitat types, support species with larger home ranges etc.). Corridors facilitate the movement of individual species between hubs, they allow species to access hubs containing potentially different features and habitat conditions and movement also encourages genetic diversity (Diamondhead 2014).

Within NCP Area #3 there is one recognized (by the City's GIN) corridor that follows 16th Avenue (Figure 4). Although there is high suitability habitat within forested portions of this corridor, it is discontinuous/disturbed due to urban development in the area, and the corridor is also directly adjacent to a busy roadway (16th Avenue). Habitat suitability within this corridor ranges considerably from nil to very high (Figure 3). Based on habitat suitability and connectivity, there are also other areas to be considered as potential GIN, which are discussed in the Section 4.1.

3.5 Soil and Terrain

NCP Area #3 consists entirely of Bose soils (Figure 5; Luttmerding 1984). These soils are classified as Duric Humo-Ferric Podzols. Bose soils have up to 10 cm of organic forest litter on the soil surface under which is a discontinuous, light grey (leached), thin (4cm) sandy layer[1]. This is underlain by a dark -brown to reddish-brown, loose, gravel zone approximately 60 cm thick that grades to yellowish - brown gravel[2]. Abruptly underlying this is a hard, cemented layer of parent material (glaciofluvial and glacial tills) containing mottles followed by uncemented parent materials (Luttmerding 1984).

Bose soils are moderately well to well drained with pervious soils found at the surface and slowly pervious subsoils beneath. Generally, these soils have limited agricultural use due to stone content and occurrence on steeper slopes; however, the soil bearing capacity of these soils is typically good for development; although, the low subsoil permeability can be a limiting factor related to septic systems (Bertrand et al. 1991).

Slopes within NCP Area #3 range from <5% to 17%. A Steep Slope Hazard Development Permit (DP) area, exists through the forested portion of the Sam Hill watershed (Figure 5).

[1] Surface textures of gravelly sand, gravelly loamy sand, sand or gravel.
[2] Subsoil texture is gravelly sandy loam.

4 RECOMMENDATIONS FOR CONSERVATION AND ENHANCEMENT

4.1 Green Infrastructure Network

To maintain biodiversity, Development Permit Applications (DPAs) are required for sensitive ecosystems in the watershed: GIN and Streamside Areas (i.e., within 50 m of the Green Infrastructure Network as defined in the BCS, or within 50 m of a Class A, AO, or B stream) (Bylaw No. 18784, 2016 [18020 amended]).

Through the review of existing information and field assessment, there is opportunity to improve the conservation efforts of the GIN. Currently, the corridor following 16th Avenue has low ecological value and has low potential for enhancement. However, it is important to maintain the linkage between major hubs (i.e. Fergus Creek Hub to the west and the Redwood Park Hub to the east). Modifying the corridor along 16th Avenue through the moderately high and higher habitat suitability areas within NCP Area #3 could provide this linkage, while also preserving the ecological value of the area. Furthermore, the forested area contains several watercourses (with their associated setbacks and high value forested and riparian habitat for species-at-risk) and conservation of a site in this area should be considered. Figure 4 outlines the City's preferred corridor and a potential site location (i.e. proposed GIN) within the NCP. This corridor alignment reflects a balance between environmental and planning objectives. Protection of this portion of GIN would:

- Maintain connectivity between two regional hubs;
- Conserve more moderately high to high value vegetation including older conifer stands;
- Conserve more moderately high to high value wildlife habitat and preserve a resting site for wildlife travelling between hubs;
- Conserve more habitat associated with potential species-at-risk including the red-listed Pacific water shrew (moderate to high quality habitat in forested areas adjacent to watercourses), the red-listed Oregon forestsnail (associated with bigleaf maple forests), the blue-listed Trowbridges shrew (associated with mixed forests), and the blue-listed Northern Red-legged Frog (associated with forests that are connected to breeding sites [i.e. ponds or streams]); and
- Align with the City's other objectives (e.g. steep slope hazards, farm protection buffering, pathways).

There is opportunity for park conservation within the GIN (i.e. the previously mentioned proposed site). Park protection will help to conserve the natural ecosystem within the GIN; however, parks should be designed following environmental guidelines to help minimize disturbance and maintain ecosystem function (CoS PRC n.d., and Ward et al. n.d.). Trail classification within the proposed GIN should be limited to Nature Trails (0.5-1.0 m wide) with potentially one Recreational Nature Trail or General Access and Recreational trail (1.5-2.5 m wide) along the edge of the proposed GIN (as to not block the proposed corridor and minimize human-wildlife conflicts). Any proposed trails should have a base consisting of natural materials (e.g. crushed rock, wood mulch). Trail alignment should avoid wildlife trees and should be placed 10 m away from creeks where possible. The amount of stream crossings should be minimized and where crossings are necessary, and clear-span pedestrian foot bridges should be installed.

4.2 General Recommendations

There are several opportunities for enhancement and restoration of aquatic, riparian, forest vegetation and wildlife habitat within NCP Area #3. A general overview of enhancement opportunities and best management practices is included below.

4.2.1 Aquatic /Instream Habitat

- Conserve water quality and fish habitat by:
  - Conducting a site inventory of all watercourses (including unidentified watercourses) prior to development to confirm classification and appropriate SPEAs.
  - Maintaining SPEA setbacks, especially around Class A, A/O, and B watercourses. Minimize impacts to SPEAs and develop as far as possible from SPEAs. If development is not possible outside of a SPEA, guidelines for development within a SPEA should be followed (CoS 2017).
  - Implementing strategies to maximize infiltration to groundwater as part of development planning in the NCP area.
- Enhance water quality and fish habitat by:
  - Installing fencing between private property and watercourses to protect environmentally sensitive areas from encroachment and access by humans, domestic pets, and/or livestock (i.e., Watercourse 3). Fencing and signage along SPEAs may help to maintain their integrity.
  - Stabilizing stream banks.
  - Installing instream cover (i.e., large woody debris) in sections of Watercourse 7 where cover is sparse to improve the amount of cover available for fish, and enhance habitat diversity and production.
  - Improving fish access to habitat in Watercourse 7 through daylighting, reducing the length and gradient of the road culverts south of Watercourse 7, adding notches to the concrete weirs and creating channel meanders and realignments to reduce gradients and height of vertical drops.
  - Planting native aquatic vegetation to provide water quality treatment.
- Protect water quality and fish habitat during or following construction activities by:
  - Installing open-bottom culverts, where culverts are necessary, to maintain natural bed material in the stream.
  - Implementing sediment and erosion control, and spill prevention and emergency response measures;
  - Keeping fueling stations and fueling equipment >30 m from watercourses;
  - Preventing concrete wash and fresh concrete from entering watercourses;
  - Conducting any necessary instream works in fish-bearing or potentially fish-bearing watercourses within the appropriate timing window (i.e., August 1 to September 15) (MOE 2006).;
  - Monitoring water quality upstream and downstream of the construction; and
  - Isolating work sites and completing fish salvages in fish-bearing watercourses (i.e., Watercourse 7).

4.2.2 Riparian Habitat

- Conserve riparian areas by:
  - Maintaining SPEA setbacks, especially around Class A, A/O, and B watercourses. Minimize impacts to SPEAs and develop as far as possible from SPEAs. If development is not possible outside of a SPEA, a DP must be obtained and guidelines for development with a SPEA should be followed (CoS 2017).
- Enhance riparian habitat by:
  - Planting native riparian vegetation (i.e., trees and shrubs) in areas with limited vegetation growth and establishing a protected stream setback on both banks (i.e., Watercourses 4 and 7). Where a utility right-of-way exists, this may be limited to shrubs and low-growing trees.
  - Retaining and possibly enhancing coarse woody debris (i.e., manual placement) in the proposed GIN to help improve habitat for potential species at risk and other small mammals and amphibians.
- Protect riparian habitat during or following construction activities by:
  - Minimizing clearing and grubbing activities to those areas required to complete construction activities;
  - Minimizing the removal of vegetation, natural woody debris, rocks, or other materials from the banks and in-stream. If material (excluding introduced invasive vegetation) is removed from the waterbody, set it aside and return it to the original location once construction activities are completed;
  - Avoiding the nesting season (approximately March 26 – August 18) (*Migratory Birds Convention Act, 1994*; GOC 2016b). If working outside of the window is not possible and vegetation clearing is required, a qualified environmental professional should conduct pre-clearing surveys to identify and avoid any potential active nesting in an area.

4.2.3 Valuable Vegetation

- Conserve valuable vegetation by:
  - Retaining existing vegetation, where possible. Especially in areas with moderate vegetation value or higher. As wildlife trees occur throughout these areas, wildlife trees and especially stands (i.e. more than one tree within a 10 m^2 area) should be retained. These areas potentially provide refuge, feeding and breeding areas for a wide range of wildlife including Oregon forestsnail, Pacific water shrew, Trowbridge's shrew, and red-legged frog.
  - Encouraging connectivity of retained vegetation, especially within the proposed GIN and SPEAs.
  - Retaining understory vegetation where possible
  - Identifying and protecting trees that provide important wildlife habitat. This includes wildlife trees, trees with raptors nests and any significant trees or species outlined in the City's Tree Protection By-law (No. 12880, 2006).
  - Limiting recreational access within these areas to reduce disturbance to high value natural vegetation.
- Enhance vegetation by:
  - Reconnecting fragmented portions of the GIN and SPEA where practical.

  - Re-vegetating cleared areas with native plant species suited to local climate conditions as soon as feasible to assist in preventing the spread of invasive plant species. If seed-mixes are used during re-vegetation, confirm they do not contain weeds or invasive species.
  - Hosting community planting events, which are well received.
- Protect vegetation during or following construction activities by:
  - Protecting trees or existing vegetation within the development site and any trees on adjacent City property in accordance with the City's Tree Preservation Bylaw (No. 12880, 1996).
  - Delineating the work area using a physical barrier (e.g., snow fencing) to limit clearing and grubbing to areas in the Project footprint and areas required to complete construction activities.
  - Restricting fill placement to only those areas where this is required to complete construction activities.
  - Re-vegetating cleared areas with native plant species suited to local climate conditions as soon as feasible to assist in preventing the spread of invasive plant species. If seed-mixes are used during re-vegetation, confirm they do not contain weeds or invasive species.

4.2.4 Wildlife and Species at Risk

- Conserve wildlife and wildlife habitat by:
  - Restricting vehicle speeds (i.e. by speed limits, speed bumps, traffic circles etc.) on roadways that border the proposed GIN if there are no culverted underpasses for wildlife passage.
  - Removing garbage from forest retention zones to help ensure that wastes dot not harm wildlife (i.e. trap, ingest, entangle or otherwise disturb).
  - Minimizing fragmentation of forests and protecting corridors with fencing and signage to minimize disturbance.
  - Creating artificial nests and roosting cavities (i.e. nest boxes) for local birds and bats.
  - Raising wildlife awareness through signage and potentially community events that help to reduce wildlife-human conflicts associated with recreational use of wildlife areas, food attractants, effects of waste etc.
  - Providing wildlife movement corridors along the proposed GIN and riparian areas. Do not block corridors with trails, fencing, cement barriers etc.
  - Directing development away from corridors, SPEAs, and other areas with moderate to high habitat suitability.
  - Preventing wildlife collision mortalities with wildlife road crossing signs.
  - Protecting active nests of all raptors and inactive nests of the Bald Eagle, Peregrine Falcon, Gyrfalcon, and Osprey. If a nest is identified, it is legally protected (*BC Wildlife Act*) and a species appropriate buffer and timing windows should be established (MOE 2013).
  - Conducting species specific wildlife surveys to confirm species-at-risk presence in areas with potential habitat. If there is presence, direct the impacts of development and recreational access away from these areas, maintain buffers to protect these species and their critical habitats. Furthermore, confer with recovery strategies and applicable BMPs for the species.
- Enhance wildlife habitat by:

    - Encouraging the presence of species-at-risk by retaining, restoring or enhancing habitat features including course woody debris, wildlife trees, snags, rock outcrops and wetland /off-channel habitats.
- Protect wildlife habitat during or following construction activities by:
    - Installing open-bottom culverts and bridges as wildlife crossing structures, in key habitat corridor areas as determined through NCP Process, and as per environmental DP guidelines, as they provide a direct connection for small mammals (e.g. Pacific water shrew), amphibians (e.g. red-legged frog), and reptiles across roads. Earthworks or wing walls may be appropriate to channel wildlife towards culvert or bridge crossings. Culverts should not be more than 30 m in length and should not have large drops that would impede the movement of wildlife. Avoid armouring culverts, and consider MSE walls, imbedded rocks, or vegetation, which can allow for small to medium sized mammal travel.
    - Developing area specific road cross sections that limit pavement width.
    - Minimizing clearing and grubbing activities to those areas required to complete construction activities;
    - Avoiding the nesting season (approximately March 26 – August 18) (*Migratory Birds Convention Act, 1994*; GOC 2016b*)*. If working outside of the window is not possible and vegetation clearing is required, a qualified environmental professional should conduct pre-clearing surveys to identify and avoid any potential active nesting in an area.
    - Avoiding daily sensitive times for wildlife, such as dawn or dusk;
    - Implementing standard best management practices for sediment and erosion control and spill prevention and emergency response to prevent release of deleterious substances;
    - Implementing standard best management construction practices to minimize noise generation during construction;
    - Planting native tree and shrub species to re-establish valuable terrestrial breeding, nesting, and shelter habitat for various wildlife species and prevent the establishment and spread of invasive species, while providing groundcover to minimize erosion; and
    - Conducting wildlife salvages in areas with habitat suitability aligned with species at risk (*Species at Risk Act,* SC 2002).

4.2.5 Invasive Species

- Enhance areas with invasive species by:
    - Identifying areas of invasive plants, remove with root structures and dispose of off-site (i.e., to an appropriate location to prevent proliferation of invasive, non-native species in adjacent areas). Soils near these identified areas will be contaminated (seeds, roots), and should not be transported to another location to prevent spread.
- Prevent the establishment and spread of invasive species during or following construction activities by:
    - Re-vegetating cleared areas with native plant species suited to local climate conditions as soon as feasible to assist in preventing the spread of invasive plant species. If seed-mixes are used during re-vegetation, confirm they do not contain weeds or invasive species.
    - Washing construction equipment before and after entering an area with invasive species to prevent spread.

5 CLOSURE

This memo is intended to present existing environmental conditions and provide recommendations regarding environmental components of the NCP Area #3 as a part of the Sam Hill ISMP and in support the NCP process. We trust that you will find the report satisfactory.

If you have questions or comments, please contact us.

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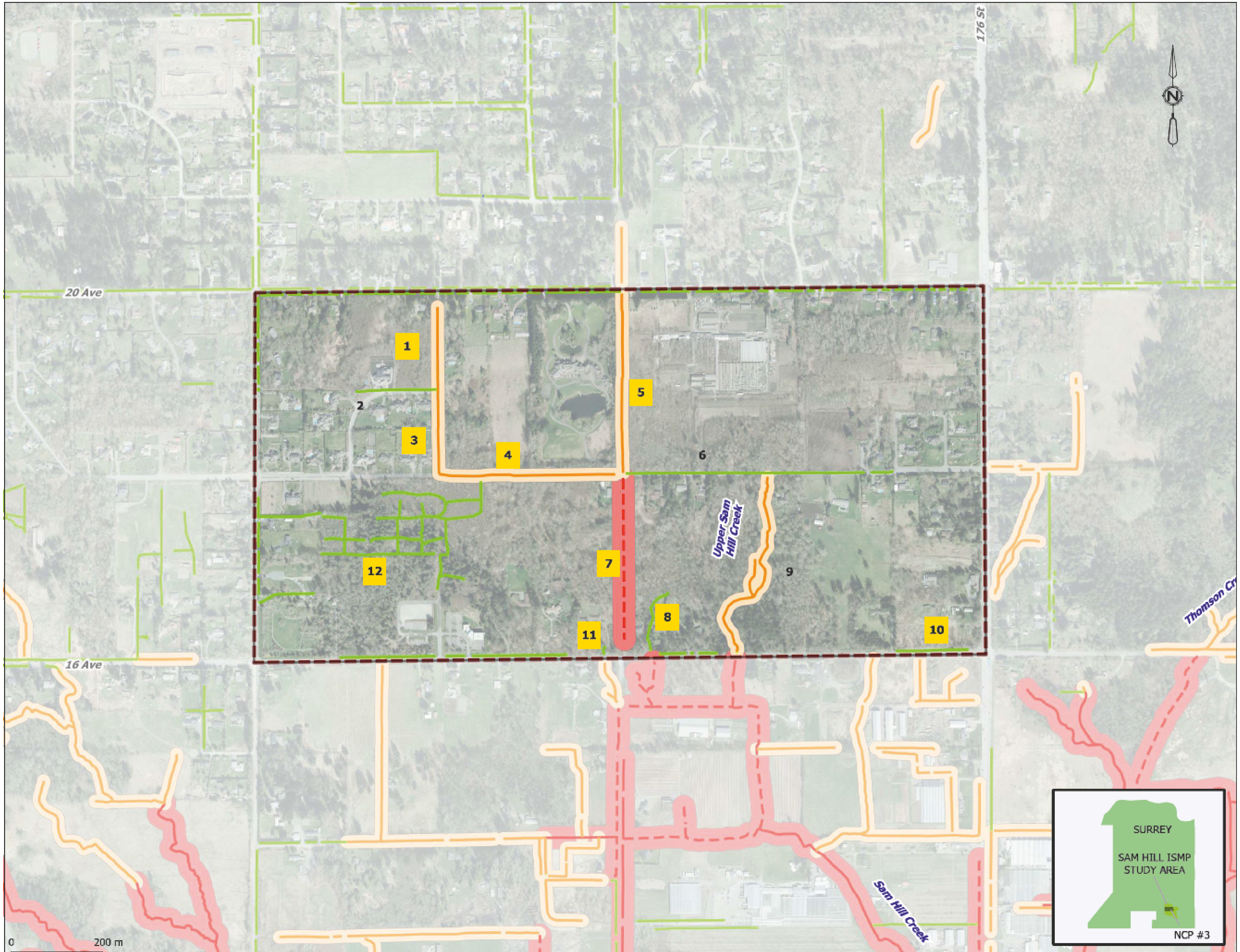

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LEGEND

Grandview Heights #3 NCP

Watercourse Classification

- A
- AO
- B
- C
- UN

A/AO Watercourse Setbacks

B Watercourse Setbacks

1 Watercourse ID

5 Recommended Watercourse Reclassifications

SCALE:	AS SHOWN		
PROJECT NO.	2017-2991	INITIAL	DATE
DRAWN		EF	17-10-06
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

Associated Engineering — GLOBAL PERSPECTIVE. LOCAL FOCUS.

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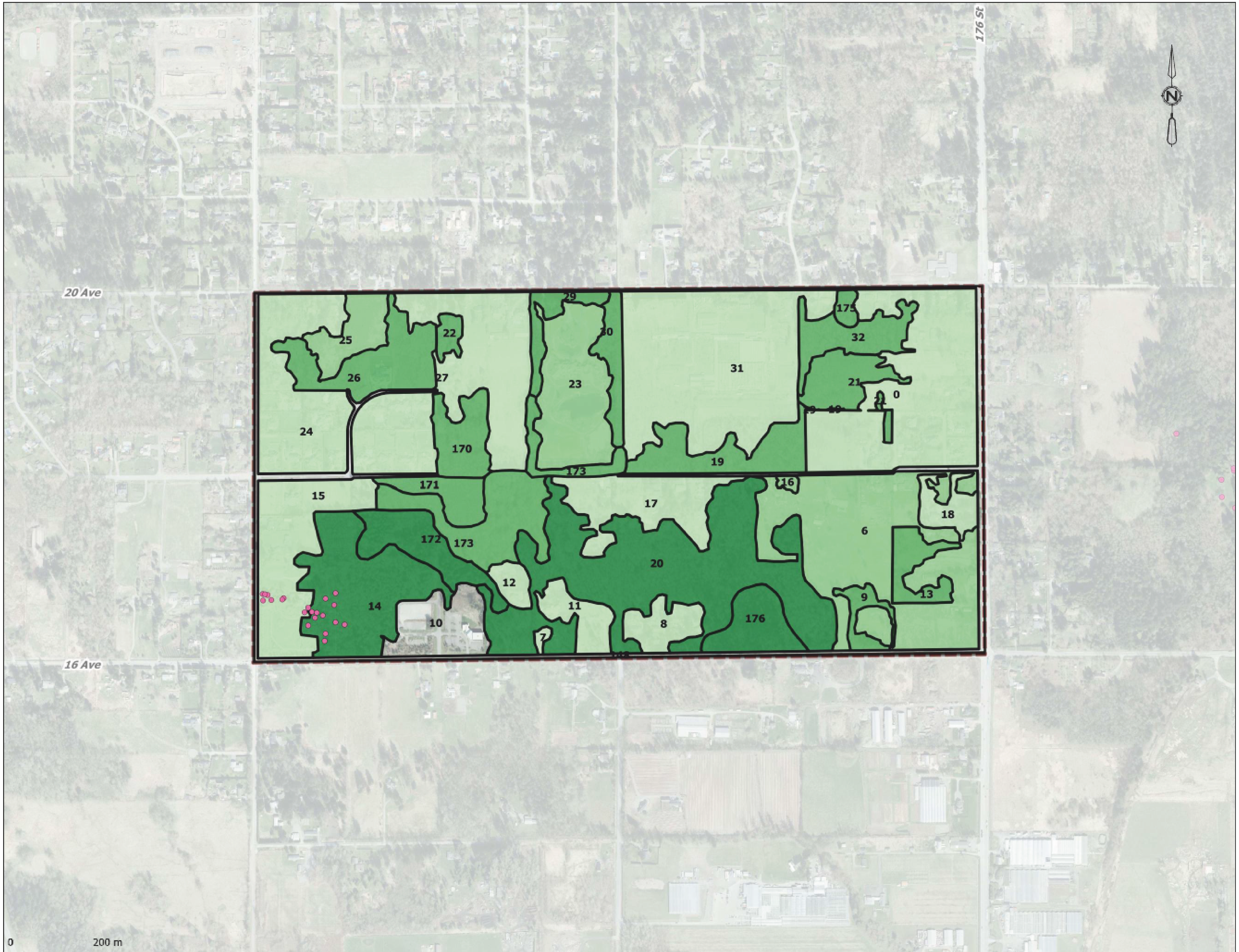
SAM HILL CREEK ISMP GRANDVIEW HEIGHTS #3 NCP ENVIRONMENTAL STUDY

WATERCOURSE CLASSIFICATION

DRAWING NUMBER	REV. NO.	SHEET
FIGURE 1		



LEGEND

Grandview Heights #3 NCP

12 Polygon ID

Vegetation Rank

1 - High

2 - Moderately High

3 - Moderate

4 - Low

5 - Very Low

6 - Nil

Significant Tree

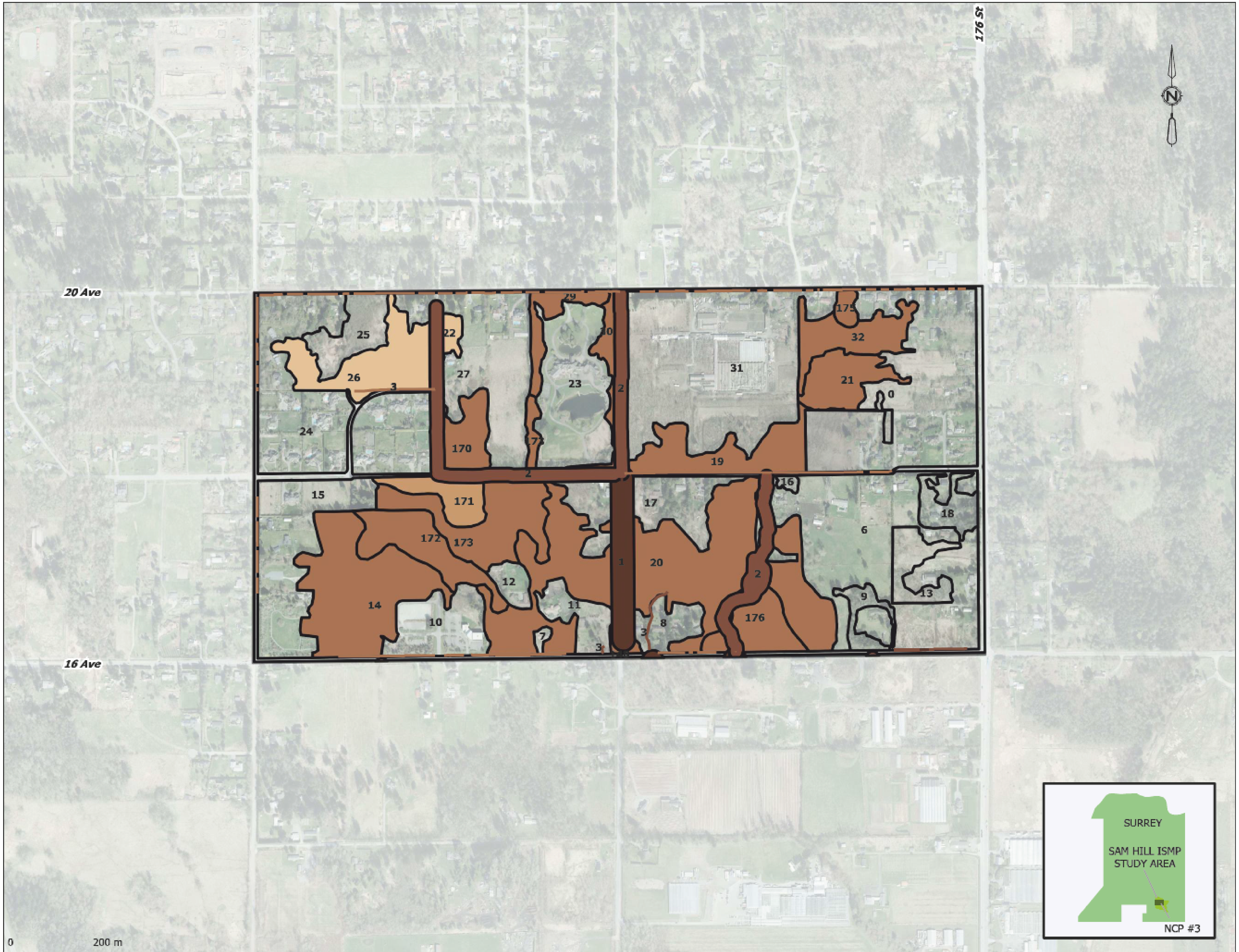
SCALE:	AS SHOWN		
PROJECT NO.	2017-2991	INITIAL	DATE
DRAWN		JT	17-06-23
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

Associated Engineering GLOBAL PERSPECTIVE. LOCAL FOCUS.

CITY OF SURREY the future lives here.

SAM HILL CREEK ISMP GRANDVIEW HEIGHTS #3 NCP ENVIRONMENTAL STUDY
VEGETATION VALUE AND SIGNIFICANT TREES

DRAWING NUMBER	REV. NO.	SHEET
FIGURE 2		



LEGEND

Grandview Heights #3 NCP

12 Polygon ID

Habitat Suitability

- 1-21 Very Low
- 21 - 40 Low
- 41 - 60 Moderate
- 61 - 80 Moderately High
- 81- 100 High
- >100 Very High

SCALE:	AS SHOWN		
PROJECT NO.	2017-2991	INITIAL	DATE
DRAWN		EF	17-10-06
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

Associated Engineering — GLOBAL PERSPECTIVE. LOCAL FOCUS.

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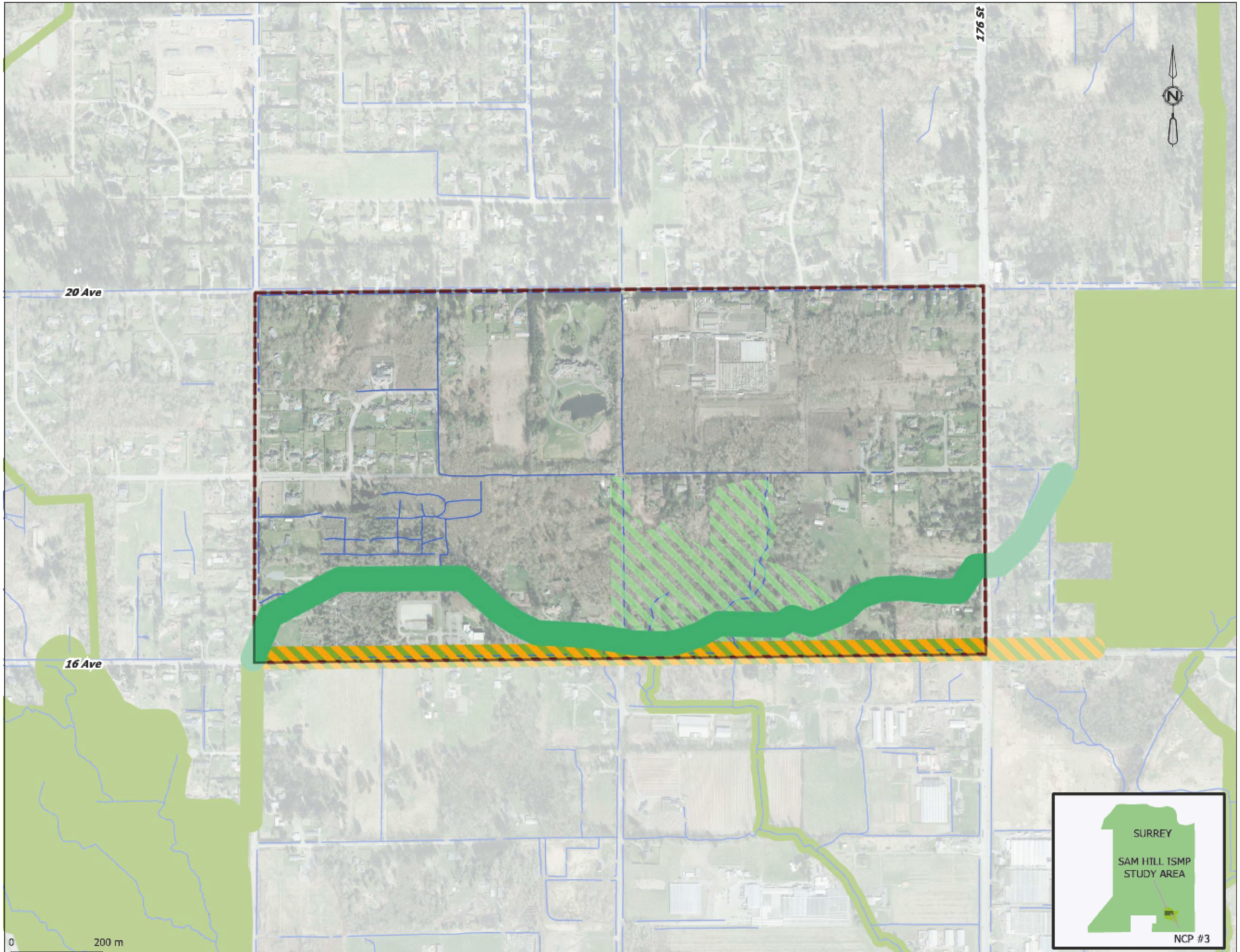
SAM HILL CREEK ISMP GRANDVIEW HEIGHTS #3 NCP ENVIRONMENTAL STUDY

HABITAT SUITABILITY

DRAWING NUMBER	REV. NO.	SHEET
FIGURE 3		



LEGEND

- Grandview Heights #3 NCP
- Watercourse

Existing GIN

- Green Infrastructure Network (Recognized GIN)

Proposed GIN

- City of Surrey's Preferred Corridor Alignment
- Proposed Site Location
- Proposed Removed Corridor

SCALE:	AS SHOWN		
PROJECT NO.	2017-2991	INITIAL	DATE
DRAWN		EF	17-10-06
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

Associated Engineering — GLOBAL PERSPECTIVE. LOCAL FOCUS.

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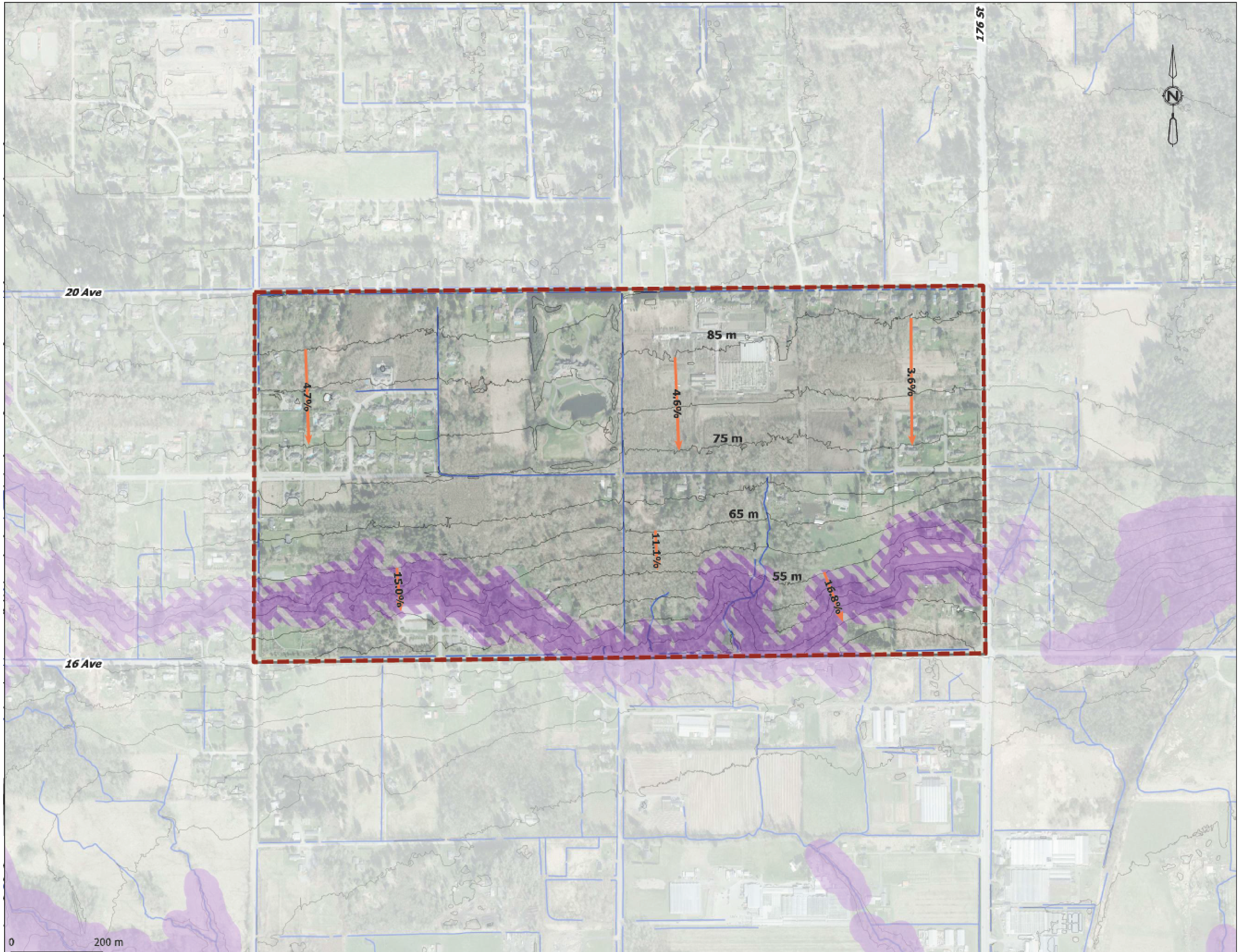
SAM HILL CREEK ISMP GRANDVIEW HEIGHTS #3 NCP ENVIRONMENTAL STUDY
GREEN INFRASTRUCTURE NETWORK

DRAWING NUMBER	REV. NO.	SHEET
FIGURE 4		



LEGEND

Watercourse	
DPA	
DPA Buffer Zone	
Slope	
35 m	Elevation

SCALE:	AS SHOWN		
PROJECT NO.	2017-2991	INITIAL	DATE
DRAWN		JT	17-06-23
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

Associated Engineering — GLOBAL PERSPECTIVE. LOCAL FOCUS.

CITY OF SURREY — the future lives here.

SAM HILL CREEK ISMP GRANDVIEW HEIGHTS #3 NCP ENVIRONMENTAL STUDY
TERRAIN MAP

DRAWING NUMBER	REV. NO.	SHEET
FIGURE 5		

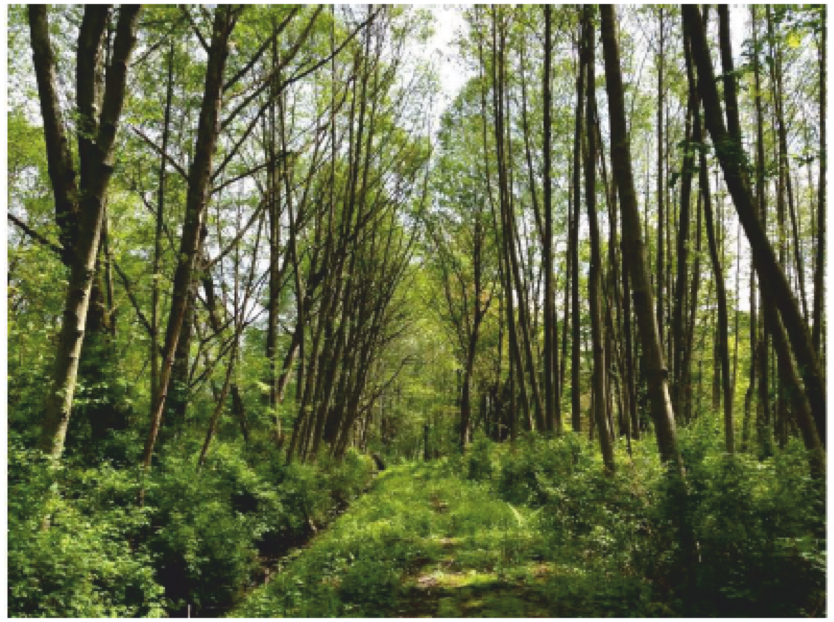


Photo 1: Terrestrial habitat. Deciduous forest along watercourse 4

Photo 2: Terrestrial habitat. Bigleaf maple within polygon 20

Photo 3: Terrestrial habitat. Agricultural field in polygon 27

Photo 4: Terrestrial habitat. Suburban home in polygon 24

	Project Number: 2013-8108.050.004	Date: Oct 11 2017	**Sam Hill ISMP- Grandview Heights #3 NCP Environmental Study**	
	Prepared For: CITY OF SURREY	Drawn by SB Data Sources: Field Photos May 9 and Oct 5 2017	Associated Environmental	Site Visit photos

Photo 5: Terrestrial habitat. Botanical garden in polygon 14

Photo 6: Terrestrial habitat. Acreages in polygon 6

Photo 7: Class A(O) Watercourse. Upstream view of Watercourse 7 with steep, modified step-pool habitat with concrete weirs creating barriers to fish passage.

Photo 8: Class A(O) Watercourse. Downstream view of Watercourse 7 from the upstream end near 18 Avenue.

Photo 9: Class A(O) Watercourse. Upstream view of Watercourse 7.

Photo 10: Class B Watercourse. Downstream view of Watercourse 1. Well defined, scoured channel with cobble/fines substrate.

Photo 11: Class B Watercourse. Upstream view of Watercourse 1. Well defined, scoured channel with cobble/fines substrate.

Photo 12: Class B Watercourse. Upstream view of Watercourse 3. Well defined, scoured channel.

	Project Number: 2013-8108.050.004	Date: Oct 11 2017	**Sam Hill ISMP- Grandview Heights #3 NCP Environmental Study**	
	Prepared For: CITY OF SURREY	Drawn by SB Data Sources: Field Photos May 9 and Oct 5 2017	Associated Environmental	Site Visit photos

Photo 13: Class B Watercourse. Upstream view of Watercourse 3 from mid-channel with fines/gravel substrate.

Photo 14: Class B Watercourse. Downstream view of Watercourse 3 from mid-channel with gravel substrate.

Photo 15: Class B Watercourse. Upstream view of Watercourse 4. Scoured channel with fines/organic substrate.

Photo 16: Class B Watercourse. Downstream view of Watercourse 4. Scoured channel with fines/organic substrate.

	Project Number: 2013-8108.050.004	Date: Oct 11 2017	**Sam Hill ISMP- Grandview Heights #3 NCP Environmental Study**	
	Prepared For: CITY OF SURREY	Drawn by SB Data Sources: Field Photos May 9 and Oct 5 2017	Associated Environmental	Site Visit photos

Photo 17: Class B Watercourse. Downstream view of Watercourse 5 at upstream end, south of 20 Avenue.

Photo 18: Class B Watercourse. Downstream view of Watercourse 5 at downstream end, north of 18 Avenue.

Photo 19: Class B Watercourse. Upstream view of natural barrier with concrete flume in Watercourse 5 approximately 100 m upstream from 18 Avenue.

Photo 20: Class B Watercourse. Downstream view of Watercourse 9 at 20 Avenue.

	Project Number: 2013-8108.050.004	Date: Oct 11 2017	**Sam Hill ISMP- Grandview Heights #3 NCP Environmental Study**	
	Prepared For: CITY OF SURREY	Drawn by SB Data Sources: Field Photos May 9 and Oct 5 2017	Associated Environmental	Site Visit photos

Photo 21: Class B Watercourse. Steep habitat conditions with abundance of large woody debris creating natural barriers to fish passage in Watercourse 9.

Photo 22: Class C Watercourse. West (Upstream) view of Watercourse 2, immediately upstream of confluence with Watercourse 1.

Photo 23: Class C Watercourse. West (Upstream) view of Watercourse 6 near concrete culvert leading to Watercourse 9.

Photo 24: Class C Watercourse. East (Upstream) view of Watercourse 6 near concrete culvert leading to Watercourse 9.

Project Number: 2013-8108.050.004	Date: Oct 11 2017	**Sam Hill ISMP- Grandview Heights #3 NCP Environmental Study**	
Prepared For: CITY OF SURREY	Drawn by SB Data Sources: Field Photos May 9 and Oct 5 2017	Associated Environmental	Site Visit photos

Photo 25: Class C Watercourse. Upstream view of Watercourse 8; no defined channel in shallow ravine.

Photo 26: Class C Watercourse. Upstream view of Watercourse 8; no defined channel in shallow ravine.

Photo 27: Class C Watercourse. Downstream view of Watercourse 10, west of 176 Street; a shallow roadside ditch.

Photo 28: Class C Watercourse. Upstream view of Watercourse 10, west of 176 Street; a shallow roadside ditch.

	Project Number: 2013-8108.050.004	Date: Oct 11 2017	**Sam Hill ISMP- Grandview Heights #3 NCP Environmental Study**	
	Prepared For: CITY OF SURREY	Drawn by SB Data Sources: Field Photos May 9 and Oct 5 2017	Associated Environmental	Site Visit photos

Photo 29: Class C Watercourse. Upstream view of Watercourse 11; a shallow swale leading to a storm drain.

Photo 30: Class C Watercourse. Relic agricultural drainage channel in young red alder stand, south of 18 Avenue.

Photo 31: Class C Watercourse. Relic agricultural drainage channel in young red alder stand, south of 18 Avenue.

Photo 32: Class C Watercourse. Relic agricultural drainage channel in young red alder stand, south of 18 Avenue.

	Project Number: 2013-8108.050.004	Date: Oct 11 2017	**Sam Hill ISMP- Grandview Heights #3 NCP Environmental Study**	
	Prepared For: City of Surrey	Drawn by SB Data Sources: Field Photos May 9 and Oct 5 2017	Associated Environmental	Site Visit photos

Photo 33: Class C Watercourse. South view of roadside ditch along east side of 168 Street.

Photo 34: Class C Watercourse. East view of roadside ditch along south side of 20 Avenue, east of 168 Street.

Photo 35: Class C Watercourse. East view of roadside ditch along south side of 20 Avenue, west of 176 Street.

Photo 36: Class C Watercourse. East view of roadside ditch along north side of 16 Avenue, between Watercourses 8 and 9.

Project Number: 2013-8108.050.004	Date: Oct 11 2017	**Sam Hill ISMP- Grandview Heights #3 NCP Environmental Study**	
Prepared For: CITY OF SURREY	Drawn by SB Data Sources: Field Photos May 9 and Oct 5 2017	Associated Environmental	Site Visit photos

Photo 37: Class C Watercourse. East view of roadside ditch along north side of 20 Avenue, west of 168 Street.

Project Number: 2013-8108.050.004	Date: Oct 11 2017	**Sam Hill ISMP- Grandview Heights #3 NCP Environmental Study**	
Prepared For: CITY OF SURREY	Drawn by SB Data Sources: Field Photos May 9 and Oct 5 2017	Associated Environmental	Site Visit photos

Appendix B - Environmental Assessment Photos

Photo A: US (north) view of ditch west of 176 St. that drains south into Sam Hill Creek

Photo B: US (west) view of Sam Hill Creek at 176 St. and 12 Ave.

Photo C: DS (east) view of Sam Hill Creek at 176 St. and 12 Ave.

Photo D: Stormwater outfall west of 176 St. draining to Sam Hill Creek

Photo E: DS (north) view of ditch east of 176 St. draining north to Sam Hill Creek

Photo F: US (north) view of unnamed tributary to Sam Hill Creek, east of 176 St., north of 12 Ave.

US – Upstream

DS – Downstream

Project Number: 2017-2991.010.004

Date: May 2017

PROJECT: **Sam Hill Creek Integrated Stormwater Management Plan**

Prepared For:

CITY OF SURREY the future lives here.

Drawn By: CH

Data Sources: Field Photos May 2017

Associated Environmental AN ASSOCIATED ENGINEERING COMPANY

Appendix A: Aquatic Habitat Assessment Photographs

Photo G: US (north) view of unnamed tributary to Sam Hill Creek, east of 176 St., south of 12 Ave.

Photo H: DS (south) view of Thompson Creek, east of 176 St., south of 12 Ave.

Photo I: US (north) view of Thompson Creek, east of 176 St., north of 12 Ave.

Photo J: US (north) view of agricultural drainage ditch east of Thomson Creek at 12 Ave.

Photo K: DS (east) view of roadside ditch east of Thomson Creek along the north side of 12 Ave.

Photo L: DS (south) view of Thomson Creek at 16 Ave. east of 176 St.

US – Upstream DS – Downstream	Project Number: 2017-2991.010.004	Date: May 2017	PROJECT: **Sam Hill Creek Integrated Stormwater Management Plan**	
	Prepared For: CITY OF SURREY the future lives here.	Drawn By: CH Data Sources: Field Photos May 2017	Associated Environmental AN ASSOCIATED ENGINEERING COMPANY	**Appendix A: Aquatic Habitat Assessment Photographs**

Photo M: Unnamed tributary to Sam Hill Creek east of 176 St., south of 16 Ave.

Photo N: US (north) view of Thomson Creek east of 176 St., south of 16 Ave.

Photo O: US (west) view of drainage ditch east of 176 St., south of 16 Ave.

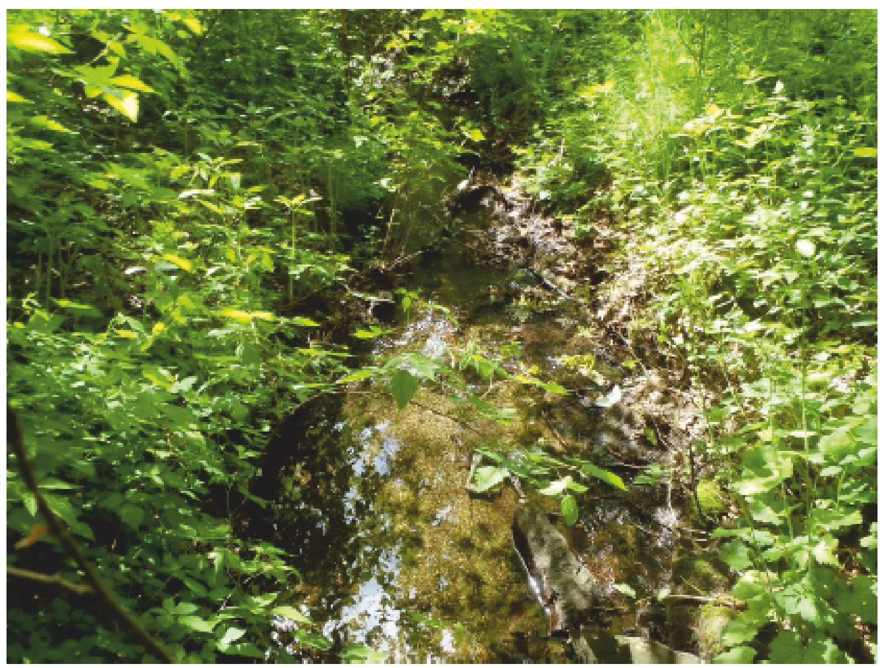


Photo P: DS (south) view of Upper Sam Hill Creek east of 172 St., south of 16 Ave.

Photo Q: DS (south) view of concrete culvert at 16 Ave., east of 172 St.

Photo R: US (north) view of Upper Sam Hill Creek east of 172 St., north of 16 Ave.

US – Upstream DS – Downstream	Project Number: 2017-2991.010.004	Date: May 2017	PROJECT: **Sam Hill Creek Integrated Stormwater Management Plan**	
	Prepared For: CITY OF SURREY the future lives here.	Drawn By: CH Data Sources: Field Photos May 2017	Associated Environmental AN ASSOCIATED ENGINEERING COMPANY	**Appendix A: Aquatic Habitat Assessment Photographs**

Photo S: Ravine east of 172 St., north of 16 Ave.

Photo T: DS (east) view of roadside ditch along north side of 16 Ave., east of 172 St.

Photo U: DS (east) view of roadside ditch along north side of 16 Ave., east of 172 St.

Photo V: Roadside drainage west of 172 St., south of 16 Ave.

Photo W: DS (south) view of Sam Hill Creek south of 16 Ave., on the east side of 172 St.

Photo X: DS (south) view of roadside ditch along the west side of 172 St., south of 16 Ave.

US – Upstream

DS – Downstream

Project Number: 2017-2991.010.004	Date: May 2017	PROJECT: **Sam Hill Creek Integrated Stormwater Management Plan**	
Prepared For: City of SURREY the future lives here.	Drawn By: CH Data Sources: Field Photos May 2017	Associated Environmental AN ASSOCIATED ENGINEERING COMPANY	**Appendix A: Aquatic Habitat Assessment Photographs**

Photo Y: US (west) view of Sam Hill Creek west of 172 St.

Photo Z: DS (south) view of Sam Hill Creek on the east side of 172 St., south of 16 Ave.

Photo AA: DS (east) view of Sam Hill creek east of 172 St. at the 12 Ave. right-of-way

Photo AB: US (northeast) view of unnamed tributary to Sam Hill Creek south of 16 Ave., between 172 St. and 176 St.

Photo AC: DS (southeast) view of Sam Hill Creek south of 16 Ave., between 172 St. and 176 St.

Photo AD: US (northwest) view of Sam Hill Creek and perched culvert between 172 St. and 176 St.

US – Upstream DS – Downstream	Project Number: 2017-2991.010.004	Date: May 2017	PROJECT: **Sam Hill Creek Integrated Stormwater Management Plan**	
	Prepared For: CITY OF SURREY the future lives here.	Drawn By: CH Data Sources: Field Photos May 2017	Associated Environmental AN ASSOCIATED ENGINEERING COMPANY	**Appendix A: Aquatic Habitat Assessment Photographs**

Photo AE: DS (south) view of Upper Sam Hill Creek west of 172 St., south of 16 Ave.

Photo AF: US (north) view of tributary to Upper Sam Hill Creek at 172 St., north of 16 Ave.

Photo AG: US (north) view of tributary to Upper Sam Hill Creek at 172 St., north of 18 Ave.

Photo AH: DS (east) view of tributary to Upper Sam Hill Creek at 18 Ave. right-of-way, east of 168 St.

Photo AI: US (west) view of roadside ditch on the north side of 18 Ave., west of 176 St.

US – Upstream DS – Downstream	Project Number: 2017-2991.010.004	Date: May 2017	PROJECT: **Sam Hill Creek Integrated Stormwater Management Plan**	
	Prepared For: CITY OF SURREY the future lives here.	Drawn By: CH Data Sources: Field Photos May 2017	Associated Environmental — AN ASSOCIATED ENGINEERING COMPANY	**Appendix A: Aquatic Habitat Assessment Photographs**

Appendix C - Hydraulic Inventory

Culvert 101	
Diameter and Inlet	1800 mm x 1200 mm projecting box culvert
Material	Concrete
Inlet Condition	Projecting
Additional Notes	• Inlet has several channels draining to it • 600 mm Diameter CSP pipe drains near outlet (to right of box culvert)

Culvert inlet (top left), outlet (top right), downstream of outlet (bottom right), upstream of inlet (bottom left)

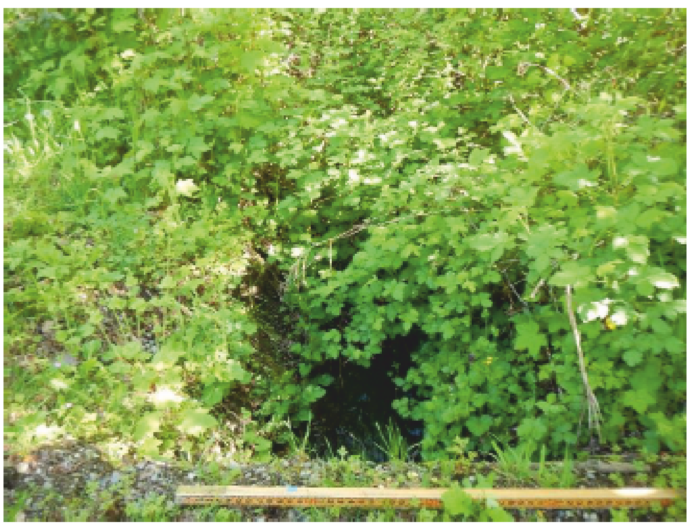
Watercourse	Height (m)	Base (m)	Side Slopes
W103 (Downstream of C101)	1.8	3.0	3H:1V

Culvert 102	
Diameter and Inlet	Inlet: 250 mm diameter with headwall Outlet: 600 mm diameter
Material	Inlet: PVC Outlet: concrete
Additional Notes	• Inlet pipe leads to larger sewer which then drains to outlet • Inlet dry while outlet had small amount of flow

Culvert inlet (top left), outlet (top right), downstream of outlet (bottom right), upstream of inlet (bottom left)

Watercourse name	Height (m)	Base (m)	Side Slopes
W801 (upstream of C102)	0.1	0.2	3H:1V

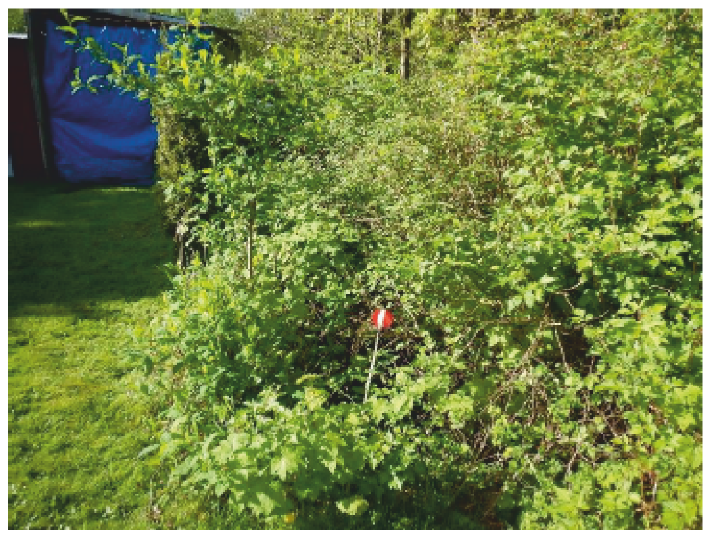
Culvert 105	
Diameter and Inlet	600 mm diameter with headwall
Material	Concrete
Additional Notes	• Pipe outlets alongside culvert 901 into a small box culvert • 0.4 m step in channel approximately 30 m downstream of outlet



Culvert inlet (top left), outlet in right of image (top right), downstream of outlet (bottom right), upstream of inlet (bottom left)

Watercourse name	Height (m)	Base (m)	Side Slopes
W109 (upstream of C901)	1	1	1H:1V

Culvert 106	
Diameter and Inlet	600 mm diameter with headwall and grate
Material	Concrete
Additional Notes	

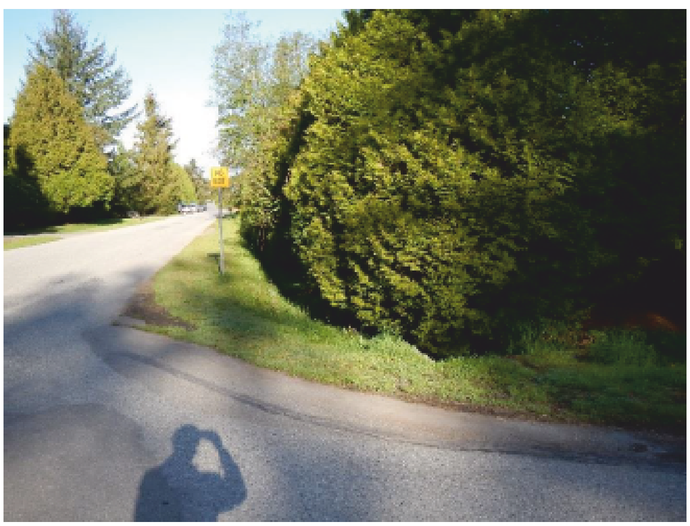


Culvert inlet (top left), outlet (top right), downstream of outlet (bottom right), upstream of inlet (bottom left)

Watercourse name	Height (m)	Base (m)	Side Slopes
W111 (upstream of C106)	0.8	0.8	2H:1V

Culvert 110	
Diameter and Inlet	450 mm diameter with headwall
Material	Concrete
Additional Notes	• Culvert appears to be about 1/3 full of sediment






Culvert inlet (top left), outlet (top right), downstream of outlet (bottom right), upstream of inlet (bottom left)

Watercourse name	Height (m)	Base (m)	Side Slopes
W112 (downstream of C110)	0.8	1.7	3H:1V

Culvert 201	
Diameter and Inlet	600 mm diameter projecting
Material	Concrete
Additional Notes	• Culvert appears quite old and overgrown




Culvert inlet (top left), outlet (top right), downstream of outlet (bottom right), upstream of inlet (bottom left)

Watercourse name	Height (m)	Base (m)	Side Slopes
W201 (downstream of C201)	1	0.5	4H:1V

Culvert 202	
Diameter and Inlet	750 mm diameter with headwall and grate
Material	Concrete
Additional Notes	• Grate is damaged




Culvert inlet (top left), outlet (top right), downstream of outlet (bottom right), upstream of inlet (bottom left)

Watercourse name	Height (m)	Base (m)	Side Slopes
W204 (downstream of C202)	1	1	4H:1V

Culvert 251	
Diameter and Inlet	300 mm diameter projecting
Material	Concrete
Additional Notes	• Appears to cross 12 Ave and discharge into a poorly defined channel on south side. • Could not find outlet



Culvert inlet (top left), outlet of upstream culvert (top right), upstream of inlet (bottom)

Culvert 301	
Diameter and Inlet	1.4 m x 0.95 m arch with headwall and grate
Material	Corrugated steel pipe
Additional Notes	• Elbow in culvert immediately downstream of inlet • Pipe tap-in near inlet

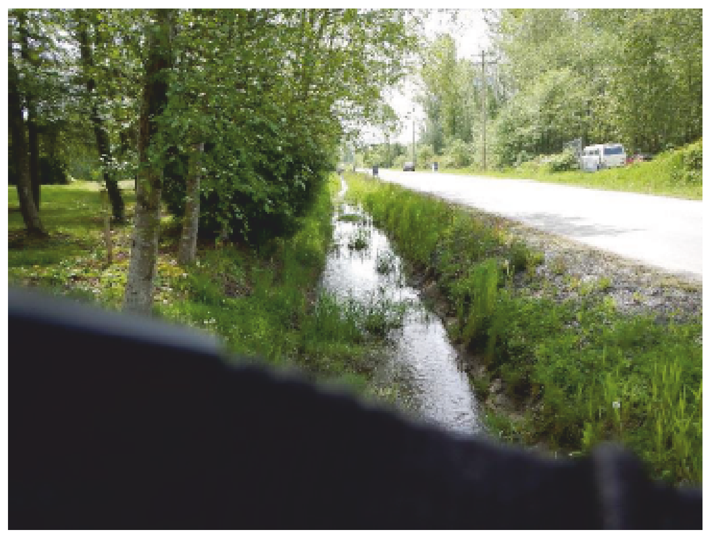



Culvert inlet (top left), outlet (top right), downstream of outlet (bottom right), Pipe tap-in near inlet (bottom left)

Watercourse name	Height (m)	Base (m)	Side Slopes
W301 (downstream of C301)	1.5	1.8	3H:1V

Culvert 401	
Diameter and Inlet	600 mm diameter projecting
Material	Concrete
Additional Notes	• Culvert outlet is part of headwall for driveway box culvert • Culvert joins channel W402 and does not connect through to W601



Culvert inlet (top left), outlet (top right), downstream of outlet (bottom right), upstream of inlet (bottom left)

Watercourse name	Height (m)	Base (m)	Side Slopes
W402 (downstream of C401)	1.5	1.5	1.5H:1V

Culvert 523	
Diameter and Inlet	N/A
Material	N/A
Additional Notes	• As-built drawings show this culvert as now being part of a piped curb and gutter system • Field reconnaissance supports this as a culvert inlet could not be found

Looking upstream along old ditch alignment (top left), looking downstream of old ditch alignment (top right), catchbasin on HWY 15 suggesting piped storm system (bottom right), ditch may have been filled to provide noise abatement berm for residents (bottom left)

Culvert 551	
Diameter and Inlet	400 mm diameter outlet (inlet condition unknown)
Material	Concrete
Additional Notes	• Inlet could not be accessed • Downstream channel is heavily overgrown




Culvert downstream channel (top left), culvert outlet (top right), downstream of outlet (bottom right), downstream of outlet (bottom left)

Watercourse name	Height (m)	Base (m)	Side Slopes
W551 (downstream of C551)	0.4	0.8	2H:1V

Culvert 602	
Diameter and Inlet	600 mm diameter with headwall
Material	Concrete
Additional Notes	• Upstream channel heavily overgrown • Culvert crosses road and changes direction from south-east flow to southward flow along W602

Culvert inlet (top left), outlet (top right), downstream of outlet (bottom right), upstream of inlet (bottom left)

Watercourse name	Height (m)	Base (m)	Side Slopes
W602 (downstream of C602)	2	1	1H:1V

Culvert 603	
Diameter and Inlet	600 mm diameter with headwall
Material	Concrete
Additional Notes	• Could not access outlet • Downstream channel heavily overgrown




Culvert inlet is pipe in left side of image (top left), joints appear to have separated just inside inlet (top right), downstream of outlet (bottom right), downstream of outlet (bottom left)

Culvert 605	
Diameter and Inlet	450 mm diameter with headwall and grate
Material	Concrete
Additional Notes	• Downstream channel is heavily overgrown

Culvert inlet (top left), outlet (top right), downstream of outlet (bottom right), upstream of inlet (bottom left)

Watercourse name	Height (m)	Base (m)	Side Slopes
W604 (downstream of C605)	1.5	0.7	1.5H:1V

Culvert 701	
Diameter and Inlet	900 mm diameter with headwall
Material	Concrete
Additional Notes	




Culvert inlet (top left), outlet (top right), downstream of outlet (bottom right), upstream of inlet (bottom left)

Watercourse name	Height (m)	Base (m)	Side Slopes
W702 (upstream of C701)	0.5	1.5	4H:1V

Culvert 901	
Diameter and Inlet	600 mm diameter with headwall
Material	Concrete
Additional Notes	• Outlet joins outlet of Culvert 105 in box culvert

Culvert inlet (top left), outlet in left of image (top right), downstream of outlet (bottom right), upstream of inlet (bottom left)

Culvert 902	
Diameter and Inlet	600 mm diameter (measured at outlet) with headwalls at inlets
Material	Concrete
Additional Notes	• Appears that E-W running ditches join in a manhole then run south along W902




Culvert inlet-west (top left), inlet-east (top right), downstream of outlet (bottom right), looking upstream of outlet (bottom left)

Watercourse name	Height (m)	Base (m)	Side Slopes
W902 (downstream of C902)	1	0.5	1.5H:1V

Culvert 999	
Diameter and Inlet	600 mm diameter mitred
Material	PVC
Additional Notes	• Appears to connect drainage areas to the south and west into the study area

Culvert inlet (top left), outlet (top right), downstream of outlet (bottom right), upstream of inlet (bottom left)

Watercourse	Height (m)	Base (m)	Side Slopes
W108	0.7	0.7	3H:1V

Downstream of Culvert 102

Watercourse	Height (m)	Base (m)	Side Slopes
W502	1.4	1.0	1H:1V

Upstream (left), downstream (right)

Watercourse	Height (m)	Base (m)	Side Slopes
W601	1.0	0.6	2H:1V

Upstream (left), downstream (right)

Appendix D - ADS Rainfall Events

Sam Hill Creek ISMP
City of Surrey
Design Rainfall Events - ADS (based on White Rock STP)

5-Year Return Period

	Design Rainfall Intensity [mm/hr]	
	Historic	Climate Change
Time Step [hh:mm]	5-year	5-year
0:00	1.61	2.17
0:05	1.61	2.17
0:10	1.61	2.17
0:15	1.61	2.17
0:20	1.61	2.17
0:25	1.61	2.17
0:30	1.61	2.17
0:35	1.61	2.17
0:40	1.61	2.17
0:45	1.61	2.17
0:50	1.61	2.17
0:55	1.61	2.17
1:00	1.61	2.17
1:05	1.61	2.17
1:10	1.61	2.17
1:15	1.61	2.17
1:20	1.61	2.17
1:25	1.61	2.17
1:30	1.61	2.17
1:35	1.61	2.17
1:40	1.61	2.17
1:45	1.61	2.17
1:50	1.61	2.17
1:55	1.61	2.17
2:00	1.61	2.17
2:05	1.61	2.17
2:10	1.61	2.17
2:15	1.61	2.17
2:20	1.61	2.17
2:25	1.61	2.17
2:30	1.61	2.17
2:35	1.61	2.17
2:40	1.61	2.17
2:45	1.61	2.17
2:50	1.61	2.17
2:55	1.61	2.17
3:00	1.92	2.59
3:05	1.92	2.59
3:10	1.92	2.59
3:15	1.92	2.59
3:20	1.92	2.59
3:25	1.92	2.59
3:30	1.92	2.59
3:35	1.92	2.59
3:40	1.92	2.59
3:45	1.92	2.59
3:50	1.92	2.59
3:55	1.92	2.59
4:00	1.92	2.59
4:05	1.92	2.59
4:10	1.92	2.59
4:15	1.92	2.59
4:20	1.92	2.59
4:25	1.92	2.59
4:30	1.92	2.59
4:35	1.92	2.59
4:40	1.92	2.59
4:45	1.92	2.59
4:50	1.92	2.59
4:55	1.92	2.59
5:00	1.92	2.59
5:05	1.92	2.59
5:10	1.92	2.59
5:15	1.92	2.59
5:20	1.92	2.59
5:25	1.92	2.59
5:30	1.92	2.59
5:35	1.92	2.59
5:40	1.92	2.59
5:45	1.92	2.59
5:50	1.92	2.59
5:55	1.92	2.59

	Design Rainfall Intensity [mm/hr]	
	Historic	Climate Change
Time Step [hh:mm]	5-year	5-year
6:00	2.32	3.13
6:05	2.32	3.13
6:10	2.32	3.13
6:15	2.32	3.13
6:20	2.32	3.13
6:25	2.32	3.13
6:30	2.32	3.13
6:35	2.32	3.13
6:40	2.32	3.13
6:45	2.32	3.13
6:50	2.32	3.13
6:55	2.32	3.13
7:00	2.32	3.13
7:05	2.32	3.13
7:10	2.32	3.13
7:15	2.32	3.13
7:20	2.32	3.13
7:25	2.32	3.13
7:30	2.78	3.75
7:35	2.78	3.75
7:40	2.78	3.75
7:45	2.78	3.75
7:50	2.78	3.75
7:55	2.78	3.75
8:00	2.78	3.75
8:05	2.78	3.75
8:10	2.78	3.75
8:15	2.78	3.75
8:20	2.78	3.75
8:25	2.78	3.75
8:30	2.78	3.75
8:35	2.78	3.75
8:40	2.78	3.75
8:45	2.78	3.75
8:50	2.78	3.75
8:55	2.78	3.75
9:00	3.26	4.40
9:05	3.26	4.40
9:10	3.26	4.40
9:15	3.26	4.40
9:20	3.26	4.40
9:25	3.26	4.40
9:30	3.63	4.90
9:35	3.63	4.90
9:40	3.63	4.90
9:45	3.63	4.90
9:50	3.63	4.90
9:55	3.63	4.90
10:00	4.15	5.60
10:05	4.15	5.60
10:10	4.15	5.60
10:15	4.15	5.60
10:20	4.15	5.60
10:25	4.15	5.60
10:30	4.97	6.71
10:35	4.97	6.71
10:40	4.97	6.71
10:45	4.97	6.71
10:50	4.97	6.71
10:55	4.97	6.71
11:00	5.98	8.07
11:05	5.98	8.07
11:10	5.98	8.07
11:15	7.17	9.68
11:20	7.17	9.68
11:25	7.17	9.68
11:30	8.41	11.35
11:35	18.75	25.31
11:40	18.75	25.31
11:45	18.75	25.31
11:50	18.75	25.31
11:55	18.75	25.31

	Design Rainfall Intensity [mm/hr]	
	Historic	Climate Change
Time Step [hh:mm]	5-year	5-year
12:00	18.75	25.31
12:05	18.75	25.31
12:10	18.75	25.31
12:15	18.75	25.31
12:20	18.75	25.31
12:25	8.41	11.35
12:30	7.17	9.68
12:35	7.17	9.68
12:40	7.17	9.68
12:45	5.98	8.07
12:50	5.98	8.07
12:55	5.98	8.07
13:00	4.97	6.71
13:05	4.97	6.71
13:10	4.97	6.71
13:15	4.97	6.71
13:20	4.97	6.71
13:25	4.97	6.71
13:30	4.15	5.60
13:35	4.15	5.60
13:40	4.15	5.60
13:45	4.15	5.60
13:50	4.15	5.60
13:55	4.15	5.60
14:00	3.63	4.90
14:05	3.63	4.90
14:10	3.63	4.90
14:15	3.63	4.90
14:20	3.63	4.90
14:25	3.63	4.90
14:30	3.26	4.40
14:35	3.26	4.40
14:40	3.26	4.40
14:45	3.26	4.40
14:50	3.26	4.40
14:55	3.26	4.40
15:00	2.78	3.75
15:05	2.78	3.75
15:10	2.78	3.75
15:15	2.78	3.75
15:20	2.78	3.75
15:25	2.78	3.75
15:30	2.78	3.75
15:35	2.78	3.75
15:40	2.78	3.75
15:45	2.78	3.75
15:50	2.78	3.75
15:55	2.78	3.75
16:00	2.78	3.75
16:05	2.78	3.75
16:10	2.78	3.75
16:15	2.78	3.75
16:20	2.78	3.75
16:25	2.78	3.75
16:30	2.32	3.13
16:35	2.32	3.13
16:40	2.32	3.13
16:45	2.32	3.13
16:50	2.32	3.13
16:55	2.32	3.13
17:00	2.32	3.13
17:05	2.32	3.13
17:10	2.32	3.13
17:15	2.32	3.13
17:20	2.32	3.13
17:25	2.32	3.13
17:30	2.32	3.13
17:35	2.32	3.13
17:40	2.32	3.13
17:45	2.32	3.13
17:50	2.32	3.13
17:55	2.32	3.13

	Design Rainfall Intensity [mm/hr]	
	Historic	Climate Change
Time Step [hh:mm]	5-year	5-year
18:00	1.92	2.59
18:05	1.92	2.59
18:10	1.92	2.59
18:15	1.92	2.59
18:20	1.92	2.59
18:25	1.92	2.59
18:30	1.92	2.59
18:35	1.92	2.59
18:40	1.92	2.59
18:45	1.92	2.59
18:50	1.92	2.59
18:55	1.92	2.59
19:00	1.92	2.59
19:05	1.92	2.59
19:10	1.92	2.59
19:15	1.92	2.59
19:20	1.92	2.59
19:25	1.92	2.59
19:30	1.92	2.59
19:35	1.92	2.59
19:40	1.92	2.59
19:45	1.92	2.59
19:50	1.92	2.59
19:55	1.92	2.59
20:00	1.92	2.59
20:05	1.92	2.59
20:10	1.92	2.59
20:15	1.92	2.59
20:20	1.92	2.59
20:25	1.92	2.59
20:30	1.92	2.59
20:35	1.92	2.59
20:40	1.92	2.59
20:45	1.92	2.59
20:50	1.92	2.59
20:55	1.92	2.59
21:00	1.61	2.17
21:05	1.61	2.17
21:10	1.61	2.17
21:15	1.61	2.17
21:20	1.61	2.17
21:25	1.61	2.17
21:30	1.61	2.17
21:35	1.61	2.17
21:40	1.61	2.17
21:45	1.61	2.17
21:50	1.61	2.17
21:55	1.61	2.17
22:00	1.61	2.17
22:05	1.61	2.17
22:10	1.61	2.17
22:15	1.61	2.17
22:20	1.61	2.17
22:25	1.61	2.17
22:30	1.61	2.17
22:35	1.61	2.17
22:40	1.61	2.17
22:45	1.61	2.17
22:50	1.61	2.17
22:55	1.61	2.17
23:00	1.61	2.17
23:05	1.61	2.17
23:10	1.61	2.17
23:15	1.61	2.17
23:20	1.61	2.17
23:25	1.61	2.17
23:30	1.61	2.17
23:35	1.61	2.17
23:40	1.61	2.17
23:45	1.61	2.17
23:50	1.61	2.17
23:55	1.61	2.17
0:00	1.61	2.17

Sam Hill Creek ISMP
City of Surrey
Design Rainfall Events - ADS (based on White Rock STP)

100-Year Return Period

	Design Rainfall Intensity (mm/hr)			Design Rainfall Intensity (mm/hr)			Design Rainfall Intensity (mm/hr)			Design Rainfall Intensity (mm/hr)	
	Historic	Climate Change		Historic	Climate Change		Historic	Climate Change		Historic	Climate Change
Time Step [hh:mm]	100-year	100-year	Time Step [hh:mm]	100-year	100-year	Time Step [hh:mm]	100-year	100-year	Time Step [hh:mm]	100-year	100-year
0:00	2.49	3.36	6:00	3.67	4.95	12:00	34.54	46.63	18:00	3.01	4.06
0:05	2.49	3.36	6:05	3.67	4.95	12:05	34.54	46.63	18:05	3.01	4.06
0:10	2.49	3.36	6:10	3.67	4.95	12:10	34.54	46.63	18:10	3.01	4.06
0:15	2.49	3.36	6:15	3.67	4.95	12:15	34.54	46.63	18:15	3.01	4.06
0:20	2.49	3.36	6:20	3.67	4.95	12:20	34.54	46.63	18:20	3.01	4.06
0:25	2.49	3.36	6:25	3.67	4.95	12:25	14.39	19.43	18:25	3.01	4.06
0:30	2.49	3.36	6:30	3.67	4.95	12:30	12.15	16.40	18:30	3.01	4.06
0:35	2.49	3.36	6:35	3.67	4.95	12:35	12.15	16.40	18:35	3.01	4.06
0:40	2.49	3.36	6:40	3.67	4.95	12:40	12.15	16.40	18:40	3.01	4.06
0:45	2.49	3.36	6:45	3.67	4.95	12:45	10.03	13.54	18:45	3.01	4.06
0:50	2.49	3.36	6:50	3.67	4.95	12:50	10.03	13.54	18:50	3.01	4.06
0:55	2.49	3.36	6:55	3.67	4.95	12:55	10.03	13.54	18:55	3.01	4.06
1:00	2.49	3.36	7:00	3.67	4.95	13:00	8.24	11.12	19:00	3.01	4.06
1:05	2.49	3.36	7:05	3.67	4.95	13:05	8.24	11.12	19:05	3.01	4.06
1:10	2.49	3.36	7:10	3.67	4.95	13:10	8.24	11.12	19:10	3.01	4.06
1:15	2.49	3.36	7:15	3.67	4.95	13:15	8.24	11.12	19:15	3.01	4.06
1:20	2.49	3.36	7:20	3.67	4.95	13:20	8.24	11.12	19:20	3.01	4.06
1:25	2.49	3.36	7:25	3.67	4.95	13:25	8.24	11.12	19:25	3.01	4.06
1:30	2.49	3.36	7:30	4.45	6.01	13:30	6.8	9.18	19:30	3.01	4.06
1:35	2.49	3.36	7:35	4.45	6.01	13:35	6.8	9.18	19:35	3.01	4.06
1:40	2.49	3.36	7:40	4.45	6.01	13:40	6.8	9.18	19:40	3.01	4.06
1:45	2.49	3.36	7:45	4.45	6.01	13:45	6.8	9.18	19:45	3.01	4.06
1:50	2.49	3.36	7:50	4.45	6.01	13:50	6.8	9.18	19:50	3.01	4.06
1:55	2.49	3.36	7:55	4.45	6.01	13:55	6.8	9.18	19:55	3.01	4.06
2:00	2.49	3.36	8:00	4.45	6.01	14:00	5.9	7.97	20:00	3.01	4.06
2:05	2.49	3.36	8:05	4.45	6.01	14:05	5.9	7.97	20:05	3.01	4.06
2:10	2.49	3.36	8:10	4.45	6.01	14:10	5.9	7.97	20:10	3.01	4.06
2:15	2.49	3.36	8:15	4.45	6.01	14:15	5.9	7.97	20:15	3.01	4.06
2:20	2.49	3.36	8:20	4.45	6.01	14:20	5.9	7.97	20:20	3.01	4.06
2:25	2.49	3.36	8:25	4.45	6.01	14:25	5.9	7.97	20:25	3.01	4.06
2:30	2.49	3.36	8:30	4.45	6.01	14:30	5.27	7.11	20:30	3.01	4.06
2:35	2.49	3.36	8:35	4.45	6.01	14:35	5.27	7.11	20:35	3.01	4.06
2:40	2.49	3.36	8:40	4.45	6.01	14:40	5.27	7.11	20:40	3.01	4.06
2:45	2.49	3.36	8:45	4.45	6.01	14:45	5.27	7.11	20:45	3.01	4.06
2:50	2.49	3.36	8:50	4.45	6.01	14:50	5.27	7.11	20:50	3.01	4.06
2:55	2.49	3.36	8:55	4.45	6.01	14:55	5.27	7.11	20:55	3.01	4.06
3:00	3.01	4.06	9:00	5.27	7.11	15:00	4.45	6.01	21:00	2.49	3.36
3:05	3.01	4.06	9:05	5.27	7.11	15:05	4.45	6.01	21:05	2.49	3.36
3:10	3.01	4.06	9:10	5.27	7.11	15:10	4.45	6.01	21:10	2.49	3.36
3:15	3.01	4.06	9:15	5.27	7.11	15:15	4.45	6.01	21:15	2.49	3.36
3:20	3.01	4.06	9:20	5.27	7.11	15:20	4.45	6.01	21:20	2.49	3.36
3:25	3.01	4.06	9:25	5.27	7.11	15:25	4.45	6.01	21:25	2.49	3.36
3:30	3.01	4.06	9:30	5.9	7.97	15:30	4.45	6.01	21:30	2.49	3.36
3:35	3.01	4.06	9:35	5.9	7.97	15:35	4.45	6.01	21:35	2.49	3.36
3:40	3.01	4.06	9:40	5.9	7.97	15:40	4.45	6.01	21:40	2.49	3.36
3:45	3.01	4.06	9:45	5.9	7.97	15:45	4.45	6.01	21:45	2.49	3.36
3:50	3.01	4.06	9:50	5.9	7.97	15:50	4.45	6.01	21:50	2.49	3.36
3:55	3.01	4.06	9:55	5.9	7.97	15:55	4.45	6.01	21:55	2.49	3.36
4:00	3.01	4.06	10:00	6.8	9.18	16:00	4.45	6.01	22:00	2.49	3.36
4:05	3.01	4.06	10:05	6.8	9.18	16:05	4.45	6.01	22:05	2.49	3.36
4:10	3.01	4.06	10:10	6.8	9.18	16:10	4.45	6.01	22:10	2.49	3.36
4:15	3.01	4.06	10:15	6.8	9.18	16:15	4.45	6.01	22:15	2.49	3.36
4:20	3.01	4.06	10:20	6.8	9.18	16:20	4.45	6.01	22:20	2.49	3.36
4:25	3.01	4.06	10:25	6.8	9.18	16:25	4.45	6.01	22:25	2.49	3.36
4:30	3.01	4.06	10:30	8.24	11.12	16:30	3.67	4.95	22:30	2.49	3.36
4:35	3.01	4.06	10:35	8.24	11.12	16:35	3.67	4.95	22:35	2.49	3.36
4:40	3.01	4.06	10:40	8.24	11.12	16:40	3.67	4.95	22:40	2.49	3.36
4:45	3.01	4.06	10:45	8.24	11.12	16:45	3.67	4.95	22:45	2.49	3.36
4:50	3.01	4.06	10:50	8.24	11.12	16:50	3.67	4.95	22:50	2.49	3.36
4:55	3.01	4.06	10:55	8.24	11.12	16:55	3.67	4.95	22:55	2.49	3.36
5:00	3.01	4.06	11:00	10.03	13.54	17:00	3.67	4.95	23:00	2.49	3.36
5:05	3.01	4.06	11:05	10.03	13.54	17:05	3.67	4.95	23:05	2.49	3.36
5:10	3.01	4.06	11:10	10.03	13.54	17:10	3.67	4.95	23:10	2.49	3.36
5:15	3.01	4.06	11:15	12.15	16.40	17:15	3.67	4.95	23:15	2.49	3.36
5:20	3.01	4.06	11:20	12.15	16.40	17:20	3.67	4.95	23:20	2.49	3.36
5:25	3.01	4.06	11:25	12.15	16.40	17:25	3.67	4.95	23:25	2.49	3.36
5:30	3.01	4.06	11:30	14.39	19.43	17:30	3.67	4.95	23:30	2.49	3.36
5:35	3.01	4.06	11:35	34.54	46.63	17:35	3.67	4.95	23:35	2.49	3.36
5:40	3.01	4.06	11:40	34.54	46.63	17:40	3.67	4.95	23:40	2.49	3.36
5:45	3.01	4.06	11:45	34.54	46.63	17:45	3.67	4.95	23:45	2.49	3.36
5:50	3.01	4.06	11:50	34.54	46.63	17:50	3.67	4.95	23:50	2.49	3.36
5:55	3.01	4.06	11:55	34.54	46.63	17:55	3.67	4.95	23:55	2.49	3.36
									0:00	2.49	3.36

Appendix E - Water Balance Model Results

WATER Balance MODEL Powered By QUALHYMO

Report for

320_OAR_large

SH_320_OAR_large

Report Details

Project

Site Name	SH_320_OAR_large
Site Description	
Site Location	Surrey, City of
Site Type	Site
Site Size	320 sq. m
Stream Present	No
Climate Data File	White Rock STP
Climate Start & End Dates	01/01/1965 to 12/31/1990

Scenario

Scenario Name	320_OAR_large
Scenario Description	
This is the base case or pre-development scenario for: SH_320_OAR_large	

Timestamps

Report Generated	Mon, 30 Oct 2017 15:11:57 -0500
Processed by QUALHYMO	Mon, 30 Oct 2017 15:11:55 -0500

Drainage Area Configuration

Drainage Areas

Drainage Areas	Native Soil Types	Land Uses	Surface Conditions	Source Controls
Modelled Area **Area** 320 sq. m **Length** 20 m **Slope** 0.005 m/m	Silty Loam **Area** 320 sq. m **Depth** 100 mm **Field Capacity** 33.7% **Wilting Point** 18.5%	Park **Area** 320 sq. m **Description** Park, Recreation, and Open Space Zones: PC, CPR, CPG Floor Area Ratio: 0.10 to 0.40 Maximum building coverage – 10% to 40% Note: Surface Conditions are based on maximum values where ranges are shown. For zone specific values refer to the District of Surrey zoning bylaws.	Pervious Cover **Area** 266.656 sq. m **Depth** 100 mm	
			Rooftop - Building **Area** 53.344 sq. m	

Surface Conditions

Name	Area	Type	Depression Storage	Rational Coefficient	Retardance Roughness	Field Capacity	Wilting Point
Pervious	266.656	Pervious	6 mm	.3	.03	19%	10%

Cover	sq. m						
Rooftop - Building	53.344 sq. m	Impervious	0 mm	-	.013	-	-

Stored Results of Last Scenario Run

Volume Summary (m³)

Rainfall Total	11415.75
Total Discharge	4.315465e+3
Total Losses	3.191150e+3
Catchment Infiltration	3.909140e+3
Source Control Infiltration	0.000000e+0

Exceedance Summary

Duration (hours)	Rate (m³/sec)
227904	0
450	0
32	0.001
5	0.001
3	0.001
2	0.002
1	0.002
1	0.002
1	0.002
0	0.003

WATER Balance MODEL Powered By QUALHYMO

Report for

320_OAR_small

SH_320_OAR_small

Report Details

Project

Site Name	SH_320_OAR_small
Site Description	
Site Location	Surrey, City of
Site Type	Site
Site Size	320 sq. m
Stream Present	No
Climate Data File	White Rock STP
Climate Start & End Dates	01/01/1965 to 12/31/1990

Scenario

Scenario Name	320_OAR_small
Scenario Description	
This is the base case or pre-development scenario for: SH_320_OAR_small	

Timestamps

Report Generated	Mon, 30 Oct 2017 15:14:46 -0500
Processed by QUALHYMO	Mon, 30 Oct 2017 15:14:44 -0500

Drainage Area Configuration

Drainage Areas

Drainage Areas	Native Soil Types	Land Uses	Surface Conditions	Source Controls
Modelled Area **Area** 320 sq. m **Length** 20 m **Slope** 0.005 m/m	Silty Loam **Area** 320 sq. m **Depth** 100 mm **Field Capacity** 33.7% **Wilting Point** 18.5%	Park **Area** 320 sq. m **Description** Park, Recreation, and Open Space Zones: PC, CPR, CPG Floor Area Ratio: 0.10 to 0.40 Maximum building coverage – 10% to 40% Note: Surface Conditions are based on maximum values where ranges are shown. For zone specific values refer to the District of Surrey zoning bylaws.	Pervious Cover **Area** 186.656 sq. m **Depth** 100 mm	
			Rooftop - Building **Area** 133.344 sq. m	

Surface Conditions

Name	Area	Type	Depression Storage	Rational Coefficient	Retardance Roughness	Field Capacity	Wilting Point
Pervious	186.656	Pervious	6 mm	.3	.03	19%	10%

Cover	sq. m						
Rooftop - Building	133.344 sq. m	Impervious	0 mm	-	.013	-	-

Stored Results of Last Scenario Run

Volume Summary (m³)

Rainfall Total	11415.75
Total Discharge	5.429750e+3
Total Losses	3.155290e+3
Catchment Infiltration	2.830710e+3
Source Control Infiltration	0.000000e+0

Exceedance Summary

Duration (hours)	Rate (m³/sec)
227904	0
411	0
27	0.001
6	0.001
3	0.001
2	0.002
1	0.002
1	0.002
1	0.003
0	0.003

WATER Balance MODEL Powered By QUALHYMO

Report for

320_80RF

SH_320_80RF

Report Details

Project

Site Name	SH_320_80RF
Site Description	
Site Location	Surrey, City of
Site Type	Site
Site Size	320 sq. m
Stream Present	No
Climate Data File	White Rock STP
Climate Start & End Dates	01/01/1965 to 12/31/1990

Scenario

Scenario Name	320_80RF
Scenario Description	
This is the base case or pre-development scenario for: SH_320_80RF	

Timestamps

Report Generated	Mon, 30 Oct 2017 15:15:19 -0500
Processed by QUALHYMO	Mon, 30 Oct 2017 15:15:18 -0500

Drainage Area Configuration

Drainage Areas

Drainage Areas	Native Soil Types	Land Uses	Surface Conditions	Source Controls
Modelled Area **Area** 320 sq. m **Length** 20 m **Slope** 0.005 m/m	Silty Loam **Area** 320 sq. m **Depth** 100 mm **Field Capacity** 33.7% **Wilting Point** 18.5%	Residential Level 3 **Area** 320 sq. m **Description** Multi-Family Residential, Ground-Oriented, Low Density Zones: RM-10, RM-15, RMS-1, RMS-1A, RMS-2 Floor Area Ratio: 0.50 to 0.60 Maximum building coverage = 25% to 45% Maximum total impervious coverage = 82% Note: Surface Conditions are based on maximum values where ranges are shown. For zone specific values refer to the District of Surrey zoning bylaws.	Impervious Cover **Area** 128 sq. m	
			Pervious Cover **Area** 64 sq. m **Depth** 100 mm	
			Rooftop - Building **Area** 128 sq. m	

Surface Conditions

			Depression	Rational	Retardance	Field	Wilting

Name	Area	Type	Storage	Coefficient	Roughness	Capacity	Point
Impervious Cover	128 sq. m	Impervious	2 mm	-	.013	-	-
Pervious Cover	64 sq. m	Pervious	6 mm	.3	.03	19%	10%
Rooftop - Building	128 sq. m	Impervious	0 mm	-	.013	-	-

Stored Results of Last Scenario Run

Volume Summary (m^3)

Rainfall Total	11415.75
Total Discharge	7.361730e+3
Total Losses	3.024070e+3
Catchment Infiltration	1.029950e+3
Source Control Infiltration	0.000000e+0

Exceedance Summary

Duration (hours)	Rate (m^3/sec)
227904	0
376	0
23	0.001
6	0.001
2	0.002
2	0.002
1	0.002
1	0.003
1	0.003
0	0.003

WATER Balance MODEL Powered By QUALHYMO

Report for

320_80RF_IMP_LIM

SH_320_80RF_IMP_LIM

Report Details

Project

Site Name	SH_320_80RF_IMP_LIM
Site Description	
Site Location	Surrey, City of
Site Type	Site
Site Size	320 sq. m
Stream Present	No
Climate Data File	White Rock STP
Climate Start & End Dates	01/01/1965 to 12/31/1990

Scenario

Scenario Name	320_80RF_IMP_LIM
Scenario Description	

This is the base case or pre-development scenario for: SH_320_80RF_IMP_LIM

Timestamps

Report Generated	Mon, 30 Oct 2017 15:15:50 -0500
Processed by QUALHYMO	Mon, 30 Oct 2017 15:15:49 -0500

Drainage Area Configuration

Drainage Areas

Drainage Areas	Native Soil Types	Land Uses	Surface Conditions	Source Controls
Modelled Area **Area** 320 sq. m **Length** 20 m **Slope** 0.005 m/m	Silty Loam **Area** 320 sq. m **Depth** 100 mm **Field Capacity** 33.7% **Wilting Point** 18.5%	Residential Level 3 **Area** 320 sq. m **Description** Multi-Family Residential, Ground-Oriented, Low Density Zones: RM-10, RM-15, RMS-1, RMS-1A, RMS-2 Floor Area Ratio: 0.50 to 0.60 Maximum building coverage = 25% to 45% Maximum total impervious coverage = 82% Note: Surface Conditions are based on maximum values where ranges are shown. For zone specific values refer to the District of Surrey zoning bylaws.	Impervious Cover **Area** 32 sq. m	
			Pervious Cover **Area** 160 sq. m **Depth** 100 mm	
			Rooftop - Building **Area** 128 sq. m	

Surface Conditions

			Depression	Rational	Retardance	Field	Wilting

Name	Area	Type	Storage	Coefficient	Roughness	Capacity	Point
Impervious Cover	32 sq. m	Impervious	2 mm	-	.013	-	-
Pervious Cover	160 sq. m	Pervious	6 mm	.3	.03	19%	10%
Rooftop - Building	128 sq. m	Impervious	0 mm	-	.013	-	-

Stored Results of Last Scenario Run

Volume Summary (m^3)

Rainfall Total	11415.75
Total Discharge	5.857710e+3
Total Losses	3.121340e+3
Catchment Infiltration	2.436700e+3
Source Control Infiltration	0.000000e+0

Exceedance Summary

Duration (hours)	Rate (m^3/sec)
227904	0
390	0
26	0.001
6	0.001
3	0.001
2	0.002
1	0.002
1	0.002
1	0.003
1	0.003

WATER Balance MODEL Powered By QUALHYMO

Report for

320_80RF

SH_320_80RF_BMP

Report Details

Project

Site Name	SH_320_80RF_BMP
Site Description	
Site Location	Surrey, City of
Site Type	Site
Site Size	320 sq. m
Stream Present	No
Climate Data File	White Rock STP
Climate Start & End Dates	01/01/1965 to 12/31/1990

Scenario

Scenario Name	320_80RF
Scenario Description	
This is the base case or pre-development scenario for: SH_320_80RF_BMP	

Timestamps

Report Generated	Mon, 30 Oct 2017 15:16:22 -0500
Processed by QUALHYMO	Mon, 30 Oct 2017 15:16:21 -0500

Drainage Area Configuration

Drainage Areas

Drainage Areas	Native Soil Types	Land Uses	Surface Conditions	Source Controls
Modelled Area **Area** 320 sq. m **Length** 20 m **Slope** 0.005 m/m	Silty Loam **Area** 320 sq. m **Depth** 100 mm **Field Capacity** 33.7% **Wilting Point** 18.5%	Residential Level 3 **Area** 320 sq. m **Description** Multi-Family Residential, Ground-Oriented, Low Density Zones: RM-10, RM-15, RMS-1, RMS-1A, RMS-2 Floor Area Ratio: 0.50 to 0.60 Maximum building coverage = 25% to 45% Maximum total impervious coverage = 82% Note: Surface Conditions are based on maximum values where ranges are shown. For zone specific values refer to the District of Surrey zoning bylaws.	Impervious Cover **Area** 128 sq. m	**Perv Paving** **Size** 64 sq. m
			Pervious Cover **Area** 64 sq. m **Depth** 100 mm	**Abs Landscaping** **Size** 64 sq. m
			Rooftop - Building **Area** 128 sq. m	

Surface Conditions

			Depression	Rational	Retardance	Field	Wilting

Name	Area	Type	Storage	Coefficient	Roughness	Capacity	Point
Impervious Cover	128 sq. m	Impervious	2 mm	-	.013	-	-
Pervious Cover	64 sq. m	Pervious	6 mm	.3	.03	19%	10%
Rooftop - Building	128 sq. m	Impervious	0 mm	-	.013	-	-

Source Controls - Surface Enhancements

Abs Landscaping

[Absorbent Landscaping]

Size	Crop Coefficient	Design Soil Rooting Depth
64 sq. m	1	450 mm

Soil Definition

Name	Type	Depression Storage	Rational Coefficient	Retardance Roughness	Field Capacity	Wilting Point
Sandy Loam	Pervious	7 mm	0.2	0.03	20.3%	13.7%

Perv Paving

[Pervious Paving]

Size	Design Soil Rooting Depth
64 sq. m	600 mm

Soil Definition

Name	Type	Depression Storage	Rational Coefficient	Retardance Roughness	Field Capacity	Wilting Point
Silty Loam	Pervious	7 mm	0.2	0.03	33.7%	18.5%

Stored Results of Last Scenario Run

Volume Summary (m^3)

Rainfall Total	11415.75
Total Discharge	6.014830e+3
Total Losses	3.093530e+3
Catchment Infiltration	2.307390e+3
Source Control Infiltration	0.000000e+0

Exceedance Summary

Duration (hours)	Rate (m^3/sec)
227904	0
394	0
27	0.001
6	0.001
3	0.001
2	0.002
1	0.002
1	0.002
1	0.003
0	0.003

WATER Balance MODEL Powered By QUALHYMO

Report for

2000_OAR_large

SH_2000_OAR_large

Report Details

Project

Site Name	SH_2000_OAR_large
Site Description	
Site Location	Surrey, City of
Site Type	Site
Site Size	2000 sq. m
Stream Present	No
Climate Data File	White Rock STP
Climate Start & End Dates	01/01/1965 to 12/31/1990

Scenario

Scenario Name	2000_OAR_large
Scenario Description	
This is the base case or pre-development scenario for: SH_2000_OAR_large	

Timestamps

Report Generated	Mon, 30 Oct 2017 15:21:16 -0500
Processed by QUALHYMO	Mon, 30 Oct 2017 15:21:14 -0500

Drainage Area Configuration

Drainage Areas

Drainage Areas	Native Soil Types	Land Uses	Surface Conditions	Source Controls
Modelled Area **Area** 2000 sq. m **Length** 50 m **Slope** 0.005 m/m	Silty Loam **Area** 2000 sq. m **Depth** 100 mm **Field Capacity** 33.7% **Wilting Point** 18.5%	Park **Area** 2000 sq. m **Description** Park, Recreation, and Open Space Zones: PC, CPR, CPG Floor Area Ratio: 0.10 to 0.40 Maximum building coverage – 10% to 40% Note: Surface Conditions are based on maximum values where ranges are shown. For zone specific values refer to the District of Surrey zoning bylaws.	Pervious Cover **Area** 1666.6 sq. m **Depth** 100 mm	
			Rooftop - Building **Area** 333.4 sq. m	

Surface Conditions

Name	Area	Type	Depression Storage	Rational Coefficient	Retardance Roughness	Field Capacity	Wilting Point
Pervious	1666.6	Pervious	6 mm	.3	.03	19%	10%

Cover	sq. m						
Rooftop - Building	333.4 sq. m	Impervious	0 mm	-	.013	-	-

Stored Results of Last Scenario Run

Volume Summary (m³)

Rainfall Total	71348.41
Total Discharge	3.609996e+4
Total Losses	1.081634e+4
Catchment Infiltration	2.443211e+4
Source Control Infiltration	0.000000e+0

Exceedance Summary

Duration (hours)	Rate (m³/sec)
227904	0
439	0.002
31	0.004
5	0.006
3	0.008
2	0.01
1	0.012
1	0.013
1	0.015
1	0.017

WATER Balance MODEL Powered By QUALHYMO

Report for

2000_OAR_small

SH_2000_OAR_small

Report Details

Project

Site Name	SH_2000_OAR_small
Site Description	
Site Location	Surrey, City of
Site Type	Site
Site Size	2000 sq. m
Stream Present	No
Climate Data File	White Rock STP
Climate Start & End Dates	01/01/1965 to 12/31/1990

Scenario

Scenario Name	2000_OAR_small
Scenario Description	
This is the base case or pre-development scenario for: SH_2000_OAR_small	

Timestamps

Report Generated	Mon, 30 Oct 2017 15:21:44 -0500
Processed by QUALHYMO	Mon, 30 Oct 2017 15:21:42 -0500

Drainage Area Configuration

Drainage Areas

Drainage Areas	Native Soil Types	Land Uses	Surface Conditions	Source Controls
Modelled Area **Area** 2000 sq. m **Length** 50 m **Slope** 0.005 m/m	Silty Loam **Area** 2000 sq. m **Depth** 100 mm **Field Capacity** 33.7% **Wilting Point** 18.5%	Park **Area** 2000 sq. m **Description** Park, Recreation, and Open Space Zones: PC, CPR, CPG Floor Area Ratio: 0.10 to 0.40 Maximum building coverage – 10% to 40% Note: Surface Conditions are based on maximum values where ranges are shown. For zone specific values refer to the District of Surrey zoning bylaws.	Pervious Cover **Area** 1166.6 sq. m **Depth** 100 mm	
			Rooftop - Building **Area** 833.4 sq. m	

Surface Conditions

Name	Area	Type	Depression Storage	Rational Coefficient	Retardance Roughness	Field Capacity	Wilting Point
Pervious	1166.6	Pervious	6 mm	.3	.03	19%	10%

Cover	sq. m						
Rooftop - Building	833.4 sq. m	Impervious	0 mm	-	.013	-	-

Stored Results of Last Scenario Run

Volume Summary (m^3)

Rainfall Total	71348.41
Total Discharge	4.556680e+4
Total Losses	8.089680e+3
Catchment Infiltration	1.769193e+4
Source Control Infiltration	0.000000e+0

Exceedance Summary

Duration (hours)	Rate (m^3/sec)
227904	0
390	0.002
27	0.004
6	0.006
3	0.008
2	0.011
1	0.013
1	0.015
1	0.017
0	0.019

WATER Balance MODEL Powered By QUALHYMO

Report for

2000_65RM

SH_2000_65RM

Report Details

Project

Site Name	SH_2000_65RM
Site Description	
Site Location	Surrey, City of
Site Type	Site
Site Size	2000 sq. m
Stream Present	No
Climate Data File	White Rock STP
Climate Start & End Dates	01/01/1965 to 12/31/1990

Scenario

Scenario Name	2000_65RM
Scenario Description	
This is the base case or pre-development scenario for: SH_2000_65RM	

Timestamps

Report Generated	Mon, 30 Oct 2017 15:16:59 -0500
Processed by QUALHYMO	Mon, 30 Oct 2017 15:16:57 -0500

Drainage Area Configuration

Drainage Areas

Drainage Areas	Native Soil Types	Land Uses	Surface Conditions	Source Controls
Modelled Area **Area** 2000 sq. m **Length** 50 m **Slope** 0.005 m/m	Silty Loam **Area** 2000 sq. m **Depth** 100 mm **Field Capacity** 33.7% **Wilting Point** 18.5%	Residential Level 3 **Area** 2000 sq. m **Description** Multi-Family Residential, Ground-Oriented, Low Density Zones: RM-10, RM-15, RMS-1, RMS-1A, RMS-2 Floor Area Ratio: 0.50 to 0.60 Maximum building coverage = 25% to 45% Maximum total impervious coverage = 82% Note: Surface Conditions are based on maximum values where ranges are shown. For zone specific values refer to the District of Surrey zoning bylaws.	Impervious Cover **Area** 700 sq. m	
			Pervious Cover **Area** 700 sq. m **Depth** 100 mm	
			Rooftop - Building **Area** 600 sq. m	

Surface Conditions

			Depression	Rational	Retardance	Field	Wilting

Name	Area	Type	Storage	Coefficient	Roughness	Capacity	Point
Impervious Cover	700 sq. m	Impervious	2 mm	-	.013	-	-
Pervious Cover	700 sq. m	Pervious	6 mm	.3	.03	19%	10%
Rooftop - Building	600 sq. m	Impervious	0 mm	-	.013	-	-

Stored Results of Last Scenario Run

Volume Summary (m^3)

Rainfall Total	71348.41
Total Discharge	5.400520e+4
Total Losses	6.421380e+3
Catchment Infiltration	1.092183e+4
Source Control Infiltration	0.000000e+0

Exceedance Summary

Duration (hours)	Rate (m^3/sec)
227904	0
387	0.002
24	0.005
6	0.007
3	0.009
2	0.012
1	0.014
1	0.016
1	0.018
1	0.021

WATER Balance MODEL Powered By QUALHYMO

Report for

2000_65RM_IMP_LIM

SH_2000_65RM_IMP_LIM

Report Details

Project

Site Name	SH_2000_65RM_IMP_LIM
Site Description	
Site Location	Surrey, City of
Site Type	Site
Site Size	2000 sq. m
Stream Present	No
Climate Data File	White Rock STP
Climate Start & End Dates	01/01/1965 to 12/31/1990

Scenario

Scenario Name	2000_65RM_IMP_LIM
Scenario Description	
This is the base case or pre-development scenario for: SH_2000_65RM_IMP_LIM	

Timestamps

Report Generated	Mon, 30 Oct 2017 15:22:09 -0500
Processed by QUALHYMO	Mon, 30 Oct 2017 15:22:07 -0500

Drainage Area Configuration

Drainage Areas

Drainage Areas	Native Soil Types	Land Uses	Surface Conditions	Source Controls
Modelled Area **Area** 2000 sq. m **Length** 50 m **Slope** 0.005 m/m	Silty Loam **Area** 2000 sq. m **Depth** 100 mm **Field Capacity** 33.7% **Wilting Point** 18.5%	Residential Level 3 **Area** 2000 sq. m **Description** Multi-Family Residential, Ground-Oriented, Low Density Zones: RM-10, RM-15, RMS-1, RMS-1A, RMS-2 Floor Area Ratio: 0.50 to 0.60 Maximum building coverage = 25% to 45% Maximum total impervious coverage = 82% Note: Surface Conditions are based on maximum values where ranges are shown. For zone specific values refer to the District of Surrey zoning bylaws.	Impervious Cover **Area** 450 sq. m	
			Pervious Cover **Area** 1100 sq. m **Depth** 100 mm	
			Rooftop - Building **Area** 450 sq. m	

Surface Conditions

			Depression	Rational	Retardance	Field	Wilting

Name	Area	Type	Storage	Coefficient	Roughness	Capacity	Point
Impervious Cover	450 sq. m	Impervious	2 mm	-	.013	-	-
Pervious Cover	1100 sq. m	Pervious	6 mm	.3	.03	19%	10%
Rooftop - Building	450 sq. m	Impervious	0 mm	-	.013	-	-

Stored Results of Last Scenario Run

Volume Summary (m^3)

Rainfall Total	71348.41
Total Discharge	4.672290e+4
Total Losses	7.763990e+3
Catchment Infiltration	1.686152e+4
Source Control Infiltration	0.000000e+0

Exceedance Summary

Duration (hours)	Rate (m^3/sec)
227904	0
399	0.002
27	0.004
6	0.006
3	0.009
2	0.011
1	0.013
1	0.015
1	0.017
1	0.019

WATER Balance MODEL Powered By QUALHYMO

Report for

2000_65RM_BMP

SH_2000_65RM_BMP

Report Details

Project

Site Name	SH_2000_65RM_BMP
Site Description	
Site Location	Surrey, City of
Site Type	Site
Site Size	2000 sq. m
Stream Present	No
Climate Data File	White Rock STP
Climate Start & End Dates	01/01/1965 to 12/31/1990

Scenario

Scenario Name	2000_65RM_BMP
Scenario Description	
This is the base case or pre-development scenario for: SH_2000_65RM_BMP	

Timestamps

Report Generated	Mon, 30 Oct 2017 15:22:38 -0500
Processed by QUALHYMO	Mon, 30 Oct 2017 15:22:37 -0500

Drainage Area Configuration

Drainage Areas

Drainage Areas	Native Soil Types	Land Uses	Surface Conditions	Source Controls
Modelled Area **Area** 2000 sq. m **Length** 50 m **Slope** 0.005 m/m	Silty Loam **Area** 2000 sq. m **Depth** 100 mm **Field Capacity** 33.7% **Wilting Point** 18.5%	Residential Level 3 **Area** 2000 sq. m **Description** Multi-Family Residential, Ground-Oriented, Low Density Zones: RM-10, RM-15, RMS-1, RMS-1A, RMS-2 Floor Area Ratio: 0.50 to 0.60 Maximum building coverage = 25% to 45% Maximum total impervious coverage = 82% Note: Surface Conditions are based on maximum values where ranges are shown. For zone specific values refer to the District of Surrey zoning bylaws.	Impervious Cover **Area** 700 sq. m	**Perv Paving** **Size** 350 sq. m
			Pervious Cover **Area** 700 sq. m **Depth** 100 mm	**Abs Landscaping** **Size** 350 sq. m
			Rooftop - Building **Area** 600 sq. m	

Surface Conditions

			Depression	Rational	Retardance	Field	Wilting

Name	Area	Type	Storage	Coefficient	Roughness	Capacity	Point
Impervious Cover	700 sq. m	Impervious	2 mm	-	.013	-	-
Pervious Cover	700 sq. m	Pervious	6 mm	.3	.03	19%	10%
Rooftop - Building	600 sq. m	Impervious	0 mm	-	.013	-	-

Source Controls - Surface Enhancements

Abs Landscaping

[Absorbent Landscaping]

Size	Crop Coefficient	Design Soil Rooting Depth
350 sq. m	1	450 mm

Soil Definition

Name	Type	Depression Storage	Rational Coefficient	Retardance Roughness	Field Capacity	Wilting Point
Sandy Loam	Pervious	7 mm	0.2	0.03	20.3%	13.7%

Perv Paving

[Pervious Paving]

Size	Design Soil Rooting Depth
350 sq. m	600 mm

Soil Definition

Name	Type	Depression Storage	Rational Coefficient	Retardance Roughness	Field Capacity	Wilting Point
Silty Loam	Pervious	7 mm	0.2	0.03	33.7%	18.5%

Stored Results of Last Scenario Run

Volume Summary (m^3)

Rainfall Total	71348.41
Total Discharge	4.562090e+4
Total Losses	7.396840e+3
Catchment Infiltration	1.833067e+4
Source Control Infiltration	0.000000e+0

Exceedance Summary

Duration (hours)	Rate (m^3/sec)
227904	0
397	0.002
27	0.004
6	0.006
3	0.008
2	0.01
1	0.012
1	0.014
1	0.016
0	0.018

Appendix F - ISMP Summary Sheet

Sam Hill Creek ISMP
ISMP Summary Sheet

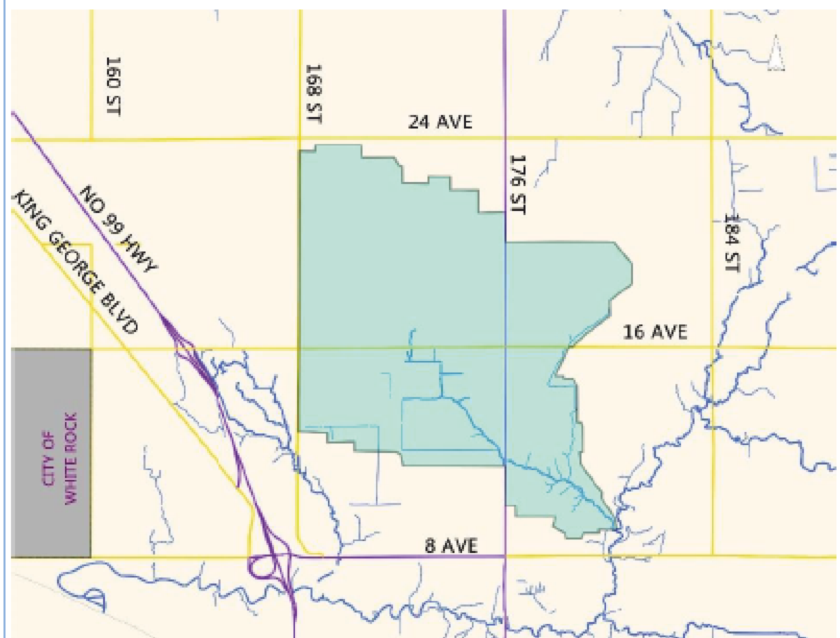
Consultant	Associated Engineering
Date Issued	May 2019

Watershed Overview:
The Sam Hill Creek watershed is currently developed with low-density residential and agricultural land uses. 16 Avenue is the boundary between residential areas to the north and the Agricultural Land Reserve (ALR) to the south. There are significant forested areas including a unique redwood tree park.

16 Avenue also represents the dividing line between the higher gradient systems to the north and lower gradient systems to the south.

Future redevelopment is expected as part of the Grandview Heights Neighbourhood Community Plan #3. This area will be redeveloped with a mixture of urban single family, multi-family residential, and some commercial and institutional land uses.

Watershed health differs across the 16 Avenue divide with the northern section estimated to have lower effective imperviousness and higher riparian forest integrity.



ISMP Overview:
Future re-development of the NCP in the northern part of the watershed is the main focus of the ISMP. This area has the most intact riparian and forested areas within the watershed. The City has a better opportunity to protect this land than the land to the south of 16 Avenue, which is part of the ALR and where watershed health is poorer. Grandview Heights Neighbourhood Community Plan was developed in conjunction with this ISMP.

Recommendations for City	Description
Infrastructure Upgrades	As part of the NCP development, implement 6 proposed storage ponds (Table 8-6) A - Upgrade 78 m of 750 mm Ø storm sewer on 172 Street north of 20 Avenue. B - Upgrade 191 m of 675 mm Ø and 203 m of 900 mm Ø storm sewer on 20 Avenue west of 176 Street C2 - Upgrade 600 mm Ø culvert to 1500 mm Ø at 18 Avenue along 172 Street C3 - Upgrade 600 mm Ø culvert to 1500 mm Ø at 20 Avenue along 172 Street C4 - Upgrade 450 mm Ø culvert to 750 mm Ø at 171 Street along 21 Avenue C5 - Upgrade 600 mm Ø culvert to 675 mm Ø at 12 Avenue at 17800 Block C7 - Upgrade 300 mm Ø culvert to 375 mm Ø at 12 Avenue at 17900 Block C11 - Upgrade 450 mm Ø culvert to 750 mm Ø at 170 Street along 16 Avenue C13 - Upgrade 600 mm Ø culvert to 1500 mm Ø at 18 Avenue along 172 Street ROW All proposed upgrades are listed in Table 10-1 in Section 10.1 (see Map 10-1).
Environmental Enhancement Projects	Removal of barriers to fish passage and daylighting a long culvert/sewer. See details in Table 10-1 and Section 10.1. Amendments to the Green Infrastructure Network are proposed in Section 4.4.5 and Map 4-1. Recommended watercourse re-classifications as per Table 4-5 and Map 4-3. Several recommendations including installing fencing along streams, removing invasive plants, re-establishing native riparian plants, and restoring a hydraulic connection to Sam Hill Creek. See Section 4.3.2.5.
Erosion Mitigation Measures	A storm outfall draining to Sam Hill Creek located on along 176 Street should be armoured. See Section 4.3.2.5.

(Continued on next page)

Note: This summary sheet summarizes the contents of the ISMP only. Other documents may supersede or complement the guidance found here. The designer should ensure all relevant guidance is followed when designing within the ISMP study area. Design for site servicing to be in accordance with the City's Design Criteria Manual.

Recommendations for Development & Re-Development	Land Use Categories			
	Single Family (Urban Single Family, Semi-Detached Residential)	Multi-Family Residential (Multiple Residential Cluster, Low-Density Multiple Residential, Medium Density Residential, and Townhouse Residential)	Commercial, Institutional, and School Land Uses	Road Right-of-Ways
Rainwater Capture Requirements	72% of the 2-year return period event or 38.3 mm			
Stormwater Detention Requirements	278 m^3/ha for the 5-year post-development event			
Release Rate	0.25 L/s/ha for the rainwater capture event for BMPs 6.6 L/s/ha for the 5-year post-development event for detention			

Additional Information:
Detention pond volumes and maximum release rates. See Section 8.6.1 and Map 10-1 for more details. Average values below can be used for designing stormwater storage for facilities other than the six already identified or if the catchment area of the proposed pond changes with final land use plans.

Storage Location	Total Catchment Area [ha]	Criteria 1: Control 5-year Post-Development Flow to 50% of 2-year Post-Development Flow*			
		Maximum Design Outflow [m^3/s]	Allowable Release Rate [L/s/ha]	Required Storage Volume [m^3]	Storage Volume per unit area [m^3/ha]
1	42	0.3325	**7.9**	12,391	295
2	47	0.314	**6.7**	13,362	287
3	32	0.1705	**5.3**	4,222	131
4	32	0.242	**7.7**	9,104	288
5	32	0.247	**7.7**	10,595	331
6	32	0.127	**4.0**	10,644	336
		Average	**6.6**		278

(Continued on next page)

Note: This summary sheet summarizes the contents of the ISMP only. Other documents may supersede or complement the guidance found here. The designer should ensure all relevant guidance is followed when designing within the ISMP study area. Design for site servicing to be in accordance with the City's Design Criteria Manual.