SURREY
CITY OF PARKS

Hyland Creek

Integrated Stormwater Management Plan

1072.0137.01 / July 20, 2007

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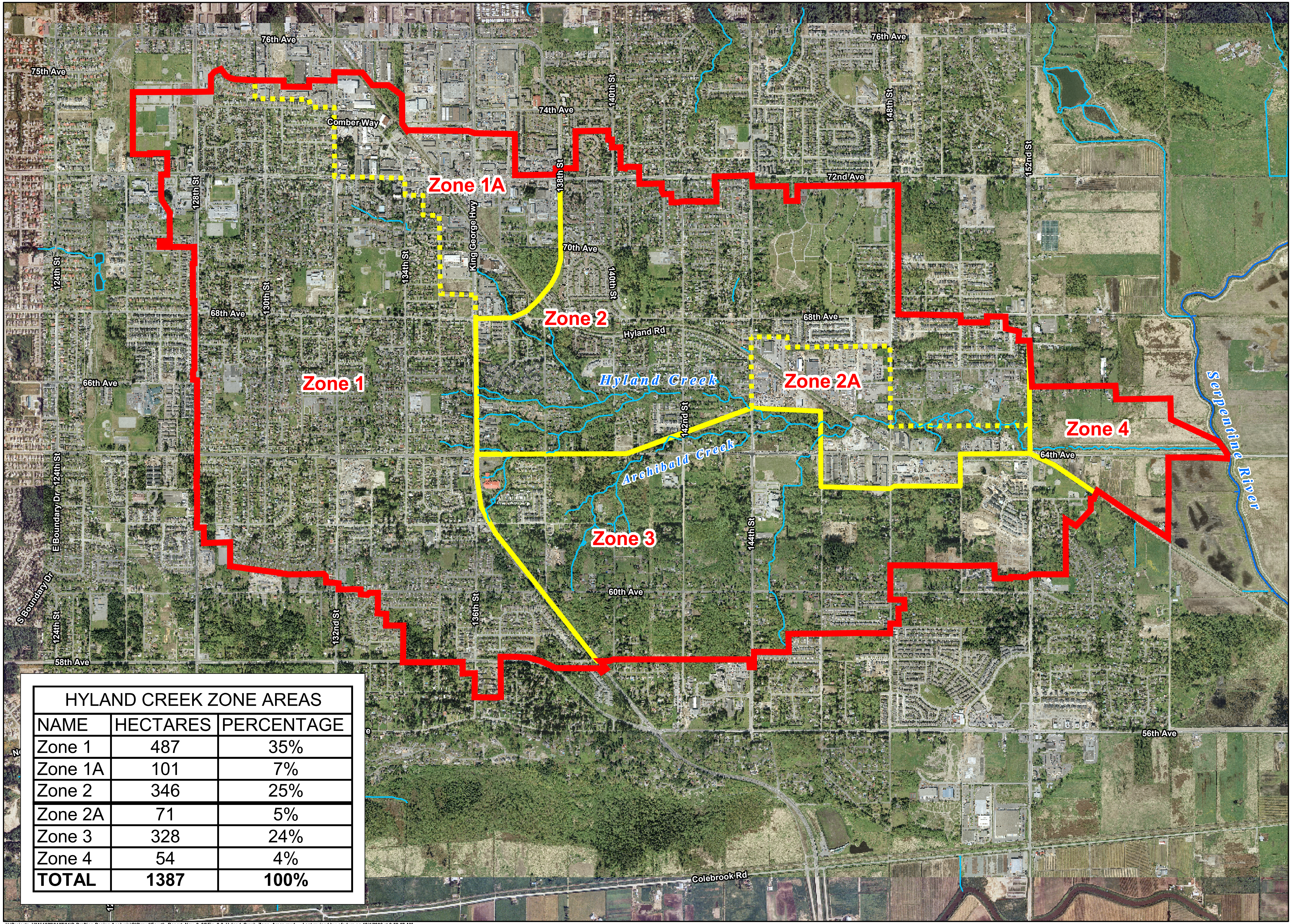
EXECUTIVE SUMMARY

The recent trend towards integrated stormwater management represents an evolution in the way that watershed health and development impacts are viewed. An Integrated Stormwater Management Plan (ISMP) recognizes stormwater as a resource to be valued, rather than a nuisance by-product of land development that must be managed. It links stormwater with land use planning (including parks, recreation, policy and finance) and environmental factors (including aquatic, terrestrial and wildlife). It also examines the hydrological characteristics of the watershed by considering all aspects of the hydrological regime in pre-development conditions and tailoring a plan for development which aims to keep that regime intact to the greatest extent possible.

The need to take an integrated approach to stormwater management is well recognized in the Lower Mainland. Under the Greater Vancouver Regional District's (GVRD) Liquid Waste Management Plan, all member municipalities, including the City of Surrey (City), have committed to undertaking ISMPs for all of their watersheds by 2014. In response to this commitment, the City retained Urban Systems to prepare an ISMP for the Hyland Creek watershed. Urban Systems evaluated the stormwater management, land use planning, parks, and policy and finance components of this project, while their subconsultant Jacques Whitford AXYS undertook aquatic, wildlife, terrestrial and hydrogeology assessments. At the City's direction, the Hyland Creek ISMP has been completed in accordance with the GVRD ISMP Template.

To undertake an ISMP for the Hyland Creek watershed at this time is somewhat unique, as a significant portion of the watershed is already developed and detailed land use plans already exist for the remaining undeveloped areas. The Hyland Creek watershed is a mature, urbanized watershed, thus one of the challenges in developing achievable solutions for this watershed is that there are limited opportunities to affect existing development, or to affect development applications for green field sites which are already in process prior to the completion and adoption of this ISMP.

The Hyland Creek watershed is centrally located in Surrey. The catchment is approximately 1,387 hectares in size, and is roughly bounded by 72 Avenue to the north, 128 Street to the west, 58 Avenue to the south, and 156 Street to the east, as shown on Figure ES-1. The creek itself is approximately 6.0 kilometres long and runs east-west from its headwater area near King George Highway to its discharge point at the Serpentine River just east of 156 Street. Hyland Creek is a second order tributary of the Serpentine River, with a confluence approximately 13.5 kilometres upstream of the Serpentine's outlet into Mud Bay. Archibald Creek is a major tributary; however, there are also eight smaller tributaries which drain to Hyland Creek. The majority of the catchment is within the Surrey upland area, with a small contributing area of lowland drainage east of 152 Street. This lowland area is influenced by tidal fluctuations in Mud Bay.



HYLAND CREEK ZONE AREAS

NAME	HECTARES	PERCENTAGE
Zone 1	487	35%
Zone 1A	101	7%
Zone 2	346	25%
Zone 2A	71	5%
Zone 3	328	24%
Zone 4	54	4%
TOTAL	**1387**	**100%**

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Hyland Creek Integrated Stormwater Management Plan

Figure ES-1

HYLAND CREEK WATERSHED

Zone Boundary
Sub-Zone Boundary
Hyland Creek Watershed Area

0 250 500
Metres

Scale 1:20 000

Source: City of Surrey
2005 Aerial Photography

Prepared By:
URBANSYSTEMS.
1072.0137.01 July 2007

Given the current characteristics of the watershed, different areas have unique issues and challenges that should be identified and addressed within the overall context of the Hyland Creek ISMP. The ISMP should therefore address these specific issues and challenges rather than attempt to group unique areas of the watershed together using generalized statements. Thus, for the purposes of this study, the Hyland Creek watershed has been divided into a series of zones, as shown on Figure ES-1. Each zone was delineated based on the unique characteristics, issues and needs of that area, such as the level of existing development, existing land use type(s), potential development and future land use, and specific environmental and/or drainage features. The watershed was divided into four (4) primary zones, as follows:

- Zone 1 – Headwater area of Hyland Creek, west of King George Highway
- Zone 2 – North of Hyland Creek, between King George Highway and 152 Street
- Zone 3 – South of Hyland Creek, between King George Highway and 152 Street
- Zone 4 – Lowland area of Hyland Creek, east of 152 Street (mainly Agricultural Land Reserve (ALR) lands)

Zones 1 and 2 were further divided into Zone 1A and Zone 2A, respectively, to isolate existing and/or future commercial and industrial development in these two zones for discussion and evaluation purposes.

Existing development in the Hyland Creek watershed is fairly extensive, particularly in areas west of King George Highway and north of Hyland Creek (Zones 1, 1A, 2 and 2A). Existing development typically has infrastructure in place, and in some instances the environmental and drainage features have been altered or compromised due to encroachment by development. On the other hand, there are still significant tracts of agricultural and undeveloped land in the watershed where the riparian corridor is mainly intact (Zones 3 and 4). Zone 3 in particular is under intense pressure to develop and appreciable short-term growth is anticipated in this zone.

The City outlined several overall goals and objectives for the Hyland Creek ISMP, which include:

- To identify how the City, development community, government agencies and residents will grow and live within the Hyland Creek watershed
- To outline how resources within the watershed will be managed to balance land development with environmental protection, preservation and enhancement
- To develop and implement a program to identify the existing value of habitat in Hyland Creek and its tributaries, including wildlife and fisheries

- To identify and categorize discharge points into the creek based on area, existing land use, water quantity and quality impact, potential development and future land use
- To classify probable and sustainable future land uses within the watershed
- To determine targets for stormwater runoff quantity and quality for future development
- To outline an implementation strategy for mitigation, including proposed locations of future structures, benefiting areas, costs and financing methods
- To highlight how the City can monitor the long-term effectiveness of the proposed mitigation strategy once it is implemented

The following sections highlight the main findings of the Hyland Creek ISMP.

Stormwater Management

Although significant portions of the Hyland Creek watershed have already been developed, there are still opportunities to mitigate the impacts of this level of development on the watershed, as well as to implement stormwater best management practices (BMPs) to address future development. The focus of stormwater related improvements for the watershed should first consider ways to stabilize current watershed conditions, and second, to identify opportunities to improve conditions where practical and economically feasible, with the intent of making a meaningful and effective impact on the overall health of the watershed. The specific approaches taken for each zone are summarized below:

- *Zone 1* – Opportunities to implement stormwater BMPs are somewhat limited as the area is essentially built out and significant redevelopment is not anticipated. However, actions can be taken by the City and individual property owners on a lot-by-lot basis to reduce the generation, and/or improve the quality, of stormwater runoff. Opportunities to make best use of existing drainage infrastructure should be identified. Additional community-level detention is also a possibility to address uncontrolled flows from a significant portion of this zone.
- *Zone 2* – This zone is also highly developed; however, there are large parcels of pervious area that remain, including the cemetery and several municipal parks. Retention of these pervious areas assists in offsetting the impacts of existing development in Zone 2. Opportunities to make best use of existing drainage infrastructure should also be identified.
- *Zones 1A and 2A* – Since both of these zones contain significant commercial and industrial areas, stormwater BMPs which address high and frequent runoff rates as well as water quality should be considered.

- *Zone 3* – This zone contains the vast majority of undeveloped and rural areas remaining in the watershed. This zone also appears to contribute a significant portion of total base flows to Hyland Creek (via Archibald Creek). Therefore, Zone 3 provides the greatest opportunity of all of the zones to have a positive impact on overall watershed health through stormwater management improvements, such as implementing stormwater BMPs as part of future development.
- *Zone 4* – This zone is located in the lowland area of the watershed, where agricultural operations are the predominant land use. Public education will be the most effective opportunity in this zone to address water quality concerns.

The Hyland Creek watershed has been studied extensively from a hydraulic perspective in the past; however, these studies did not fully integrate their drainage analyses with environmental, planning and hydrogeological perspectives to the extent undertaken in the ISMP. Nonetheless, the hydraulic characteristics of the watercourse were already well understood prior to the ISMP.

Recent erosion studies for Hyland and Archibald Creeks have confirmed that not only have the number of erosion sites on Hyland Creek increased over time, but the severity of these erosion sites have increased as well. In particular, the north branch of Hyland Creek (which receives flows from the northern portions of Zone 1 as well as Zone 1A) is experiencing significant stresses from increased flow rates and frequency, as stormwater runoff currently receives little to no attenuation prior to being discharged to this branch. Further, erosion issues have begun to emerge on Archibald Creek, which may be attributable to the recent initiation of development in Zone 3.

In an undeveloped watershed, base flows in a watercourse remain fairly constant over the course of a year. Base flows are critical to the overall health of a watercourse, and specifically on the health of aquatic species and their habitat. A review of gauged flow data on Hyland Creek indicates that base flows in the creek are significantly reduced in the summertime, suggesting that existing development in the watershed has already altered the natural hydrologic regime of the creek. Furthermore, a comparison of gauged flow data for Archibald Creek (its catchment area, Zone 3, has remained largely undeveloped until recently) shows that summer base flows are starting to diminish as well. Future development practices, particularly in Zone 3, will need to enact stormwater BMPs to ensure that seasonal base flows to the creeks are maintained.

Currently, there are 48 municipal and 20 private detention facilities within the Hyland Creek watershed that service approximately 24% of the overall watershed area. The City has expressed concern about the performance of these facilities and whether opportunities exist to improve their function. Most of these facilities are located in Zones 1 and 2, and were intended to service individual developments rather than be community based. These facilities were designed to activate only under a surcharged condition when the capacity of the downstream drainage system was exceeded, meaning that frequent, low intensity storms are allowed to discharge directly to Hyland Creek with little to no flow attenuation. The hydrologic / hydraulic analysis conducted for the ISMP concluded that many of the existing municipal detention facilities currently provide little to no benefit for smaller storm events, and only provide minimal to moderate benefits for larger storm events. However, any benefits that these facilities do provide are essentially negligible by the time that flows reach Hyland Creek due to their placement and configuration in the drainage system, and the amount of developed area that is not currently serviced by a detention facility.

Given the maturity of the existing infrastructure, more pragmatic decisions are required to make the best use of existing features. These decisions may be different than those made when planning for new drainage infrastructure. The ISMP analysis indicated that detention facilities servicing predominantly single family residential development should strive for a unit storage volume of 200 m^3 / hectare and a unit release rate of 1.5 to 2.5 L/s/hectare for management of the Mean Annual Rainfall (MAR) event. The MAR is an important parameter to consider, as it is often correlated to the "channel forming", or bankfull event for creeks and watercourses in the Lower Mainland and is also often used to set performance targets for addressing stormwater runoff onsite. The analysis also identified future community-scale municipal detention facilities needed to service the northwest sector of the watershed (to mitigate the ongoing erosion and water quality issues within the north branch of Hyland Creek), and also supported the future municipal detention facilities identified in the South Newton NCP to service future development in Zone 3. The City's drainage capital works program was also updated to reflect the findings of the ISMP.

Several stormwater BMPs are recommended for new, infill and redevelopment parcels in the Hyland Creek watershed, particularly within Zone 3 where the vast majority of future development is expected to occur. These include:

- Disconnect roof leaders for all land use types (limit effective impervious area)
- Add additional topsoil to pervious areas to retain the 6 month, 24 hour post-development storm event on site (e.g. 450mm of topsoil would be required on an RF-12 zoned single family small lot)
- Incorporate linear infiltration / groundwater recharge systems in the municipal road right-of-way to direct flows up to the 2 year pre-development flow to the creeks
- Use porous pavements in low traffic areas, such as driveways, patios, sidewalks, on-street parking areas, etc (limit total impervious area)

These BMPs should be designed to achieve the performance targets set out in the ISMP.

Aquatic Habitat

The Watershed Health Tracking System outlined in the GVRD ISMP Template uses total impervious area (TIA), riparian forest integrity (%RFI) and benthic community sampling (B-IBI) results to measure the overall health of a watershed. In anticipation of the Hyland Creek ISMP, the City began a sampling program for B-IBI and water quality in 2005. The B-IBI information, along with data on TIA and %RFI, was used to determine the health of the watershed. With a TIA of 51% (excluding Zone 4, which are ALR lands) and an RFI of 64%, the current health of the watershed is classified as "poor", and is expected to decrease to "very poor" with future development. In general, most streams begin to exhibit stresses once TIA exceeds 10 – 15% in the watershed.

A cursory water quality sampling program was conducted in the Hyland Creek watershed in May and June 2006 at four locations. Sources of pollutants in stormwater runoff are predominately associated with impervious areas, and can include sediment, oil and grease, nitrogen, phosphorus, fecal coliforms and heavy metals (particularly zinc, copper and lead). Baseline water quality at three of the four sites generally was good, and within applicable water quality standards (protection of aquatic life and recreational use) for all but two data points. However, there were several indications of degraded water quality along the north branch of Hyland Creek downstream of King George Highway, which conveys stormwater runoff from the northern portion of Zone 1, as well as Zone 1A.

The aquatic habitat studies conducted for the ISMP indicate that most watercourses in the Hyland Creek watershed are Class A and that most barriers to fish passage occur in the headwater areas near King George Highway. Thus, most of Hyland Creek and its tributaries are fish bearing and there are relatively few concerns about access to habitat. Hyland Creek also has high spawning and rearing capability for salmon, and diverse aquatic habitat types through most of the main stem and larger tributaries. Consequently, removal of migration barriers is of relatively low priority. Of higher priority are addressing water quality, riparian vegetation and flow regime issues, based on increasing incidence of erosion, exceedance of some water quality guidelines for protection of aquatic life during storm events, and the importance of determining the amount of riparian protection through setbacks that adequately protect for fish, geotechnical, wildlife and other values.

For riparian setbacks, the ISMP recommends that the setbacks defined in the recently completed Neighbourhood Concept Plans (NCP), such as the South Newton NCP for Zone 3, be used for applicable areas. The City currently requires a 15 metre to 30 metre riparian setback for fish-bearing streams (30 metre setback for residential areas with more than six units per acre, 15 metre setback for less than 6 units per acre). In some cases, wider setbacks will be needed to fully protect all environmental and property values, and will need to be assessed on a site-by-site basis.

Wildlife and Terrestrial Habitat

The Hyland Creek watershed is located within the Coastal Western Hemlock Zone (CWH xm1 biogeoclimatic zone), characterized by warm, dry summers and moist, mild winters with relatively little snowfall. Typical forests within the CWH xm1 sites are dominated by Douglas-fir, accompanied by western hemlock and western red cedar. Major understory species include salal, dull Oregon-grape and red huckleberry.

Wildlife using the Hyland Creek watershed is likely to include small mammals (e.g. mice and voles), skunks, racoons, coyotes and a wide range of birds, including songbirds, small raptors and herons. Nesting by songbirds and hunting, foraging, shelter and migratory stopovers by other animals and birds constitute the anticipated use of the existing natural habitat. Amphibians such as tree frog, long-toed salamander, northwestern salamander rough-skinned newt, ensatina and red-legged frog, and reptiles, such as garter snake and perhaps northern alligator lizard, are also likely to inhabit the watershed.

Given that much of the watershed has been developed, many of the remaining patches of natural habitat are small and fragmented, thus limiting the watershed's ability to support mammals with large home ranges (e.g. black-tailed deer) while supporting the presence of tolerant species. Existing patches provide habitat for smaller mammals, although the small size of these patches leads to a high proportion of edge habitat, which is typically inhabited by nest predators or opportunistic species. Riparian habitat along Hyland Creek and its tributaries provide the main wildlife corridors, along with park space. Given the extent of urbanization in the watershed, the quality of wildlife corridors in tenuous and expected to decrease as areas develop further.

Hydrogeology

The surficial geology of the Hyland Creek watershed is comprised primarily of Capilano Sediments (medium to coarse sand, as well as marine and glaciomarine silt loam to clay loam) and Vashon Drift (lodgement till and minor flow till containing lenses and interbeds of glaciolacustrine laminated stony silt). These materials tend to have a lower saturated hydraulic conductivity, meaning that infiltration rates are slow. The majority of the upland area in the Hyland Creek watershed is anticipated to act as a recharge or potential recharge area. Discharge areas are expected to occur proximate to Hyland Creek and its tributaries and are also known to occur in areas where seepage problems have been reported. Two aquifers underlie the study area; the Newton Upland aquifer and the Nicomekl-Serpentine Aquifer. Both aquifers are classified as lightly to moderately developed with low vulnerability to surface sources of contamination.

Much of the Hyland Creek watershed is already developed, and from qualitative descriptions of the surficial soil units and the results of the infiltration testing program conducted for the ISMP, it does not appear likely that shallow infiltration of stormwater will be feasible at the community scale. However, in upland areas where groundwater is naturally recharging, such as Zone 3, shallow infiltration of stormwater may be possible on a lot-by-lot basis. This opportunity should be examined in Zone 3, as a method of maintaining seasonal base flows in the watercourses. Prior to implementing any form of artificial infiltration system, detailed hydrogeologic and geotechnical studies should be performed to ensure that such activities will not create seepage or stability issues.

Land Use Planning / Parks and Recreation

Future land development within the Hyland Creek watershed will be guided by Surrey's Official Community Plan (OCP), which contains the City's long-term land use planning objectives, as well as related Neighbourhood Concept Plans (NCPs), which provide more detailed land use plans for specific areas within the City. Development within the watershed is also guided by several plans and bylaws which can have an impact on stormwater management and environmental protection, such as zoning, tree preservation, and soil removal and depositing bylaws. Most of the future development within the Hyland Creek watershed is expected to occur within those areas covered by an NCP, and a large portion of each NCP area is already either developed or under development application. The three most prominent NCPs in the watershed are the East Newton South, South Newton, and East Newton Business Park NCPs. The Newton Town Centre Study, while not a formal NCP, also provides information regarding future development near King George Highway (north of 68 Avenue). Each NCP includes provisions to help protect Hyland Creek and its tributaries through riparian setbacks and stormwater detention facilities. The South Newton NCP also specifically discusses the use of stormwater infiltration systems to provide base flows to the watercourses. Outside of the NCP areas, the watershed is nearly at build-out, and appreciable redevelopment of these areas is not expected in the near future.

The City's ability to improve the integrity of the watershed through land use regulations is constrained by the fact that the entire watershed has either already been developed or is the subject of a Neighbourhood Concept Plan (NCP). Furthermore, the undeveloped areas of the watershed are currently under considerable development pressure, which may give the City little time to amend land use bylaws. Consequently, there are only limited opportunities to make any significant changes to current or proposed land use patterns, which in turn constrains some of the creative and innovative practices and methods that could otherwise have been developed for the ISMP. The City may also find that enforcement of new regulations is difficult or impractical. On the other hand, the City still has the option to amend the Zoning Bylaw, OCP or other policies and bylaws to try to affect future infill development, by ensuring that it is more sensitive to stormwater and environmental issues. These amendments could possibly be made applicable on a City-wide basis which would have an impact on future ISMP studies.

While the City is currently reviewing and updating the Parks, Recreation and Culture Master Plan, there are no significant changes planned for the Hyland Creek watershed.

Recommendations

Recommended action items resulting from the ISMP, and their respective priority levels, have been comprehensively listed in Table ES-1. Figure ES-2 also highlights the Priority Level 1 works. Priority Level 1 works include:

- Create three new municipal detention facilities in the northwest sector of the watershed to mitigate erosion and water quality issues in the north branch of Hyland Creek
- Continue to monitor flow, benthic invertebrate and water quality conditions and utilize this data to track the overall health of the watershed over time
- Adopt stormwater performance targets for new, infill and redevelopment areas
- Establish and enforce riparian setbacks (particularly for the Archibald Creek and 144 Street tributaries)
- Undertake pilot projects in the watershed to test the feasibility and quantify the effectiveness of performance-based BMPs
- Implement new or revise existing City policies and bylaws to more proactively protect drainage and environmental features

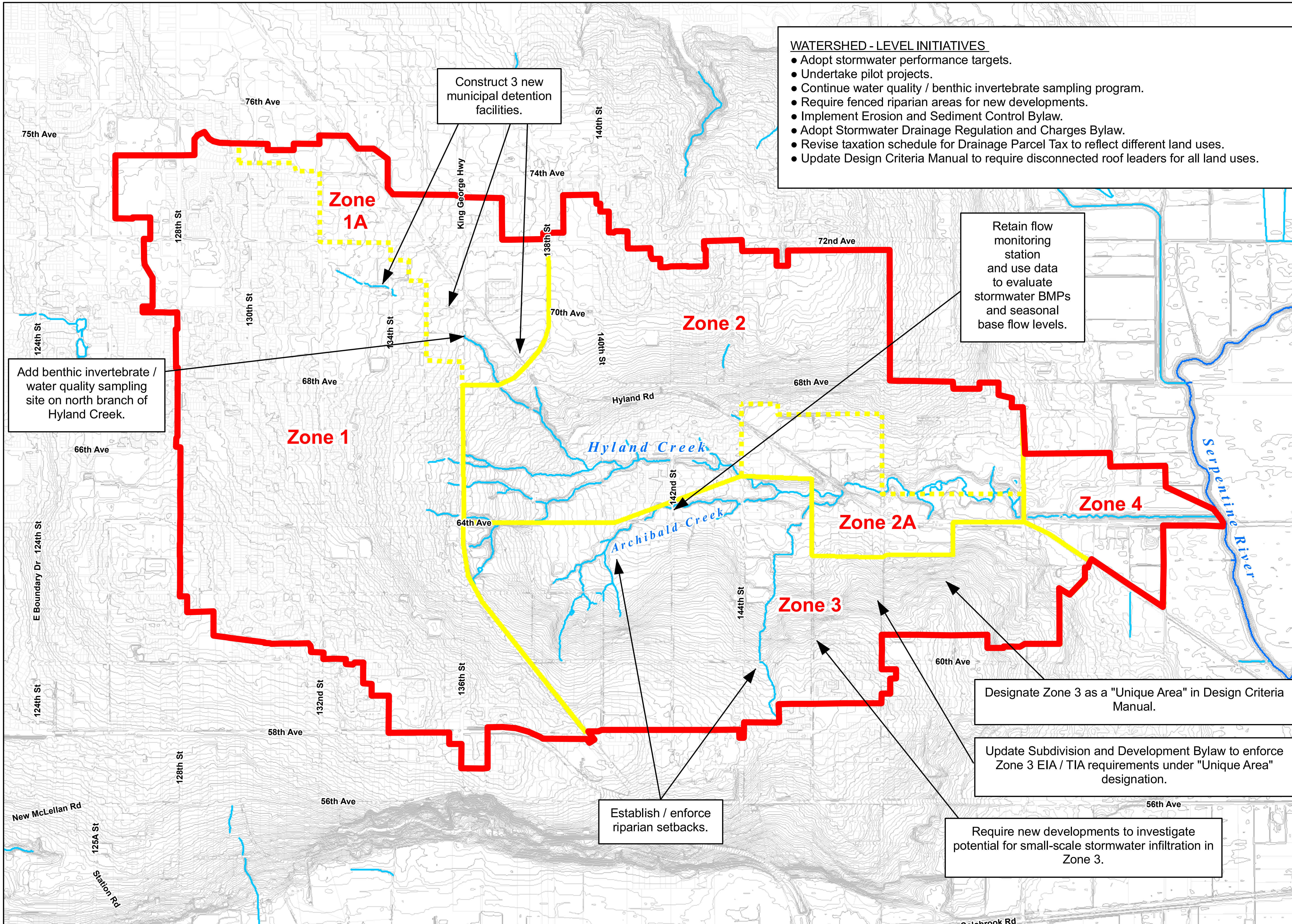
Preliminary costs for capital works projects have been grouped by priority level and are summarized in Table ES-2 below. Costs associated with the Priority Level 1 works (new detention facilities) include land acquisition costs. The City could recover capital costs by requiring works and services for new development under the Subdivision and Development bylaw (provided the bylaw is amended to require BMPs), or through rezoning, drainage parcel tax / stormwater utility fees, development cost charges (DCC), or through the sale of lands containing municipal detention facilities that could be removed based on the performance assessment.

Table ES.1
Hyland Creek Watershed Recommended Works

Recommendation	Zone	Section Reference	Priority Level 1	2	3
Construct 3 new municipal detention facilities in Zones 1 / 1A	1 / 1A	10.2, 12.1.2	♦		
Retain flow monitoring station on Archibald Creek and use data to evaluate BMPs and seasonal base flow levels	3	12.1.5	♦		
Adopt performance targets for new, infill and redevelopment areas	All	12.1.1	♦		
Adopt additional performance targets for Zone 3	3	12.1.5	♦		
Undertake pilot projects in the watershed	All	12.1.1	♦		
Establish adequate riparian setbacks on Archibald Creek and 144 Street tributary	3	12.2.1, 12.2.5	♦		
Continue water quality monitoring and benthic invertebrate sampling programs (3 sites) and add 4th site on the north branch of Hyland Creek	All	12.2.1	♦		
Continue practice of requiring riparian areas to be fenced for new developments	All	12.3.1	♦		
Require new developments to investigate potential of small-scale stormwater infiltration as part of achieving on-lot performance targets	3	12.4.5	♦		
Implement Erosion and Sediment Control bylaw to land development and City capital works projects	All	12.5.1	♦		
Finalize and adopt the Stormwater Drainage Regulation and Charges bylaw	All	12.5.1	♦		
Revise taxation schedule for the Drainage Parcel Tax to reflect impacts of different land uses	All	12.5.1	♦		
Designate Zone 3 as a "Unique Area" in the City's Design Criteria Manual	3	12.1.5	♦		
Update Subdivision and Development Bylaw to enforce Zone 3 EIA / TIA requirements under "Unique Area" Designation	3	12.1.5	♦		
Update Design Criteria Manual to require disconnected roof leaders for all land uses	All	12.1.1	♦		
Undertake erosion remediation works at high risk site on the north branch of Hyland Creek	2	11.4, 12.1.3		♦	
Retrofit or remove existing municipal detention facilities	1, 2	10.1, 11.2, 12.1.1		♦	
Construct new municipal detention facilities in Zone 3 at locations shown in South Newton NCP; size facilities to achieve ISMP performance targets	3	11.3, 12.1.5		♦	
Upgrade culvert crossing on Hyland Creek at 148 Street and raise road profile	2A	11.1, 12.1.1		♦	
Remove or upgrade 600mmØ interim culvert in 66 Avenue ditch	2A	10.3, 11.1, 12.1.1		♦	

Recommendation	Zone	Section Reference	Priority Level		
			1	2	3
Develop and implement a public education program for residents, commercial businesses, industrial operations, developers, and builders	All	12.1.1		♦	
Prepare a brochure for developers, builders and new home owners in Zone 3 on how to install and maintain stormwater and environmental BMPs	3	12.1.1		♦	
Continue to work with local schools, SHARP and SNAP on planting, cleanup and in-stream activities	All	12.1.1		♦	
Initiate a developer recognition award for developers who demonstrate a commitment to achieving stormwater and environmental ISMP objectives	All	12.1.1		♦	
Support a designated site for developers to use for topsoil stockpiling and screening within the watershed	3	12.1.5		♦	
Establish and maintain wildlife migration corridor connections between the watershed and external areas	All	12.3.1		♦	
Adopt City policy of using native plants in passive park spaces, preservation/natural areas and green spaces	All	12.3.1		♦	
Monitor impacts of local seeps and springs on the northern slope of Zone 3 as BMPs are implemented	3	12.4.5		♦	
Ensure basements are properly designed and protected against high water table	All	12.4.1		♦	
Minimize alteration of natural surfaces during development	All	12.4.1		♦	
Require retention and planting of native vegetation for new, infill and redevelopment areas	All	12.5.1		♦	
Review opportunities to enhance existing park space to achieve stormwater and environmental objectives	All	12.5.1		♦	
Amend definition of "lot coverage" in Zoning bylaw to include driveways, patios and other impervious surfaces	All	12.5.1		♦	
Impose minimum topsoil regulations	All	12.5.1		♦	
Set maximum limits on amount of off-street parking that can be constructed of impervious materials	All	12.5.1		♦	
Implement a stormwater utility fee	All	12.5.1		♦	
Update operation and maintenance program to include stormwater and environmental BMPs	All	12.5.1		♦	
Continue to support ALR designation	4	12.3.6, 12.5.6		♦	
Continue to encourage the agricultural community to implement agricultural BMPs	4	12.1.6, 12.2.6			♦
Encourage the formation of a watershed stewardship group	All	12.1.1			♦
Undertake storm sewer upgrade projects listed in capital works program; coordinate with road improvement projects where applicable	All	11.1, 12.1.1			♦
Monitor and track medium and low risk erosion sites identified by 2006 Ravine Stability Assessment report	All	11.4			♦
Remove fish migration barriers at culvert crossings as part of road upgrade projects	All	12.2.1			♦

Recommendation	Zone	Section Reference	Priority Level		
			1	2	3
Continue to monitor beaver dams and partial debris jams, and assess risk of flooding	2, 2A, 4	12.2.1			♦
Remove yard waste barrier along tributary reach near 148 Street	2A	12.2.1			♦
Remove foreign objects (car, hydro pole) in creek near benthic monitoring site H2	2	12.2.3			♦
Conduct periodic cleanup campaigns at storm sewer outfalls to creek	1	12.2.2			♦
Encourage farming community to plant continuous corridor of native trees / shrubs along creek banks	4	12.2.6			♦
Retain sufficient green space in City-owned parcel in Newton Town Centre area	1A	12.5.4			♦
Amend Subdivision and Development bylaw to require use of stormwater and environmental BMPs to meet performance targets	3	12.5.5			♦
Lower development cost charges for developments that incorporate stormwater and environmental BMPs	All	12.5.1			♦



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SURREY CITY OF PARKS

Hyland Creek Integrated Stormwater Management Plan

Figure ES-2

PRIORITY LEVEL 1 - RECOMMENDED WORKS

Hyland Creek Watershed Area

Zone Boundary

Sub-Zone Boundary

0 250 500

Metres

Scale 1:20 000

Source: City of Surrey
2005 Aerial Photography

Prepared By:
URBANSYSTEMS.
1072.0137.01 July 2007

Table ES-2
Costs for Capital Works (by Priority Level)

Priority Level	Project	Costs
1	Pond 1, Pond 2 and Newton Town Centre Pond	$ 15,171,400
2	Erosion Site HYLD-12	$ 148,000
	Existing Detention Facility Retrofits	$ 985,400
	New Municipal Detention Facilities in Zone 3	$ 5,594,300
	66 Avenue Ditch – Culvert Upgrade	$ 10,000
	Culvert Upgrade (Hyland Creek at 148 Street)	$ 199,200
3	Remaining Storm Sewer Upgrades	$ 8,483,400
	Sediment Control Facilities	$ 495,800
	TOTAL	**$ 31,087,500**

If all NCP related works (total value of $ 6,974,800) were 100% recoverable through DCC's, and if existing municipal detention facilities recommended for removal are removed and the land sold ($ 1,262,300), the total cost to complete the projects listed in the capital works program could be reduced to approximately $ 22,850,400.

In anticipation of future ISMPs prepared for other watersheds in the City, the City should consider undertaking an audit of regulatory tools to gain a comprehensive understanding of its regulatory powers pertaining to stormwater management and environmental protection. This would include developing an inventory of relevant powers under the Local Government Act and Community Charter, as well as conducting an audit of the City's current regulations, bylaws and policies. The City should also consider developing a decision-making framework document, which would assist staff and Council in developing comprehensive Terms of References for future ISMPs that are based on community values and objectives, while recognizing trade-offs among objectives.

1.0 INTRODUCTION

1.1 What is an Integrated Stormwater Management Plan (ISMP)?

In the past, stormwater management on a watershed scale was typically addressed through a Master Drainage Plan (MDP). An MDP predominantly focused on the analysis of the hydraulic characteristics of the watercourse and existing municipal drainage infrastructure, with the goal of identifying locations of hydraulic inefficiencies and flooding risks. The analysis was typically focused on determining peak flows under infrequent, higher risk storm events and often did not consider the small, frequent rainfall events which have a strong influence on the health of a watercourse. The main outcome of an MDP was limited to a capital works program for municipal system upgrades in the watershed, which was based on the engineering perspective alone. Some MDP's provided recommendations to accommodate future development conditions, however, MDP's often focused only on recommending system upgrades to address performance shortfalls under existing development conditions.

The MDP approach to stormwater management was more reactionary than proactive, as they developed mitigative stormwater measures to combat the effects of land development without giving consideration to the policies and criteria that guided development in the watershed. Land development, particularly the amount of impervious area and its connectivity to the watercourse, has a direct linkage to the overall health of a watershed. MDP's usually only discussed environmental factors (such as aquatic life) in a limited sense, and rarely included an assessment of terrestrial environments or wildlife usage of the watershed. Furthermore, limited consideration was given to the hydrological changes in the watershed due to development.

The recent trend towards integrated stormwater management represents an evolution in the way that watershed health and development impacts are viewed. An integrated stormwater management plan (ISMP) recognizes stormwater as a resource to be valued, rather than a nuisance by-product of land development that must be managed. It links stormwater with land use planning (including parks, recreation, policy and finance) and environmental factors (including aquatic, terrestrial and wildlife). The stormwater analysis is expanded in an ISMP to review the hydraulic characteristics of drainage infrastructure under a wider range of real-time events. Finally, an ISMP examines the hydrological characteristics of the watershed by considering all aspects of the hydrological regime in pre-development conditions and tailoring a plan for development which aims to keep that regime intact to the greatest extent possible.

The need to take an integrated approach to stormwater management is well recognized in the Lower Mainland. Under the Greater Vancouver Regional District's (GVRD) Liquid Waste

Management Plan, all member municipalities, including the City of Surrey, have committed to undertaking ISMPs for all of their watersheds by 2014. In response to this commitment, the City retained Urban Systems to prepare an ISMP for the Hyland Creek watershed. Urban Systems evaluated the stormwater management, land use planning, parks, and policy and finance components of this project while their subconsultant, Jacques Whitford AXYS, undertook aquatic, wildlife, terrestrial and hydrogeology assessments.

1.2 GVRD ISMP Template

A rapid increase in population growth is anticipated in the GVRD region over the next several decades, thus the GVRD commissioned the development of an ISMP template in 2002 to provide direction to its member municipalities on how to maintain natural or current stream flow regimes and watershed health during development. A draft update to the 2002 document was issued in early 2006.

The ISMP template includes 35 clauses which outline a vast range of potential components for an ISMP study. Each clause discusses the typical tasks to be completed, and the minimum and maximum effort involved. Clauses include traditional components such as mapping and information gathering, drainage system inventory and hydrological / hydraulic analysis, however, the template also includes clauses relating to compiling land use information, undertaking a benthic community sampling program, conducting a terrestrial species and habitat assessment, and completing an ecological health analysis. As each municipality will have different issues and priorities to address for each of their watersheds, the template allows the municipality to choose relevant clauses to tailor a unique, comprehensive ISMP plan for each watershed. On the other hand, the template also provides guidelines which should result in a level of consistency between ISMP plans developed by different municipalities. The template also includes discussions on stormwater discharge criteria, stakeholder involvement, sign-off strategy by environmental agencies and adaptive management programs.

Regardless of how "pristine" or how "degraded" a watershed may be initially, steps can be taken to improve the conditions resulting from urbanization by treating stormwater as a resource. However, municipalities can choose when it is best to take these steps, what level of commitment to make towards protecting, enhancing or restoring a watershed, and how to use the various management tools that are available.

At the direction of the City of Surrey, the Hyland Creek ISMP has been completed in accordance with the GVRD ISMP template.

1.3 Rationale for an ISMP for the Hyland Creek Watershed

Ideally, an ISMP should be undertaken for a watershed prior to, or in conjunction with, the preparation of detailed land use plans to guide future development in that catchment. This would allow for the identification of significant environmental and drainage features while still in their natural state, and secure their protection and preservation within the context of future development.

To undertake an ISMP for the Hyland Creek watershed at this time is somewhat unique, as a significant portion of the watershed is already developed and detailed land use plans already exist for the remaining undeveloped areas. Thus, one of the challenges in developing an ISMP for the Hyland Creek watershed is that there are limited opportunities to affect development applications which are already in process prior to the completion and adoption of this ISMP. However, there are opportunities to mitigate impacts from existing development (which could be implemented through a rezoning, subdivision or building permit process in an infill or redevelopment situation) and for undeveloped areas which are not currently in an application process. Where possible, recommendations should fit within the context of existing land use plans. However for this ISMP, as well as future ISMPs prepared for other Surrey watersheds, the City should give consideration to modifying existing land use plans if the ISMP process determines that a significant benefit to the health of the watershed could be achieved by doing so.

Given the current development pressures in the watershed, the maximum potential benefit will occur if an ISMP is conducted for the Hyland Creek watershed in the short term.

1.4 Communications Strategy

To ensure that the ISMP process was successful, involvement and support from a variety of groups was essential. Over the course of the project, the following groups were consulted.

1.4.1 City of Surrey

A series of meetings were held with City staff over the project duration to define and address several issues such as the scope of work, assessment results, schedule and milestone dates, as well as to review and receive feedback on working paper submissions. City staff from the Engineering, Planning and Development, Parks and Recreation, and Transportation departments participated in the meetings. The project team worked closely with City staff throughout the project to ensure that the ISMP reflected the City's goals and objectives for the Hyland Creek watershed.

1.4.2 General Public

Contact with the general public was primarily made through media releases and informal interactions. At the outset of the project, a media release was published in the local newspaper as well as posted on the City's website. The media release announced the project, outlined the City's rationale for the project, and provided contact information for City staff and the project team. City staff and the project team responded to questions from the public on an ongoing basis throughout the project. At the City's direction, a formal public consultation session was not conducted.

1.5 Project Team

The project team assembled for the Hyland Creek ISMP is comprised of members with expertise in stormwater management; planning and land use; policy and finance; aquatic, wildlife and terrestrial habitat; and hydrogeology. All team members have past experience in developing ISMPs for other municipalities in British Columbia, including the City of Campbell River, District of 100 Mile House, District of Mission and the City of West Vancouver. The role of each team member for this project is listed below, along with contact information.

Table 1.1
Project Team Members (Consultants)

<table>
<tr><th>Company</th><th>Area of Expertise</th><th>Team Member</th><th>Role</th><th>Phone Number</th></tr>
<tr><td rowspan="5">Urban Systems</td><td rowspan="3">Stormwater Management</td><td>Samantha Ward, P.Eng.</td><td>Project Manager / Stormwater Engineer</td><td rowspan="5">(604) 273-8700</td></tr>
<tr><td>Glen Shkurhan, P.Eng.</td><td>Senior Reviewer / Stormwater Engineer</td></tr>
<tr><td>Jeffrey Rice, P.Eng.</td><td>Water Quality / ISMP Advisor</td></tr>
<tr><td>Planning and Land Use</td><td>Sara Stevens, M.Pl., MCIP</td><td>Planner</td></tr>
<tr><td>Policy and Finance</td><td>Fraser Smith, P.Eng.</td><td>Policy / Finance</td></tr>
<tr><td rowspan="7">Jacques Whitford</td><td rowspan="2">Aquatic</td><td>Karen Munro, M.Sc., R.P.Bio.</td><td>Sr. Aquatic Scientist</td><td rowspan="7">(604) 436-3014</td></tr>
<tr><td>Shelley Norum, B.Sc.</td><td>Fisheries Biologist</td></tr>
<tr><td rowspan="3">Wildlife / Terrestrial</td><td>Norma Powell, M.Sc., R.P.Bio.</td><td>Wildlife Biologist</td></tr>
<tr><td>Tracy Anderson, B.Sc., BIT</td><td>Terrestrial Biologist</td></tr>
<tr><td>Colin Bailey, Dip. Tech.</td><td>Environmental Technologist</td></tr>
<tr><td rowspan="2">Hydrogeology</td><td>Trevor Crozier, M.Eng., P.Eng.</td><td>Sr. Hydrogeologist</td></tr>
<tr><td>Justin Bourne, B.A.Sc., EIT</td><td>Hydrogeologist</td></tr>
</table>

City of Surrey municipal staff are also an integral part of the project team. The ideas, input and feedback received from City staff were invaluable to the development of this ISMP. Contact information for City of Surrey staff involved in this project is listed below.

Table 1.2
Project Team Members (Municipal Staff)

<table>
<tr><th>Department</th><th>Contact</th><th>Role</th><th>Phone Number</th></tr>
<tr><td rowspan="4">Engineering</td><td>David Hislop, P.Eng.</td><td>Project Supervisor,
Uplands Drainage Engineer</td><td rowspan="8">(604) 591-4011</td></tr>
<tr><td>Carrie Baron, P.Eng.</td><td>Drainage and Utilities Manager</td></tr>
<tr><td>Lanny Englund,
M.Sc., BIT</td><td rowspan="2">Environmental Coordinator</td></tr>
<tr><td>Rachael Jones,
M.Sc., R.P.Bio.</td></tr>
<tr><td rowspan="2">Planning & Development</td><td>Raul Allueva</td><td>Senior Planner</td></tr>
<tr><td>Gertrude Kwan, MRTPI</td><td>Senior Planner</td></tr>
<tr><td>Parks, Recreation & Culture</td><td>Ted Uhrich, MBCSLA</td><td>Parks Designer</td></tr>
<tr><td>Transportation</td><td>Jaime Boan, P.Eng.</td><td>Transportation Engineer</td></tr>
</table>

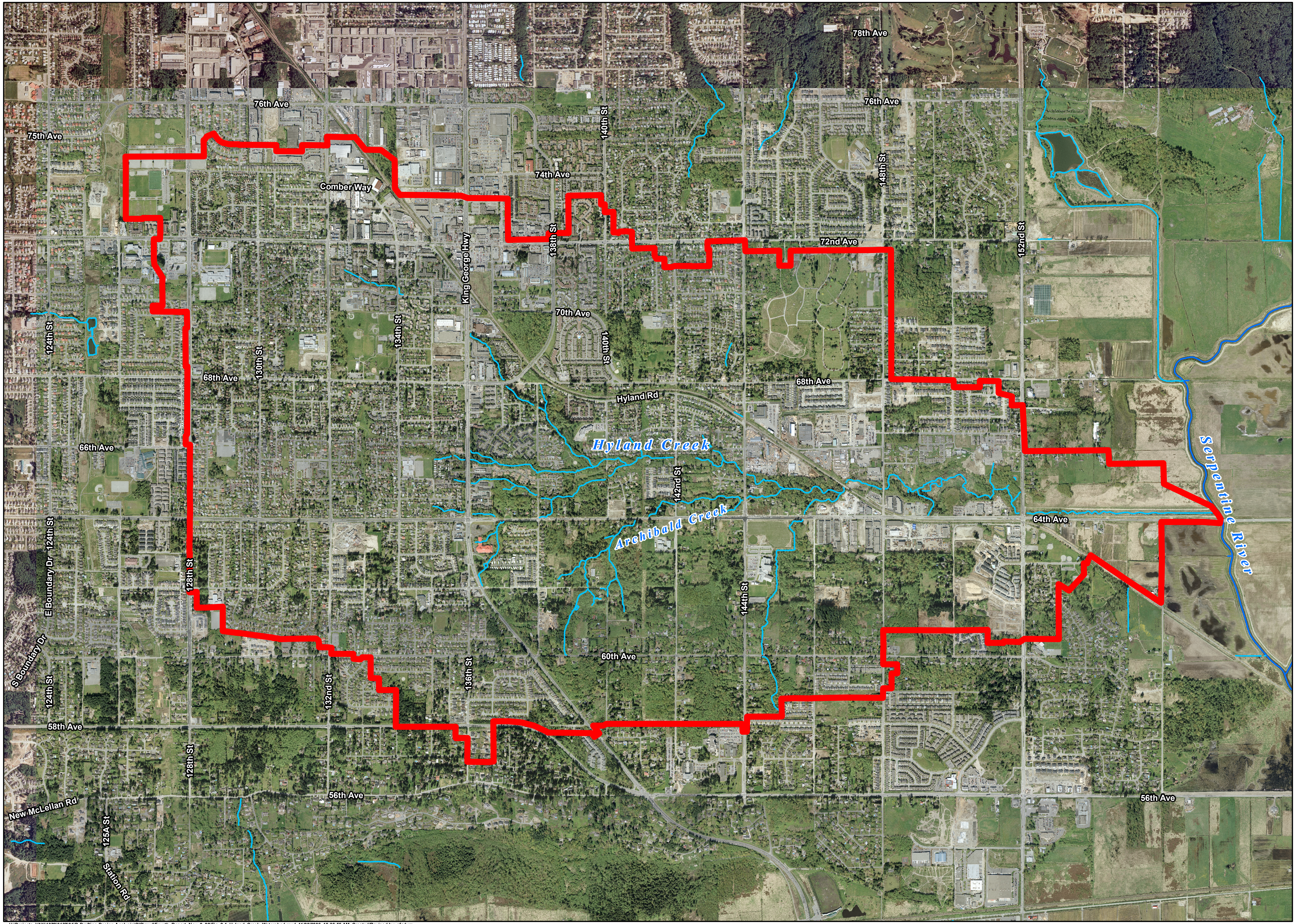
2.0 HYLAND CREEK WATERSHED ZONES

The Hyland Creek watershed is centrally located in the City of Surrey. The catchment is approximately 1,387 hectares in size, and is roughly bounded by 72 Avenue to the north, 128 Street to the west, 58 Avenue to the south, and 156 Street to the east, as shown on Figure 2.1. The creek itself is approximately 6.0 kilometres long and runs east-west from its headwater area near King George Highway to its discharge point at the Serpentine River just east of 156 Street. Hyland Creek is a second order tributary of the Serpentine River, with a confluence approximately 13.5 kilometres upstream of the Serpentine's outlet into Mud Bay. Five unnamed creeks and Archibald Creek drain to Hyland Creek from the south, according to the Fisheries and Oceans Canada (DFO) website; however, a previous study identified an additional three tributaries draining into Hyland Creek from the north [ECL Envirowest Consultants Limited 1995]. The majority of the catchment is within the Surrey upland area, with a small contributing area of lowland drainage east of 152 Street. This lowland area is influenced by tidal fluctuations in Mud Bay [ECL Envirowest Consultants Limited 1995].

The headwaters of Hyland Creek, which originate near King George Highway, can be grouped into three main branches. The north branch conveys flows generated by areas north of 68 Avenue and west of 140 Street. The central branch receives flows from the area between 64 Avenue and 68 Avenue, west of King George Highway. The south branch conveys flows from the area south of 64 Avenue and west of 138 Street. All three headwater branches converge just east of 140 Street to form the main branch of Hyland Creek.

Topographically, the Hyland Creek watershed generally slopes from west to east at approximately 1 – 3%. North-south topographic gradients are higher (up to 25% in the southern escarpment, and up to 3 – 10% in the upland and flank regions around the creek) and oriented towards Hyland Creek. Topography of the Hyland Creek watershed is shown on Figure 2.2.

Existing development in the Hyland Creek watershed is fairly extensive, particularly in areas west of King George Highway and north of Hyland Creek. Existing development typically has infrastructure in place, and in some instances the environmental and drainage features have been altered or compromised due to encroachment by development. On the other hand, there are still significant tracts of agricultural and undeveloped land in the watershed where the riparian corridor is mainly intact. Most of these areas are under pressure to develop and appreciable short-term growth is anticipated. It would be appropriate to identify and protect drainage and environmental features in these areas now as development proceeds. There are also both upland and lowland areas of the watershed, where issues such as erosion, sedimentation and flooding are specific concerns.



SURREY
CITY OF PARKS

Hyland Creek Integrated Stormwater Management Plan

Figure 2.1

HYLAND CREEK WATERSHED

Hyland Creek Watershed Area

0 250 500
Metres

Scale 1:20 000

Source: City of Surrey
2005 Aerial Photography

Prepared By:
URBANSYSTEMS.
1072.0137.01 July 2007

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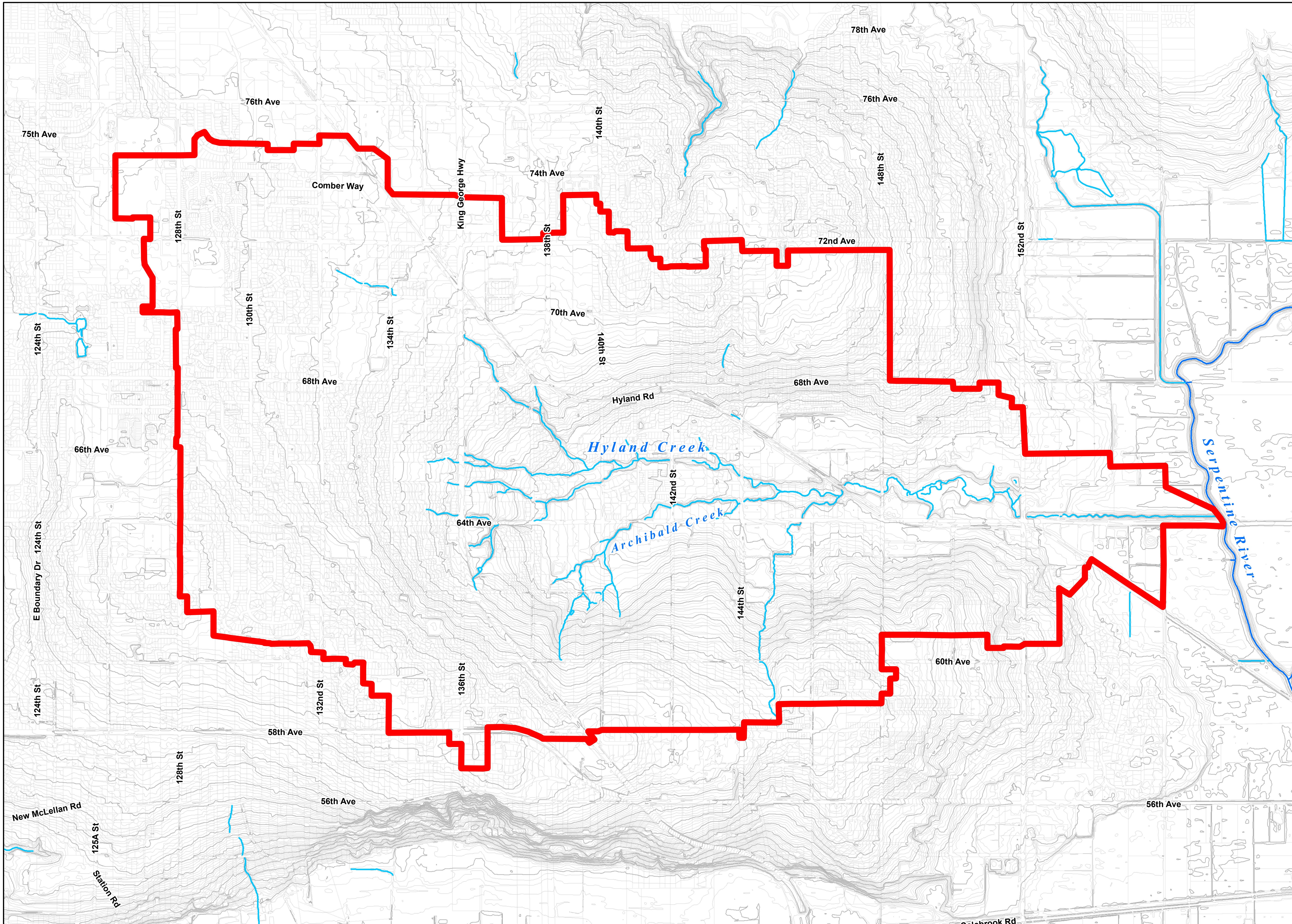

SURREY
CITY OF PARKS

Hyland Creek Integrated Stormwater Management Plan

Figure 2.2

TOPOGRAPHY

Hyland Creek Watershed Area

0 250 500
Metres

Scale 1:20 000

Source: City of Surrey
2005 Aerial Photography

Prepared By:
URBANSYSTEMS.
1072.0137.01 July 2007

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Given the current characteristics of the watershed, different areas have unique issues and challenges that should be identified and addressed within the overall context of the Hyland Creek ISMP. The ISMP should therefore address these specific issues and challenges rather than attempt to group unique areas of the watershed together using generalized statements. Thus, for the purposes of this study, the Hyland Creek watershed has been divided into a series of zones, as shown on Figure 2.3. Each zone was delineated based on the unique characteristics, issues and needs of that area, such as the level of existing development, existing land use type(s), potential development and future land use, and specific environmental and/or drainage features. The watershed was divided into four (4) primary zones, as follows:

- Zone 1 – Headwater area of Hyland Creek, west of King George Highway
- Zone 2 – North of Hyland Creek, between King George Highway and 152 Street
- Zone 3 – South of Hyland Creek, between King George Highway and 152 Street
- Zone 4 – Lowland area of Hyland Creek, east of 152 Street

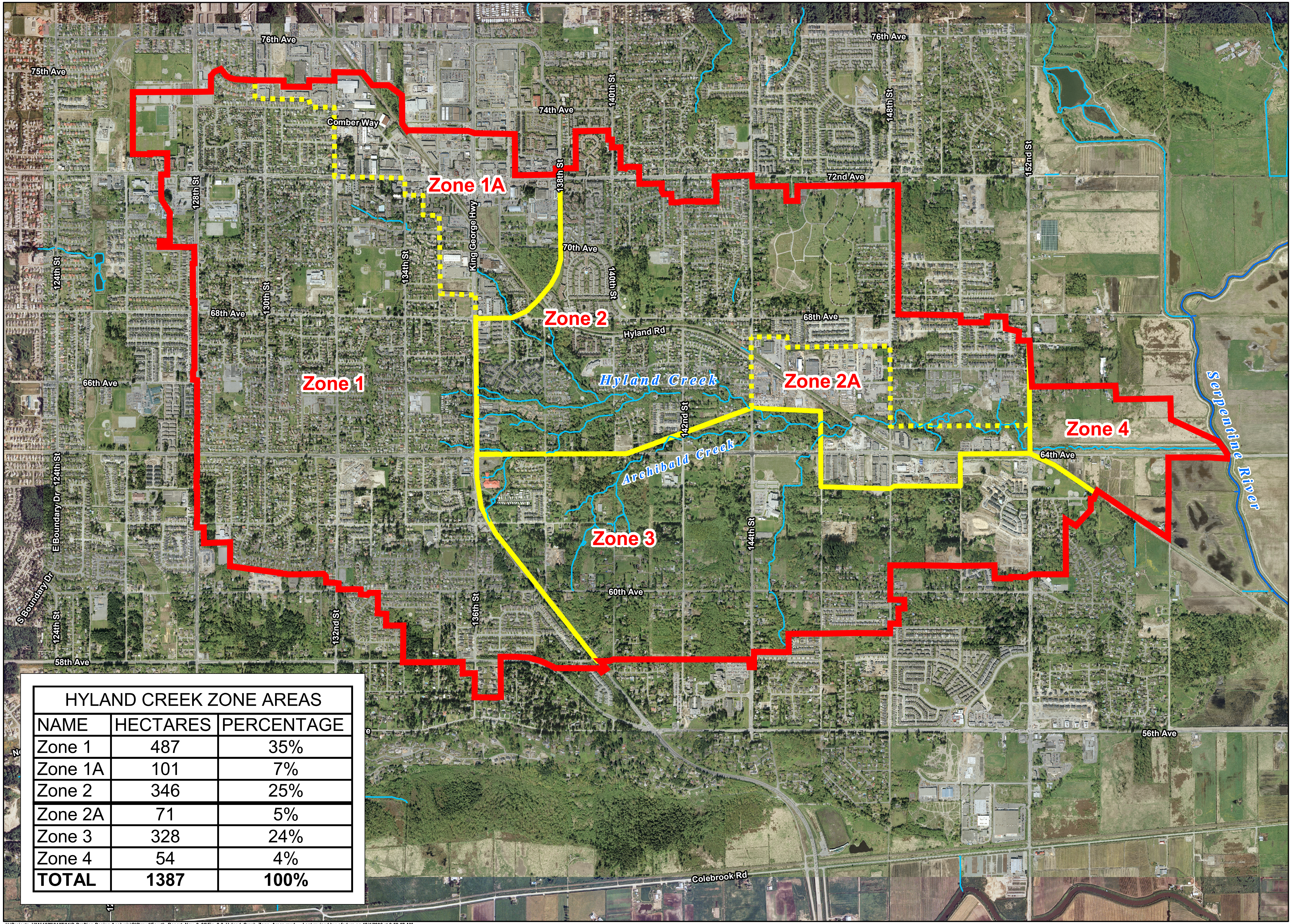
Zones 1 and 2 were further divided into Zone 1A and Zone 2A, respectively, to isolate existing and/or future commercial and industrial development in these two zones for discussion and evaluation purposes.

The following sections provide a brief description of each zone in the Hyland Creek watershed.

2.1 Zone 1

Zone 1 is located in the headwaters of the Hyland Creek watershed west of King George Highway, as shown on Figure 2.3. Existing land use in Zone 1 consists of single family residential and low-density multi-family residential development, along with schools, parks and a few small commercial areas. Zone 1 is predominantly built out, and rezoning or subdivision of existing land parcels is not anticipated in the near future. Any future redevelopment or densification in this zone, if it occurs, is expected to be minimal.

From a drainage perspective, Zone 1 is serviced by an extensive storm drainage network, as shown on Figure 2.4. Aside from short tributary reaches near 134 Street and 70B Avenue, and at King George Highway just north of 64 Avenue, the natural headwater tributaries of Hyland Creek in Zone 1 have been enclosed in piped systems. There are also several existing municipal and private detention facilities in this zone which service individual developments.



HYLAND CREEK ZONE AREAS		
NAME	HECTARES	PERCENTAGE
Zone 1	487	35%
Zone 1A	101	7%
Zone 2	346	25%
Zone 2A	71	5%
Zone 3	328	24%
Zone 4	54	4%
TOTAL	**1387**	**100%**

SURREY
CITY OF PARKS

Hyland Creek Integrated Stormwater Management Plan

Figure 2.3

ZONE AREAS

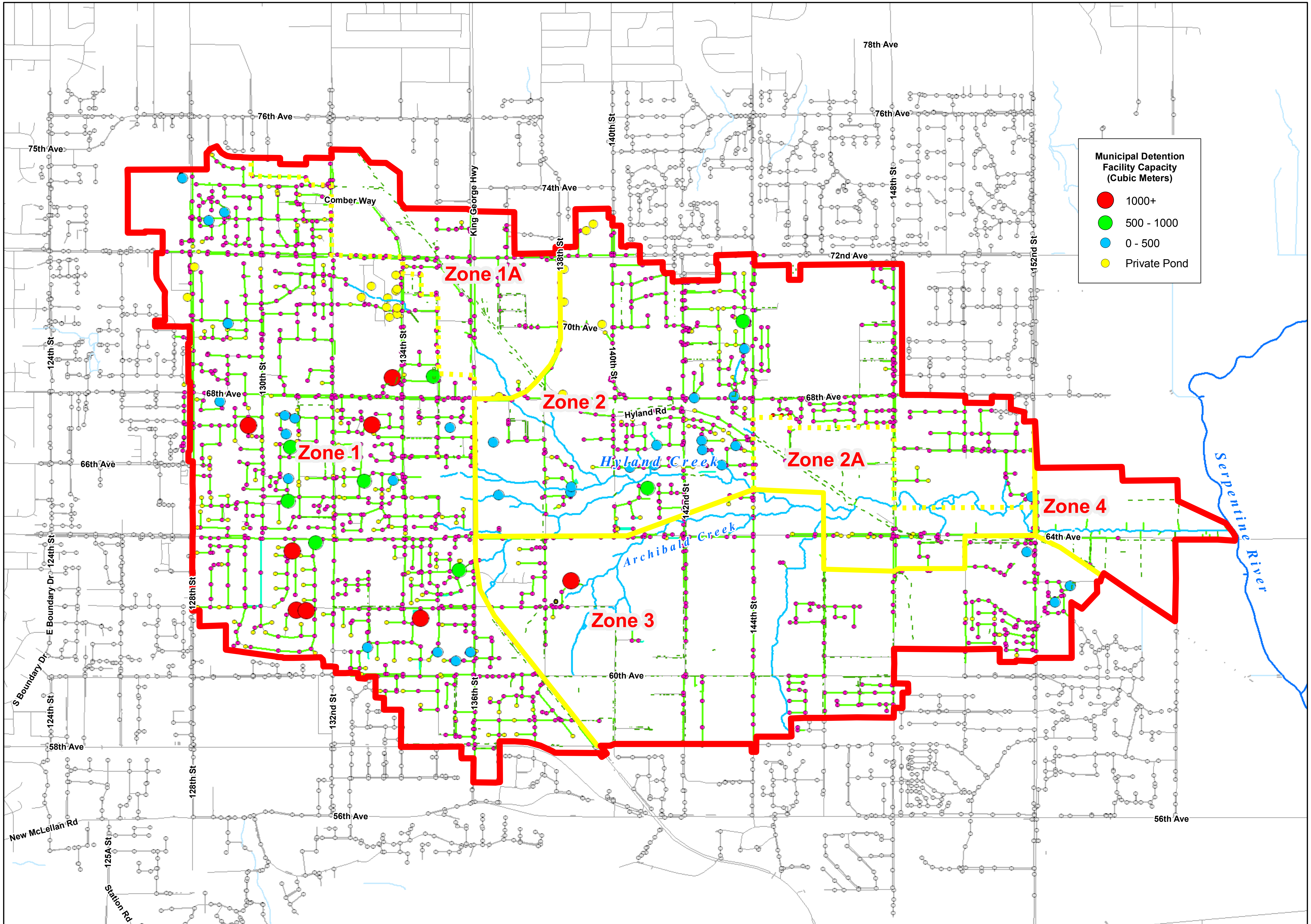
- Zone Boundary
- Sub-Zone Boundary
- Hyland Creek Watershed Area

0 250 500
Metres

Scale 1:20 000

Source: City of Surrey
2005 Aerial Photography

Prepared By:
URBANSYSTEMS.
1072.0137.01 July 2007



SURREY
CITY OF PARKS

Hyland Creek Integrated Stormwater Management Plan

Figure 2.4

EXISTING DRAINAGE INFRASTRUCTURE

Drainage Manholes
- Catch Basin Manhole
- Cleanout
- Grillage
- Oil Interceptor
- Regular

Drainage Mains
- Cross Tile
- Discharge Pipe
- Foundation Drain
- French Drain
- Gravity
- Stub
- Unknown

Water Channels
- Ditch
- Creek
- River
- Hyland Creek Watershed Area
- Zone Boundary
- Sub-Zone Boundary

0 250 500
Metres

Scale 1:20 000

Source: City of Surrey

Prepared By:
URBANSYSTEMS.
1072.0137.01 July 2007

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As Zone 1 is largely developed, there are limited opportunities to identify, preserve and enhance natural environmental and drainage features. There are also limited opportunities to mitigate detrimental stormwater or environmental conditions on a large scale. Therefore, the ISMP should focus on retrofitting, optimizing and simplifying existing systems, as well as identifying and preserving remaining natural features, where they exist.

2.2 Zone 2

Zone 2 was delineated as the area north of Hyland Creek between King George Highway and 152 Street, as shown on Figure 2.3. Existing land use in Zone 2 predominantly consists of a mix of single family residential and multi-family residential development, with the multi-family residential development comprising a larger proportion of the overall residential development than in Zone 1. Schools, parks, community amenities, some commercial areas and a large cemetery are also present. Although a significant portion of this zone is built out, there are opportunities for new infill development, as well as redevelopment of existing parcels.

Existing development in Zone 2 is predominantly serviced by a storm drainage network, as shown in Figure 2.4. Municipal and private detention facilities also exist. Similar to Zone 1, the ISMP should focus on retrofitting, optimizing and simplifying existing systems, as well as preserving remaining natural features. However, there are also opportunities to encourage sustainable stormwater and environmental best management practices where new development or redevelopment occurs.

2.3 Zones 1A and 2A

Zones 1A and 2A were delineated based on the extent of existing and/or future commercial and industrial development within Zones 1 and 2, respectively. Both zones are shown on Figure 2.3. Commercial and industrial land uses can pose unique issues and challenges from both the stormwater and environmental perspectives, which is why these areas have been separated from Zones 1 and 2 for discussion and evaluation purposes.

Both zones are serviced from a drainage perspective by an existing storm drainage network, as shown on Figure 2.4. As the majority of the areas in Zones 1A and 2A are already developed, the ISMP should focus on understanding existing conditions and characteristics, and identifying opportunities to retrofit and enhance existing features and facilities. Particular attention should be given to water quality, as commercial and industrial land uses can pose a significant potential risk to water quality degradation in urbanized watersheds.

2.4 Zone 3

Zone 3 is located south of Hyland Creek between King George Highway and 152 Street, as shown on Figure 2.3. Land use in Zone 3 has historically consisted of large rural acreages and farms. While there are a few schools and parks present in this zone, most of the land has been left as open grassed areas or woodlots. Over the past few years, pressure to develop this area has increased dramatically and the first phases of development near the 152 Street and 64 Avenue corridors have already begun. Development is now beginning to trend west from the 152 Street corridor and several development applications are currently in process or have recently been approved as far west as 144 Street. It is expected that the vast majority of future development in the Hyland Creek watershed will occur in this zone. As such, Zone 3 provides the greatest opportunity to integrate stormwater, environmental, planning and parks objectives to influence development in the Hyland Creek watershed.

Zone 3 is the main base flow source for the headwaters of several tributaries of Hyland Creek, including the Archibald Creek tributary. As shown on Figure 2.4, there is a minimal storm drainage network within this zone, aside from trunk sewers along the main road corridors and local sewers associated with new development near 152 Street and 64 Avenue. Other rural areas in Zone 3 are serviced by a network of open ditches.

Development in Zone 3 has been guided to date by the City's Official Community Plan (OCP) and the South Newton Neighbourhood Concept Plan (NCP). The South Newton NCP provides an outline of the stormwater, environmental, land use planning and parks works proposed to coincide with future development in this zone. As the NCP has already been approved and adopted by the City, and is being implemented by the development community, it will shape the direction of the ISMP for this zone to a certain degree. However, the intent of the ISMP will be to identify opportunities within the context of the NCP to shift stormwater, environmental, planning and parks goals towards a more sustainable and integrated model. It is recognized that the ISMP can not influence those development applications which are already in process or have been approved, but that the outcomes and recommendations of the ISMP could be implemented for future developments within this zone.

2.5 Zone 4

Zone 4, located east of 152 Street, is located within the Surrey lowland area as shown on Figure 2.3. Agricultural operations are the predominant land use, however, there is a small amount of residential and industrial areas present. Much of the land is located within the Agricultural Land Reserve (ALR), therefore development potential is expected to be low in this zone.

3.0 GOALS AND OBJECTIVES OF THE HYLAND CREEK ISMP

The Terms of Reference (ToR) for the Hyland Creek ISMP outlined several overall goals and objectives that the City desired to achieve with this study. Goals and objectives listed in the ToR include:

- To identify how the City, development community, government agencies and residents will grow and live within the Hyland Creek watershed
- To outline how resources within the watershed will be managed to balance land development with environmental protection, preservation and enhancement
- To develop and implement a program to identify the existing value of habitat in Hyland Creek and its tributaries, including wildlife and fisheries
- To identify and categorize discharge points into the creek based on area, existing land use, water quantity and quality impact, potential development and future land use
- To classify probable and sustainable future land uses within the watershed
- To determine targets for stormwater runoff quantity and quality for future development
- To outline an implementation strategy for mitigation, including proposed locations of future structures, benefiting areas, costs and financing methods
- To highlight how the City can monitor the long-term effectiveness of the proposed mitigation strategy once it is implemented

Table 3.1 below provides a more comprehensive list of the goals and objectives for the Hyland Creek ISMP. The goals and objectives listed below also take into account the overall objectives that the City outlined in the ToR. For ease of organization and discussion, goals and objectives have been grouped into the following categories: stormwater management, aquatic habitat, wildlife and terrestrial habitat, hydrogeology, land use / planning, and parks and recreation.

Table 3.1
Goals and Objectives of the Hyland Creek ISMP

Discipline	Goal / Objective	Applicability	ISMP Tasks to Achieve Goal
Stormwater Management	To evaluate the need for the works listed in the City's drainage capital works program	Entire Watershed	• Review past studies and consider the suitability of proposed works as they relate to the ISMP objectives • Verify need for works through modeling, engineering calculations, etc. • Prepare project definition reports and preliminary cost estimates for required works
	To identify opportunities to retrofit existing drainage infrastructure to improve the level of service or to optimize the overall drainage network		• Assess need / function of works listed in capital works program • Identify opportunities to retrofit or optimize existing / previously defined works to improve effectiveness
	To evaluate the effectiveness of existing detention facilities and determine whether any facilities could be removed or retrofitted for quantity control / water quality treatment		• Summarize properties of existing municipal detention facilities (such as contributing drainage area, upstream storm drainage network size / configuration, above ground versus underground facilities, visual observations, etc) • Evaluate effectiveness for quantity control, through simplified hydrologic / hydraulic models using continuous simulation and/or other methods • Identify opportunities for water quality enhancement
	To identify areas of erosion concern along Hyland Creek		• Review findings from previous ravine stability assessment reports and assess erosion degradation over time • Relate erosion concerns with upstream contributing factors and overall watershed health
	To identify opportunities where onsite stormwater best management practices (BMPs) could be implemented at new or redevelopment sites		• Identify opportunities to trigger BMP requirement through the subdivision or building permit process • Review City's existing design criteria, documents, bylaws, policies and practices, and evaluate whether BMPs can be implemented within the context of the current standards • Recommend amendments to existing policies or creation of new policies as needed to allow BMPs • Consider and consult with the City on the status of development applications already in progress

Discipline	Goal / Objective	Applicability	ISMP Tasks to Achieve Goal
Stormwater Management	To obtain an understanding of the current state of water quality in Hyland Creek	Entire Watershed	• Undertake water quality sampling program in Hyland Creek (dry and wet weather samples) • Assess quality of stormwater generated by different land use types • Identify pollutants of potential concern and recommend future actions
	To identify opportunities to retrofit existing commercial and industrial areas with water quality controls and/or other BMPs	Zones 1A / 2A	• Utilize results from water quality sampling program to discuss potential BMPs to target pollutants of concern • Identify areas in watershed where existing commercial and industrial uses may be contributing to water quality degradation
	To establish water quality targets for higher density developments		• Review standards and requirements of other local municipalities and environmental agencies and use findings to set target removal rates and performance levels for water quality BMPs • Identify monitoring methods for the field
	To gain an understanding of the hydrologic and hydraulic characteristics under pre-development conditions and recommend stormwater BMPs to respect these characteristics in future development	Zone 3	• Undertake a hydrogeological screening-level assessment to identify general opportunities for stormwater infiltration • Identify BMPs (lot, road right-of-way and community levels) to preserve and enhance base flows to Hyland Creek and its tributaries
	To identify measures to limit the effective and total impervious area for future development		• Review existing City policies and bylaws for impervious area requirements • Identify amendments to documents to encourage or require limits on effective and total impervious area for future development
	To establish stormwater runoff release rates and water quality targets for future development		• Establish targets and performance levels based on stormwater, environmental and hydrogeology assessments • Consider standards used by other local municipalities and environmental agencies
	To protect the watercourse from water quality degradation resulting from agricultural practices	Zone 4	• Briefly review stormwater BMPs for agricultural operations and list possible BMPs to mitigate water quality impacts from agricultural operations
	To review conveyance of flows within Hyland Creek to its discharge to the Serpentine River		• Review existing hydraulic studies and available flow data • Observe signs of degradation during field visit

Discipline	Goal / Objective	Applicability	ISMP Tasks to Achieve Goal
Aquatic Habitat	To expand fish accessibility and protect downstream aquatic habitat	Entire Watershed	• Identify existing fish barriers and explore strategies for their removal • Evaluate spawning potential and rearing capacity through review of past reports and field observations • Investigate potential to daylight enclosed lengths of the creek • Evaluate measures to improve water quality
	To preserve and improve aquatic habitat		• Monitor effectiveness of previous enhancement activities and define areas where future enhancement would be most effective • Identify valuable riparian corridors and identify measures for their future protection
	To maintain the riparian corridor and improve watershed health		• Measure the current watershed health using the GVRD ISMP template procedure • Verify areas of good habitat and identify measures to protect it • Establish appropriate riparian setbacks to stabilize and improve watershed health
	To protect salmonid rearing habitat	Zone 4	• Identify areas where riparian planting would be beneficial • Explore potential enhancement opportunities
Wildlife and Terrestrial Habitat	To protect and enhance riparian, aquatic and forest habitats	Entire Watershed	• Conduct biophysical surveys to identify riparian and naturally vegetated areas, and determine the level of disturbance within these areas resulting from existing development encroachment • Inventory wildlife use and document vegetation communities within undeveloped areas • Locate rare or uncommon flora and fauna (if they exist) • Identify linkages to adjacent watersheds
	To maintain and enhance biodiversity		• Identify baseline biodiversity conditions through biophysical survey • Establish measures to maintain and enhance current conditions
	To protect, restore and link habitat reservoirs and patches		• Identify potential wildlife travel corridors through biophysical survey and aerial photo interpretation • Identify opportunities to link fragmented or isolated patches
	To improve habitat quality and complexity for wildlife		• Identify opportunities to conserve and restore riparian habitat
	To promote use of native vegetation and control of non-native species		• Identify education opportunities for homeowners, businesses and the general public

Discipline	Goal / Objective	Applicability	ISMP Tasks to Achieve Goal
Hydrogeology	To identify areas with potential for shallow infiltration of stormwater	Entire Watershed	• Undertake desktop assessment of available geology mapping • Conduct field reconnaissance to evaluate existing soil characteristics
	To quantify infiltration potential (on a preliminary basis)	Zone 3	• Perform *in situ* infiltration tests at three locations to approximate infiltration capacity
Land Use / Planning	To identify regulatory tools to encourage the implementation of best management practices (BMPs) and low impact development (LID) techniques	Entire Watershed	• Identify and evaluate the use of various tools that regulate pollution generation, lot coverage (i.e. impervious area), soil deposit and removal (erosion control), environmental impacts, stormwater runoff, landscaping and subdivision servicing requirements (including road standards) • Identify appropriate regulatory tools to adopt stormwater runoff volume, rate, and water quality performance targets
	To identify incentives to encourage the development community to incorporate stormwater and environmental recommendations		• Identify and evaluate various incentives that the City could use with the development community to meet the ISMP stormwater management and environmental targets
	To provide clarity and direction to the City and the development community on the forms of stormwater and environmental works required for future development in the watershed		• Organize the format of the ISMP to allow both the City and the development community to quickly and easily find relevant information • Formulate a process which provides clarity to the City (in implementing and enforcing requirements) and the development applicant (in understanding what is required to streamline the approvals process)
	To strive to make recommendations that fit within the context of previously adopted land use plans		• Put greater emphasis (where appropriate) on actions that could be accomplished within the context of existing documents and policies
	To identify feasible and practical changes that could be made to existing land use plans to better support stormwater and environmental objectives		• Identify modifications to existing plans through their review, results of environmental studies and stormwater analysis, and discussions with City staff (for instances where recommended works cannot be met through existing documents)
	To strive to achieve endorsement of the ISMP by the Department of Fisheries and Oceans (DFO)		• Strive to produce an ISMP document that could be endorsed by DFO (for example, through a Memorandum of Understanding)

Discipline	Goal / Objective	Applicability	ISMP Tasks to Achieve Goal
Land Use / Planning	To identify regulatory tools to address water quality in commercial and industrial areas	Zones 1A / 2A	• Evaluate potential tools for effectiveness in meeting the water quality targets determined in the ISMP • Review practices and experiences in other local jurisdictions
	To identify policies and practices specific to stormwater management and agriculture	Zone 4	• Review the City's and the ALR's agricultural land use policies and plans • Identify further practices to promote stormwater management and environmental enhancement in agricultural areas
Parks and Recreation	To identify opportunities to increase the stormwater and environmental function of existing parks, and to improve the recreational amenity value of existing stormwater facilities	Entire Watershed	• Review existing developed areas and current land use plans • Identify opportunities for improved integration of parks and green spaces into the overall stormwater management plan

4.0 HYDROLOGY OF A WATERSHED

In the past, people have tended to think about water only during two periods – when there was too little of it (drought) or when there was too much of it (flood). When it came to drinking water, the former was most on people's minds, but when it came to urban drainage, the latter tended to rule. Since the focus was on preventing flooding and thus protecting people and their property, efficiency in removal was the goal. The faster water could be moved away from flood-threatened areas, the sooner people could forget about it.

For centuries, with respect to water supply, water has been treated as a resource, that is, as something to protect and maintain. But in the latter part of the 20th century, many people began to recognize that stormwater represents a resource as well. If treated wisely, stormwater contributes to the well-being of the natural environment, including fish-bearing water bodies and groundwater resources. But if treated unwisely, stormwater can become a nuisance at best or a serious factor in environmental degradation at worst.

The first step in understanding that stormwater is a resource is to understand the hydrologic cycle and the implications of disrupting that cycle by urban development practices. The next few sections provide a simplified outline of the hydrologic cycle, the typical characteristics of a healthy watershed and the stormwater impacts associated with urban development.

4.1 The Hydrologic Cycle

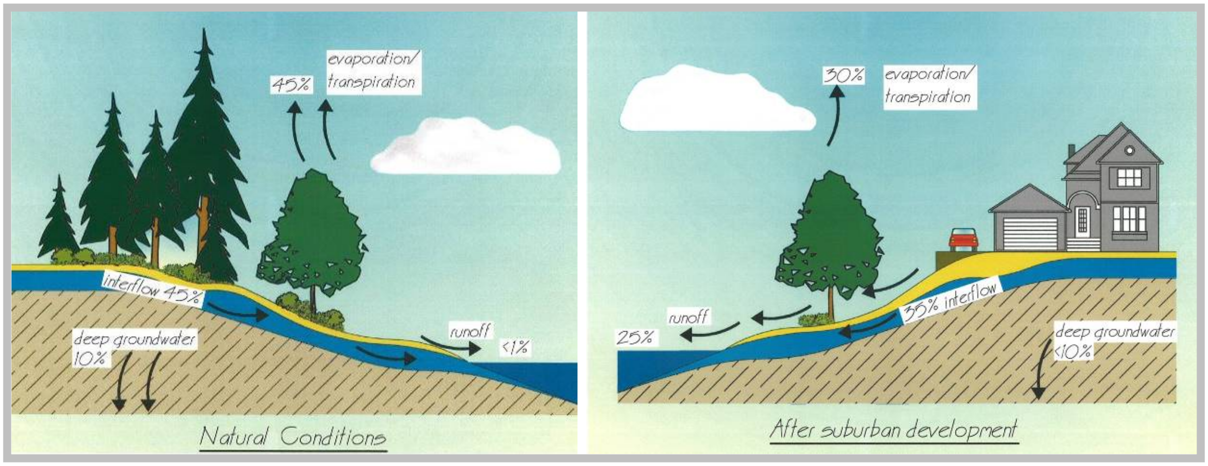
Precipitation that falls on any piece of land, whether natural or built, can basically move in only four directions:

- Back into the air via evaporation from surfaces and transpiration from leaves (*evapotranspiration*)
- Into the surface soils via soaking where it can move slowly to streams (*interflow*)
- Into deep groundwater aquifers via seepage (*groundwater recharge*)
- Directly into streams via the land surface or built structures (surface runoff, or *stormwater*)

Surface runoff from a forested or naturally vegetated watershed is very small, representing between 1 – 10% of rainfall volume in many cases. Except during occasional extreme rainfall events, the flow that is observed in streams (commonly called *base flow*) is actually a product of *interflow,* the slow movement of water through soils into streams.

Land development alters this natural water balance. When natural vegetation and soils are replaced with roads and buildings, less rainfall infiltrates into the ground, less is taken up by vegetation and more becomes direct surface runoff. Runoff volumes increase in direct proportion to impervious area – land uses with extensive roof and paved area create more runoff than land uses with extensive areas of absorbent soils and forest cover (see Figure 4.1).

Figure 4.1
Typical Annual Water Balance for the Lower Mainland British Columbia
Pre- and Post-Development Conditions



4.2 Land Use Characteristics of a Healthy Watershed

The Watershed Health Tracking System outlined in the GVRD template uses total impervious area (TIA), riparian forest integrity (% RFI) and benthic community sampling (B-IBI) results to measure the overall health of a watershed. Section 6 provides a more detailed description of the Watershed Health Tracking System and discusses the overall health of the Hyland Creek watershed under existing conditions.

In general, once a watershed goes beyond the range of what is considered to be "healthy", streams tend to exhibit a host of "unhealthy" conditions that are attributable to the process of urbanization, as discussed in the next section.

4.3 Impacts of Urban Development

Work at the Center for Urban Water Resources[1] (University of Washington) clearly demonstrates that the most important impacts of development (urbanization) on streams, in order of importance, are:

- Changes in hydrology
- Disturbance of the riparian corridor
- Deterioration of water quality
- Disturbance of the physical habitat within the stream

In addition, if these impacts are not avoided, there can be serious legal, financial and political implications.

4.3.1 Hydrology

One of the major impacts of urbanization on streams is its effect on stream hydrology. Hydrology is defined as the study of the movement (or flow) of water in all its phases. Understanding the water balance is essential to understanding the impact of development on the hydrology of streams.

The water balance, as shown in Figure 4.1, is the concept that the sum total of precipitation is equal to the amount infiltrated (interflow), absorbed (deep groundwater), and evapotranspired, plus the volume of surface runoff generated from the watershed. In a pre-developed setting, much of the precipitation is absorbed by the surrounding vegetation, soil and ground cover. In a developed setting, the water balance changes and a disproportionate amount becomes surface runoff.

Changes in the water balance in urban streams are exemplified by increased flood peaks, increased frequency of bankfull flows, widening of the floodplain and decreased dry weather flows (see Figure 4.2). Bankfull flows are simply runoff events that fill the normal channel of a stream to the top of the banks (not including its floodplain). Bankfull flows are significant because they are considered the channel forming flow condition in a stream and they are highly erosive, turbid ("cloudy") and damaging to the natural morphology of the stream.

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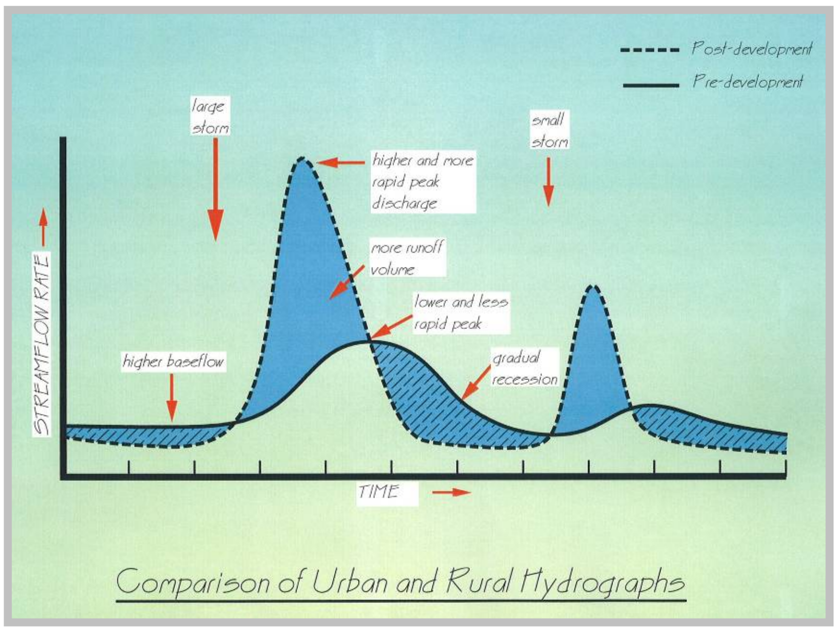
1 Integrated Stormwater and Stream Corridor Management forums, 2001.

Further, traditional pipe and ditch systems were designed to remove stormwater runoff from impervious surfaces as quickly as possible and deliver it to receiving waters. With increased land development, stormwater arrives at the receiving waters much faster, which in turn increases the peak rate of flow.

By the time a watershed is fully developed with buildings, roads and parking lots, 15 to 20 times more runoff can occur as compared to conditions prior to development.

Figure 4.2
Change in Streamflow Response with Urban Development



4.3.2 Disturbance of Riparian Corridor

In general, most streams begin to enlarge as impervious cover exceeds 10 – 15% in the watershed. The enlargement process may take up to 50 years to fully occur, but urban streams in watersheds with more than about 10 – 15% impervious cover are characterized by various degrees of stream enlargement and widening, erosion, downcutting, decreased channel stability and embeddedness. An undeveloped watershed with less than about 5% impervious cover is characterized by excellent stream conditions— good riparian cover, high quality substrate (stream bottom) and wetted perimeter during low flow conditions.

Detrimental impacts on the stream result when development encroaches into the riparian area. Loss of riparian habitat in close proximity to the stream results in changes to the soil structure of the banks. The loss of vegetation root systems can also destabilize the bank slopes, leading to erosion issues and stream bed migration. Even though a developed area does not entirely encompass a watershed, the sections of a stream that are located downstream of development are likely to experience these changing conditions.

4.3.3 Deterioration of Water Quality

In addition to hydrologic changes and changes to the riparian corridor of the stream, urbanization directly impacts the quality of the receiving water. Some of the indicators of the impact of urbanization on water quality include an increase in stream temperature and pollutant concentrations.

Stream temperature is a very important parameter for fish and insects. Temperature variability can dictate the growth of aquatic insects and timing of migration and emergence. Warm water holds less dissolved oxygen than cold water, so elevated temperatures affect survival of fish, particularly salmonids. Impervious cover increases air, soil and water temperatures, and can generate temperature increases as much as 3°C to 6°C in urban streams[2]. Loss of vegetation beside the stream also results in increased water temperatures.

In addition to increased stream temperature, urbanization can increase the amount of pollutants entering water bodies, such as sediment, nutrients, organic matter, trace metals (e.g. copper, cadmium, lead, zinc), pesticides, herbicides and hydrocarbons, and others. During storm events, the quality of urban stormwater declines sharply which adversely affects human and aquatic life uses of downstream waters.

The sources of pollutants in stormwater are predominately associated with impervious areas. Impervious areas act as a collector and conveyor for pollutants that arrive from many pathways. Pollutants can fall out of the sky during dryfall. They may also arrive in rain or snow as wetfall. Automobiles are also sources of pollutants. Wear of tires (a known source of zinc), deteriorating brake pads, or just leaks, drips and spills of oil and other pollutants from the automobile can accumulate on impervious surfaces. Pollutants can also be blown in from adjacent pervious areas. Pollutants land on the street where they often accumulate in curbs, cracks and other areas until the next storm event, where they are washed off the surface into the storm drain system and ultimately to receiving streams.

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2 Stormwater Best Management Practice Design Guide: Volume 1, General Considerations. U.S. Environmental Protection Agency, September 2004 (pg. 2-9) (EPA/600/R-04/121).

Excess nutrients (nitrogen and phosphorous) can create eutrophic conditions that lead to excessive algal growth, which affects fish habitat by smothering stream substrates and by consuming oxygen during decomposition.

Another common pollutant in urban stormwater is sediment. Sediment can smother bottom organisms and it can clog or damage gills of fish and aquatic insects when it is in the water column. Sources of sediment include stream bank erosion, construction sites and the wash off from impervious surfaces.

Fecal coliform levels in urban stormwater runoff can be derived from human and nonhuman sources. In fact, research indicates that much of the fecal coliform in urban runoff is from nonhuman sources such as dogs, cats, cattle, horses, squirrels, geese, pigeons and ducks. However, very high levels of bacteria may also be due to leaks of human sewage from sanitary sewer overflows, leaking septic systems, combined sewers or illicit discharge of sewage.

Stormwater hotspots are areas that produce higher concentrations of pollutants than normally found in urban runoff. Certain areas of the urban landscape are known to be hotspots of stormwater pollution. Examples include gas stations, parking lots and auto recycling facilities. Data sources have shown that industrial areas can contribute up to two times the concentrations of trace metals and hydrocarbons in stormwater runoff than other land uses[3]. These hotspots merit special management and pollution prevention activities.

Trace metals are frequently found in urban stormwater and sometimes at concentrations that can be acutely toxic to aquatic life. In nearly every stormwater sample, one generally will find zinc, copper and lead. Hydrocarbons, zinc, copper, cadmium, and lead are known to accumulate in the tissue of fish. In some cases, this may make the fish unsuitable for human consumption.

4.3.4 Disturbance of the Physical Habitat within a Stream

The habitat value of urban streams diminishes with increased impervious cover and development, with loss of habitat complexity through changes in substrate composition, recruitment of spawning gravel and large woody debris, and bank stabilization. There are numerous impacts to the aquatic habitat as well as the riparian corridor, particularly adjacent to the stream.

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[3] Urban Subwatershed Restoration Manual Series - An Integrated Framework to restore Small Urban Watersheds, Version 2.0. Center for Watershed Protection, February 2005.

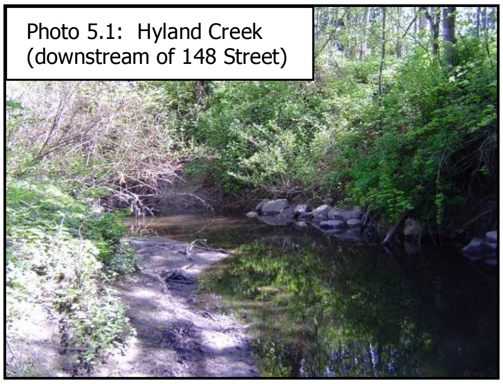
The creation of partial or complete barriers to fish movement is another impact of urban development. Culverts installed at stream crossings for roads and other urban infrastructure are common barriers, particularly if they are perched, steeply graded or have a bend in them that restricts light. Extremely long culverts can be a barrier if poorly designed or with a steep gradient as they do not provide resting areas for fish. Smooth culvert surfaces produce higher water velocities than in areas of natural substrate, creating a potential flow barrier for fish. Culverts can become impassable over time, as the stream erodes down with increasing urban development, creating vertical barriers to fish movement. These barriers can alienate fish from spawning or overwintering habitat upstream.

5.0 HYLAND CREEK WATERSHED CHARACTERISTICS

5.1 Field Investigation

Field investigations were conducted by the stormwater, aquatic, wildlife, terrestrial and hydrogeology team members in May 2006 and June 2006 to gather additional information on watershed characteristics and verify the information provided in background data and reports.

Photo 5.1: Hyland Creek (downstream of 148 Street)



Stormwater team members undertook a cursory review of the existing detention facilities in the watershed, focusing on those which are listed as "optimize pond" in the City's current capital works program. Ponds were assessed in the field for their apparent function and performance level (in terms of catchment area serviced). Team members also evaluated the characteristics of Hyland Creek and its tributaries at several major road crossings, where bed substrate composition, erosion and/or sedimentation issues, culvert capacity, storm sewer outfall(s), water flow depth and velocity, channel cross section, etc. were reviewed in a general sense. Finally, various types and forms of land uses were identified in the watershed. Active development in Zone 3 was reviewed in particular, as this zone is experiencing a sharp increase in the number of development applications and the majority of future development in the watershed is expected to occur in this zone. A complete photo inventory from the field investigation by stormwater team members can be found in Appendix K.

The aquatic team members investigated areas with reported habitat or pollution problems, as well as obstructions (debris jams, culverts, beaver activity). Previous enhancement work was surveyed by assessing instream and riparian habitat. As well, *in situ* water quality measurements and analytical water quality samples were taken at four sites across the watershed, as discussed further in Section 8. Three of these sites correspond to the City's benthic invertebrate monitoring sites. Data gained from the field assessment updated knowledge about the quality of habitat available to salmonids and other fisheries resources.

For terrestrial habitat, representative natural areas in each zone were surveyed for wildlife observations, wildlife signs, vegetation characteristics, level of disturbance and the capability of the habitat(s) to support wildlife. Special emphasis was placed on species of concern and recording exotic vegetation species.

The hydrogeology team members conducted a field investigation and testing program to evaluate existing soil characteristics and to assess the suitability of specific areas of the watershed for stormwater infiltration. The testing program concentrated on rural areas in Zone 3 where future development is anticipated. Further discussion on the testing results is provided in Section 9.

5.2 Stormwater Management

5.2.1 Available Background Information and Data

A drainage plan for the Hyland Creek watershed was first completed in 1978 by Sigma Resource Consultants. Further work was conducted by UMA Environmental (UMA) in 1995 in their Master Drainage Plan (MDP) and most recently by Dillon Consulting (Dillon), who undertook a drainage and erosion study for Hyland Creek in 2000. The UMA and Dillon studies evaluated the performance of existing drainage infrastructure and detention facilities in the watershed, as well as identified areas of erosion or slope stability concern. The Dillon report is essentially an update and expansion of the UMA 1995 MDP recommendations. In general, these previous studies indicate that the watercourse and associated hydraulic structures are adequate to convey flows during frequent, low-intensity storm events for existing development levels. Both studies also touch briefly on the use of source control Best Management Practices (BMPs), such as roof leader disconnections, rain barrels, and soak away pits, as well as water quality inlets for commercial and industrial areas. It is apparent, based on a review of these previous drainage studies, that significant work has already been done to understand the hydraulic nature of the municipal drainage system and the creek itself.

Modeling completed by Dillon in 2000 to evaluate the hydraulic capacity of the creek and drainage infrastructure was calibrated using flow data from a flow monitoring station which was in operation at the 140 Street crossing of Hyland Creek in 1996 and 1997. Dillon's work predicted that, while the watercourse and hydraulic structures could convey frequent, low-intensity flows, surcharging and flooding would occur throughout the watercourse for higher return events, with the 148 Street road crossing being overtopped during a 5-year event.

The 1995 UMA report stated that there were 64 stormwater detention facilities within the Hyland Creek watershed at the time of that study. Furthermore, the 2000 Dillon report stated that these facilities only provided runoff quantity control for approximately 15% of the total watershed area. The City's GIS database currently indicates that there are 68 stormwater detention facilities in the watershed, with 20 facilities being private facilities and 48 facilities being owned and operated by the City. The high number of facilities in the watershed is likely due to the fact that many were designed and constructed before the practice of community stormwater detention facilities was adopted. Thus, many of the older developments in the watershed were likely required to have onsite stormwater detention. Aside from the significant operation and maintenance implications for the City, most of these existing detention facilities are quite small and are designed to activate only under surcharge conditions (typically greater than the 5-year event), thus they may not be providing appreciable quantity control benefits under frequent, low-intensity storm events.

A significant effort has been made in past studies to understand the hydraulic nature of the municipal drainage system. As such, a focus of the ISMP will be to utilize this information and expand where necessary to fully integrate stormwater management objectives with environmental considerations.

5.2.2 GIS Database

GIS data was obtained from the City of Surrey for use in the Hyland Creek ISMP. A summary of the data is provided in Table 5.1 below. This information was utilized to gain a better understanding of the existing municipal drainage system, its configuration, function and level of service, as well as topographical features of the watershed and the extent of existing development.

Table 5.1
Available GIS Data for Hyland Creek Watershed

File Name	Description	Attributes
Manholes.shp	Storm Manholes	Manhole Type (Regular, Cleanout, Grillage, CBMH), Rim Elevation, Invert Elevation, Material, Year Installed
Mains.shp	Storm Sewer Mains	Main Type (Gravity, Cross Tile, Foundation Drain, French Drain, Gravity), Main Size, Material, Upstream Invert, Downstream Invert, Year Installed
WaterChannels.shp	Natural and Constructed Waterways	Channel Type (Creek/Ditch/River/Unknown)
RoadCentrelines.shp	Representational Roadway Centreline	Road Name, Road Class, Speed, Restrictions
SubCatchments.shp	Drainage Subcatchments Zones	Delineated Subcatchment Boundaries
MajorCatchments.shp	Drainage Major Catchment Zones	Delineated Catchment Boundary
DrivewayCulverts.shp	Drainage Driveway Culvert	Location of Driveway Culvert
DetentionPonds.shp	Drainage Detention Pond Delineations	Location of Detention Pond
FlowArrows.shp	Drainage Flow Direction Indicator	Arrow Rotation Value
actvdrprblm.shp	Active Drainage Problems reported to City	Location, Problem, Cause, Action taken by City

File Name	Description	Attributes
nov2003pblm.shp	November 2003 Drainage Problems reported to City	Location, Problem, Cause, Action taken by City
oct2003drnprb.shp	October 2003 Drainage Problems reported to City	Location, Problem, Cause, Action taken by City
1997_drnprblm.shp	1997 Drainage Problems reported to City	Location, Problem, Cause, Action taken by City
ContoursIntermediate.shp	Topographic Contours @ 1m Interval	Elevation
Contours5m.shp	Topographic Contours @ 5m Interval	Elevation
cadLots.shp	Lot Line Boundaries of Land Parcels	Owner Type (Private, BC Hydro, City Park, City Land, Provincial, School, GVRD), Plan No., Plan Year, PID, Name
AerialHYLAND2005.tif	Aerial Photograph taken in 2005	Colour, 10cm Resolution, Multiband TIF, Associated world file (.tfw)

For the data files containing information on existing storm manholes and storm sewers, an analysis was conducted to evaluate the completeness of these data sets. Results of the analysis are shown in Table 5.2 below. The configuration of the existing municipal drainage system was previously shown in Figure 2.4.

Table 5.2
Relative Completeness of GIS Data Set

GIS Shape File	Parameter	Data Completeness (%)
Manholes	Manhole Type	100
	Node Number	100
	Material	100
	Rim Elevation	80
	Invert Elevation	90
	Year Installed	20
Storm Sewers	Main Type	99
	Upstream Node	99
	Downstream Node	100
	Size	100
	Material	70
	Upstream Invert	80
	Downstream Invert	85
	Year Installed	25

In general, the City's GIS database relating to existing storm manholes and storm sewers is fairly complete, with the exception of some sewer invert elevations as well as the years when storm manholes and storm sewers were installed.

5.2.3 Watershed Boundary Delineation

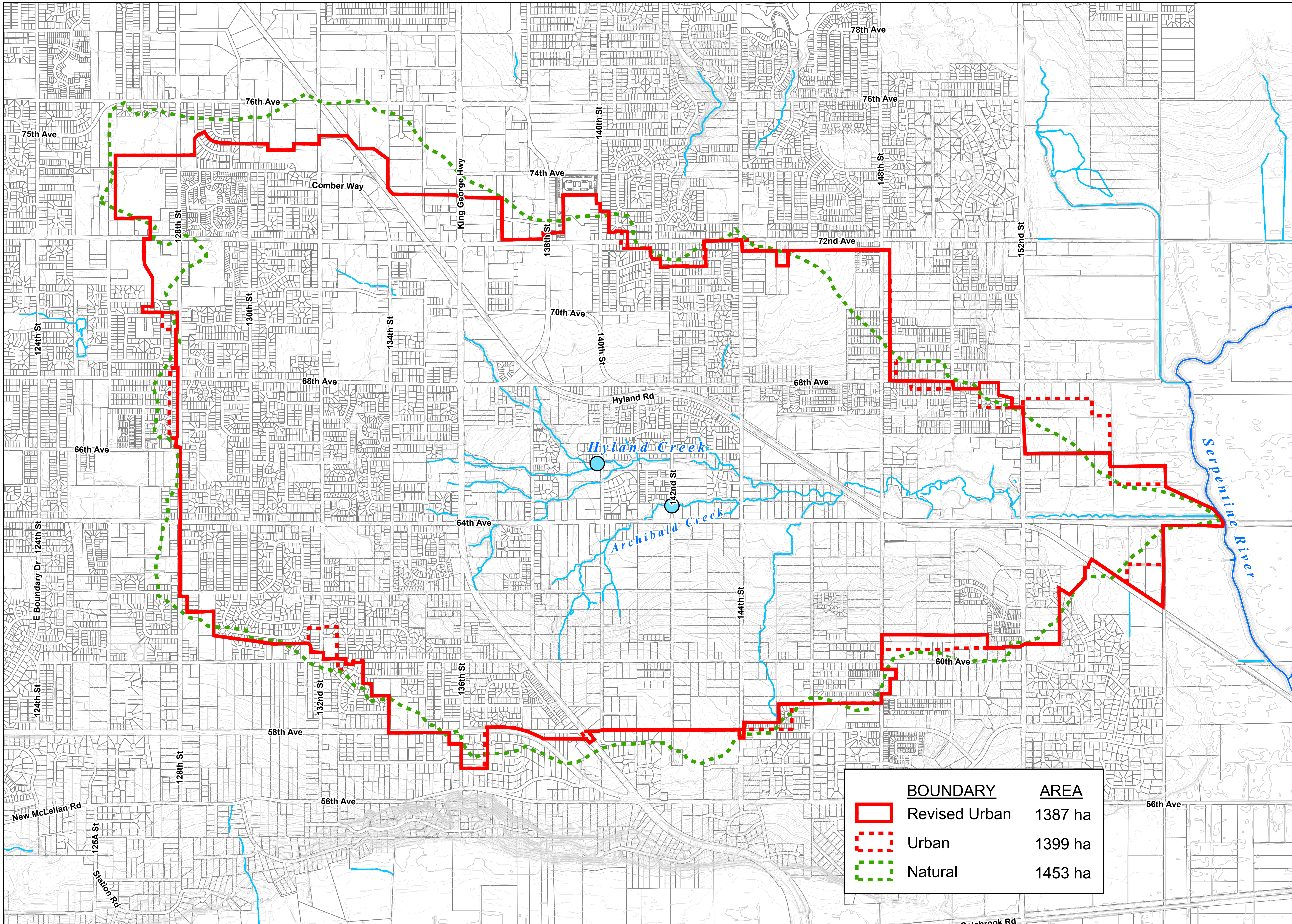
According to the City's GIS database, Hyland Creek and its tributaries drain a total area of 1,399 hectares. This is the "urban" drainage boundary for the watershed, as defined by the network of storm sewers and roadside ditches that service the majority of the watershed. Upon further review of the existing drainage network configuration, however, the total watershed boundary was revised to 1,387 hectares to account for some inaccuracies in the City's GIS database layer. The original and revised "urban" watershed boundaries are shown on Figure 5.1.

To determine the pre-development, or "natural" watershed boundary for Hyland Creek, topographical information was reviewed. Based on the available contour information in the City's GIS database, the natural watershed boundary for Hyland Creek is predicted to be 1,453 hectares, as indicated on Figure 5.1. Thus, 66 hectares, or 4.5% of the total watershed area, has been diverted from Hyland Creek through development in the watershed. This value may fluctuate slightly as development continues to proceed in the watershed, particularly within Zone 3.

All of the analysis completed as part of the Hyland Creek ISMP has been based on the revised urban watershed boundary area of 1,387 hectares.

5.2.4 Mean Annual Rainfall

The Mean Annual Rainfall (MAR) is an important parameter to consider, as it is often correlated to the " channel forming", or bankfull event for creeks and watercourses in the Lower Mainland and is also often used to set performance targets for addressing stormwater runoff onsite. Approximately 90% of the total annual rainfall volume experienced in the Lower Mainland corresponds to events that are less than a MAR intensity. Statistically, the MAR is defined as the 24-hour rainfall event with a 2.33-year return period.



SURREY
CITY OF PARKS

Hyland Creek Integrated Stormwater Management Plan

Figure 5.1

WATERSHED BOUNDARY DELINEATION

Natural Boundary (based on topography)

Urban Boundary (from City of Surrey GIS database)

Revised Urban Boundary (based on existing drainage network configuration)

Flow Monitoring Station

0 250 500
Metres

Scale 1:20 000

Source: City of Surrey
2005 Aerial Photography

Prepared By:
URBANSYSTEMS.
1072.0137.01 July 2007

U:\Projects_VAN\1072\0137\01\D-Drafting-Design-Analysis\GIS\mxd\Fourth_Report_Nov_9_06\Fig_5-1_Hyland_Creek_Watershed_Boundary_Delin.mxd 11/29/2006 3:03:16 PM Created/Revised by: sfadum

For the Hyland Creek watershed, the MAR was calculated using a blend of data from two rain gauge stations, Surrey Municipal Hall and Kwantlen Park. While the Surrey Municipal Hall station is located much closer to the Hyland Creek watershed than the Kwantlen Park station, previous drainage studies for the watershed have shown that a blend of data from the two stations was required to calibrate previous hydrology models. This was thought to be due to the fact that the Surrey Municipal Hall rain gauge station is located on the south slope of the main drainage divide to Mud Bay, whereas the Hyland Creek watershed is located on the north slope where the terrain is more undulating. Following this rationale, the MAR was calculated based on a blend of 80% Kwantlen Park rainfall data and 20% Surrey Municipal Hall rainfall data.

Based on the above discussion, the MAR for the Hyland Creek watershed is estimated to be 68 millimetres. Detailed calculations can be found in Appendix D.

A rain gauge also exists at the City's Parks and Recreation Operations Yard at 14645-66 Avenue. The rain gauge has been in place for approximately 5 years. Rainfall data is currently only measured as a daily total rainfall depth, therefore this data was not used in the ISMP analysis.

5.2.5 Annual Rainfall Pattern

Rainfall data for the Surrey Municipal Hall station was reviewed to gain an understanding of the fluctuations in total annual rainfall over the past several years. Table 5.3 summarizes the total annual rainfall between November 1996 and November 2005. November 1996 was chosen as the starting time for this assessment as it corresponds to the available flow information for Hyland Creek. For the 1996 – 2005 period, the average total annual rainfall was 1,336 millimetres.

Table 5.3
Annual Total Rainfall (Surrey Municipal Hall Rain Gauge)

Year	Total Rainfall (mm)
1996 (from October 25th)	442
1997	1,535
1998	1,306
1999	1,576
2000	1,314
2001	1,275
2002	962
2003	1,387
2004	1,336
2005 (to November 17th)	1,044

Flow data is available for Hyland Creek (at the 140 Street crossing) between November 1996 and October 1997. During this period, the total rainfall depth was 1,659 millimetres. Thus, measured flows in Hyland Creek during this period are representative of a higher than average rainfall period.

5.2.6 Base Flow Conditions

Base flows were estimated using flow data from the station that was in operation at the 140 Street crossing of Hyland Creek between November 1996 and October 1997. The flow station location is shown on Figure 5.1. This flow monitoring station measured contributing flows from the north and central branches of Hyland Creek only, as the south branch converges with the main stem of Hyland Creek downstream of the station location. The total catchment area is estimated to be 480 hectares. In 1996 / 1997, the vast majority of the upstream catchment area (from Zones 1, 1A and 2) was already developed, therefore, it is anticipated that base flows in Hyland Creek at 140 Street are likely similar in magnitude and seasonal distribution today as they were in 1996 / 1997.

The average base flow for each month was estimated by averaging the flows between rainfall events. A summary of average base flows in Hyland Creek from November 1996 to October 1997 is shown in Table 5.4. Hydrographs for each month can be found in Appendix D.

Table 5.4
Average Base Flows in Hyland Creek (1996 – 1997)

Date	Average Base Flow (m^3/s)
November 1996	0.043
December 1996	0.018
January 1997	0.057
February 1997	0.037
March 1997	0.042
April 1997	0.013
May 1997	0.024
June 1997	0.012
July 1997	0.014
August 1997	Non-measurable
September 1997	0.009
October 1997	0.032

Table 5.4 indicates that base flows decreased appreciably in the summer months, with non-measurable base flow recorded in August 1997 other than the flows immediately associated with a rainfall event. Over the entire data period, the average base flow was 0.025 m^3/s.

The flow data was graphed with the corresponding rainfall data from the Surrey Municipal Hall rain gauge station, as shown in Appendix D. A comparison of the timing of rainfall and flow data suggests that Hyland Creek is highly responsive to rainfall events, as well as to the lack of rainfall during summer months. Response time in the creek to rainfall events appears to be almost immediate, which suggests that the upstream drainage catchment is highly developed and that the majority of impervious surfaces are directly connected to the urban drainage network.

A second flow monitoring station has been in place at the 142 Street crossing of Archibald Creek since 1996, as shown on Figure 5.1. The total catchment area to this station is estimated to be 150 hectares. Flow data from this station is extremely useful, as the majority of the catchment area to Archibald Creek is located in Zone 3, which until recently has remained largely undeveloped. It is anticipated that a significant portion of the base flows to Hyland Creek under current development conditions originate from Archibald Creek.

To provide a useful comparison of base flows in Hyland Creek and Archibald Creek, flow data for Archibald Creek was reviewed for the period between November 1996 and October 1997. Flow data from January 2005 to September 2005 was also analyzed to determine if seasonal base flows have changed in Archibald Creek since 1996 – 1997 as a result of development in Zone 3. Hydrographs for Archibald Creek for both time periods can be found in Appendix D. Table 5.5 summarizes the average base flows in Archibald Creek for these two time periods.

Table 5.5
Average Base Flows in Archibald Creek (1996 – 1997, 2005)

Month	Average Base Flow (m^3/s)	
	1996 – 1997	2005
November	0.041	Data not available
December	0.038	Data not available
January	0.052	0.026
February	0.085	0.039
March	0.093	0.036
April	0.071	0.034
May	0.063	0.022
June	0.073	0.019
July	0.070	0.020
August	0.059	0.017
September	0.052	0.021
October	0.073	Data not available

The 1996 – 1997 flow data indicates that base flows in Archibald Creek remained fairly constant throughout the year, including the summer months. This is in contrast to base flows in Hyland Creek, which decreased substantially during the summer months. The data suggests that the catchment area to Archibald Creek was able to provide year round base flows to the creek because it was not highly developed at that time. Furthermore, notable peak flows tended to occur in Archibald Creek only during more extreme rainfall events. This suggests that rainfall was either infiltrated or retained close to the source and released to the creek over time for the smaller, more frequent events. It also suggests that impervious surfaces in the catchment area were disconnected from the drainage network, thus they were only capable of contributing stormwater runoff to the creek during larger storm events. Finally, the data indicates that flows from a given storm event take much longer to reach Archibald Creek than Hyland Creek (as indicated by the long recession limb in the corresponding hydrographs), suggesting that an appreciable proportion of the total flow in Archibald Creek originates from groundwater sources.

For the 2005 flow data period, a modest reduction of base flows in the summer months was noted in Archibald Creek, as shown in Table 5.5. The reduction suggests that, as development has proceeded in this catchment area (mainly Zone 3) over the last 10 years, base flows to Archibald Creek may be slowly diminishing. Another potential reason may be that the 1996 / 1997 period had a higher total rainfall depth than the 2005 period.

When base flows for Hyland Creek and Archibald Creek are related to their contributing catchment areas ($m^3/s/ha$), the data shows that unit base flows in Archibald Creek are in the order of ten times higher than unit base flows in Hyland Creek.

Previous work completed by Piteau Associates [1996] also looked at base flows in Hyland Creek in June 1996. At that time, they estimated that about one half of the base flow in Hyland Creek was provided by about one quarter of its catchment area, namely from Archibald Creek. This conclusion reinforces the importance of maintaining year round base flows in Archibald Creek, particularly given that further development is anticipated in this catchment area.

5.2.7 Erosion and Sedimentation

Several studies have been undertaken in the past to evaluate erosion and sedimentation processes in Hyland Creek and Archibald Creek, including:

- Envirowest [1995], which recorded sloughing banks and/or depositional areas along most tributaries surveyed; this work was completed as part of the Master Drainage Plan by UMA Engineering [1995]
- Dillon Consulting [2000], which investigated channel erosion along the main stem of Hyland Creek and identified fourteen significant erosion sites (six high priority and eight medium priority sites); five of the six high priority sites received restorative attention in 1999
- Urban Systems [2002], which assessed ravine stability and erosion issues along Hyland Creek and Archibald Creek
- Associated Engineering [2006], which updated the 2002 Urban Systems ravine stability assessment

The 2002 and 2006 ravine stability assessments were based on a detailed site reconnaissance of the creeks. Erosion and/or instability sites were identified and given a relative risk designation, which was based on the following criteria:

- **High Risk** – likely or immediate risk (within 1 year) to public safety, or damage to structures or infrastructure
- **Medium Risk** – no anticipated risk to structures and no significant risk to public safety, but increasing risk may develop over time (beyond 1 year). May involve some impact to yard area but no immediate risk to structures

- **Low Risk** – minimal risk to impact to private property or public safety in the near or foreseeable future

In 2002, there were 15 erosion or instability sites in total on Hyland Creek and 1 site on Archibald Creek. The 2006 update increased the total number of erosion sites to 31 and 6, respectively. The relative risk designation of the erosion sites for each year is shown in Table 5.6 below. The locations of the erosion sites are also shown on Figure 5.2.

Table 5.6
Relative Risk of Erosion Sites on Hyland Creek and Archibald Creek

Watercourse	Relative Risk Designation	Year	
		2002	2006
Hyland Creek	High	0	1
	Medium	7	11
	Low	8	19
	Total	**15**	**31**
Archibald Creek	High	0	0
	Medium	0	4
	Low	1	2
	Total	**1**	**6**

In general, erosion sites tend to be concentrated along the north branch and main stem of Hyland Creek between King George Highway and 148 Street. In 2002, there were 2 erosion sites along the north branch of Hyland Creek immediately downstream of King George Highway. In 2006, the number of erosion sites along this branch increased to 12, including 1 high risk and 4 medium risk sites, as shown on Figure 5.2. Archibald Creek does not appear to have any major erosion concerns at this point, as no erosion sites were identified upstream of 64 Avenue. However, as development proceeds in Zone 3, it is anticipated that erosion and degradation will occur unless measures are implemented now to protect the watercourse.

While it is important to note that the 2002 and 2006 assessments were conducted by different consultants and thus may be somewhat subjective, both studies were based on the relative risk designation criteria noted above.

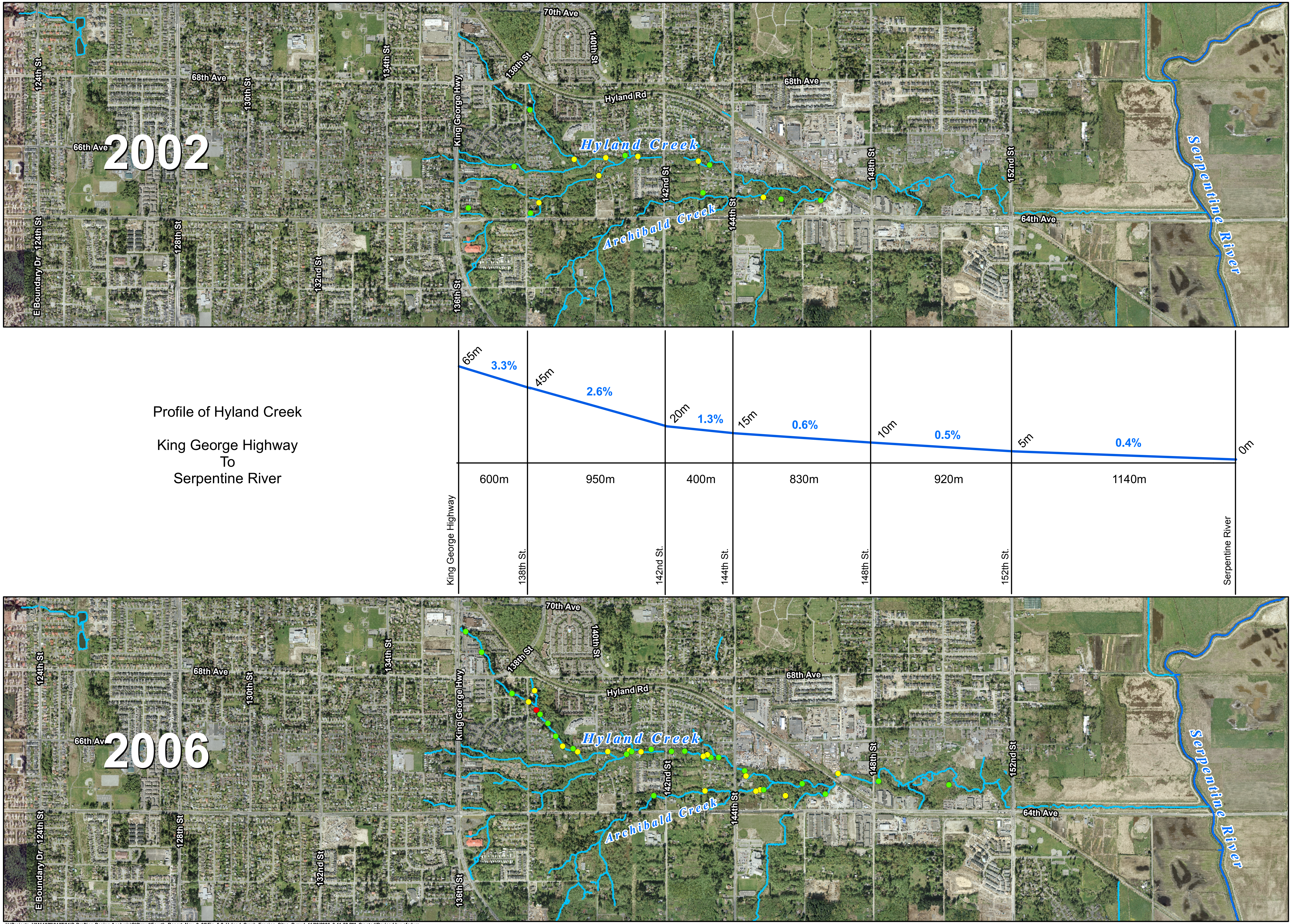


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Figure 5.2

2002 vs 2006 EROSION SITES

- High Risk
- Medium Risk
- Low Risk

0 250 500
Metres
Scale 1:15 000

Source: City of Surrey
2005 Aerial Photography

Prepared By:
URBANSYSTEMS.
1072.0137.01 July 2007

A review of the catchment area draining to the north branch of Hyland Creek indicates that a significant portion of the catchment area drains uncontrolled to the creek. The north branch conveys flows from Zones 1 and 1A, as well as the extreme western portion of Zone 2. Zone 1A is almost entirely commercial and industrial development, whereas Zones 1 and 2 contain mainly urban residential development. Both land use types tend to have a rapid, flashy response to rainfall events as they are directly connected to the drainage network. Thus, stormwater runoff is conveyed quickly to the watercourse in large volumes, and with little attenuation of peak flows. Erosion issues continue downstream along the main stem of Hyland Creek, where the profile slope of the channel ranges from 1.3 % to 3.3 %. The increase in the number and severity of erosion sites along the north branch and main stem from 2002 to 2006 suggests that the watercourse is unable to withstand the current flow conditions and is continuing to degrade as a result.

Erosion and degradation issues in Hyland Creek may be further exacerbated by the fact that existing development has encroached on the creek in numerous locations. Typically, a creek responds to changes in the flow regime by shifting either vertically (downcutting) and/or horizontally (widening its floodplain) to increase its cross sectional area. Much of the existing development was built quite close to the top of the creek banks, and often closer than what is considered to be an acceptable development setback by today's standards. The ability for the creek to shift horizontally in response to increases in flow may be limited, thus the creek is primarily downcutting to respond to the flow regime changes. Downcutting has led to oversteepened banks which then collapse or recede, creating erosion issues. It appears overall that both Hyland Creek and Archibald Creek are sensitive to erosion processes and that conditions have continued to worsen over time, particularly along the north branch and main stem of Hyland Creek.


Photo 5.2: 148 Street Culvert Crossing

Downstream of 148 Street, there does not appear to be any erosion issues. As shown on Figure 5.2, the profile slope of Hyland Creek changes from 1.3% to 0.5% between 144 Street and 148 Street. The flatter slope induces a slower flow velocity in the creek, which in turn allows sediments suspended in the flow to be deposited, particularly in and around the 148 Street culverts, which are shown in Photo 5.2. Water levels and velocities near the 148 Street culverts may also be partially influenced by the Serpentine River (backwater / tidal effects). The sedimentation process was verified during the site reconnaissance, as large deposits of cobble, sand and silts were noted upstream, downstream and within the culverts themselves at 148 Street. Until the upstream erosion issues are addressed, the occurrence of sedimentation is expected to continue. When the 148 Street culverts become surcharged, the area upstream of the culverts also tends to function as an online detention pond, further acting to reduce flow velocities and allow settling of suspended sediments. Another contributing factor is that there is minimal cover over the culverts at the road crossing, thus the road tends to overtop relatively easily once the culverts become surcharged. An upgrade to the 148 Street culverts is currently listed in the City's drainage capital works program (ID 6247), as the 2000 Dillon study indicated that these culverts were undersized for a 1 in 5-year storm event.

5.2.8 Existing Detention Facilities

The City's GIS database indicates that there are 68 existing municipal and private stormwater detention facilities located in the Hyland Creek watershed, with the majority of these facilities located in Zones 1 and 2. Surface ponds are the predominant facility type, although underground storage facilities also exist. Forty-eight of the facilities are owned and maintained by the City, whereas 20 are private facilities. The locations of exiting detention facilities are shown in Figure 5.3.

Many of the existing municipal detention facilities were visited by the stormwater team members during the field investigation. Facilities generally consisted of dry grassy areas and were either integrated into park space (as shown in Photo 5.3), a greenbelt, or otherwise were situated on empty lots within an existing developed area.

Photo 5.3: Existing Stormwater Detention Facility in Park

The vast majority of these ponds were designed and constructed when the City of Surrey's stormwater management policy required that the five year post development flow from urban areas be controlled to pre-development conditions. The intent of this policy was to mitigate erosion and flooding in channels and to minimize the impact to properties downstream of the developed areas. However, the policy was also applied on a site-by-site basis, requiring that each development construct a detention facility to address stormwater runoff. The result was a proliferation of detention facilities throughout the developed areas in the watershed. In addition, most of these facilities were designed to activate only under a surcharged condition, meaning that frequent, low-intensity storms (often less than the 5-year event) often bypass the detention facility completely and are allowed to discharge to the creek with little to no flow attenuation.

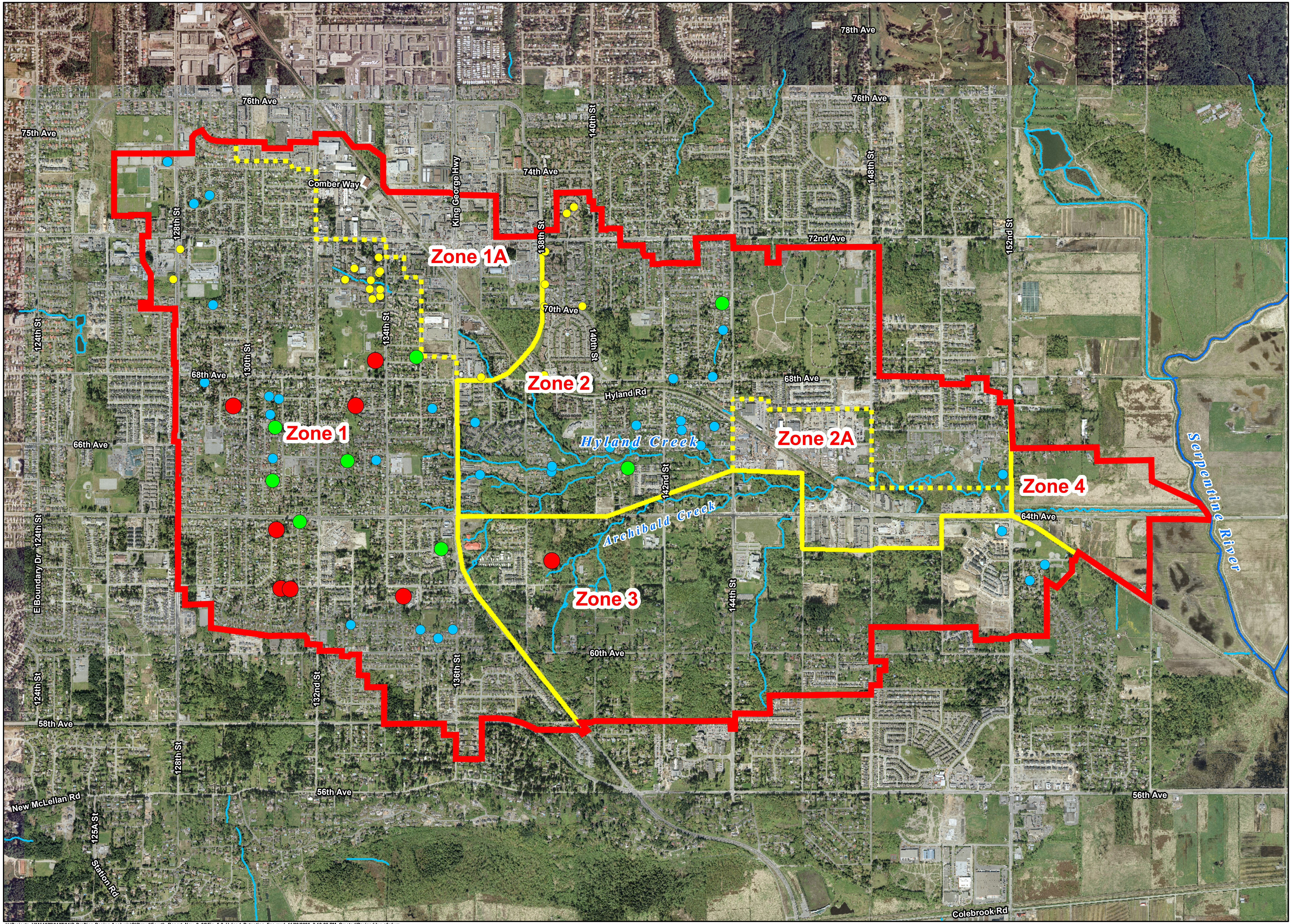

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Figure 5.3

EXISTING MUNICIPAL AND PRIVATE DETENTION FACILITIES

Hyland Creek Watershed Area
Zone Boundary
Sub-Zone Boundary

Municipal Detention Facility Capacity (cubic metres)

- 1000+
- 500 - 1000
- 0 - 500
- Private Detention Facility

N

0 250 500
Metres
Scale 1:20 000

Source: City of Surrey
2005 Aerial Photography

Prepared By:
URBANSYSTEMS.
1072.0137.01 July 2007

The 1995 UMA and 2000 Dillon studies also included information and recommendations regarding existing detention facilities in the watershed. The UMA study assessed the effectiveness of municipal detention ponds by reviewing the drainage area contributing to the facility as well as its overall location in the watershed. The study found that detention facilities with contributing areas less than ten hectares were not effective in controlling downstream flows. The study then looked at ponds with less than 10 hectare catchment areas and assessed whether downstream detention facilities had sufficient capacity to accept additional flows if these ponds were removed. Based on this analysis, 16 municipal ponds were identified as potentially suitable for removal. Nine of the ponds identified by UMA as potentially suitable for removal are currently listed in the City's capital works program as "optimize pond".

A more detailed hydraulic study of existing detention ponds located west of King George Highway (Zones 1, 1A) and north of Hyland Creek (Zone 2) was conducted by Dillon in 2000. In both areas, Dillon found that 40% of the ponds did not achieve an appreciable reduction in the two-year flow. West of King George Highway, 60% of the ponds achieved a flow reduction ranging from 7-18%. North of Hyland Creek, 60% of the ponds achieved a flow reduction ranging from 7-33%. For the 5-year flow, 50% of the ponds in both areas did not achieve a significant reduction in flows. Overall, Dillon concluded that any small local benefits of these detention ponds were found to translate into relatively insignificant reductions by the time flows reached Hyland Creek.

The Dillon study also noted that the relatively small contributing drainage area for many of the existing detention facilities had resulted in an inefficient drainage network that inhibited the opportunity to provide an improved level of service. However, the study cautioned removing the detention ponds that were recommended for removal in the UMA study, as they collectively account for more than 30% of the total available storage volume in Zones 1, 1A and 2. The report also suggested that, from a practicality standpoint, only a select number of facilities may potentially be eligible for decommissioning.

To determine the extent of the watershed that is currently serviced by municipal detention facilities, the catchment areas for each major sewer outfall to Hyland Creek were delineated, as shown on Figure 5.4. For each catchment area, the proportion of area serviced by a detention facility was calculated. As summarized in Table 5.7, the analysis indicates that, overall, only 24% of the Hyland Creek watershed is serviced by an existing detention facility. Furthermore, a review of municipal detention facilities in the catchment areas draining to the three headwater branches of Hyland Creek show that facility coverage in the headwater area ranges from 29% to 53%, as summarized in Table 5.8 below.

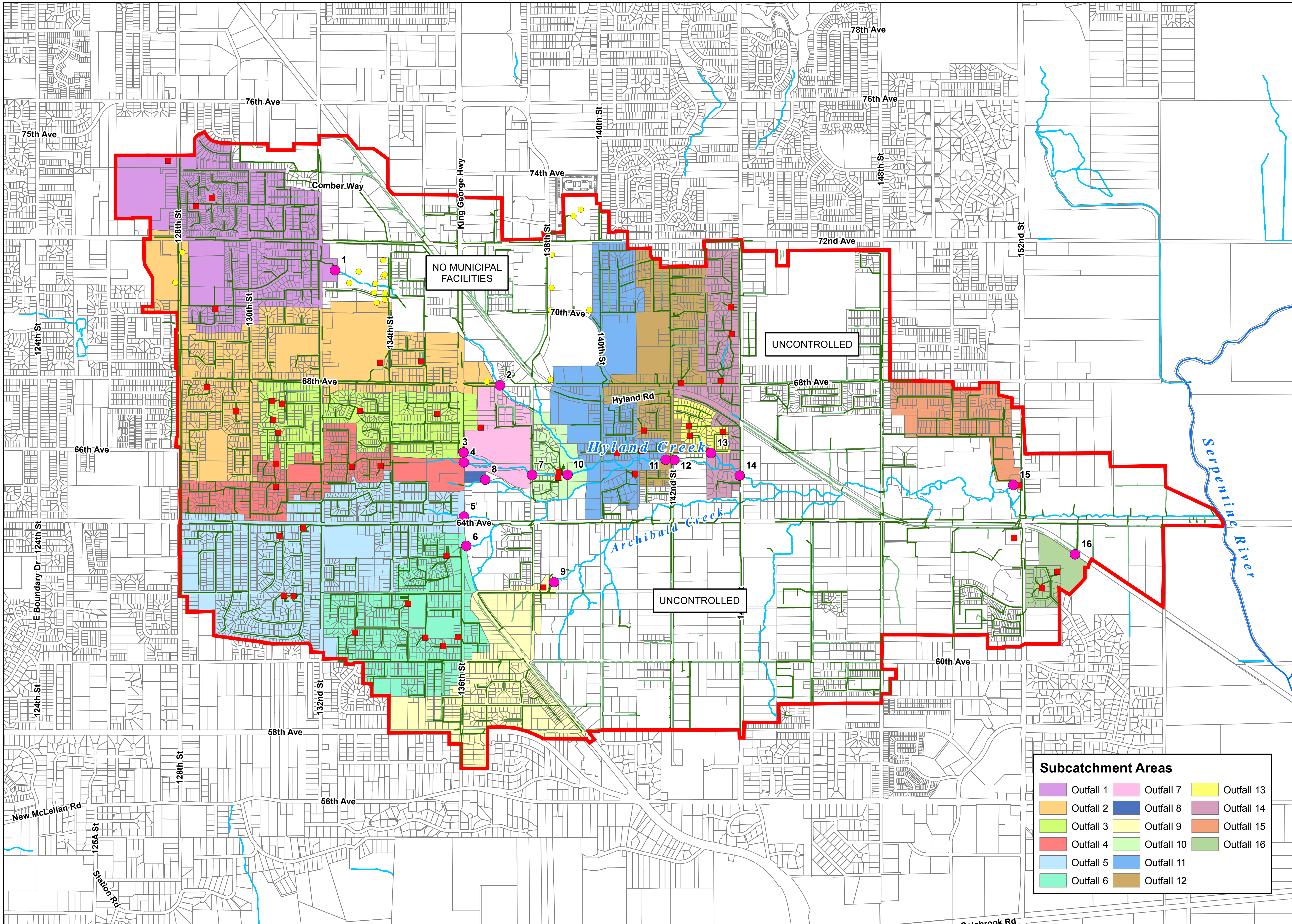

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Figure 5.4

OUTFALL CATCHMENT AREAS

- Existing Storm Sewer Outfall (Subcatchment area partially serviced by municipal detention facilities)
- Existing municipal detention facility
- Existing private detention facility
- Hyland Creek Watershed Area

0 250 500
Metres

Scale 1:20 000

Source: City of Surrey
2005 Aerial Photography

Prepared By:
URBANSYSTEMS.
1072.0137.01 July 2007

Table 5.7
Hyland Creek ISMP - Municipal Detention Pond Summary

Outfall	Total Area (ha)	Municipal							Location		Comments
		Pond ID	Drainage Area, DA (ha)	Total Contributing DA (ha)	Design Return Period	Peak Flow (m^3/s)	Unit Release Rate (L/s/ha)	Capacity (m^3)	Park / Greenbelt	Development Potential?	
1	87.6	291	7.6	7.6	5year/100year	0.010	1	147	Y	N	
		314	1.9	1.9	5year/100year	0.049	26	426	Y	M	asphalted area with 2 road frontages
		354	2.6	2.6	25 year	*0.063*	24	*130*	Y	N	
		Pond C	11.1	11.1	??	??	??	??	Y	N	no asbuilts provided
		Total (Outfall 1)	23.2 **26%**								
2	105.8	no_id3p61	77.7	87.2	5year/100year	0.740,1.290	9 / 15	*n/a*	Y	N	no asbuilts provided
		292	4.4	4.4	5year/100year	0.048	11	730	N	Y	good road frontage
		296	7.5	7.5	5year/100year	0.290	39	1510	Y	M	Good road frontage, develop frontage lots and maintain easements to pond in rear?
		no_id2p61	2.0	2.0	*5year/100year*	*0.037 / 0.225*	19 / 113	38	N	N	control structure is orifice with o/f weir; detention chamber in road
		Total (Outfall 2)	91.6 **87%**								
3	44.4	293	15.5	20.0	5year/100year	0.257	13	1410	Y	N	
		297			5year/100year	0.039	17	490	Y	M	pond is 1 lot only with narrow greenbelt to connect to Pond 298
		297 Tank1	2.3	2.3	*5year/100year*	0.100	43	51	N	N	detention chamber in road
		297 Tank2			*5year/100year*	*n/a*	*n/a*	40	N	N	not enough info on asbuilts to calculate peak flow; detention chamber in road
		298	2.2	2.2	5year/100year	0.059	27	975	Y	M	pond is 1 lot only with narrow greenbelt to connect to Pond 297
		441	3.6	3.6	*n/a*	0.018	5	320	N	N	only narrow easement for access, but not connected to park or greenbelt
		Total (Outfall 3)	23.6 **53%**								
4	37.3	294	2.7	28.7	5year/100year	0.034	1	316	N	Y	pond is 1 lot only and not connected to park or greenbelt
		295	14.2	26.0	5year/100year	0.110	4	860	Y	N	
		299	2.3	2.3	5year/100year	0.015	6	365	Y	N	
		300	9.5	11.8	5year/100year	0.210	18	860	Y	N	narrow easement access only
		Total (Outfall 4)	28.7 **77%**								
5	99.3	267	5.7	5.7	*5 year*	*0.080*	14	1170	N	Y	good road and lane frontage
		268	5.7	21.3	5year/100year	*0.799*	38	875	N	Y	good road frontage
		269	9.9	9.9	5year/100year	*0.564*	57	2109	Y	M	Good road frontage, develop frontage lots and provide easement to pond in rear?
		270			5year/100year	*0.290*	29	1111	Y	N	
		Total (Outfall 5)	21.3 **21%**								
6	57.8	272	2.0	2.0	5year/100year	0.061	31	720	N	N	narrow easement access only; pedestrian walkway on one side
		273	16.8	16.8	5year/100year	0.119	7	1350	Y	M	adjacent to school but has good road frontage
		274	5.4	5.4	5year/100year	0.129	24	752	N	N	narrow easement access only
		276	1.0	1.0	5year/100year	*n/a*	??	*71*	Y	N	missing dwg. M1341-01-09
		547	0.9	1.9	*5year/100year*	0.020	11	*90*	N	N	detention chamber in road
		no_id1p71	0.1	2.0	5year/100year	0.190	95	25	N	N	detention chamber in road
		Total (Outfall 6)	26.2 **45%**								
7	0.4	472 **(Outfall 7)**	0.4 **100%**	0.4	*n/a*	*0.004*	10	39	N	N	
8	0.8	546 **(Outfall 8)**	0.8 **100%**	0.8	5year/100year	0.006	8	32	N	N	underground detention chamber
9	51.6	Pond A **(Outfall 9)**	51.6 **100%**	51.6	*n/a*	*n/a*	??	*n/a*	Y	N	no asbuilts provided
10	383.1	305	2.6	2.6	5 year	*n/a*	??	235	Y	N	City provided dwg. SS-62-438 instead of SS-62-483
		304	1.7	1.7	*5 year*	*0.050*	29	*n/a*	Y	N	
		Total (Outfall 10)	4.3 **1%**								
11	49.7	306	5.2	5.2	5year/100year	0.145 (100 year)	28	650	N	N	narrow easement access only
		307	1.5	1.5	5year/100year	*0.036 / 0.038*	24 / 25	*320 / 400*	N	M	pond is 1 lot only; adjacent to hydro corridor
		499	0.3	0.3	5year/100year	*0.016*	53	53	N	N	detention chamber in road
		Total (Outfall 11)	7 **14%**								
12	40.7	301	3.1	3.1	5year/100year	0.156	50	46	N	N	detention chamber in road
		308	0.7	0.7	*5 year*	*0.150*	214	*725*	N	M	good road frontage; adjacent to hydro corridor
		449	2.2	2.2	*5 year*	*0.040*	18	*250*	N	Y	pond is 1 lot only and not connected to park or greenbelt
		Total (Outfall 12)	6 **15%**								
13	7	302	3.0	3.0	*5year/100year*	*0.111*	37	*n/a*	N	N	detention chamber in road
		303	0.4	0.4	5year/100year	*0.024*	60	*51*	N	N	detention chamber in road
		451	1.6	5.6	*n/a*	*0.071*	13	*35*	Y	N	in creek corridor
		452	0.6	3.6	*5year/100year*	*0.130 / 0.383*	36 / 106	*38*	N	N	detention chamber in road
		Total (Outfall 13)	5.6 **80%**								
14	207.4	309	2.3	8.8	5year/100year	0.486	55	109	N	N	in rear of developed lot
		450	6.3	15.1	*5year/100year*	*n/a*	??	262	Y	N	missing sheet 27 with pond details
		1126	6.5	6.5	5 year	0.086	13	660	N	Y	may have already been removed? Aerial appears to show two houses on pond area
		Total (Outfall 14)	15.1 **7%**								
15	24.1	Pond B **(Outfall 15)**	24.1 **100%**	24.1	*n/a*	*n/a*	??	*n/a*	Y	N	no asbuilts provided
16	190.2	277	3.3	4.9	*n/a*	*n/a*	??	*n/a*	N	Y	missing sheet 15 with pond details; pond is 1 log only with good road frontage
		502	1.6	1.6	*n/a*	0.165	103	*765*	N	N	norrow easement access only
		Total (Outfall 16)	4.9 **3%**								

Total Watershed Area = 1,387 ha
Total Area Serviced by Ponds = 334.4 ha
or **24%**

N=No, Y=Yes, M=Maybe

Note: Values shown in *italics* were calculated using available information shown on the as-built drawings. Values not in italics were provided by the City on pond summary sheets.

Table 5.8
Detention Facility Coverage in Headwater Catchment Areas of Hyland Creek

Branch	Total Drainage Area (ha)	Area Serviced by Municipal Detention Facility (ha)	% Coverage
North	353	115	33%
Central	202	57	29%
South	93	49	53%

In most cases, municipal detention facilities are offline and configured to only activate in a surcharge condition when storm sewer capacities are exceeded. As the storm sewer network is typically designed for a 5-year event, this means that the facilities were designed to only detain runoff during storm events greater than the 5-year event. For smaller, more frequent storm events, these ponds do not typically provide flow attenuation. Research has shown that it is these smaller storm events that can cause the most damage to the creek and its habitat. It is also anticipated that, due to the dispersed nature of ponds in the watershed, any flow attenuation benefits that the ponds do provide are substantially reduced by the time the flow reaches Hyland Creek. Overall, it is apparent that many of these facilities are not providing much benefit to Hyland Creek, and opportunities to retrofit these ponds to provide a benefit, particularly under smaller storm events, should be examined.

5.2.9 Capital Works Program

The City has an extensive list of drainage related projects in their capital works program for the Hyland Creek watershed. Most of these projects were initially identified through previous drainage studies or reports for the area, or from resident complaints. One of the tasks of the ISMP is to determine the need for these projects, and identify if any projects could be removed from the capital works program.

A summary of the current capital works projects is provided in Table 5.9 below. The City had assigned priority levels to each project as follows:

S Short Term (1-2 years)
M Medium Term (2-5 years)
L Long Term (5-10 years)
X Very Long Term (+10 years)
N Identified in Neighbourhood Concept Plan (NCP)

Table 5.9
Drainage Capital Works Program for the Hyland Creek Watershed

ID	Project Name	Project Location	Start	Priority
Storm Sewer Upgrades				
3809	500m Pipe Upgrade	65A Ave.: 130 - 132 St.	2016	L
6238	1200m Pipe Upgrade	68 Ave.: 130 - KG Hwy	2017	X
6419	900m Pipe Upgrade	64 Ave.: 130 - 134 St.	2011	M
7032	195m Pipe Upgrade	67A Ave.: 133 - 134 St.	2017	X
6032	Trunk on 66 Ave.: 145A to 147 St.	66 Ave.: 145A - 147 St.	2006	S
6041	1200m - 600m on 144 St.	144 St.: 65 - south of 60 Ave.	2011	N
6244	900mm Upgrade Existing Storm	68 Ave.: 141 - 142 St.	2007	S
6247	Culvert Crossing Upgrade	Hyland Crk: 148 St.	2007	S
10315	300m - 525mm New Storm Sewer	6165 - 6267 148 St.	2006	N
10316	560m - 900mm New Trunk Sewer	148 - 150 St.: 63 Ave.	2006	N
Existing Detention Pond Retrofits				
6231	Optimize Pond at 66A: East of 141 St.	66A: east of 141 St.	2009	S
6234	Optimize Pond at 63A Ave.	63A Ave.	2009	S
6235	Optimize Pond at 132A St.	132A St. - 61 Ave.	2009	S
6221	Optimize Pond at 73 Ave.	73 Ave: 128B St.	2013	L
6223	Optimize Pond at 130A St.	130A St. - 66B Ave.	2013	L
6224	Optimize Pond at 65 Ave.	65 Ave. - 130A St.	2013	L
6225	Optimize Pond at 65A Ave.	65A Ave.: 130A St.	2014	L
6226	Optimize Pond at 130 St.	130 St. - 66B Ave.	2015	L
6227	Optimize Pond at 69 Ave.: 135 St.	69 Ave: 135 St.	2013	L
6228	Optimize Pond at 135 St.	135 St.	2014	L
6229	Optimize Pond at KG Hwy	67 Ave. at 137 St.	2015	L
6256	Existing Dry Pond Upgrade	Greenbelt 67 Ave. 133 St.	2006	S
6257	Existing Dry Pond Upgrade	Greenbelt 65 Ave. 133 St.	2006	S
New Detention Ponds				
6036	Recharge Pond - P4B	141 St. / 62 Ave.	2009	N
6240	Creation of Detention Pond - P7	64 Ave.: 144 St. - 148 St.	2006	N
6241	Creation of Detention Pond - P5	64 Ave.: W of 144 St.	2008	N
6242	Creation of Detention Pond - P4A	140 St.: 62 Ave. - 64 Ave.	2007	N
6243	Creation of Detention Pond - P1C	62 Ave. 138 St. - 140 St.	2009	N
8565	Archibald Detention Pond P1B	138 St. / 62 Ave.	2007	S
6022	Newton Town Centre Stormwater Detention Pond	138 Street: 68 Ave.	2012	M

ID	Project Name	Project Location	Start	Priority
Erosion Remediation and Sediment Control				
6246	Erosion Remediation G2, G3, G4	Hyland Crk: 68 Ave. - 70 Ave.	2017	X
9339	4 sites (ID=ARCH-1.2, HYLD-1; risk=M/L)	Archibald & Hyland Crks: 144 St. / 64 Ave.	2007	S
9340	2 sites (ID=HYLD-10,11; risk=L)	Hyland Crk: 137 St. / 65 Ave.	2008	S
9341	2 sites (ID=HYLD-12,13; risk=M/L)	Hyland Crk: 138 St. / 66 Ave.	2007	S
9345	5 sites (ID=HYLD-2,3, ARCH-3; risk=M/L)	Hyland & Archibald Crks: 143A St. / 65 Ave.	2008	S
9346	2 sites (ID=HYLD-4,5; risk=M/L)	Hyland Crk: 138 St. / 64 Ave.	2006	S
9347	6 sites (ID=HYLD-6 to 9; risk=M/L)	Hyland Crk: 140 St. / 66 Ave.	2008	S
10314	Sediment Control Device (2 Req)	6191 148 St.	2006	N
10317	Sediment Control Device (2 Req)	6315 150 St.	2008	N
10318	Sediment Control Device (2 Req)	6159 & 6257 150 St.	2008	N

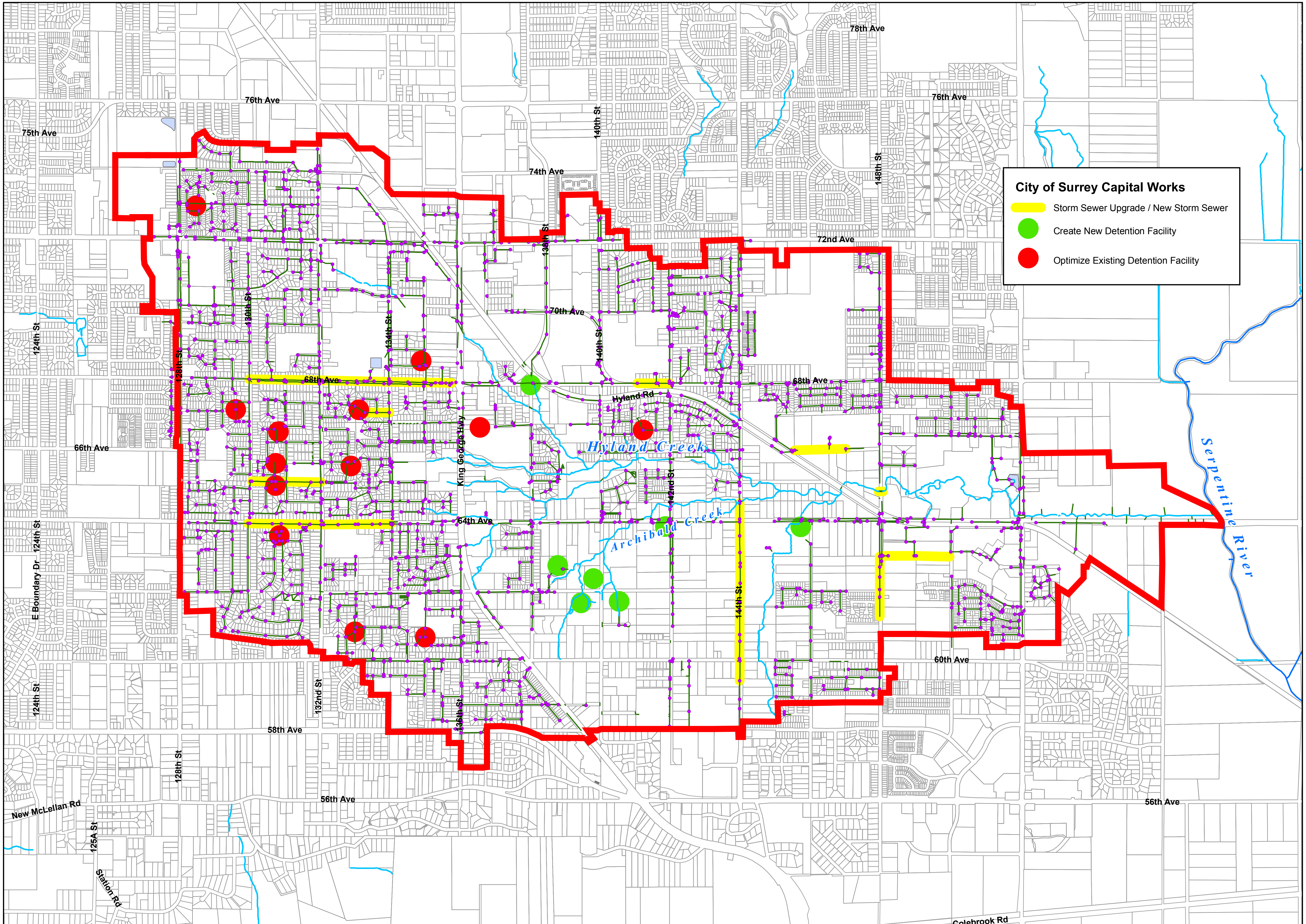
The locations of the capitals works are also shown on Figure 5.5. Further discussion on the need for these capital works projects is provided in Section 11.

5.3 Aquatic Habitat

5.3.1 Available Background Information and Data

Among the early studies conducted on Hyland Creek was a study of the benthic invertebrate community by Backman and Simonson in 1985. Three sites on the Hyland Creek main stem and three tributary sites were sampled. Sites on Hyland Creek were separated into high, medium and low gradient categories. Results at the high gradient site (low diversity and an abundance of moderately pollution-tolerant species) indicated water quality degradation [Backman and Simonson 1995; Simonson 1985]. Several instances of water quality problems in upper Hyland Creek were reported in the late 1980s and early 1990s and related to release of soapy water and liquid waste from a food processing plant, which resulted in odour and sewage fungus growth in the creek [Visser 1991]. These issues were subsequently resolved through improved connections with the sanitary sewer system.

As part of the watershed health assessment associated with the ISMP, the City of Surrey began a benthic invertebrate and water quality sampling program in 2005 and completed a second round of sampling in the spring of 2006. While the 2006 results were not available for this study, results from the 2005 sampling program were obtained and are discussed in Section 6.



Hyland Creek Integrated Stormwater Management Plan

Figure 5.5

CAPITAL WORKS PROGRAM

Hyland Creek Watershed Area

0 250 500
Metres

Scale 1:20 000

Source: City of Surrey
2005 Aerial Photography

Prepared By:
URBANSYSTEMS.
1072.0137.01 July 2007

U:\Projects_VAN\1072\0137\01\D-Drafting-Design-Analysis\GIS\mxd\Fourth_Report_Nov_9_06\Fig_5-5_Hyland_Capital_Works_Program.mxd Last revised by: sfadum on 12/11/2006 at 1:37:44 PM

A bioinventory of Hyland Creek [Envirowest 1995] provided reach-by-reach descriptions and identified aquatic and riparian values, fish passage obstructions and potential enhancement opportunities. Eight reaches (lengths of uniform fish habitat) and a number of subreaches accounted for the main stem and its tributaries (see Table 5.10 and Figure 5.6). In some cases, reaches identified by Envirowest [1995] cross one or more zones as identified by the ISMP. Table 5.10 is supplemented by additional observations made during the May 2006 field investigation for the ISMP. Assessment areas for the 2006 field investigation are shown on Figure 5.7.

In general, Hyland Creek has high spawning and rearing capability for salmon, and diverse aquatic habitat types through most of the main stem and larger tributaries, from the confluence with the Serpentine River to the King George Highway. Five culverts and one dam present partial or impassable barriers to fish migration. The culvert upstream of the King George Highway is completely impassable to fish [Backman and Simonson 1985; DFO 2006].

Table 5.10
Fish Habitat in Hyland Creek (summarized from Envirowest 1995)

Reach[1]	Description	Spawning Habitat	Rearing Habitat	Characteristics / Obstructions
1.0	Main stem from the Serpentine River to 152 St	low	high	Channelized into a low gradient glide and diked to prevent flooding onto adjacent agricultural fields. Substrate dominantly fines. No canopy; riparian cover low.
2.0	Main stem from 152 St to 148 St	low	high	Low gradient, meandering glides and pools. Open floodplain with shrubs and grasses the dominant cover. Substrate dominantly fines. Recent beaver activity evident.
2.1	Unnamed tributary to Hyland Creek, draining from the north	negligible	negligible	Fish passage barrier 115 m upstream of Hyland Creek. Supplies food and nutrient value to Hyland Creek.
2.2	Unnamed tributary to Hyland Creek, draining from the south	low	moderate	Shallow glides in the Hyland Creek floodplain; riffle-pool channel upstream towards 64 Ave. Substrate dominantly fines. Riparian cover from dense shrub layer.
3.0	Main stem from 148 St to confluence with R6 and R7	high	high	Dominantly glides to the east and riffle-pools to the west. Substrate dominantly gravels. Dense riparian vegetation with an established canopy. Some erosion evident.
3.1	Unnamed tributary to Hyland Creek, channelized along the railway	negligible	moderate	Flows channelized for most of reach. Substrates dominantly fines. Residential development encroached to within 5.0 m of top-of-bank in areas.

Reach[1]	Description	Spawning Habitat	Rearing Habitat	Characteristics / Obstructions
3.2	Unnamed tributary to Hyland Creek (confluence at 14336-66 Ave)	low	low	Channel primarily riffles with periodic glides. Substrates dominantly fines. Low base flows. Riparian vegetation impacted by residential encroachment.
4.0	Unnamed tributary to Hyland Creek (confluence 40 m south of the railway intersection)	moderate	moderate	Substrate dominated by gravels and clay hardpan. Riparian vegetation thin in some areas.
5.0	Archibald Creek from Hyland Creek to 62 Ave	High (variable)	High (variable)	Channel primarily riffle-pool and glides. Substrates dominantly gravel beds interspersed with fines upstream. Riparian vegetation impacted by residential development in some areas. Channel reinforcements occur throughout reach.
5.1	Unnamed tributary to Archibald Creek (locally known as Peggy Bear Creek)	low	low	Small channel with limited base flows. Riparian vegetation is limited and often replace with grass lawn. Many fish passage barriers exist.
5.2	Unnamed tributary to Archibald Creek (confluence at the 140 St alignment)	negligible	negligible	Small channel with limited base flows. Substrates predominantly clay hardpan. Several steep sections averaging 25% gradient would likely limit fish passage.
5.3	Unnamed tributary to Archibald Creek (confluence 130 m west of the 140 St alignment)	low	low	Channel displayed shallow riffle and glide morphology. Occasionally opened into ponded or wetland areas. Substrates dominantly fines or clay hardpan. Limited by low base flows.
6.0	Unnamed tributary to Hyland Creek (confluence 120 m east of 140 St)	high to moderate	high to low	Channel displayed riffle-pool and glide morphology. Some residential encroachment onto the top-of-bank is evident. Substrates dominantly gravels interspersed with fines. A culvert alongside 64 Ave may prevent upstream salmonid movement due to the restriction of light. A driveway culvert and riser pipe from an ornamental pond are additional barriers to fish passage.
6.1	Unnamed tributary to Reach 6.0 (confluence 75 m east of 138 St)	low	low	Small channel with limited base flows. Substrates dominated by fines.
6.2	Unnamed tributary to Reach 6.0 (confluence just south of 64 Ave)	high (low above KG Hwy)	high (low above KG Hwy)	Tributary with riffle-pool morphology. Substrates dominated by gravels. Perched culverts under 64 Ave and KG Hwy (1.3 m) impassable to salmonids.

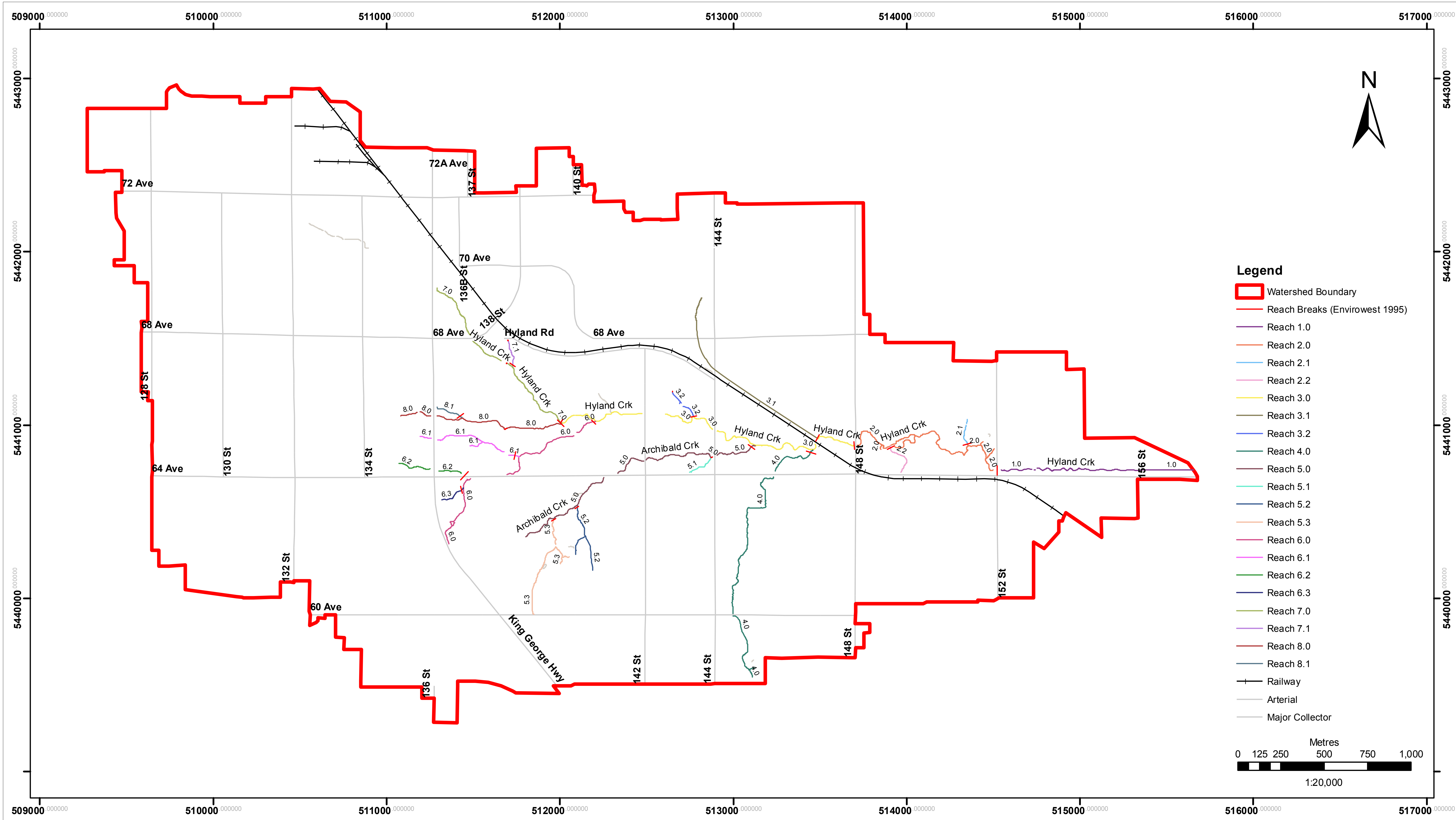
Reach[1]	Description	Spawning Habitat	Rearing Habitat	Characteristics / Obstructions
6.3	Unnamed tributary to Reach 6.0 (confluence 60 m south of 64 Ave)	moderate	moderate	Channel displays riffle-pool and glide morphology. Substrates dominated by fines, gravels, and clay hardpan. Boulder may restrict upstream movement of salmonids. KG Hwy also a barrier.
7.0	Main stem from R3 and R8 to 132 St and 71A Ave	high (low above KG Hwy)	high (low above KG Hwy)	Channel displays riffle-pool and glide morphology. Substrates dominated by gravels with some fines. Culverts under 138 St and 68 Ave may inhibit upstream fish migration. Impassable culvert at KG Hwy.
7.1	Unnamed tributary to R7 (confluence 40 m east of 138 St)	low to moderate	low to moderate	Channel primarily riffles with periodic glides. Pool habitats lacking. Substrates dominated by gravels and fines.
8.0	Unnamed tributary to Hyland Creek with a confluence in Hyland Creek Park	high (low above KG Hwy)	high (low above KG Hwy)	Channel primarily riffles-pool with periodic glides. Substrate dominated by gravels with some fines. Culvert under KG Hwy a fish barrier.
8.1	Unnamed tributary to Reach 8.0	moderate	moderate	Channel primarily riffles with periodic glides. Substrates dominated by gravels and fines.

Notes: King George Highway (KG Hwy)

1. Reaches shown in Figure 5.6

Sensitive Habitat Inventory Mapping (SHIM) was also conducted in March and April 2006 by MarLim Ecological Consulting Ltd., on behalf of the City of Surrey. The SHIM report provides detailed, geo-referenced information about stream habitat (erosion sites, modifications, obstructions, previous enhancement works) and identifies opportunities for restoration or improvement of fish habitat [Susan Owen, MarLim Ecological Consulting, pers. comm.]. Where available, SHIM information is incorporated into this ISMP report.

A watershed health assessment was also conducted for Hyland Creek [GVRD 1999] to provide predictions of change associated with population growth. The assessment measured intactness of the riparian corridor in the Hyland Creek watershed to be 55%, which was not expected to change between 1996 and 2036. The 41% total impervious area (TIA) measured in 1996 was predicted to increase to 63% in 2036 under growth strategies in place at that time. This increase would result in the watershed health rating dropping from "fair" in 1996 to "poor" in 2036.



PROJECT:	HYLAND CREEK ISMP
LOCATION:	HYLAND CREEK, SURREY, BRITISH COLUMBIA
PROJECT No:	1010479

CLIENT: URBAN SYSTEMS

TITLE: **REACH BREAKS**

HYLAND CREEK WATERSHED

DATE: 20-Dec-06

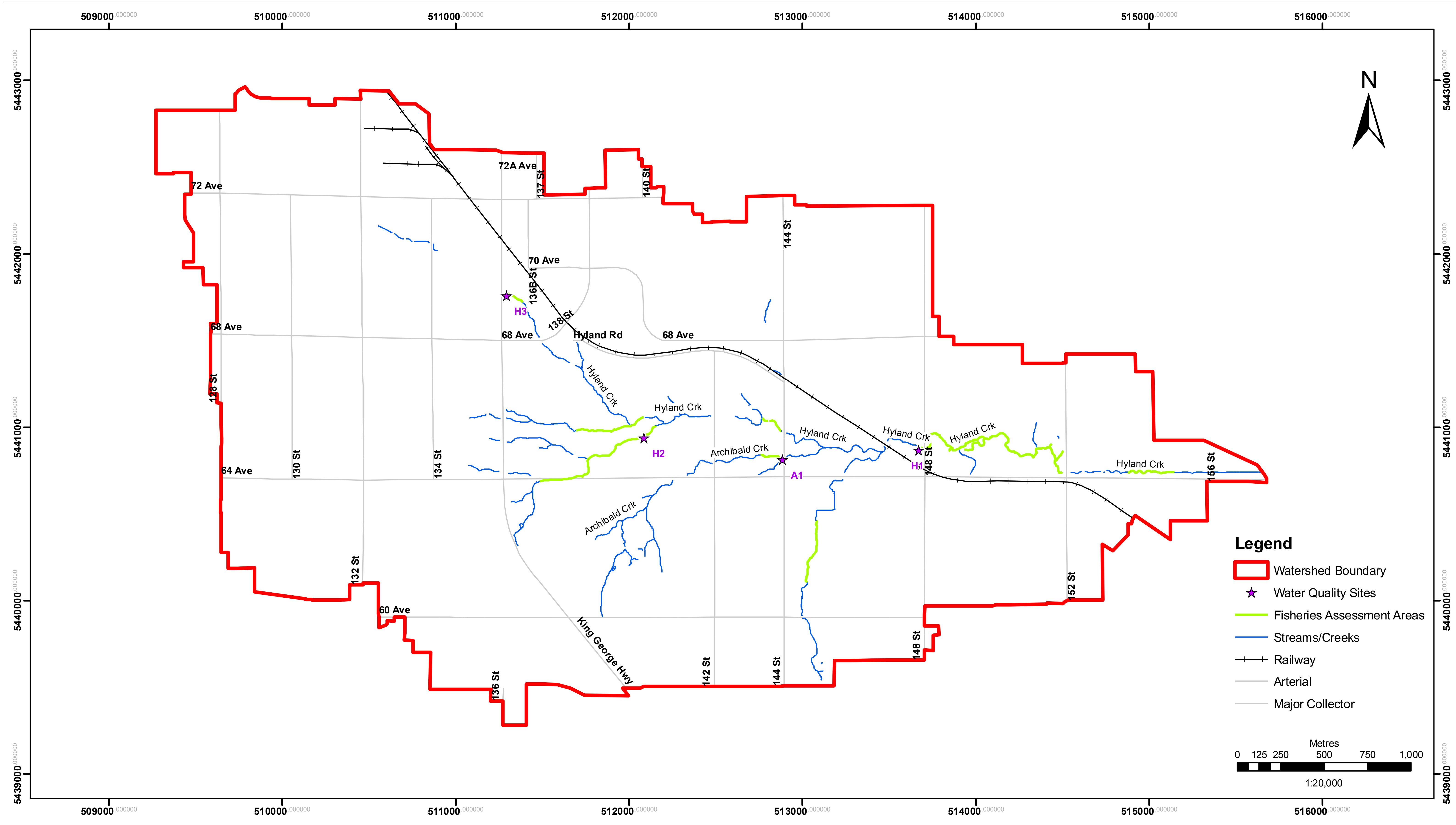
PROJECTION: UTM

AUTHOR: MC

APPROVED: KM

DATUM: NAD 83 - ZONE 10

FIGURE No. 5.6



PROJECT:	HYLAND CREEK ISMP
LOCATION:	HYLAND CREEK, SURREY, BRITISH COLUMBIA
PROJECT No:	1010479

Jacques Whitford

CLIENT: URBAN SYSTEMS

TITLE:

FISHERIES ASSESSMENT & WATER SAMPLING LOCATIONS

HYLAND CREEK WATERSHED

DATE:	PROJECTION:	FIGURE No.
20-Dec-06	UTM	5.7

AUTHOR:	APPROVED:	DATUM:
MC	KM	NAD 83 - ZONE 10

5.3.2 Stream Classification System

In 1995, the City of Surrey developed a watercourse classification system that colour coded the value of streams to fish (Table 5.11). Class A (red) indicates year-round presence of salmonid species, Class AO (dashed red) indicates fish presence mainly over winter, Class B (yellow) indicates non-fish bearing streams that contribute substantial amounts of food and nutrients to downstream waters and Class C (green) indicates no fish presence and no significant food and nutrient value (mainly ditches). Most tributaries in the Hyland Creek watershed were designated Class A [City of Surrey 1995], as illustrated in Figure 5.8.

Table 5.11
City of Surrey Stream Classification System

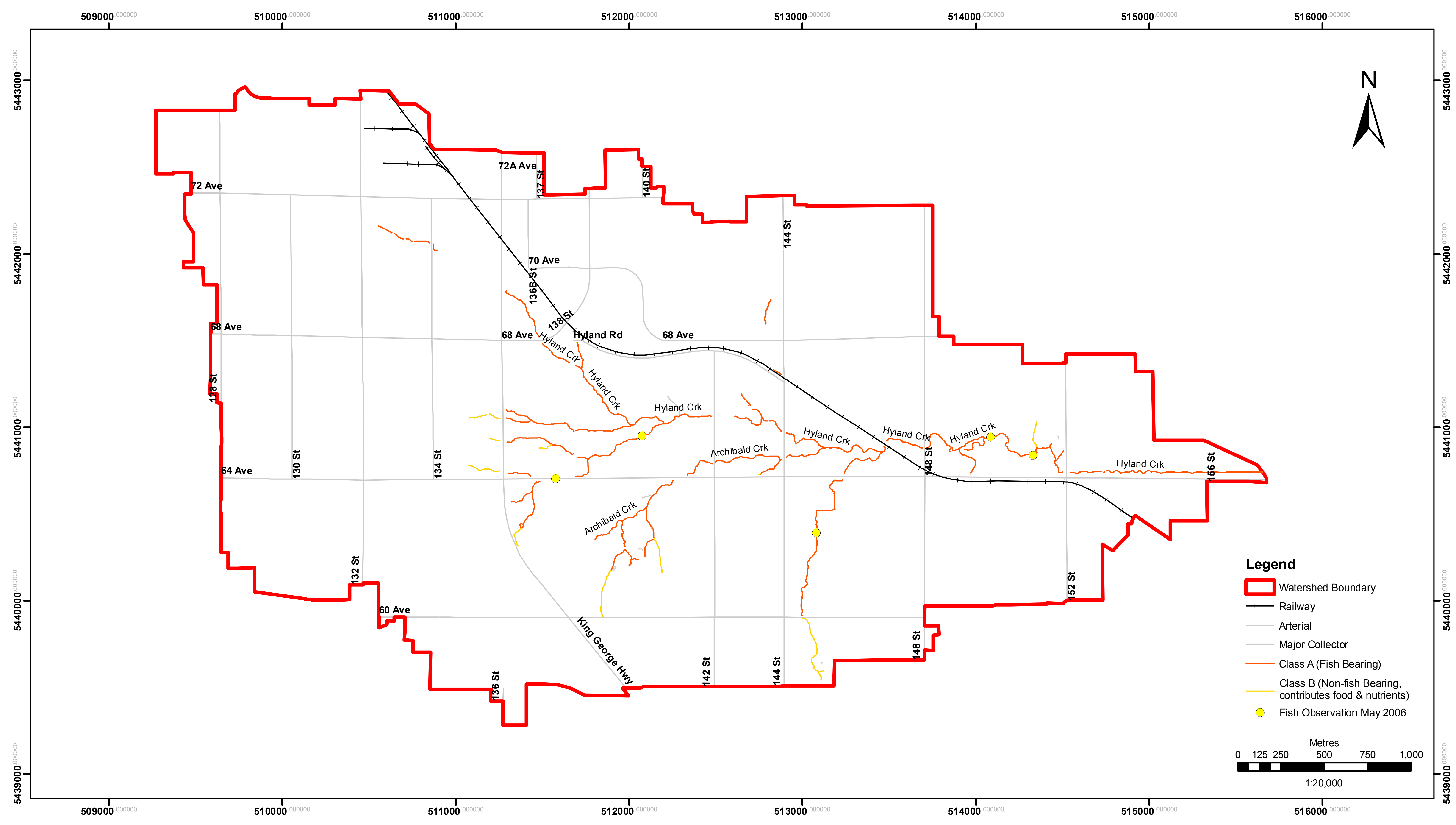
Class[1]	Map Colour	Definition
A	Red	Inhabited by salmonids year round or potentially inhabited year round.
AO	Red dashed	Inhabited by salmonids primarily during the over-wintering period or potentially inhabited during the over-wintering period with access enhancement.
B	Yellow	Significant food/nutrient value. No fish present.
C	Green	Insignificant food/nutrient value. No fish present.

1. (Source: City of Surrey) – 'The phrase "No fish present" for stream classifications B and C implies that fish presence is unknown. However, based on habitat characteristics such as stream gradient, access and proximity to known fish-bearing waters (and limited sampling results) in most cases it may be interpreted as "No Fish are Present". The distinction must be made between fish-bearing and non-fish-bearing waters in order for the City to apply the appropriate mitigation and compensation procedure with respect to instream works for both "scheduled" and "emergency" project types.'

5.3.3 Fish Species

There are records of all five Pacific salmon species, several trout species and numerous other fish species in Hyland Creek (Table 5.12). Of those known to be present in Hyland Creek, the BC Conservation Data Centre lists Dolly Varden as blue-listed and sturgeon as red-listed. If cutthroat trout are the subspecies *O. clarki clarki*, they too are blue-listed.

It is noted that many records have not been verified by expert taxonomists, some are old and may not indicate current conditions for the watershed, and some may reflect isolated occurrences. For example, it is unlikely that sockeye or kokanee (a land-locked subspecies of sockeye) inhabit Hyland Creek, given that both species require lake habitat for part of their life. Sturgeon prefer deep (10 m), high velocity rivers with fine substrate, so are unlikely to be present in Hyland Creek, or are likely restricted to the lower reaches near the confluence with the Serpentine River. Similarly, the likelihood of Dolly Varden occurrence is low, given their preference for deep runs and pools in the cold headwaters of small to large rivers.



Jacques Whitford	PROJECT: HYLAND CREEK ISMP	CLIENT:	TITLE:	DATE: 20-Dec-06
	LOCATION: HYLAND CREEK, SURREY, BRITISH COLUMBIA	URBAN SYSTEMS	**STREAM CLASSIFICATION AND FISH HABITAT DISTRIBUTION**	PROJECTION: UTM
	PROJECT No: 1010479		HYLAND CREEK WATERSHED	AUTHOR: MC; APPROVED: KM; DATUM: NAD 83 - ZONE 10
				FIGURE No. 5.8

Table 5.12
Fish Species Reported in Hyland Creek and Tributaries

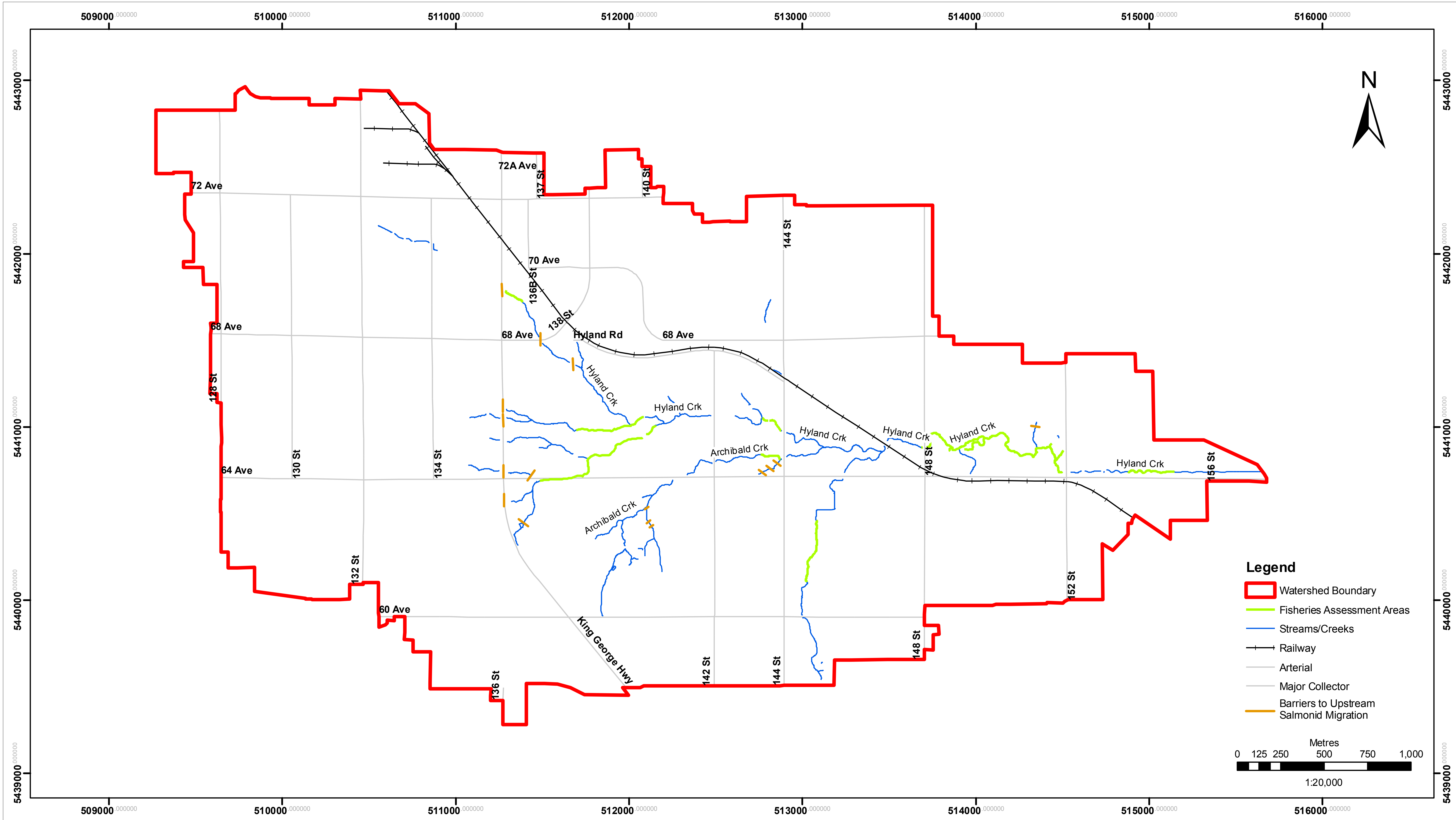
Salmonid Species	Other Fish Species
chinook salmon (*Oncorhynchus tshawytcha*)	sturgeon (*Acipencer* sp.)
chum salmon (*O. keta*)	brown bullhead (*Ictalurus nebulosus*)
coho salmon (*O. kisutch*)	coastrange sculpin (*Cottus aleuticus*)
kokanee salmon (*O. nerka*)	prickly sculpin (*C. asper*)
pink salmon (*O. gorbuscha*)	lamprey (*Petromyzontidae*)
sockeye salmon (*O. nerka*)	peamouth (*Mylocheilus caurinus*)
cutthroat trout (*O. clarki*)	threespine stickleback (*Gasterosteus aculeatus*)
anadromous cutthroat trout (*O. clarki*)	pumpkinseed (*Lepomis gibbosus*)
Dolly Varden (*Salvelinus malma*)	redside shiner (*Richardonius balteatus*)
steelhead salmon (*O. mykiss*)	
rainbow trout (*O. mykiss*)	

Source: Fisheries and Oceans Canada (DFO) [2006] and Envirowest [1995]

5.3.4 Habitat Quality

Aquatic habitat was assessed at several locations in the watershed, as shown in Figure 5.7. In contrast to reports from the early 1990s, there were no visual indications of sewage fungus or thick algal mats and no foul doors noted during the May 2006 stream survey, although a small patch of orange iron bacteria was observed in a slow moving side channel.

A number of obstacles present partial or impassable barriers to salmonid migration. Table 5.13 and Figure 5.9 summarize the existence of currently identified barriers, based on reports by Envirowest [1995] and updated in the May 2006 ISMP field survey and 2006 SHIM survey of the entire watershed [MarLim 2006].



Jacques Whitford	PROJECT: HYLAND CREEK ISMP LOCATION: HYLAND CREEK, SURREY, BRITISH COLUMBIA PROJECT No: 1010479	CLIENT: URBAN SYSTEMS	TITLE: **BARRIERS TO MIGRATION** HYLAND CREEK WATERSHED	DATE: 20-Dec-06 AUTHOR: MC APPROVED: KM PROJECTION: UTM DATUM: NAD 83 - ZONE 10 FIGURE No. 5.9

Table 5.13
Barriers to Salmonid Migration in Hyland Creek and Tributaries, 2006

Zone	Reach[1]	Location	Description
1, 1A	6.2, 7.0, 8.0, 8.1	King George Highway	Culvert (~35 m) under King George Highway. Perched 1.3 m at R 6.2.
1	6.3	Upstream of King George Highway	Extensive storm network replacing native channel. Not passable to fish.
1A	7.0	138 Street	Culverts (~35 m) at a steep gradient and may inhibit upstream fish migration.
1A	7.0	68 Avenue	Perched culvert (0.8 m) would inhibit upstream fish migration.
2	6.2	64 Avenue	Perched culvert impassable to salmonids.
2A	2.1	115 upstream of Hyland Creek confluence	Fish passage barrier (debris jam).
3	5.1	30 m upstream of confluence with Archibald Creek	Steep culvert may impede the upstream migration of salmonids.
3	5.1	~65 m upstream of confluence with Archibald Creek	A weir may impede upstream movement of salmonids.
3	5.1	Outlet to 14351 64 Avenue	A wood grill would impede the upstream movement of salmonids.
3	5.2	5 m upstream of Archibald Creek	Steep gradients at 25% slope restrict upstream movement of fish.
3	5.2	75 m upstream of Archibald Creek	Steep gradients at 25% slope restrict upstream movement of fish.
3	5.2	105 m upstream of Archibald Creek	Steep gradients at 25% slope restrict upstream movement of fish.
3	6.0	6280 King George Highway	Culvert under driveway and riser pipe from an upstream pond prohibit the upstream movement of salmonids.

1. Reaches defined by Envirowest [1995] – see Table 5.10 and Figure 5.6

The most significant barriers may be the culverts under King George Highway, which are completely impassable to fish [Backman and Simonson 1985; DFO 2006]. The 2006 field survey found that many obstructions previously described by Envirowest [1995], such as debris jams in Reach 6.0 in Zone 2, are now clear. Reach 6.0 (further upstream in Zone 3) has also been cleared of a barrier at 64 Avenue. Previously, a 60 m culvert with two bends eliminated light from the 64 Avenue culvert, thus restricting upstream movement of salmonids. A channel now carries flow along 64 Avenue and a foraging heron and fry were observed here during the 2006 survey. A barrier on Archibald Creek (Reach 5.0) at 64 Avenue was also removed when the road was widened and the culvert replaced. Several blockages were previously documented for the tributary upstream of H2 towards 138 Street, although the 2006 field investigation confirmed that these had been removed and fish passage re-established. Cleared obstacles are not included in Table 5.13. Even though this table identifies a number of barriers in the Hyland watershed, potential salmonid distribution is extensive due to the location of the barriers on small tributaries (Reach 2.1, Reach 5.1, Reach 5.2) or in the Hyland Creek headwaters close to and including the King George Highway.

Barriers of a less permanent nature include the many beaver dams in the lower part of Zones 2 and 2A, between 148 Street and 152 Street and in Zone 4 east of 152 Street [Susan Owen, MarLim Ecological Consulting, pers.l comm.]. Beaver dams can reduce fish passage, depending on the time of year and extent of blockage, but also improve fish habitat by increasing complexity of the system (e.g. side channels, pools, instream debris). They also can be temporary. For example, blockages and impoundments related to beaver dams near 152 Street were considered significant during the March 2006 SHIM survey, but were not apparent in the May 2006 ISMP survey.

Several enhancement activities such as bridging, side channel development, riparian planting, bank stabilization and instream habitat enhancement (placement of large woody debris and boulder clusters) have taken place on Hyland Creek [DFO 2006]. Fish were observed in a pool just downstream from water sampling site H2 during the May 2006 field investigation.

5.4 Wildlife and Terrestrial Habitat

5.4.1 Available Background Information and Data

Limited data and literature exists concerning wildlife and terrestrial habitat conditions within the Hyland Creek watershed. Most of the available information concerns fish and fish habitat. However, the following commentary was prepared based on professional knowledge of the area and details available from the BC Conservation Data Centre.

5.4.2 Wildlife

Wildlife using the watershed is likely to include small mammals (e.g. mice and voles), skunks, racoons, coyotes and a wide range of birds, including songbirds, small raptors and herons. Nesting by songbirds and hunting, foraging, shelter and migratory stopovers by other animals and birds constitute the anticipated use of the existing natural habitat. Amphibians such as tree frog, long-toed salamander, northwestern salamander rough-skinned newt, ensatina and red-legged frog, and reptiles, such as garter snake and perhaps northern alligator lizard, are also likely to inhabit the watershed.

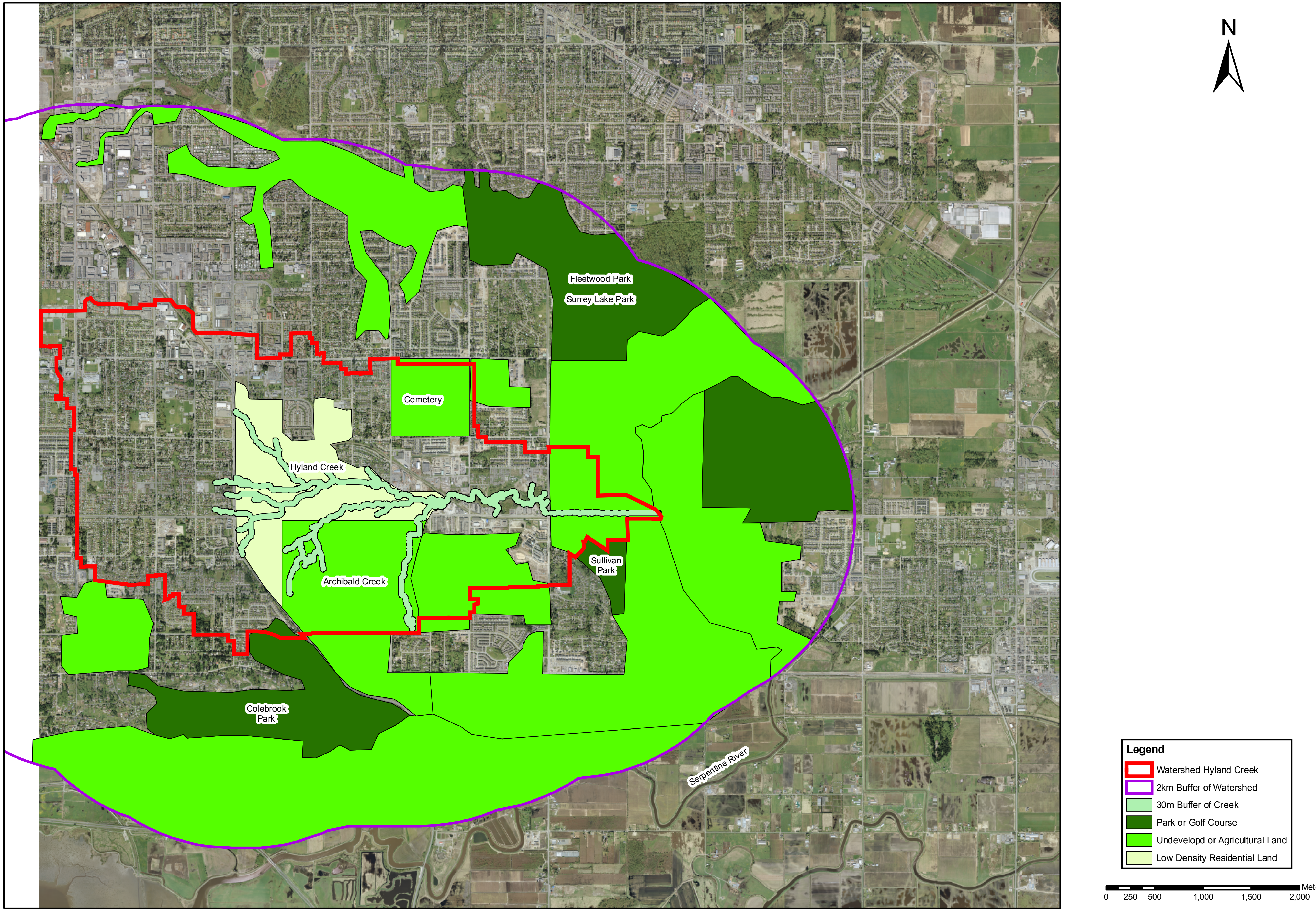
Given that much of the watershed has been developed, many of the remaining patches of natural habitat are small and fragmented, thus limiting the watershed's ability to support mammals with large home ranges, such as black-tailed deer, while supporting the presence of tolerant species such as raccoon and coyote. However, reports of black tailed deer at Hyland Creek near 148 Street were made as recently as 2005 [Lanny Englund, City of Surrey, pers. comm.]. Existing patches provide habitat for smaller mammals, such as voles, shrews, rodents and songbirds, although the small size of these patches leads to a high proportion of edge habitat, which is typically inhabited by nest predators (e.g. crows and jays) or opportunistic species (e.g. starlings), further limiting the suitability of the area to native, more desirable songbird species [Paton 1994; Flaspohler 2001; Deng and Gao 2005].

5.4.3 Wildlife Corridors

Wildlife corridors within and outside the watershed are shown in Figure 5.10. Given the extent of urbanization in the watershed, the quality of wildlife corridors is tenuous and expected to decrease as areas develop further. Riparian habitat along many areas of Hyland Creek provides the main migration corridors within the watershed. Parks also provide larger areas of undeveloped habitat for wildlife. Maintaining these linkages will be important considerations for land use planning in future development areas. If adequate protection is in place, the riparian corridors of Hyland Creek and Archibald Creek, in conjunction with golf courses and agricultural land, will support wildlife movement to varying levels of success. The level of wildlife use depends on the extent of connectivity to natural areas, width of the corridor, and level of human disturbance and urbanization in the corridor.

Currently the most noteworthy green corridors (Figure 5.10) are the following:

- Hyland Creek and Archibald Creek (mostly, east-west movement)
- Serpentine River, Colebrook Park and Mound Farm Park (east-west movement)
- Agricultural lands (east-west and north-south movement, in mostly unforested habitat)
- Sullivan Park, in conjunction with natural areas to the west (eastward movement from Hyland Creek to agricultural lands)
- Surrey Lake and Fleetwood Park, in combination with agricultural lands (a linkage from Bear Creek to the Serpentine River, a northward connection to Bothwell and Fern Park)



*NB: Orthophoto coverage for the western portion of the 2km buffer is unavailable

Jacques Whitford

PROJECT: HYLAND CREEK ISMP	CLIENT: URBAN SYSTEMS	TITLE: **TERRESTRIAL HABITAT LINKAGE BEYOND THE HYLAND CREEK WATERSHED** HYLAND CREEK WATERSHED	DATE: 20-Dec-06; PROJECTION: UTM; FIGURE No. **5-10**
LOCATION: HYLAND CREEK, SURREY, BRITISH COLUMBIA			AUTHOR: MC; APPROVED: KM; DATUM: NAD 83 - ZONE 10
PROJECT No: 1010479			

5.4.4 Terrestrial Habitat

The Hyland Creek watershed is located within the Coastal Western Hemlock Zone (CWH xm1 biogeoclimatic zone), characterized by warm, dry summers and moist, mild winters with relatively little snowfall. This zone is the wettest zone in BC and extends over the majority of Vancouver Island, the Queen Charlotte Islands and the Coast Mountains from the Alaskan Panhandle south to the Lower Mainland (south side of Fraser River to Chilliwack), at elevations between sea level and approximately 700 m [Green and Klinka 1994]. Appendix J contains a list of common and scientific names of plants that occur in the watershed.

Typical forests within the CWH xm1 sites are dominated by Douglas-fir, accompanied by western hemlock and western red cedar. Major understory species include salal, dull Oregon-grape and red huckleberry [Green and Klinka 1994]. Vegetation in undeveloped areas of the watershed consists of early seral stages of deciduous woodland and old-field habitats, with tree species such as paper birch and lesser amounts of bigleaf maple and red alder. Predominant understory shrubs are Himalayan blackberry, trailing blackberry, red elderberry, and mountain ash species.

Site specific observations of terrestrial habitat were made in May 2006 at locations indicated on Figure 5.11.

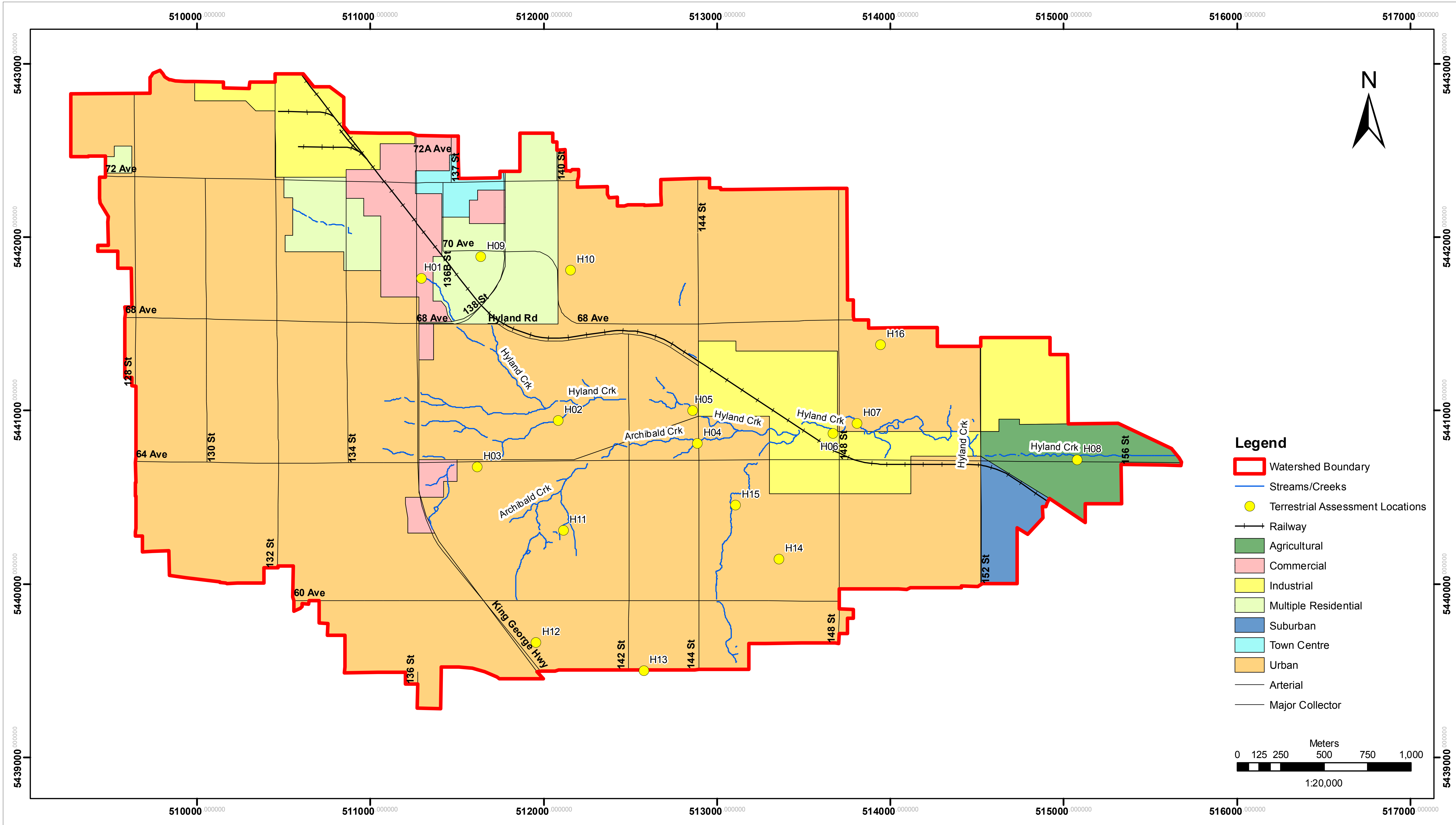
5.4.5 Terrestrial Habitat and Wildlife Usage by Zone

No habitat assessments were conducted in Zone 1, given the amount of development in the area.

The band-tailed Pigeon, listed as a species of conservation concern, can inhabit a range of disturbed and undisturbed habitats, so has the potential to occur anywhere in the watershed.

In Zone 2, the northern portion of Hazelnut Meadows Community Park (Photo 5.4 and location H03 on Figure 5.11) provides a large area of natural habitat. The park is comprised of a mixed-wood forest dominated by deciduous trees, with a well-developed understory in some areas and minimal amounts of coarse woody debris. However, there are also areas of highly disturbed or very little understory. Dominant canopy species include red alder, bigleaf maple, black cottonwood, Douglas-fir and western red cedar. Understory species include salmonberry, Indian

Photo 5.4:
Typical Undisturbed Habitat in Hazelnut Meadows Community Park, Zone 2



Jacques Whitford	PROJECT: HYLAND CREEK ISMP	CLIENT: URBAN SYSTEMS	TITLE: LAND USES AND LOCATIONS OF TERRESTRIAL HABITAT ASSESSMENT — HYLAND CREEK WATERSHED
	LOCATION: HYLAND CREEK, SURREY, BRITISH COLUMBIA		DATE: 20-Dec-06
	PROJECT No: 1010479		AUTHOR: MC; APPROVED: KM
			PROJECTION: UTM; DATUM: NAD 83 - ZONE 10
			FIGURE No. 5.11

plum, vine maple, cascara, red elderberry, trailing blackberry, thimbleberry, red huckleberry, common snowberry and Nootka rose. Herb species observed include Pacific bleeding heart and piggy-back plant. Three species of fern were also observed in the understory: bracken fern, spiny wood fern, and lady fern. This forest provides suitable habitat for song birds and small mammals, although, due to its isolation, likely does not provide habitat for mammals with large home ranges, such as deer. More tolerant mammals, such as raccoon and coyote, may be found in this habitat.

There is relatively intact riparian habitat in Zone 2 along Hyland Creek and its tributaries between King George Highway and 144 Street (Photo 5.5 and location H04 on Figure 5.11). Riparian vegetation consists of mixed-wood forest, with red alder, bigleaf maple and western red cedar being the dominant tree species. The well developed understory is dominated by salmonberry, Indian plum, willow, Himalayan blackberry, lady fern and skunk cabbage and contains some coarse woody debris. This riparian area provides suitable habitat for birds and small mammals. More tolerant mammals, such as coyotes and raccoons, and red-legged frogs, likely also use this habitat and there is the potential for Pacific water shrew to be found here.

Photo 5.5:
Hyland Creek at 140 Street, Zone 2

The eastern end of Zone 2 (Photo 5.6 and location H05 on Figure 5.11) has a large tract of riparian habitat along Hyland Creek between 148 Street and 152 Street. The habitat here differs from that of upstream areas, as the creek is slow flowing, with a large floodplain dominated by exotic reed canary grass and willow. Other vegetation includes policeman's helmet, skunk cabbage and stinging nettle. Mallard and belted kingfisher were observed during the May 2006 survey and there was extensive evidence of beaver use (dam and lodge building), which typically results in modification of instream and riparian habitat. It is likely that red-legged frog and possible that Pacific water shrew use this habitat.

Photo 5.6:
Floodplain Section of Hyland Creek between
148 Street and 152 Street, Zone 2

Some areas of Zone 2 also have the potential to support species of conservation concern, including red-legged frog, Pacific water shrew, Great Blue Heron and American Bittern in well-vegetated riparian areas, Trowbridge's shrew in upland forests, and Western Screech Owl in upland and riparian forests.

Photo 5.7:
Representative Deciduous Forest Found Within Zone 1A and 2A

In Zone 1A, there is one large (6.65 ha) parcel of forest located south of the library between 138 Street and the railway line; this City-owned property is currently zoned industrial. This site (Photo 5.7 and location H09 on Figure 5.11) contains deciduous forest with minimal amounts of conifers and a well developed, dense understory. The dominant tree species is red alder with some black cottonwood and minimal amounts of western red cedar. Understory species include red elderberry, salmonberry, mountain ash species, thimbleberry, Himalayan blackberry, trailing blackberry, Indian plum and vine maple. Herbs observed in the understory included false lily-of-the-valley, Pacific bleeding heart, spiny wood fern, sword fern and bracken fern. This forest provides suitable habitat for song birds and small mammals, although, due to its isolation, likely does not provide habitat for mammals with large home ranges, such as deer. More tolerant mammals, such as raccoon and coyote, may be found in this habitat. American Robin (*Turdus migratorius*) and Black-capped Chickadee (*Poecile atricapilla*) were observed at this location during the May 2006 survey.

Riparian habitat in Zone 1A (Photo 5.8 and location H02 on Figure 5.11) is comprised of mixed-wood forest dominated by red alder, western red cedar, Douglas fir and bigleaf maple. Species dominating the understory include Indian plum, Himalayan blackberry, salmonberry, beaked hazelnut, mountain ash species and vine maple. This riparian area may provide habitat for the red-legged frog but is unlikely to support Pacific water shrew. The riparian area is developed up to top-of-bank and the understory is highly disturbed, with very little coarse woody debris.

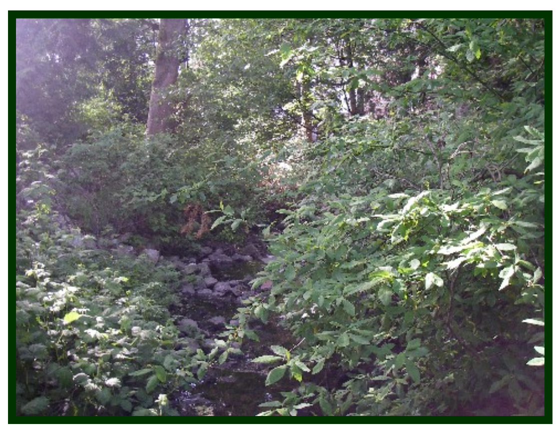


Photo 5.8:
Example of Riparian Habitat Within Zone 1A

The remaining natural vegetation in Zone 2A occurs within a narrow riparian area of Hyland Creek, within metres of top-of-ravine (Photo 5.9 and location H06 in Figure 5.11). Red alder dominates the canopy, with grasses, Himalayan blackberry and salmonberry dominating the understory. There is potential for red-legged frog to be found within riparian habitat; however, it is unlikely that Pacific water shrew would occur here, due to the lack of well developed understory and coarse woody debris.

Photo 5.9:
Hyland Creek Riparian Corridor Within Zone 2A

Undeveloped land in Zone 3 includes the riparian habitat of Archibald Creek and its tributaries. Riparian habitat along Archibald Creek is well vegetated, with red alder and black cottonwood dominant in the canopy and Himalayan blackberry dominant in the understory, along with minor amounts of Indian plum and salmonberry. There is potential for red-legged frog to be found within the Archibald Creek corridor and similar wet zones, although it is unlikely that Pacific water shrew would use this habitat, due to the lack of coarse woody debris. A Great Blue Heron was observed foraging within the stream adjacent to 64 Avenue, west of 138 Street during the May 2006 field investigation. American Bittern may also occur in well-vegetated riparian areas, along with Trowbridge's shrew in upland forests, and Western Screech Owl in upland and riparian forests.

A small patch of coniferous forest is present along Archibald Creek in Zone 3 (Photo 5.10). There is a well developed understory and some open areas amongst the canopy. Tree species observed include Douglas-fir and western red cedar, with minor amounts of red alder and bigleaf maple. Understory species include dull Oregon grape, red elderberry, vine maple, red huckleberry, Indian plum, mountain ash, Himalayan blackberry, trailing blackberry, salmonberry, vanilla leaf, sword fern and lady fern. Forest songbirds such as

Photo 5.10:
Dry or Mesic Site Within Zone 3

American Robin and Black-capped Chickadee were observed during the site visit. This site is on a hillside and it is unlikely that red-legged frog or Pacific water shrew would occur here.

In the agricultural lands in Zone 4, riparian habitat along Hyland Creek is devoid of natural vegetation. The dominant riparian species is the exotic reed canary grass; however, replanting has occurred and there are some immature trees and shrubs. Red-legged frog may occur here, but Pacific water shrew tend to inhabit areas with greater riparian cover. Barn Owls likely use the agricultural fields for hunting. Other species of conservation concern that might be found in Zone 4 include Great Blue Heron and Western Screech Owl. Typical habitat in the drainage ditches is shown in Photo 5.11 (location H08, Figure 5.11).

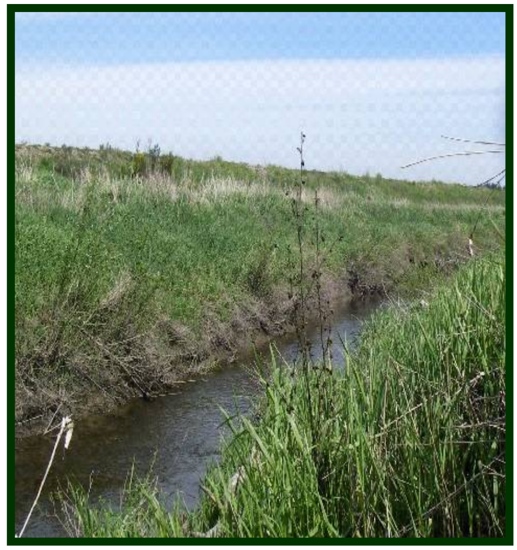


Photo 5.11:
Agricultural Drainage Ditch within Zone 4

5.4.6 Species of Conservation Concern

Some plant and animal species, or their habitat, are of conservation concern, and are listed by the BC Conservation Data Centre (BCCDC) as either blue-listed (ecological communities and indigenous species and subspecies of special concern in British Columbia) or red-listed (ecological communities and indigenous species and subspecies that are extirpated, endangered or threatened in British Columbia). The federal *Species at Risk Act* also has requirements for protection of certain species. Protection of these species, or their habitat, will be necessary during development in the watershed.

The Province of British Columbia will be changing the British Columbia *Wildlife Act* in the near future to include greater protection for species at risk. The *Wildlife Amendment Act*, 2004 received third reading and Royal Assent in May 2004 and changes will be brought into force through regulation. Components of the changes that may affect land development include prohibitions respecting species at risk and specific legislation stating that no compensation is to be paid for reduced land values or damages/losses resulting from the new legislation. The upcoming changes encompassed in the *Wildlife Amendment Act* that may affect potentially developable lands are:

"6.1 (1) *A person must not do any of the following:*

a) kill, harm, harass, capture or take a species individual of a species at risk, except as authorized by regulation or by a permit or agreement under this section;

> *(b) damage or destroy a species residence of a species at risk, except as authorized by regulation or by a permit or agreement under this section*;"

Under the amendments, "*species residence*" is defined as:

> "*a place or area in, or a natural feature of, the habitat of the species at risk, or a class of such a place, area or natural feature that is habitually occupied or used as a dwelling place by one or more species individuals of the species at risk*".

In effect, lands occupied by rare, threatened or endangered species on a regular basis will be protected from development under these provisions.

To track the status of species at risk, the BCCDC maintains a database of rare vertebrates for each Forest District in British Columbia. Species or populations at high risk of extinction or extirpation are placed on the red list, and are candidates for formal Endangered Species status. Species or subspecies considered to be of Special Concern are placed on the blue list. The yellow list includes all remaining wildlife species. Yellow-listed species are not considered "at risk." However, the BCCDC maintains a "watch list" of yellow-listed taxa that have a small range or low abundance in the province, have shown provincial declines, or are susceptible to perceived long-term threats.

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) is the federal equivalent of the BCCDC. COSEWIC is a committee of experts that assesses and designates which wild species are in some danger of disappearing from Canada. COSEWIC ratings for species are defined as follows:

Extinct – A species that no longer exists.

Extirpated – A species that no longer exists in the wild in Canada, but occurs elsewhere (for example, in captivity or in the wild in the United States).

Endangered – A species facing imminent extirpation or extinction.

Threatened – A species likely to become endangered if limiting factors are not reversed.

Special Concern – A species of special concern because of characteristics that make it particularly sensitive to human activities or natural events.

Not at Risk – A species that has been evaluated and found to be not at risk.

Data Deficient – A species for which there is insufficient scientific information to support status designation.

A COSEWIC designation of Extirpated, Endangered, Threatened or Special Concern makes a species potentially eligible for listing on Schedule 1 of the *Species at Risk Act* (*SARA*). The *SARA* provides special protection for Extirpated, Endangered and Threatened species and their critical habitats, and it mandates the development of management plans for species of Special Concern.

When *SARA* received royal assent in December 2002, Schedule 1 contained 233 plant and animal species. Since then, an additional 112 species have been added to Schedule 1.

The BCCDC has five records for blue-listed or red-listed species (two animal and three plant species) within approximately 5 km of Hyland Creek:

- 1989 report of a blue-listed American Bittern (*Botaurus lentiginosus*) observed near Elgin Road at the Serpentine Fen
- 1969 poorly documented report of a red-listed mountain beaver (*Aplodontia rufa rufa*) in Langley
- 1954 record of blue-listed Vancouver Island Beggarticks (*Bidens amplissima*) in a roadside ditch in Fleetwood
- 1989 record of blue-listed dotted smartweed (*Polygonum punctatum*) under the skytrain tracks west at Scott Road
- 1991 occurrence report for the blue-listed small-spike rush (*Eleocharis parvula*) at the Serpentine River east of Highway 99A

Other species of conservation concern for the Hyland watershed, and their preferred habitat, are described in Table 5.14. Species include red-legged frog, Pacific water shrew, Trowbridge's shrew, Great Blue Heron, American Bittern, Band-tailed Pigeon, Barn Owl and Western-screech Owl. In addition to the presence of preferred habitat for some species within the Hyland watershed, environmental assessment reports mention the presence of red-legged frogs and Pacific water shrew in other areas of Surrey, for example in north Surrey, south Fraser Perimeter Road and at the Highway 10 / 8 Ave widening project [L. Englund, City of Surrey, pers. comm.].

Table 5.14
Preferred Habitat of Wildlife Species of Conservation Concern

Species[1]	Preferred Habitat	Potential Locations in Hyland Watershed
red-legged frog (*Rana aurora*) Special Concern Blue-listed	Occurs in southwestern BC, in moist forests and treed wetlands. Adults can be found on land at a distance from water if weather is damp and logs or other debris are available for shelter. Breed in ponds or slow moving streams during late winter or early spring.	Riparian areas of Zone 2 and Zone 3
Pacific water shrew *(Sorex bendirii*) Threatened Red-listed	Limited to lowland riparian forests and marshes (usually below 600 m) and prefers habitat containing a moderate amount of ferns, mosses and rocks, a low amount of grass and exposed soil and a high percentage of fine litter [Environment Canada 2006].	Riparian areas of Zone 2 and Zone 3
Trowbridge's shrew (*Sorex trowbridgii*) Blue-listed	Occurs in BC in the Lower Mainland corridor to Boston Bar. Found in low elevation (0 to 1820 m) coastal stands, preferring habitat with dry loose leaf litter or swampy woods.	Forested areas of Zone 2 and 3
Great Blue Heron (*Ardea herodias fannini*) Special Concern Blue-listed	Occurs along the Pacific coast and occasionally in the B.C. interior. Breeds in forested locations close to wetland feeding areas.	Riparian areas of Zone 2 and 3 and agricultural fields of Zone 4
American Bittern (*Botaurus lentiginosus*) Blue-listed	Breeds in wet areas with dense growths of tall emergent vegetation or grasses adjacent to freshwater sloughs, marshes, swamps, protected sections of lakes up to 1300 m elevation [Fraser *et al*. 1999].	Riparian areas of Zone 2 and 3 and agricultural fields of Zone 4
Band-tailed Pigeon (*Columba fasciata*) Blue-listed	In coastal BC to 1,830 m elevation, frequents a wide range of disturbed and undisturbed habitats [Campbell *et al.* 1990].	Potential to occur anywhere in the watershed
Barn Owl (*Tyto alba*) Special Concern Blue-listed	Nests solitarily, usually in agricultural areas, sometimes along the edges of open woodlands. Most nests occur in man-made structures such as wooden barns and nest boxes. Hunt over agricultural fields	Suitable habitat present in agricultural portions of study area (Zone 4)
Western Screech Owl (*Megascops kennicottii kennicottii*) Special Concern Blue-listed	Occurs along the coast of BC at lower elevations in treed urban and suburban environments, and at the edge of forested habitats close to riparian, open wetlands or fields [COSEWIC 2002].	Riparian and forested areas of Zones 2 and 3 and may forage in agricultural fields of Zone 4

1. Blue or Red-listed according to BC CDC [2006], Threatened or Special Concern according to COSEWIC [2006]

5.5 Groundwater and Hydrogeology

5.5.1 Available Background Information and Data

A desktop review of available geologic and topographic maps for the Hyland Creek watershed, as well as on-line water well and aquifer data from the Ministry of Environment's British Columbia Water Resources Atlas (BCWRA)[4] and selected previous groundwater study results (prepared by other Consultants for the area) were reviewed as part of the ISMP. In particular, the hydrogeological assessment prepared by Piteau Associates Engineering Ltd. [Piteau 1996] for the South Newton Neighbourhood Concept Plan (NCP) was reviewed in detail.

5.5.2 Surficial Geology

The surficial geology of the Hyland Creek watershed is comprised primarily of Capilano Sediments (medium to coarse sand, as well as marine and glaciomarine silt loam to clay loam) and Vashon Drift (lodgement till and minor flow till containing lenses and interbeds of glaciolacustrine laminated stony silt) [Geological Survey of Canada 1977]. Surficial geology in the watershed is shown on Figure 5.12.

As shown on Figure 5.12, materials mapped in the Hyland Creek watershed include the Salish Sediments sub-units SAb and SAh, Capilano Sediment sub-units Cb, Cd and Ce, Vashon Drift-Capilano Sediment glacial drift deposits mapped as unit VC, and Vashon Drift sub-unit Va. Table 5.15 summarizes expected ranges of hydraulic conductivity for each sub-unit mapped in the Hyland Creek watershed based on available material descriptions [Geological Survey of Canada 1977], published values of hydraulic conductivity [Freeze *et al*. 1986] and the results of the comprehensive "Hydrogeological Assessment for the South Newton Neighbourhood Concept Plan" prepared by Piteau in 1996.

Materials with higher saturated hydraulic conductivities (i.e. pervious soils) are capable of transmitting greater quantities of water per unit time through a unit cross-sectional area of flow (e.g. assuming a constant hydraulic gradient and a fixed cross-sectional area flow, a sand with a hydraulic conductivity on the order of 10^{-4} m/s will transmit 2 orders of magnitude more flow than a silt with hydraulic conductivity on the order of 10^{-6} m/s). Hydraulic conductivity is a useful measure of a soil's ability to transmit water because values are widely documented in published literature, can be calculated from a number of empirical relationships based on soil grain size curves and because, as the infiltration rate of a soil becomes steady, it can be assumed to approach the saturated vertical hydraulic conductivity of that soil [Williams *et. al.* 1998].

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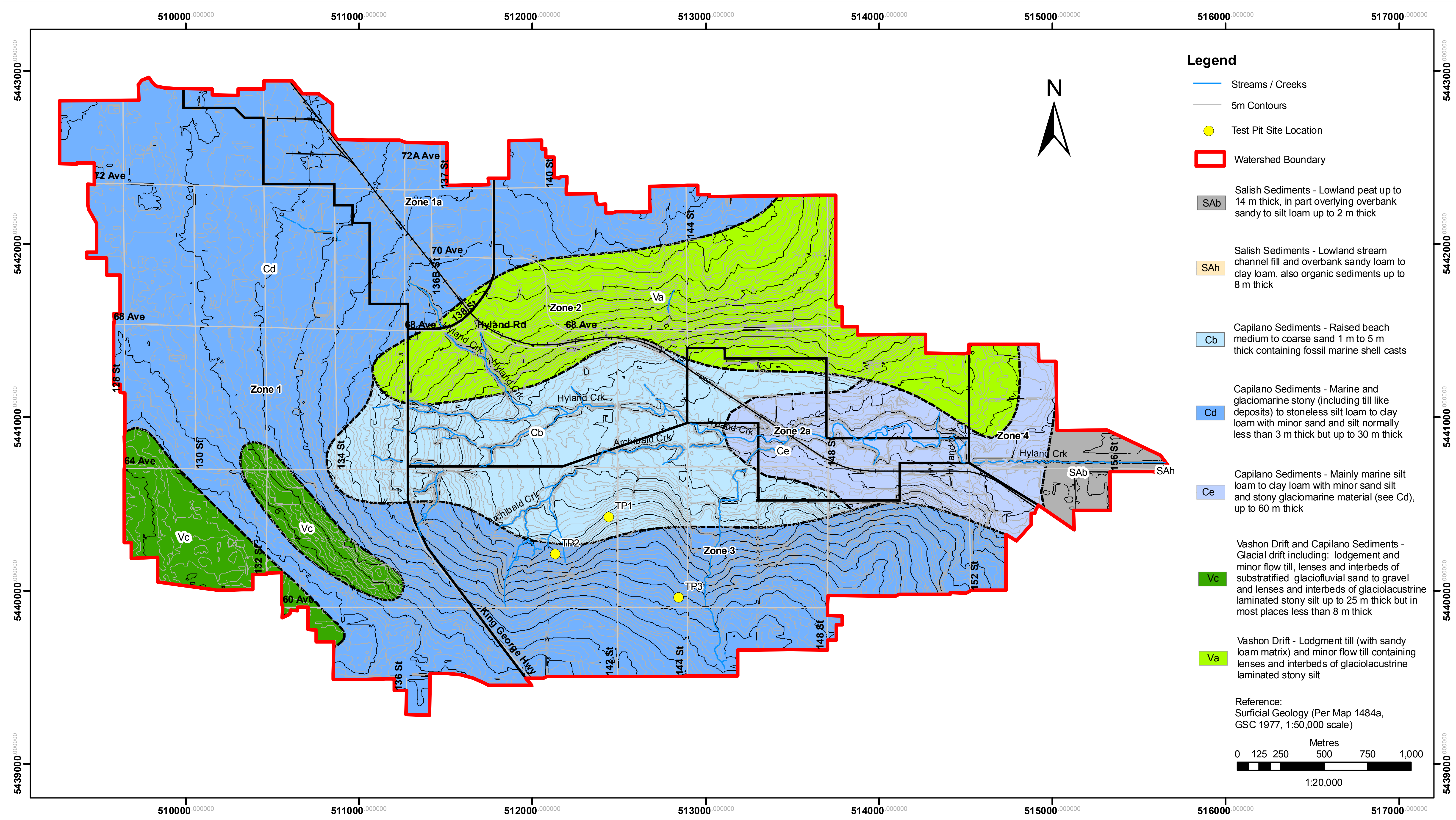
[4] http://srmapps.gov.bc.ca/apps/wrbc/



PROJECT: HYLAND CREEK ISMP	CLIENT:	TITLE:	DATE: 20-Dec-06
LOCATION: HYLAND CREEK, SURREY, BRITISH COLUMBIA	URBAN SYSTEMS	**SURFICIAL GEOLOGY** HYLAND CREEK WATERSHED	PROJECTION: UTM
PROJECT No: 1010479			AUTHOR: MC; APPROVED: TC; DATUM: NAD 83 - ZONE 10

FIGURE No. 5.12

Table 5.15
Estimated Hydraulic Conductivity by Material Type

Material Unit	Geologic Unit	Description	Estimated Range of Hydraulic Conductivity (m/s)
SAb	Salish Sediments	Lowland peat up to 14 m thick, in part overlying overbank sandy to silt loam up to 2 m thick	10^{-6} and less
SAh	Salish Sediments	Lowland stream channel fill and overbank sandy loam to clay loam, also organic sediments up to 8 m thick	Sand loam: $10^{-5} – 10^{-7}$ Clay loam: 10^{-6} and less
Cb	Capilano Sediments	Raised beach medium to coarse sand 1 m to 5 m thick containing fossil marine shell casts	$10^{-2} – 10^{-4}$
Cd	Capilano Sediments	Marine and glaciomarine stony (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. In many upland areas Cd is mantled by a thin veneer (less than 1 m) of Ca Ca: raised marine beach, spit, bar and lag veneer, poorly sorted sand and gravel	$10^{-11} – 10^{-6}$ (*Ca*: $10^{-6} – 10^{-4}$)
Ce	Capilano Sediments	Mainly marine silt loam to clay loam with minor sand silt and stony glaciomarine material (see Cd), up to 60 m thick	10^{-6} and less depending on sand, silt and clay content
VC	Vashon Drift and Capilano Sediments	Glacial drift including: lodgement and minor flow till, lenses and interbeds of substratified glaciofluvial sand to gravel and lenses and interbeds of glaciolacustrine laminated stony silt up to 25 m thick but in most places less than 8 m thick	$10^{-6} – 10^{-12}$
Va	Vashon Drift	Lodgement till (with sandy loam matrix) and minor flow till containing lenses and interbeds of glaciolacustrine laminated stony silt	$10^{-6} – 10^{-12}$

Surficial material types underlying each zone of the watershed can be referenced from Figure 5.12.

Review of well logs available on-line in the BC Water Resources Atlas and work by Piteau [1996] indicate that the upland Cd unit mapped over large areas of the watershed is typically overlain by a thin veneer of sand and gravel material, which is interpreted to be the Ca unit (refer to Cd material in Table 5.15 for a description of Ca material).

Piteau [1996] defined four units of hydrogeological significance, in order descending from ground surface: the Upper Sand; Glaciomarine Clays and Tills; Sand and Gravel Interbeds; and the Quadra Sand Unit.

The Upper Sand was described as a fine to medium sand with local variations in proportion of silt or gravel components and varying in thickness from less than 0.2 m to 1.5 m with an apparent average of 0.7 m. The Upper Sand was inferred to represent the Ca sub-unit of the Capilano Sediments.

The Glaciomarine Clays and Tills unit was described as silty sand, clayey silts, or clay, dense and till-like in consistency. In test pits and creek bank exposures, Piteau [1996] documented the presence of minor heterogeneities (e.g. very fine, less than 1 mm aperture fractures, fine sand seams less than 3mm thick, and localized "coin-sized" sand pockets) reported to greatly increase the ability of this unit to transmit water. Based on modeling, observed base flows, and assuming that total base flow equals average recharge within contributing catchments, Piteau [1996] estimated the bulk hydraulic conductivity for the Cd unit to be between 3×10^{-8} and 6×10^{-8} m/s. Piteau noted that springs in this area flow all year and therefore significant volumes of water must be infiltrating through this unit. This material unit was inferred to represent the Cd sub-unit of the Capilano Sediments.

The Sand and Gravel Interbeds were described as 2m to 3m thick, laterally discontinuous coarse-grained layers possibly with some degree of interconnection potentially resulting in a complex groundwater flow system. Materials in the Sand and Gravel Interbeds described by Piteau may be similar in texture to the Ca or Cb sub-units of the Capilano Sediments.

Piteau [1996] inferred the presence of the Quadra sands underlying the Newton Uplands based on geologic similarity of the area with the University of British Columbia peninsula and the White Rock Upland areas. The Quadra sand unit is expected to form a relatively thick aquifer that is recharged, at least partially, by infiltration from upland areas in Zones 1, 1A, 2 and 3. Piteau inferred that this material may act as an underdrain to upland areas. Data available from the BCWRA indicates that the Quadra Sand material correlates with the Newton Upland aquifer, as discussed in the following section.

5.5.3 Aquifers

Two provincially recognized, sand and gravel aquifers underlie the watershed [BCWRA 2006]. Aquifer 58 II C (11), the Nicomekl-Serpentine Aquifer, underlies a portion of Zone 4, the lowest lying area of the watershed. The mapped extent of this aquifer within the watershed appears to be associated with the floodplain of the Serpentine River. Aquifer 61 IIIC (9), the Newton Upland aquifer, appears to underlie the remaining portions of the watershed (Zones 1, 1A, 2, 2A, 3 and 4). Mapped extents of the aquifers are shown relative to the study area zones on Figure 5.13. Both aquifers are considered important in terms of long term regional water supply for the City of Surrey.

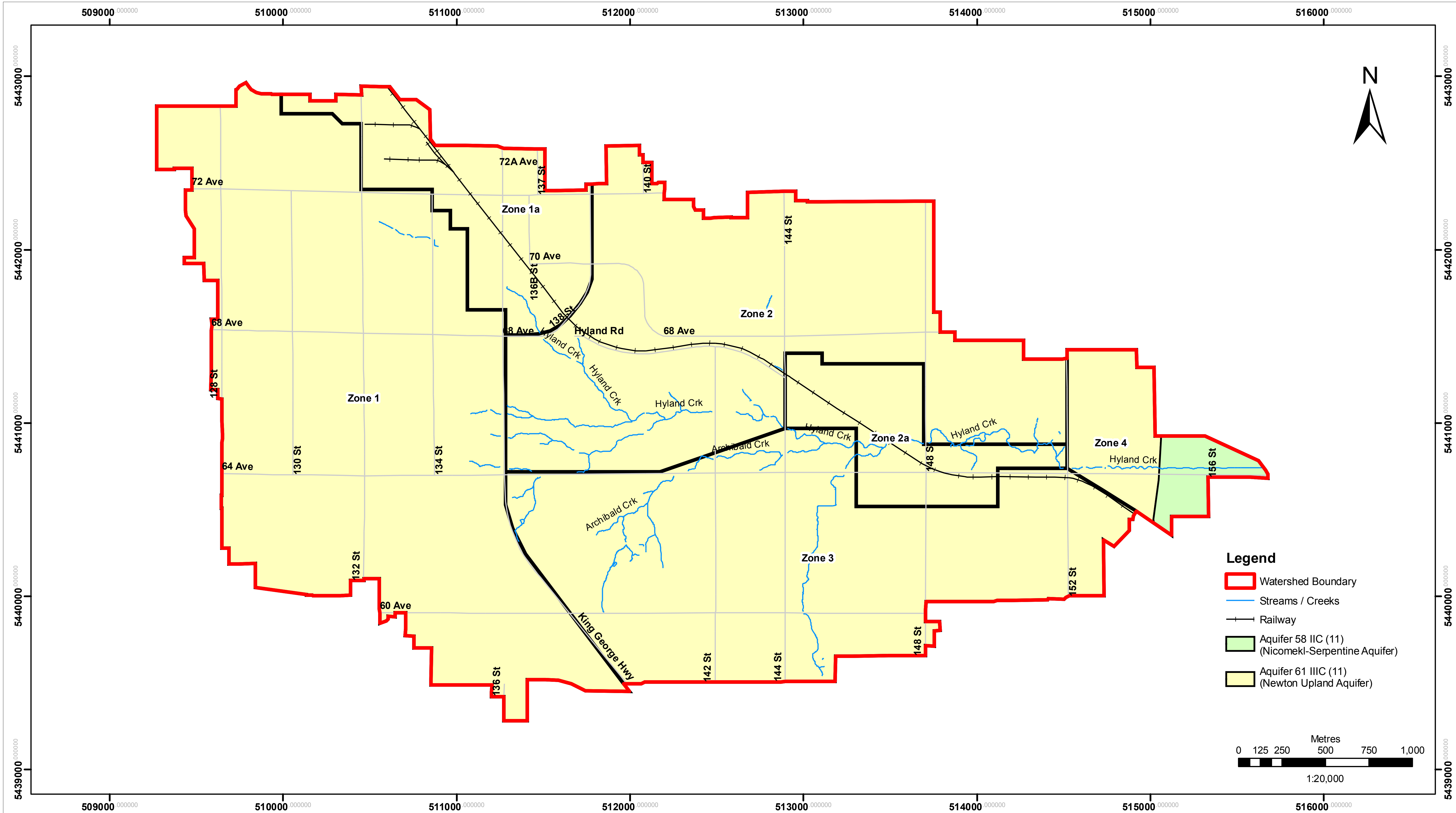
Hydrogeologic parameters (hydraulic conductivity and storage) estimated for these aquifers are summarized in Table 5.16. The hydraulic conductivity and storage parameters of an aquifer are required to quantify groundwater migration rates in the substrate, and are used to evaluate the radius of influence of pumping or injection wells. This data was provided in the event that an assessment of deep well injection of stormwater may also be considered to mitigate the effects of urbanization in the Hyland Creek watershed.

Table 5.16
Estimated Aquifer Parameters

Aquifer Name	Material Type	Water Use	Estimated Range of Hydraulic Conductivity (m/s)	Storativity Specific Storage
Newton Upland	Sand and Gravel	Domestic (potable) Agricultural Commercial	1×10^{-4} +/- factor of 30 uncertainty[(1),(2)]	1×10^{-3} +/- factor of 10 [(1),(2)]
Nicomekl-Serpentine	Sand and Gravel	Domestic (potable) Agricultural Commercial	9×10^{-5} +/- factor of 5 uncertainty [(3)]	1×10^{-3} +/- factor of 2 [(3)]

Notes
1 Based on lithologic description [Golder Associates 2003]
2 Correlates with Quadra Sand lithologic unit (BCWRA)
3 Pumping test data [Golder Associates 2003]

Aquifers in British Columbia are classified according to level of development, from heavy (I) to light (III); vulnerability, from high (A) to low (C); and ranking value component, from 5 (lower priority) to 21 (higher priority) [MWLAP 2002]. The Nicomekl-Serpentine aquifer is thereby classified as moderately developed with low vulnerability to surface sources of contamination. The Newton Upland aquifer is classified as lightly developed with low vulnerability to surface sources of contamination.



PROJECT: HYLAND CREEK ISMP	CLIENT:	TITLE:	DATE: 20-Dec-06	PROJECTION: UTM	FIGURE No.
LOCATION: HYLAND CREEK, SURREY, BRITISH COLUMBIA	URBAN SYSTEMS	**AQUIFER**	AUTHOR: MC	DATUM: NAD 83 - ZONE 10	5.13
PROJECT No: 1010479		HYLAND CREEK WATERSHED	APPROVED: TC		

Both aquifers are protected from surface sources of contamination by a thick layer of lower permeability materials (e.g. the Cd, Va and VC material units). However, both aquifers support multiple water uses including domestic, agricultural and commercial consumption [BCWRA 2006]. As such, shallow infiltration or deep well injection of stormwater from the Hyland Creek watershed, without due consideration to the quality of the water infiltrated and how it will react with the native deeper groundwater, could still result in degradation of the groundwater resource for specific water uses (e.g. potable) in localized areas of these aquifers over the long term. Both aquifers rank towards the lower end of the priority scale, on a province-wide basis.

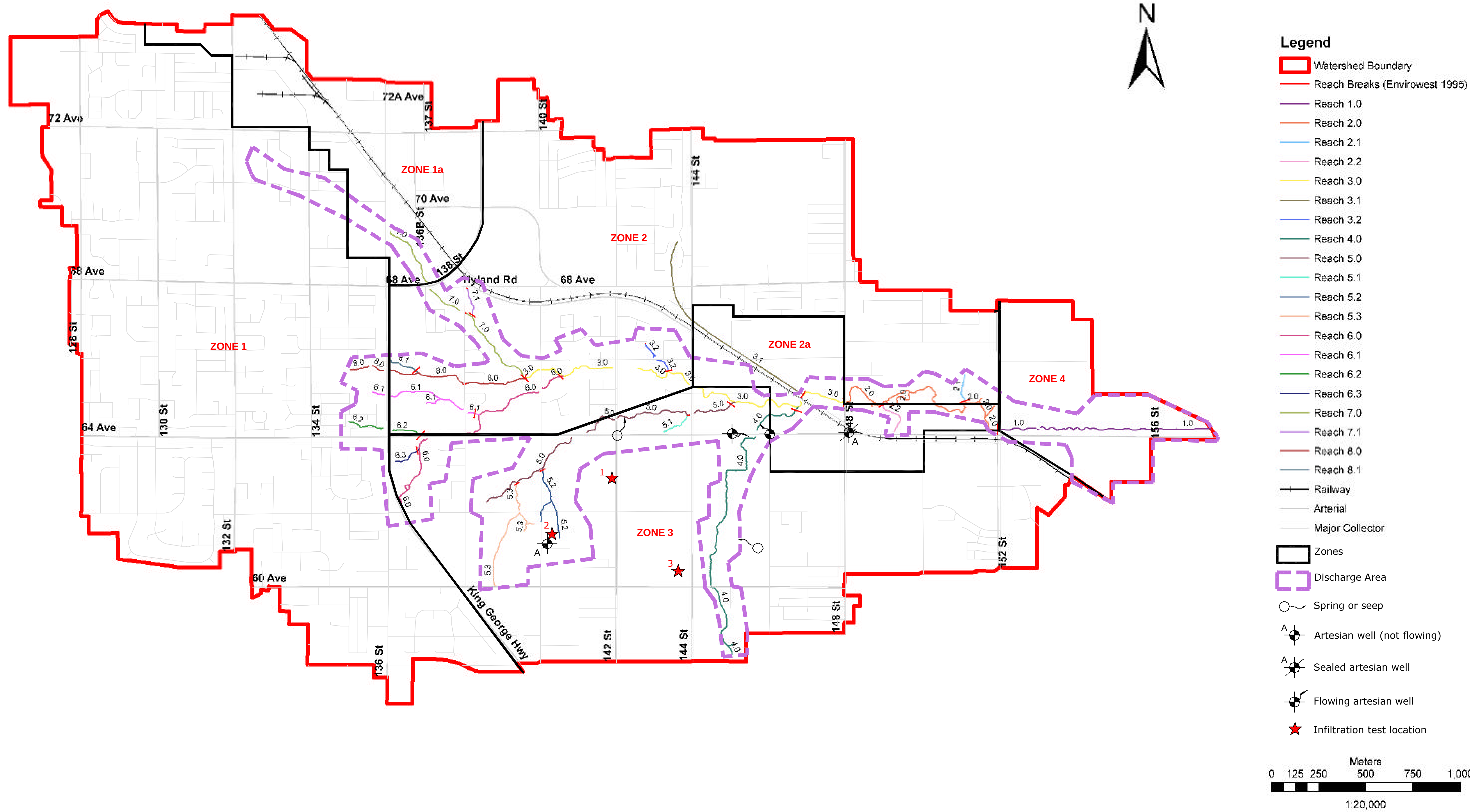
5.5.4 Recharge and Discharge Areas

The majority of the upland area in the watershed is anticipated to act as a recharge or potential recharge area. However, recharge potential in more developed areas of the watershed will be curtailed to varying degrees depending on the level of development and percent coverage by impermeable pavements or structures. Discharge areas are expected to occur proximate to Hyland Creek and its tributaries and are also known to occur in areas where seepage problems have been reported to the City of Surrey, as noted in the section below. Interpreted recharge and discharge areas, together with locations of reported seepage problems are shown on Figure 5.14.

5.5.5 Artesian Groundwater, Seepage and Springs

The City has indicated that other consultants, including Piteau and Golder, have investigated shallow seepage occurrences in the neighbourhood of 64 Avenue and 142 Street. Piteau [1996] documented the presence of artesian groundwater, springs and/or seepage at the following locations:

- North of 61 Avenue and east of 140 Street – artesian (not flowing) well
- West of 146 Street, 100m north of 60A Avenue – wet ditches with known spring north of indicated location
- West of 148 Street, north of 64 Avenue, north and south of rail-line – two poorly sealed artesian wells
- 14613-64 Avenue – two flowing artesian wells (0.02 L/s and 0.7 L/s) both drilled to 5m depth; faster flowing well was noted to discharge to Reach 4 in 1996
- 14541-64 Avenue – flowing artesian dug well (2-3 m deep in a linear depression approximately 1m below local grade, 1.0 L/s, reportedly steady flow for the 32 years preceding Piteau's investigation



Jacques Whitford	PROJECT: HYLAND CREEK ISMP	CLIENT:	TITLE:	DATE: 20-Dec-06		PROJECTION: UTM	FIGURE No.
	LOCATION: HYLAND CREEK, SURREY, BRITISH COLUMBIA	URBAN SYSTEMS	GROUNDWATER RECHARGE AREAS HYLAND CREEK WATERSHED	AUTHOR: NP	APPROVED: KM	DATUM: NAD 83 - ZONE 10	5.14
	PROJECT No: 1010479						

The City of Surrey maintains a log of concerns reported by residents in the municipality. Seepage concerns were reported to the City at the following location:

- 64 Avenue and 142 Street

The occurrence of any artesian wells, springs or seepage concerns were not verified as part of this assessment. Locations of reported seepage concerns and springs are shown on Figure 5.14.

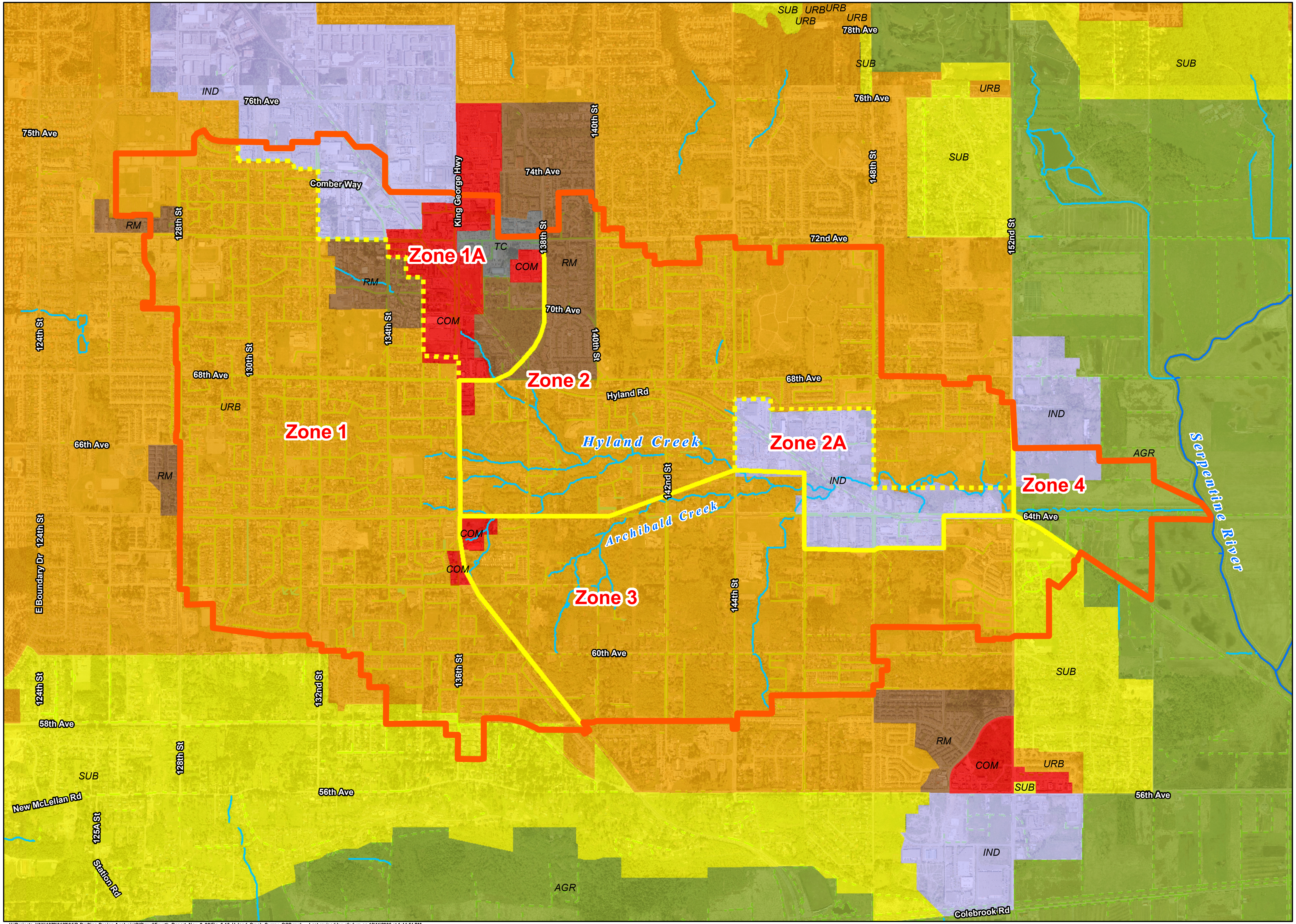
In addition to the reported problem locations, seepage issues should also be considered wherever there are breaks in slope, steep embankments, slope cuts for construction, rock outcrops, depressions, daylighting of geologic units, etc. Also, even where seepage problems do not currently exist, any alteration of the natural groundwater flow regime (e.g. artificial stormwater infiltration, groundwater diversion/control, etc) may create seepage issues. A qualified professional should be consulted prior to undertaking any activity that may affect the groundwater flow system.

5.6 Land Use

5.6.1 Available Background Information and Data

Future land development within the Hyland Creek watershed will be guided by Surrey's Official Community Plan (OCP), which contains the City's long-term land use planning objectives, as well as related Neighbourhood Concept Plans (NCPs), which provide more detailed land use plans for specific areas within the City. OCP details are shown on Figure 5.15, whereas NCP details are shown on Figure 5.16. Most of the future development within the Hyland Creek watershed is expected to occur within those areas covered by an NCP. The three most prominent NCPs in the watershed are the East Newton South, South Newton, and East Newton Business Park NCPs (the watershed also falls within portions of the West Newton North and West Newton/Highway 10 NCPs, but the areas encompassed by the watershed are minimal). As well, the Newton Town Centre Study, while not a formal NCP, provides information regarding future development near King George Highway north of 68 Avenue to the watershed boundary.

South Newton NCP – As the South Newton NCP covers a sizeable and largely undeveloped portion of the watershed (Zone 3), the South Newton NCP has the potential to have a significant impact on stormwater management and the environmental health of the watershed. According to data obtained from the City's Planning department, nearly 70% of the South Newton NCP Area was already under application as of January 2007, as shown on Figure 5.17. If this area develops as planned, the south-eastern portion of the watershed will experience significant



SURREY
CITY OF PARKS

Hyland Creek Integrated Stormwater Management Plan

Figure 5.15

City of Surrey Official Community Plan (OCP)

Land-Use Designations:

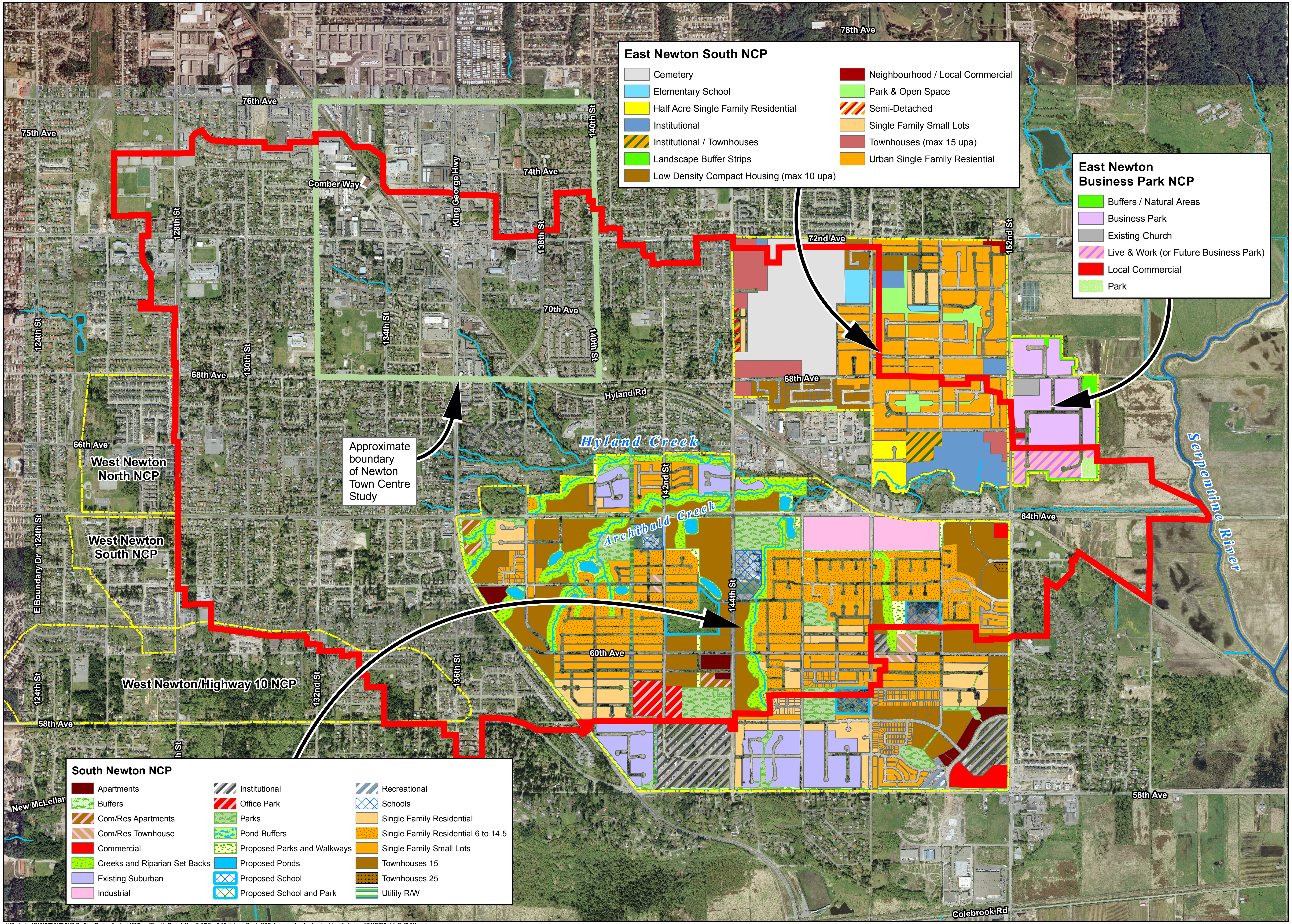
- Town Centre
- Multiple Residential
- Urban
- Suburban
- Commercial
- Industrial
- Agricultural
- Hyland Creek Watershed Area
- Sub-Zone Boundary
- Zone Boundary

0 250 500
Metres

Scale 1:20 000

Source: City of Surrey
2005 Aerial Photography

Prepared By:
URBANSYSTEMS.
1072.0137.01 July 2007



SURREY
CITY OF PARKS

Hyland Creek Integrated Stormwater Management Plan

Figure 5.16

NEIGHBOURHOOD CONCEPT PLAN (NCP) AREAS

Hyland Creek Watershed Area

0 250 500
Metres

Scale 1:20 000

Source: City of Surrey
2005 Aerial Photography

Prepared By:
URBANSYSTEMS.
1072.0137.01 July 2007

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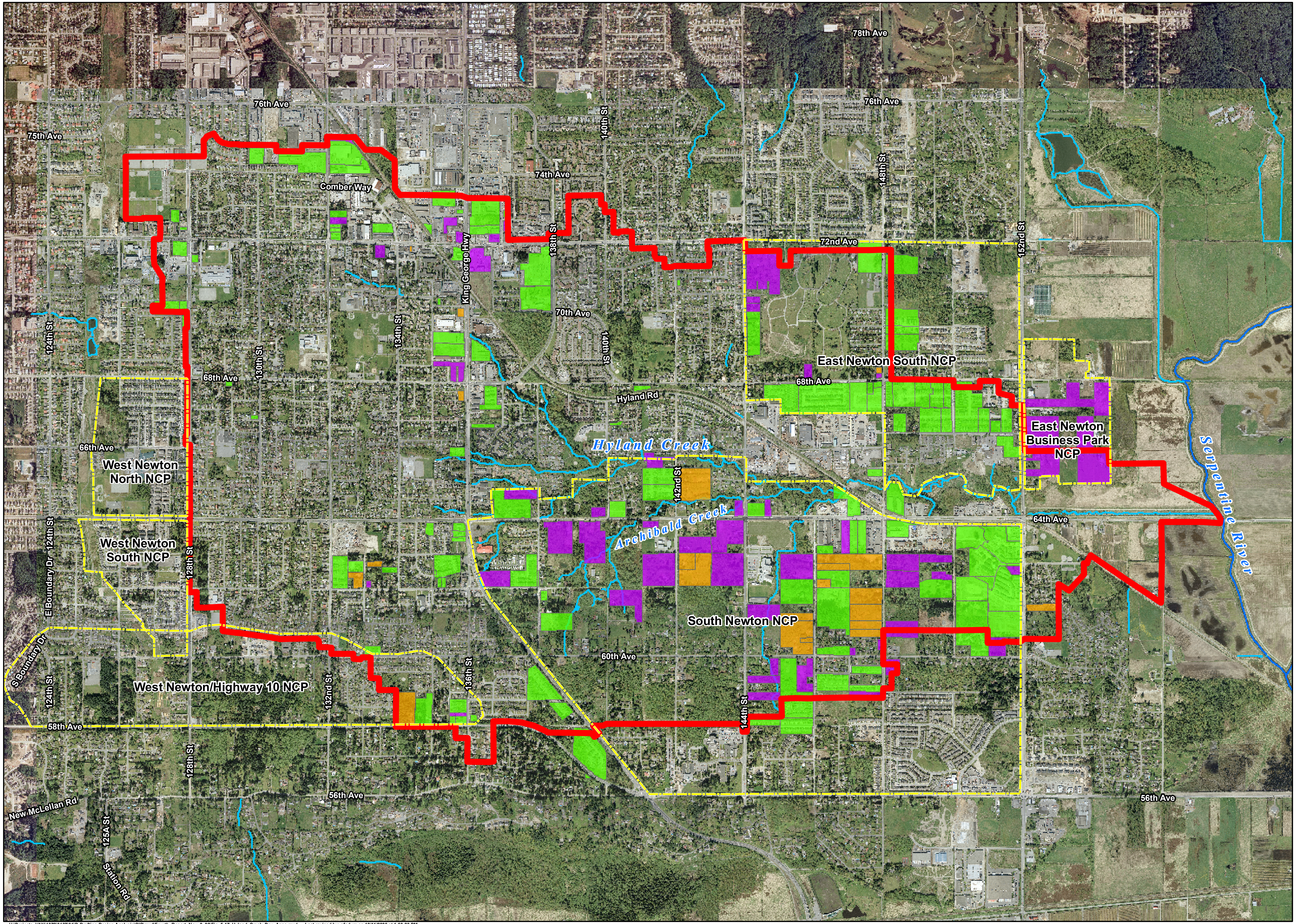


SURREY
CITY OF PARKS

Hyland Creek Integrated Stormwater Management Plan

Figure 5.17

DEVELOPMENT APPLICATIONS (AS OF JAN. 2007)

- Approved
- Third Reading
- In Process
- City of Surrey Neighbourhood Concept Plan Boundary
- Hyland Creek Watershed Area

0 250 500
Metres
Scale 1:20 000

Source: City of Surrey
2005 Aerial Photography

Prepared By:
URBANSYSTEMS.
1072.0137.01 July 2007

changes in land use as most of the area is converted from rural uses (in many cases greenfield conditions) to multi-family and small lot single family residential uses. While the South Newton NCP includes primarily residential land uses, the plan also calls for a variety of other land uses including commercial uses, industrial uses, schools, mixed-use development, and an office park. The South Newton NCP includes provisions to help protect Hyland Creek and its tributaries through riparian setbacks. The NCP also identifies a total of nine proposed stormwater detention facilities to be situated within the Hyland Creek watershed for quantity and quality control, and discusses the use of stormwater infiltration systems to provide base flows to the watercourse.

East Newton South NCP – The portion of the Hyland Creek watershed that falls within the East Newton South NCP is almost already fully developed; however, the East Newton South NCP calls for additional residential development (including townhouse and low density compact housing) bordering the cemetery in Zone 2. Like the South Newton area, the East Newton South area is experiencing considerable development pressure. Planning staff at the City estimate that approximately 60% to 70% of the East Newton South NCP Area is already developed or under application. The East Newton South NCP proposes two stormwater detention facilities to service future development in the area.

East Newton Business Park NCP – The easternmost portion of the watershed (Zone 4) falls within the East Newton Business Park NCP, which proposes "Business Park and "Live & Work" land uses. As this area is currently zoned agricultural/rural residential, the development of a business park or live/work facilities is expected to have a significant impact on stormwater management and the environment; however, the NCP does include tree retention and environmental objectives to help mitigate adverse impacts.

Outside of the NCP areas, the watershed is nearly at build-out. Consequently, the future land use patterns in these areas are not expected to differ significantly from the current land use pattern. Infill development and densification may, however, alter land uses to some degree.

While the OCP and the NCPs provide a strong basis for forecasting future land use, the actual future land use pattern will depend on a variety of factors such as market conditions and development trends (e.g. the recent trend towards small lot single family residential development). In 2004 the City amended the South Newton NCP to include a "Single-Family Residential Flex 6 to 14.5" land use designation, which allows residential densities ranging from 6 units per acre to 14.5 units per acre. According to City Staff, the amendment was made to accommodate the increasing trend towards small-lot single family development. Because the "Single-Family Residential Flex 6 to 14.5" land use designation permits such a wide range of densities, there may be increased opportunities for stormwater management and environmental protection in those areas of the watershed designated for this use.

Newton Town Centre Study – The area between 132 and 140 Streets and from 68 Avenue to the northern boundary of the watershed falls within the study area of the Newton Town Centre Study. The proposed land use concept calls for commercial development along King George Highway; a civic core that includes a library, wave pool, seniors' centre, and arena near 137 Street and 71 Avenue (these have all been developed); and high density residential development just north of the intersection of King George Highway and 138 Street. The high density residential development is proposed on City-owned land, and includes a plan for a large public amenity, such as a lake with surrounding parkland. This City-owned parcel is the last remaining greenfield parcel within the Newton Town Centre study area yet to be developed.

Development within the watershed will also be guided by the following plans and bylaws:

- Zoning Bylaw
- Soil Removal and Deposition Bylaw
- Tree Preservation Bylaw
- Waterways Protection Bylaw
- Tree Cutting Bylaw
- Natural Areas Management Plan
- Pesticide Use Policy

Provisions contained in these bylaws can have an impact on stormwater management and environmental protection. Potential modifications to some of these bylaws to encourage more sustainable stormwater and environmental practices are discussed further in Section 7.5.

5.7 Parks and Recreation

5.7.1 Available Background Information and Data

Existing land use planning documents, including the Newton Town Centre Study, South Newton, East Newton South and East Newton Business Park NCPs, include plans for passive and active park space (see Figure 5.16). The City is currently reviewing and updating the Parks, Recreation and Culture Master Plan, but at this time they do not expect any significant changes for the Hyland Creek watershed.

6.0 WATERSHED HEALTH ASSESSMENT

The Greater Vancouver Regional District (GVRD) ISMP template provides guidance on preparing watershed health assessments using two physical characteristics: total impervious area and percent riparian integrity [Kerr Wood Leidal 2002, 2005]. Watershed health ratings ranging from poor to excellent are then calculated and compared to biological assessments obtained from measurements of benthic invertebrate communities [EVS 2003]. This assessment helps identify means by which growth can continue while maintaining or improving watershed health.

Total impervious area (TIA) provides an estimate of the paved and hard surface areas in the watershed. Impervious areas (e.g. roads, buildings, parking areas, patios, etc.) reduce the amount of permeable surface available for natural infiltration of precipitation. Increases in impervious area result in changes to stream hydrology (higher high flows, lower base flows), which have been correlated to reduced ability of streams to support salmonids and other species. The TIA calculation is based on the assumption that paved and hard surface areas do not provide any infiltration.

The riparian corridor assessment describes the proportion of riparian corridor (habitat within 30 m of each bank of the stream, a total of 60 m) that contains natural forest habitat. Natural forest vegetation within this corridor provides many ecological benefits to stream and watershed health, including shade, nutrients, bank stability, stable soils that promote infiltration and purification of water, and habitat for many species of birds and wildlife. The ability to develop property within this riparian corridor is regulated through the provincial *Fish Protection Act* (Riparian Area Regulations) and/or municipal bylaws and Best Management Practices (BMPs), so changes over time in riparian integrity are not expected.

Watershed health assessments were conducted by the GVRD in 1999 (using 1996 data) and made predictions for 2036 to assess change associated with population growth using the strategies in place at that time. The Hyland Creek TIA assessment was 41% for 1996 and the prediction for 2036 was 63%. Riparian corridor intactness was estimated at 55%, and was not expected to change between 1996 and 2036 because of regulations in place to protect this habitat. Watershed health was assessed as “fair” in 1996 and was predicted to decrease to “poor” in 2036. This section discusses results of the 2006 watershed health assessment conducted for this ISMP, which was conducted to evaluate whether conditions are developing as predicted and to provide additional context for implementation of BMPs and riparian guidelines.

6.1 Impervious Area Assessment

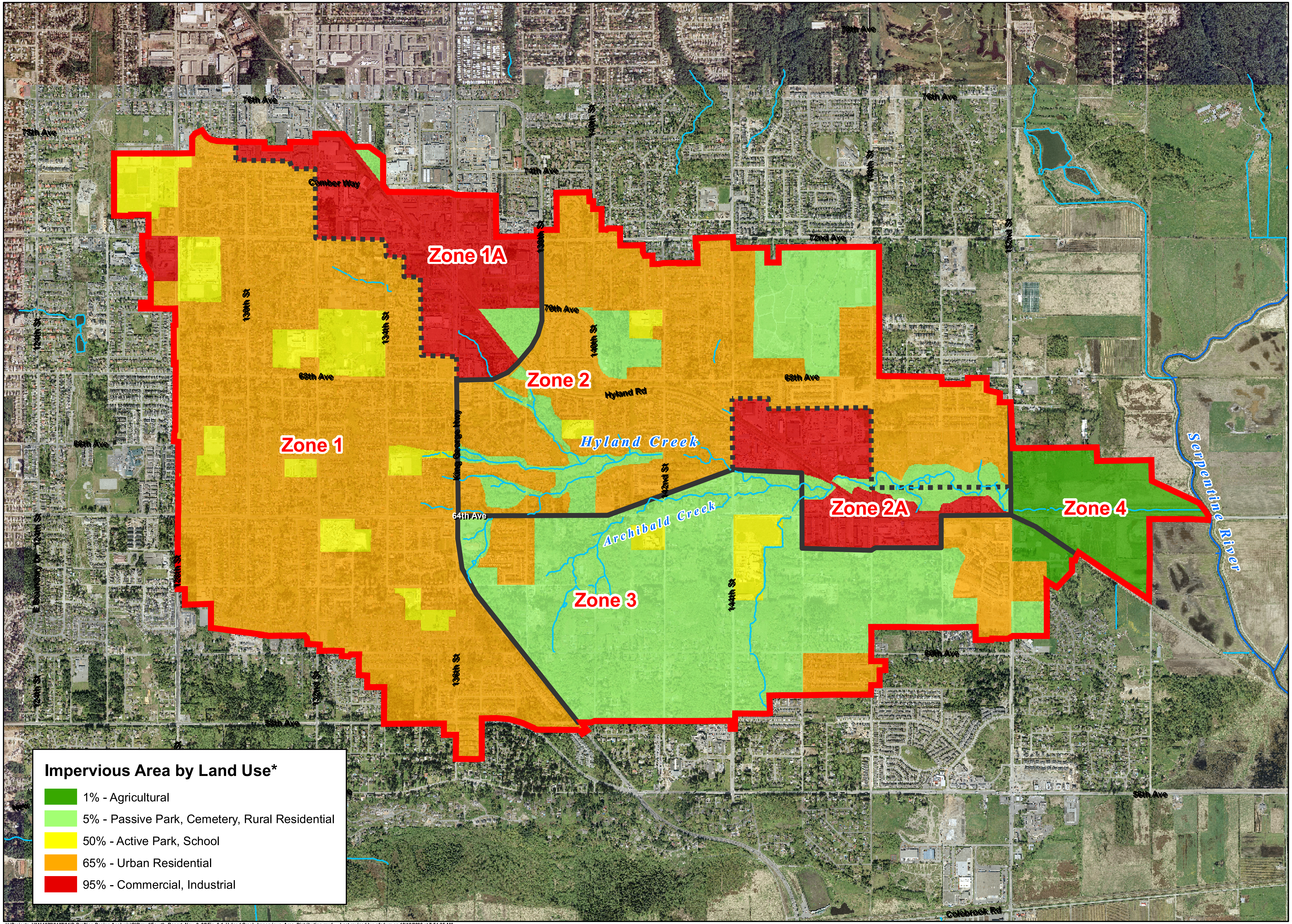
To obtain an understanding of the extent of existing development in the watershed, the total impervious area (TIA) in the watershed was calculated. Impervious areas include roofs, driveways, roads, sidewalks, parking lots, and any other hard surface areas which generate stormwater runoff and do not allow for the natural infiltration of precipitation.

Using the 2005 aerial photography supplied by the City, representative areas for each land use type in the watershed were selected and the TIA for each land use was calculated and expressed as a percentage. Based on this method, Table 6.1 below lists the % TIA associated with each land use type. While these values are slightly different than those provided in the City's design criteria, they more accurately represent characteristics of existing development in the Hyland Creek watershed.

Table 6.1
Impervious Rating by Land Use

Land Use	Total Impervious Area (%)
Agricultural	1%
Passive Park / Cemetery / Rural Residential	5%
Active Park / School	50%
Urban Residential	65%
Commercial / Industrial	95%

The impervious percentages noted above were then applied to each land use type in each zone of the watershed to arrive at a TIA for the watershed, as summarized in Table 6.2 and Figure 6.1. Table 6.2 indicates that approximately 49% of the total watershed area is covered in impervious surfaces under current development conditions. Impervious areas within each zone range from 82% to 88% in Zones 2A and 1A, respectively, and from 1% to 16% in Zones 4 and 3, respectively. From the discussion in Section 4, these values are well beyond the upper limit of 10-15% impervious area which is typical of a "healthy" watershed. Table 6.2 also summarizes the percentage of each land use type in each zone of the watershed.



SURREY
CITY OF PARKS

Hyland Creek Integrated Stormwater Management Plan

Figure 6.1

TOTAL IMPERVIOUS AREA DISTRIBUTION

Zone Boundary
Sub-Zone Boundary
Hyland Creek Watershed

Note: Refer to Table 6.2 for summary of impervious areas for entire Hyland Creek Watershed.

0 250 500
Metres
Scale 1:20 000

Source: City of Surrey
2005 Aerial Photography

Prepared By:
URBANSYSTEMS.
1072.0137.01 July 2007

Table 6.2
Total Impervious Area Assessment

Zone	Total Area (ha)	Urban Residential (65% Imp)			Rural Residential (5% Imp)			Commercial / Industrial (95% Imp)		
		Total Area (ha)	Imp. Area (ha)	% of Zone	Total Area (ha)	Imp. Area (ha)	% of Zone	Total Area (ha)	Imp. Area (ha)	% of Zone
1	487	419	272	86%	0	0	0%	5	5	1%
1A	101	0	0	0%	0	0	0%	93	88	92%
2	346	256	167	74%	0	0	0%	0	0	0%
2A	71	0	0	0%	0	0	0%	61	58	86%
3	328	48	32	15%	253	13	78%	0	0	0%
4	54	0	0	0%	0	0	0%	0	0	0%
Watershed Total	1,387	723	471	52%	253	13	18%	159	151	12%

Zone	Passive Park / Cemetery (5% Imp)			Agricultural (1% Imp)			Active Park / School (50% Imp)			Total Impervious Area (% Imp)
	Total Area (ha)	Imp. Area (ha)	% of Zone	Total Area (ha)	Imp. Area (ha)	% of Zone	Total Area (ha)	Imp. Area (ha)	% of Zone	
1	0	0	0%	0	0	0%	63	32	13%	63%
1A	8	0.5	8%	0	0	0%	0	0	0%	88%
2	85	4	24%	0	0	0%	5	2	1%	50%
2A	10	0.5	14%	0	0	0%	0	0	0%	82%
3	5	0	2%	8	0	2%	14	7	4%	16%
4	0	0	0%	54	0.5	100%	0	0	0%	1%
Watershed Total	108	5	8%	62	0.5	5%	82	41	6%	49%

Figure 6.1 has been colour coded to indicate general trends, with green signifying areas with low amounts of impervious surfaces, and orange and red indicating areas with high amounts of impervious surfaces. Overall, Zones 1, 1A, 2 and 2A have extensive development with high amounts of impervious area. Zones 3 and 4, on the other hand, tend to have low amounts of impervious area under existing development conditions. While Zone 4 is somewhat protected from future development as the majority of the zone is in the Agricultural Land Reserve (ALR), most of the future development in the watershed is anticipated to occur in Zone 3. As indicated in Figure 6.1, recent development along the 152 Street corridor has already increased the amount of impervious area in Zone 3. As development proceeds in this zone, green areas will eventually become orange or red areas if development continues in the same manner.

In 1996, the TIA for the Hyland Creek watershed was estimated as 41% and was anticipated to increase to 63% by 2036 [GVRD 1999]. Increased TIA is expected mainly for Zone 3 as development occurs, likely to the level currently reported for Zone 2 (50%). This would result in an increase to approximately 60% TIA for the watershed as a whole (similar to the calculation of 63% for 2036 [GVRD 1999]).

6.1.1 EIA and TIA

Concern has been raised in the past regarding the detrimental impacts of impervious area on the overall health of a watershed. As discussed above, TIA is essentially the sum of all impervious areas in the watershed, regardless of whether they are directly connected to the drainage system or not. The effective impervious area (EIA) is defined as the directly connected portion of the TIA. TIA in the Hyland Creek watershed (Zones 1 through 3, and omitting agricultural land in Zone 4) is currently estimated to be 51% (681 ha of the total 1,333 ha of watershed, excluding agricultural land in Zone 4). The GVRD's watershed health tracking system utilizes TIA, along with % riparian forest integrity and benthic invertebrate sampling results, to track the health of a watershed as development proceeds (see Section 6.4).

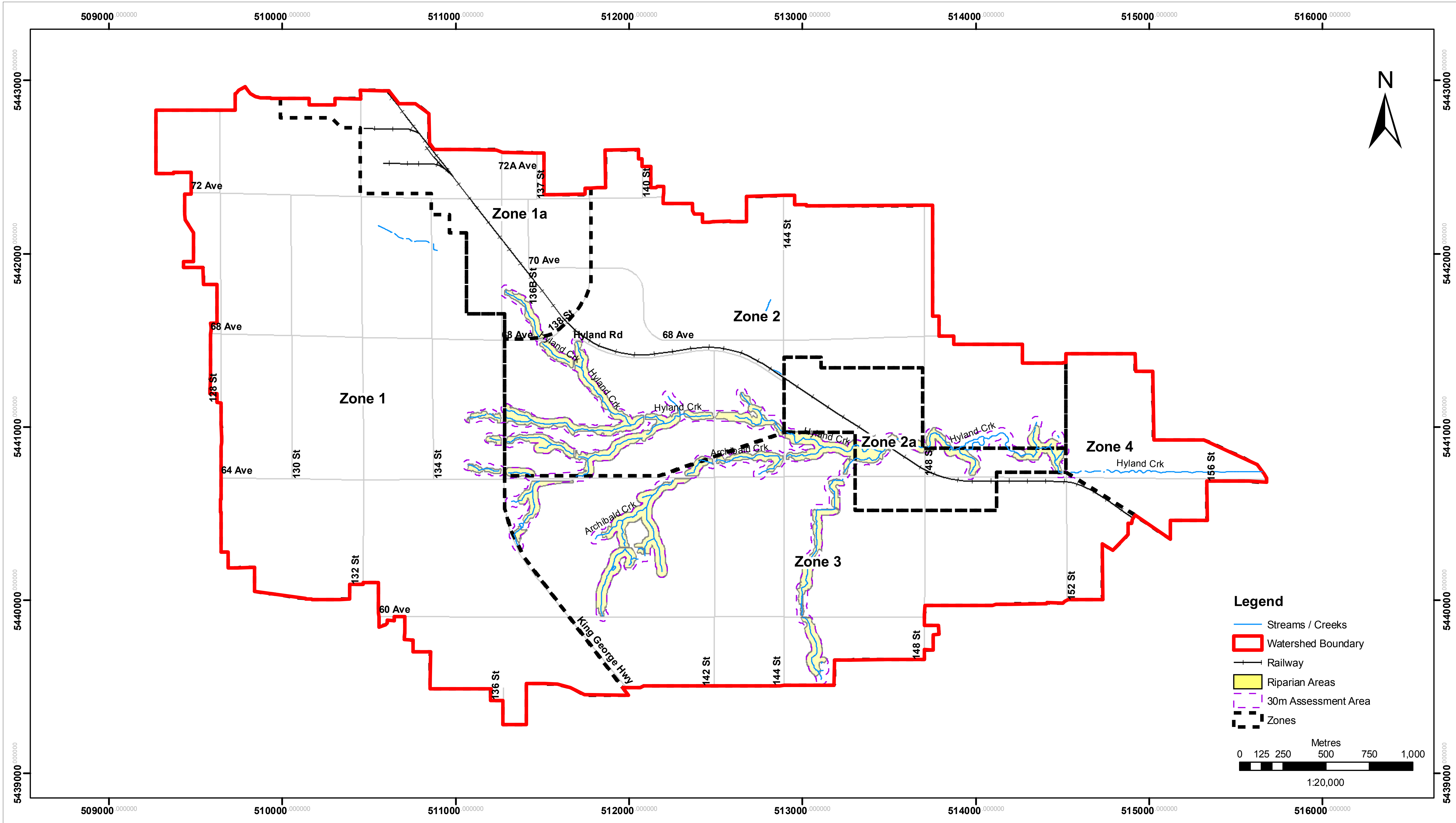
The issue is how to allow future development to proceed while mitigating the effects of increasing TIA and maintaining or reducing current EIA levels, thus avoiding further decline in watershed health. The main mechanisms available are to minimize the EIA in the watershed (i.e. the impervious area directly connected to the drainage system) and to minimize TIA increases in new development areas.

6.2 Riparian Corridor Assessment

The riparian assessment corridor is a 30 m buffer on either side of the stream (total width of 60m). The riparian corridors for Hyland Creek and its tributaries were delineated in Arc GIS, based on available TRIM data and orthophotos taken in 2005. Buffers were measured from the stream centerline, given that top-of-bank data is not available. For creeks where top-of-bank data is available, the riparian corridor width would be 60 m plus the bankfull width.

The Hyland Creek riparian corridor extends from its confluence with the Serpentine River upstream for 6 kilometres to headwaters in the King George Highway area and also extends along all tributaries. Figure 6.2 shows the extent of the riparian corridor used for the assessment, which did not include land within Zone 4 (primarily agricultural land). The watershed contains a mix of land uses and has little intact forest vegetation. Riparian habitat has been lost in some areas through urban encroachment and installation of culverts.

Riparian Forest Integrity (RFI) is one of two key factors used in the GVRD ISMP template to characterize watershed health. RFI is calculated as the proportion of intact forest cover within the riparian assessment corridor and includes culverts and other developed areas (assessed as 0% RFI).



PROJECT:	HYLAND CREEK ISMP
LOCATION:	HYLAND CREEK, SURREY, BRITISH COLUMBIA
PROJECT No:	1010479

Jacques Whitford

CLIENT: URBAN SYSTEMS

TITLE:

RIPARIAN CORRIDOR ASSESSMENT AREA

HYLAND CREEK WATERSHED

DATE:	PROJECTION:	FIGURE No.
05-Jun-06	UTM	6.2
AUTHOR: MC	APPROVED: KM	DATUM: NAD 83 - ZONE 10

RFI was calculated for the watershed (minus Zone 4, given the different requirements for agricultural land) and for the individual land use zones designated for the ISMP. The total intact riparian area is 544,000 m^2 and the total riparian assessment area is 846,000 m^2, resulting in an RFI of 64%, compared with a value of 55% calculated using orthophotos taken in 1995/1996 [GVRD 1999]. The higher value for 2006 than 1996 may be related to use of creek centre-lines (2006 assessment) rather than top-of-bank for establishing the assessment area, small changes in extent of riparian vegetation over time, or removal of Zone 4 (agricultural land) from the current assessment. Table 6.3 also shows that riparian areas have been protected to a greater extent in areas zoned commercial and industrial (66% and 67% RFI in Zones 1A and 2A) than in residential areas (37% and 62% in Zones 1 and 2), perhaps because encroachment is easier to monitor and control in industrial/commercial areas. RFI is lowest (37%) in Zone 1, with the most established residential areas and some culverted headwater tributaries. There is still substantial riparian forest in Zone 3, with 68% RFI.

Table 6.3
Riparian Forest Integrity for Hyland Creek

Watershed Zone	%RFI	Estimated % TIA (Current)	Total Land Area (ha)
Zones 1 through 3	64%	51%	1333
Zone 1	37%	63%	487
Zone 1A	66%	87%	101
Zone 2	63%	50%	346
Zone 2A	68%	82%	71
Zone 3	68%	16%	328

6.3 Benthic Invertebrate Communities

Results of benthic invertebrate community monitoring are used to augment preliminary watershed health assessments, as recommended by the ISMP template [Kerr Wood Leidal 2002, 2005] and GVRD Benthic Invertebrate Index of Biotic Integrity (B-IBI) guide [EVS 2003]. Benthic surveys provide a biologically based performance measure of the effectiveness of watershed planning and implementation processes because these organisms experience the ambient conditions and stressors of the watershed (e.g. changes in flow regime and instream habitat, inputs of sediment and toxic substances through storm drains).

B-IBI values incorporate a variety of environmental and benthic community characteristics (taxon richness and composition, pollution tolerance vs. sensitivity, feeding ecology, population structure) and have been shown to correlate with TIA and RFI [Kerr Wood Leidal 2005]. Values range from 10 (very poor) to 50 (excellent), although a maximum of 40 has been observed for pristine streams within the GVRD [Kerr Wood Leidal 2005].

The City of Surrey has initiated surveys of several creeks in anticipation of the ISMP process. Three sites in the Hyland watershed were surveyed in April 2005 [Dillon Consulting 2005], and again in April 2006 (2006 results were not available for the ISMP). Samples were collected using the East Clayton Monitoring Program Protocol. This protocol differs from the GVRD protocol [EVS 2003] in the collection of one rather than four samples in each riffle area, given that Surrey streams often have smaller or fewer riffle areas than do other streams in the GVRD. Also, samples are collected during spring (April, at the time of red-osier dogwood budding) because many Surrey streams have low flows during late summer. A Surber sampler with 250 µm mesh was used at each site to collect samples from three riffle areas, with samples preserved and identified by a taxonomic laboratory.

The three sites are those described for water quality analysis (see Figure 5.7):

- H1 (Zone 2), in the lower part of Hyland Creek east of 148 Street and north of 64 Avenue, in an area of meandering channel with well-established riparian vegetation and large gravel bars and coarse gravel substrate
- H2 (Zone 2), in upper Hyland Creek east of the 140 Street alignment and north of 64 Avenue, in an area of incised channel, established riparian vegetation on one bank and shallow gravel over compact sand substrate
- A-1 (Zone 3), in Archibald Creek west of 144 Street and north of 64 Avenue, in an area of meandering channel, riparian vegetation on one bank and sand and gravel substrate

In the April 2005 survey, water temperature was 10^{o}C, turbidity ranged from 2 to 14 FTU, pH was 7.1 to 7.4, and dissolved oxygen was approximately 11 mg/L.

B-IBI scores are listed in Table 6.4 (mean of three samples and pooled value). The individual scores ranged from 12 to 14 for H-1 and H-2 and from 12 to 18 for A-1, with pooled values ranging from 14 to 20. Scores of 10 to 16 are considered "very poor" and scores of 18 to 26 are considered "poor" according to the B-IBI system, and indicative of moderate to notable urbanization [EVS 2003].

The B-IBI was higher for A-1, in the less developed Archibald Creek subwatershed (Zone 3) than for H-1 and H-2 in Hyland Creek (Zone 2), reflecting the lower amounts of development and lower % TIA in that subcatchment. Scores were similar for the two Hyland Creek sites, whether at the lower end of the watershed near 148 Street (H-1) or upstream near 140 Street (H-2).

Table 6.4
2005 Benthic Invertebrate Surveys, Hyland and Archibald Creeks

Characteristic	H-1	H-2	A-1
Mean B-IBI score[1]	13 ± 1.2	13 ± 1.2	15 ± 3.1
Pooled B-IBI score	16	14	20
Stream Condition Rating based on Pooled Score	Very poor	Very poor	Poor
Mean taxon richness	10	9	12
Mean EPT taxon richness	1	1	3
Total organisms (3 samples)	1,752	1,380	3,280

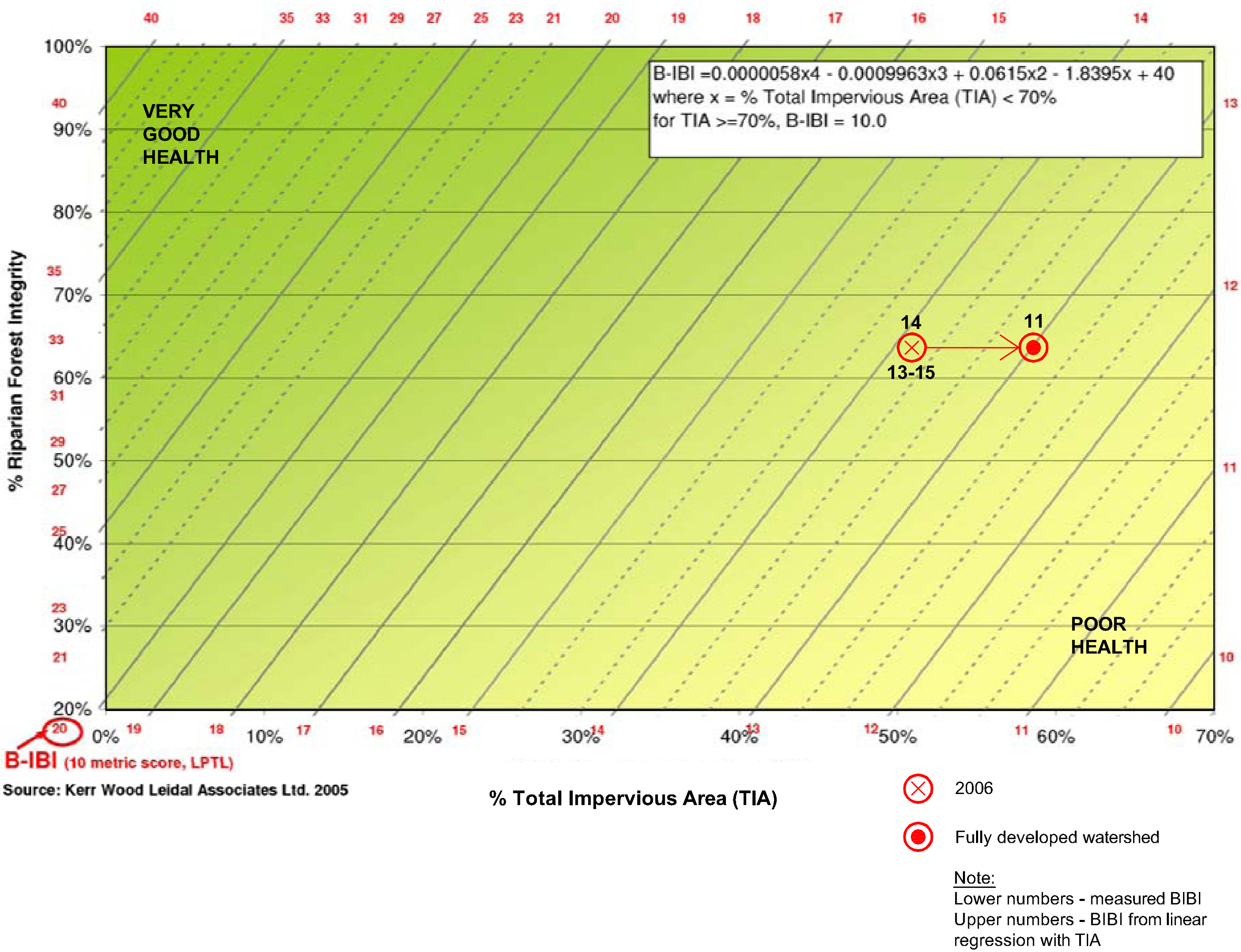
[1] Mean and standard deviation [Source: Dillon Consultants 2005]

The low B-IBI scores and ratings for stream condition were attributed to the lack of pollution intolerant species (*Ephemeroptera*, *Plecoptera* and *Trichoptera*, or mayflies, stoneflies and caddisflies), which are sensitive to siltation, excess nutrients and toxic compounds, as are salmonids [Plafkin *et al*. 1989, as cited in Dillon 2005].

The B-IBI scores for the three sites in the Hyland Creek watershed confirm the preliminary watershed assessment, which predicts "poor" conditions (Figure 6.3), based on TIA and RFI. A B-IBI score can also be calculated using a linear regression against %TIA [Kerr Wood Leidal 2005], which is useful for comparing with current conditions and for predicting changes when the watershed is fully developed. As shown in Figure 6.3, the mean B-IBI score of 13 to 15 compares well with a calculated value of 14 under current conditions. Assuming full development of the watershed and a TIA of approximately 60% (Section 6.1), B-IBI is predicted to decrease from 14 to 11 (the lowest score possible is 10).

In addition to the high TIA and associated water quality problems related to stormwater runoff implied by the low B-IBI scores, other factors, such as stream flows, substrate characteristics (more sand, less cobble), and the timing of sampling in relation to emergence of insects may have an influence on the results [Environment Canada 2002, 2006; EVS 2003].

Figure 6.3 Hyland Creek,
GVRD WATERSHED HEALTH TRACKING SYSTEM - Permanent Flow Creeks



Source: Kerr Wood Leidal Associates Ltd. 2005

The most common organisms in the samples were pollution-tolerant worms and midge larvae and pollution-sensitive mayfly nymphs:

- The oligochaete (aquatic worm) *Nais* sp. (highest % abundance at H-2)
- The mayfly *Baetis* sp. and unidentified Baetidae (highest % abundance at A-2)
- A variety of Chironomidae (nonbiting midges), including Orthocladiinae, *Eukiefferiella* sp., *Orthocladius* spp. and *Diplocladius* sp. (highest % abundance at H-2 and A-2)

Benthic invertebrate studies were also conducted in summer 1985 at three sites in the Hyland Creek mainstem (high, medium and low gradient areas) and three tributary sites [Backman and Simonson 1985]. The high gradient area was near H2, the low gradient area was downstream of H1 and the tributary site in Archibald Creek was near A-1. The number of replicates, level of taxonomic effort and time of year differed from the B-IBI protocol, although both surveys employed a Surber sampler in riffle habitat. Taxon richness was slightly lower in the 1985 surveys (likely related to taxonomic effort). At the high gradient site (near H2 and King George Highway), low diversity and predominance of moderately pollution-tolerant species (more chironomids, fewer mayflies, caddisflies and stoneflies) indicated degraded water quality related to urban runoff [Backman and Simonson 1995; Simonson 1985]. Abundance and species composition at the other two main stem and two of the tributary sites indicated better water quality and benthic productivity (more mayflies) that at the upstream high gradient site. In contrast, the 2005 survey indicated consistently low B-IBI scores at all three sites sampled, which may be indicative of changes in water and habitat quality over the past 20 years, although this trend should be verified by sampling at the same time of year.

6.4 Watershed Health Assessment

The preliminary watershed health assessment was prepared using TIA and RFI, and following the Watershed Health Tracking System described in the revised ISMP GVRD template [Kerr Wood Leidal 2005], which was modified from the originally proposed Watershed Classification System. TIA and RFI are considered key physical performance measures that correlate strongly with watershed health. Values shown in Tables 6.3 and 6.4 for existing conditions were overlain on the template chart (Figure 6.3).

Hyland Creek is ranked in the lower end of the chart ("poor" health) based on 51% TIA and 64% RFI under current conditions. The benthic invertebrate data support this assessment, with a B-IBI score of 13 to 15 (very poor) in 2005. These values might be expected to move further into the "poor" area with future development (60% TIA and 64% RFI). Implementation of the

Riparian Areas Regulation, which incorporates stream setbacks ranging from 5 m to 30 m, depending on stream classification and assessment approach, would result in a decrease in % RFI when land within the 30 m riparian assessment area is developed. However, increases in % TIA associated with development could be mitigated through initiatives to maintain EIA.

7.0 WATERSHED OPPORTUNITIES AND CONSTRAINTS

7.1 Stormwater Management

Although significant portions of the Hyland Creek watershed have already been developed, there are still opportunities to mitigate the impacts of this level of development on the watershed, as well as to implement stormwater best management practices (BMPs) to address future development. The focus of stormwater related improvements for the watershed should first consider ways to stabilize current watershed conditions, and second, to identify opportunities to improve conditions where practical and economically feasible, with the intent of making a meaningful and effective impact on the overall health of the watershed.

In Zone 1, opportunities to implement stormwater BMPs are somewhat limited as the area is essentially built out and significant redevelopment is not anticipated. However, actions can be taken by the City and individual property owners on a lot-by-lot basis to reduce the generation, and/or improve the quality, of stormwater runoff. Additional community-level detention is also a possibility to address uncontrolled flows from a significant portion of this zone, if the City is amenable to acquiring property for this purpose. Zone 2 is also highly developed; however, there are large parcels of pervious area that remain, including the cemetery and several municipal parks. Retention of these pervious areas assists in offsetting the impacts of existing development in Zone 2. In the case of Zones 1A and 2A, where significant commercial and industrial areas exist, both higher and frequent runoff rates and water quality are of particular concern.

Zone 3 currently contains the vast majority of undeveloped and rural areas remaining in the watershed. This zone also appears to contribute a significant portion of total base flows to Hyland Creek (via Archibald Creek). Therefore, Zone 3 provides the greatest opportunity of all of the zones to have a positive impact on overall watershed health through stormwater management improvements, through implementing stormwater BMPs as part of future development.

Zone 4 is located in the lowland area of the watershed, where agricultural operations are the predominant land use. Public education will be the most effective opportunity in this zone to address water quality concerns.

Stormwater opportunities and constraints for the Hyland Creek watershed are summarized in Table 7.2, located at the end of this section.

7.2 Aquatic Habitat

Maintaining and/or improving water quality is a common goal for the Hyland Creek watershed. This can be accomplished through a combination of municipal infrastructure improvements for stormwater treatment, educational initiatives, and ongoing monitoring of water quality and stream health (via sampling of benthic invertebrate communities).

The headwaters of Hyland Creek (in Zone 1) are currently contained in a network of enclosed storm sewers, with few existing natural channels. The enclosure of the natural headwaters has limited fish presence west of King George Highway. Reaches of Hyland Creek in Zone 2 have a predominantly gravel substrate, with sufficient flow and regular pools to provide excellent spawning and rearing habitat. Several enhancement activities have also taken place along Hyland Creek in this zone. Photo 7.1 shows typical fish habitat in Zone 2.

Photo 7.1:
Typical Fish Habitat in Hyland Creek, Zone 2

Photo 7.2:
Erosion in Hyland Creek near Site H2

Photo 7.3:
A Creosote-Treated Telephone Pole
Installed in Hyland Creek Near Site H2 Presents a
Restoration Opportunity

Photo 7.4:
A Small Bridge Over Hyland Creek
That May Require Upgrading

Photo 7.5:
Typical Fish Habitat in Hyland Creek,
Zones 1A and 2A

Similar to Zone 1, Zone 1A has also enclosed the natural headwaters of Hyland Creek with a storm drainage system. There are few natural channels and fish presence is restricted to the area downstream of King George Highway. The middle reaches of Hyland Creek flow through Zone 2A, where spawning potential has been described as negligible due to inadequate substrates. However, rearing capacity has been described as good, with glide habitat separated by pools [Envirowest 1995]. Photo 7.5 shows typical fish habitat in this zone.

Photo 7.6:
Typical Fish Habitat in Hyland Creek,
Zone 3

Zone 3 contains significant amounts of forested areas and several tributaries to Hyland Creek. Spawning and rearing capacity varies in the tributaries; however, good quality habitat has been documented [Envirowest 1995]. Fish were observed, particularly in areas where the stream had been enhanced or restored. Photo 7.6 shows typical fish habitat in Zone 3. Zone 3 provides the most potential to protect streamside habitat by maintaining continuous riparian corridors and appropriate riparian setbacks during future development. Protecting the existing good habitat and maintaining native vegetation and natural stream banks will provide valuable amounts of permeable surfaces and habitat for fish and wildlife.

Aquatic habitat in Zone 4 has been channelized and dyked for agricultural purposes. There is limited spawning capacity in this zone, due to lack of suitable substrates; however rearing capabilities are high in the deep wide channel. Photos 7.7 and 7.8 show typical fish habitat in this zone.

Photo 7.7:
Typical Fish Habitat in Hyland Creek,
Zone 4

Photo 7.8:
Typical Fish Habitat in Hyland Creek,
Zone 4

Opportunities and constraints for aquatic habitat in the Hyland Creek watershed are listed in Table 7.2, located at the end of this section.

7.3 Wildlife and Terrestrial Habitat

Zone 1 is highly developed with very little natural vegetation remaining. Within the few stands of mature trees remaining, the understory is highly disturbed, with very little vegetation. While there are several municipal parks in this zone, most contain space for active uses and thus have little natural vegetation.

There is relatively intact riparian habitat in Zone 2 along Hyland Creek and its tributaries between King George Highway and 144 Street. A large tract of riparian habitat along Hyland Creek also exists between 148 Street and 152 Street. The northern portion of Hazelnut Meadows Community Park provides a large area of natural habitat in this zone. There is one large (6.65ha) parcel of forest remaining in Zone 1A, which is located south of the library between 138 Street and the railway line. This city-owned property is currently zoned industrial.

Undeveloped land in Zone 3 includes the riparian habitat of Archibald Creek and its tributaries. Riparian habitat along Archibald Creek has been encroached upon, as indicated by the 68% Riparian Forest Integrity calculation for Zone 3 (Table 6.3 and Figure 6.2). There is a small patch of coniferous forest in one area, with a well developed understory and some open areas amongst the canopy. In Zone 4, riparian habitat along Hyland Creek lacks natural vegetation due to active agricultural activities.

Opportunities and constraints for wildlife and terrestrial habitat in the Hyland Creek watershed are summarized in Table 7.2, located at the end of this section.

7.4 Hydrogeology

Much of the Hyland Creek watershed is already developed, and from qualitative descriptions of the surficial soil units, it does not appear likely that shallow infiltration best management practices (BMP's) will be feasible at the community scale. However, in upland areas where groundwater is naturally recharging, it may be possible to minimize effective impervious area by re-infiltrating runoff at the individual lot-scale. These systems will likely need to be small, and should be evaluated on a lot-by-lot basis. Unfortunately, in lowland areas where most of the coarser-grained surficial soils (Cb unit, raised beach medium sand) that would typically be able to infiltrate large volumes of water are located, the groundwater table is likely to be close to or at the surface for much of the year, resulting in low infiltration capacity.

Based on a review of surficial geology, infiltration of stormwater does not appear to be feasible in Zones 1, 1A, 2A and 4; however, lot-level infiltration facilities may be feasible in Zones 2 and 3. Zone 3 appears to have the most potential for the implementation of lot-level stormwater infiltration BMPs within the Hyland Creek watershed, although impacts such as groundwater mounding and slope stability would need to be considered.

Hydrogeological opportunities and constraints for the Hyland Creek watershed are summarized in Table 7.2, located at the end of this section.

7.5 Land Use / Planning / Parks and Recreation

The City's ability to improve the integrity of the watershed through land use regulations is constrained by the fact that the entire watershed has either already been developed or is the subject of a Neighbourhood Concept Plan (NCP). Furthermore, the undeveloped areas of the watershed are currently under considerable development pressure, which may give the City little time to amend land use bylaws. Consequently, there are only limited opportunities to make any significant changes to current or proposed land use patterns, which in turn constrains some of the creative and innovative practices and methods that could otherwise have been developed for the ISMP. The City may also find that enforcement of new regulations is difficult or impractical. On the other hand, the City still has the option to amend the Zoning Bylaw, OCP or other policies and bylaws to try to affect future infill development, by ensuring that it is more sensitive to stormwater and environmental issues. Table 7.1 includes a description of the City of Surrey's current bylaws and identifies possible amendments.

Table 7.1
Land Use and Development Bylaws Relevant to Integrated Stormwater Management

Bylaw Name	Purpose	Provisions Supportive of Stormwater Management	Potential Amendments/Additions
Surrey Official Community Plan By-Law, 1996, No. 12900	• Statement of long term land use objectives to guide City planning decisions	• The GVRD Liveable Region Strategic Plan sets out a framework for the protection of natural areas throughout the GVRD. The Green Zone natural areas within the City of Surrey set a boundary for urban growth. • Major policy initiative to create compact communities encourages alternative development design. • All land development must take into account environmental considerations, such as: o Sedimentation and erosion control o Conservation of significant natural features o Maintenance of water quality & natural flow patterns o Reduce air, land and water pollution • All land outside but abutting Agricultural lands are Development Permit Areas in order to minimize urban encroachment on farming activities. • All other parcels of land containing multiple residential, commercial, or industrial projects are designated as Development Permit Areas to provide high quality built environments while protecting the natural environment. • For DPAs in or next to an ESA (high or medium rating): o Environmental Impact Study required o Minimum setback of 15 m (more for fish bearing streams) and cluster development away from ESA o No development for at least 15 m from top of bank on all watercourses o 70% of setback should be landscaped	• Set more well defined targets and performance measures for environmental considerations (e.g. as part of a Development Permit Area, set a maximum level of suspended solids on any watercourse). • Expand the application of Development Permit Area guidelines for Environmentally Significant Areas to Single Family development. • Set targets for amount of natural space and parks/open space. • Set an urban growth boundary for the City.
Surrey Zoning By-Law, 1993, No. 12000	• To regulate land use	• Maximum lot coverage regulations in most zones. • Public uses (including playgrounds and recreation areas) are allowed in all zones and require landscaping including the retention of mature trees.	• Encourage cluster development in all zones. • Consider setting a maximum for parking stalls required or require pervious materials.

Bylaw Name	Purpose	Provisions Supportive of Stormwater Management	Potential Amendments / Additions
Surrey Zoning By-Law, 1993, No. 12000 (cont'd)	• To regulate land use	• Required setbacks include: 7.5 m setback from natural boundary of sea, swamp, pond or ditch; 30 m setback from Fraser River natural boundary; 15 m setback from Nicomekl and Serpentine Rivers. • Residential Zones include an RC – Cluster Development Zone. • Increased density if 15% or more open space is preserved in natural state or retained for park and recreational purposes in some zones (such as RA-G and RH-G).	• Extend maximum impervious area regulations to all zones. • Incorporate low-impact development practices at the site level. • Require park spaces to be designed considering stormwater drainage and infiltration. • Encourage the use of bioswales, wetlands, rain gardens etc. for stormwater management in landscape design.
Surrey Subdivision and Development By-Law, 1986, No. 8830 and related Design Criteria Manual, 2004	• To set requirements and standards for servicing prior to approval of subdivision or issuance of building permits.	• The Design Criteria Manual sets stormwater management standards and outlines potential stormwater management approaches and methods, including the use of BMP's.	• Require adherence to stormwater management standards for all development. Currently, the By-Law exempts small-scale building permit applications. • Specifically require the use of on-site BMP's. • Require all land uses to disconnect roof leaders. Currently, the Design Criteria Manual requires commercial, institutional, industrial, and multiple residential land uses to connect on-site storm drainage and/or roof drains to the community system.
The Surrey Soil Removal and Depositing Regulation By-Law, 1979, No. 5880	• Regulate the removal and deposition of soil etc. from and to lands	• Soil cannot be deposited within 50 m of any watercourse or on steep slopes. • The depositing and removal of soil cannot add silt, clay, sand etc. to any drainage facility, natural watercourses, and ground water aquifers.	

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Bylaw Name	Purpose	Provisions Supportive of Stormwater Management	Potential Amendments/Additions
Erosion and Sediment Control Bylaw	• Limit the discharge of sediment from construction activities into the municipal drainage system	• No person shall discharge more than 75 mg/L of total suspended solids for a 25mm / day or less rainfall event • An ESC permit will be required for construction sites over 2,000 m^2	
Tree Preservation By-Law, 1996, No. 12880	• Regulate and prohibit the cutting and removal of trees	• All trees listed as protected or significant cannot be cut/altered/damaged without a permit and violations induce a significant fine (up to $10,000). • Trees near construction/excavation must be protected.	
Surrey Waterways Protection By-Law, 1967, 2659	• Prohibit the fouling, obstructing or impeding the flow of any stream, creek, waterway, watercourse, waterworks, ditch, drain, or sewer within the City	• Protection from the fouling, obstruction or impediment of the flow of any stream, creek, waterway, watercourse, waterworks, ditch, drain or sewer, on public or private property. • $100 /day fine is imposed for a violation.	• Set more specific requirements for water quality protection consistent to those outlined in the draft Stormwater Drainage Regulation and Charges bylaw • Set requirement not only for quality of waterways, but also for their continuous management with particular emphasis in developed areas on stormwater system maintenance.
Surrey Tree Cutting By-Law, 1979, No. 5835	• Regulate the cutting of trees on City owned properties	• No person shall, without authorization by the City, within any real property owned by the City of Surrey, remove, cut, break, injure or in any way destroy or damage any tree, shrub, plant, turf, sod, or flower. • No person shall, without authorization by the City, within the City of Surrey, cut or remove any tree on property owned by the City for timber or firewood. • Fine up to $500 for violation.	

Bylaw Name	Purpose	Provisions Supportive of Stormwater Management	Potential Amendments/Additions
Natural Areas Management Plan	• To provide strategic direction for the management of City Park natural areas	• Protect, preserve and enhance native vegetation and wildlife habitat. • Public education and information strategies to develop understanding and awareness. • Inspection, monitoring and management activities for protecting park natural areas. • Make an effort to acquire additional natural park areas to increase connectivity between parks.	• Adopt certain provisions within bylaws to strengthen enforcement of plan policies.
Pesticide Use Policy	• To maintain and enhance the functionality, safe use, enjoyment and aesthetic beauty of the City's natural and developed parks	• Using Integrated Pest Management (IPM) Principles for managing public lands: o Ecological approach o Minimize pesticide use (chemicals as a last resort) o Minimize human health risks	• Extend policy to private property.

Zones 1, 1A and 2A are largely developed, and based on discussions with City staff these areas are not expected to redevelop to any appreciable extent in the foreseeable future, thus there are limited opportunities to change land use patterns to mitigate detrimental stormwater or environmental conditions on a large scale. Zone 2 is nearing build out, and any undeveloped areas are subject to the East Newton South Neighbourhood Concept Plan. As this area is experiencing considerable development pressure, the City has limited opportunity to make any large scale amendments to the land use plan to promote stormwater management; however, redevelopment and infill situations could be required to implement BMPs through the building or subdivision process.

The South Newton NCP (Zone 3) includes several parks as well as provisions to help protect Hyland Creek and its tributaries through riparian setbacks. The City can help ensure that these natural spaces are preserved through the identification of appropriate riparian setbacks and possibly by acquiring land directly. The City may also consider allowing cluster development to protect the Hyland Creek tributaries that flow through Zone 3. Given that the City amended the NCP to allow small-lot development, the City should still be able to meet its original population targets while conserving natural space.

On the other hand, Zone 3 is still under considerable development pressure, and has already been planned to a significant level of detail. Consequently, the City may have limited opportunity to make any large scale amendments to the land use plan to promote stormwater management. Furthermore, protection of existing natural areas may be difficult due to the fact that many private landowners would require compensation.

Zone 4 falls partially within the East Newton Business Park Neighbourhood Concept Plan and as such, detailed land use planning has already been completed for a portion of this Zone. The other portion of this Zone is located in the Agricultural Land Reserve (ALR).

Opportunities and constraints for land use, planning and parks and recreation for the Hyland Creek watershed are summarized in Table 7.2.

Table 7.2
Opportunities and Constraints for the Hyland Creek Watershed

Discipline	Applicability	Opportunities	Constraints
Stormwater Management	Entire Watershed	• Promote education initiatives (e.g. rain barrels, native plantings and amended topsoil in private landscape areas, impacts of pesticide use on water quality) • In existing municipal parks incorporate native plant species and amended topsoil in non-active areas, reduce the number of parking spaces (less impervious area) or use alternative paving materials for parking areas • Implement flow monitoring programs at select sites to evaluate performance of existing drainage infrastructure and/or impacts of development to base flows and peak flows in watercourses • Do not allow roof leader connections for new homes • Require stormwater BMPs (e.g. limit impervious surface coverage) through building permit process	• Extent of existing development may limit the type and scale of stormwater management improvements that can be implemented • May be difficult and/or economically unrealistic to implement measures on a large scale
	Zone 1	• Retrofit outlet structures and/or increase volume capacity of existing detention pond(s) to improve level of service • Remove redundant or inefficient detention pond(s) to reduce operation and maintenance costs • Assess potential for City to sell land after removal of pond(s) for development and use funds for other enhancement activities in watershed • Explore opportunities to provide community detention for uncontrolled areas • Prioritize capital drainage works where possible to correspond with roads program • Explore opportunities to daylight enclosed (sewered) sections of the watercourse to restore natural headwaters of creek and provide water quality enhancements	• Detailed hydraulic analysis required to determine hydraulic grade line impacts of removing detention ponds on local downstream drainage infrastructure • Many existing detention ponds located on lands are not considered easily developable • Extent of existing development means City would need to acquire land for major stormwater improvement works
	Zone 2	• Same opportunities for existing detention ponds as outlined in Zone 1 • Implement remediation measures from 2006 Ravine Stability Assessment Update report to address erosion concerns on Hyland Creek • Identify opportunities to implement stormwater BMPs on an individual site scale through development and redevelopment applications • Encourage stormwater BMP's as part of infill or redevelopment process	• Same constraints for existing detention ponds as outlined in Zone 1

Discipline	Applicability	Opportunities	Constraints
Stormwater Management	Zones 1A / 2A	• Use results of water quality assessment to identify main contaminants (e.g. metals, coliforms) contributing to degraded water quality • Retrofit existing commercial and industrial developments with onsite water quality treatment units • Explore opportunities to provide community detention for uncontrolled areas	• Communication and cooperation from local businesses to implement water quality treatment units on private properties • May be difficult and expensive to implement on a large scale • City may need to provide financial or other incentives to businesses for program to be widespread and successful
Stormwater Management	Zone 3	• Incorporation of onsite stormwater BMPs may reduce scope of future planned community detention facilities • Retention of native vegetation and topsoil will assist in maintaining base flows to watercourses and will provide additional retention capability to offset impacts of land alteration • Identify design criteria and/or policies for future development that encourage reduction of impervious areas, retention of natural areas, etc. • Use perforated storm sewers where feasible to encourage infiltration	• Soil characteristics may not be suitable for large scale infiltration of stormwater runoff • Development pressure is so great that a significant number of development applications will have likely been approved or in process before ISMP recommendations come into effect • Previously adopted planning studies dictate (to some degree) what stormwater management works can be implemented
	Zone 4	• Provide public education opportunities specific to the agricultural community on potential risks of farming operations on water quality	• Communication and cooperation from agricultural community to consider water quality impacts of farming operations
Aquatic Habitat	Entire Watershed	• Pursue opportunities to combine stormwater detention with treatment (e.g. settling ponds to reduce sediment loads to the creek) when developing or upgrading municipal infrastructure • Protect riparian areas from residential encroachment • Reduce the amount of pesticides entering stormwater by reducing cosmetic use on residential properties and municipal lands • Provide bags and disposal containers for dog feces where there are trails near creeks • Increase the frequency of catch basin cleaning and street sweeping • Promote painting of yellow fish next to storm drains to remind residents that drains flow into fish habitat, thus discouraging disposal of deleterious substances • Promote watershed stewardship (e.g. neighbourhood tree planting, planting native species and protecting pervious areas)	• Prevalence of privately owned land, which restricts the extent to which the City can pursue stream improvements and would require cooperation from property owners or funds for purchase of land. • Many instances where riparian habitat in established neighbourhoods has been disturbed by placement of fencing, landscaping and structures.

Discipline	Applicability	Opportunities	Constraints
Aquatic Habitat	Zone 1	• Daylight enclosed sections of creek (if feasible) • Expand fish access • Improve instream habitat quality upstream of the King George Highway	• Daylighting small lengths of creek requires endorsement of numerous landowners, as Hyland Creek flows through many small, privately owned lots • High cost to providing fish access upstream of the King George Highway
	Zone 2	• Stabilize bank to repair erosion just downstream of H2 (Photo 7.2) • Remove creosote-coated telephone pole installed in creek just downstream of H2 (Photo 7.3) and replace with a "clean" pole, outside the channel • Assess and possibly replace a small residential access bridge just upstream of H2, which may be unstable (Photo 7.4) • Assess potential for hydrocarbons to leak into soil or stream from the remnants of an abandoned car, 70 m upstream of H2	• Encroachments and activities on the many small, privately owned lots along Hyland Creek affect the stream. • Aquatic habitat is limited by water quality, stream erosion, concrete flumes and fish passage barriers (culverts).
Aquatic Habitat	Zones 1A / 2A	• Explore options to remove fish migration barrier at King George Highway • Retrofit developed areas by implementing BMPs to maintain and improve water quality (e.g. oil-grit separators in commercial and industrial areas) • Add instream structures to increase habitat complexity in Zone 2A • Remove litter from stream in the area of water monitoring site H3	• The (≥35 m) long culvert under King George Highway is a barrier to fish migration into upstream areas. • The zones are highly developed (industrial and commercial areas).
	Zone 3	• Use stormwater BMPs to encourage infiltration (disconnect roof leaders, use sufficient topsoil on residential lots, etc.) • Follow NCP and GVRD recommendations for limiting amount of impervious cover • Implement BMPs to maintain and improve water quality (e.g. oil-grit separators in commercial areas) • Address identified deficiencies in riparian planting works (dislodged plants) • Remove a broken pallet being used as a footbridge (partially blocking the stream) and replace with a proper structure	• Current and future proposals for land development should follow applicable regulations for protection of riparian habitat.
	Zone 4	• Conserve the remaining riparian buffer and plant a continuous corridor of trees and shrubs along the banks • Place boulders and large woody debris for fish cover and channel complexity • Screen irrigation intake pumps (in accordance with DFO regulations) • Discourage use of pesticides and fertilizers near the stream • Encourage water conservation	• Will need cooperation with other government agencies and landowners to ensure compliance with restrictions on chemical use in agricultural areas. • Farmers may incur additional costs while updating irrigation equipment

Discipline	Applicability	Opportunities	Constraints
Wildlife and Terrestrial Habitat	Entire Watershed	• Establish a park and natural area network within the context of existing plans • Establish fenced riparian covenants (30 m from the top-of-bank or high water mark) • Prevent backyard landscaping from extending into the covenant areas • Ensure that land use zoning reflects natural area covenants • Conserve or restore native riparian vegetation • Remove exotic species and replant with native species, where possible • Encourage landscaping with native plants • Protecting riparian setbacks for fish habitat will provide protection for many wildlife species.	• Requires landowner cooperation for access and enhancement of suitable areas • On private land, establishment of covenants would require land purchases by the City or private land donations • Environmental Management Practices for Urban and Rural Land Development and provincial BMPs for protected species (e.g. raptors, Pacific water shrew, amphibians and reptiles) will need to be consulted prior to development
	Zone 1	• Protect the small area of riparian habitat at the eastern edge of Zone 1 • Make minor changes to parks (use native plants in non-active areas, amend topsoil, reduce extent of parking areas, integrate water quality BMPs into park space) to promote stormwater management and environmental objectives.	• The degree of existing development in Zone 1
Wildlife and Terrestrial Habitat	Zone 2	• Preserve remaining riparian habitat and other natural features as much as possible; enhance by planting native species and removing invasive species. • Design fish habitat enhancement projects with wildlife habitat in mind to take advantage of the synergetic relationship between fish and wildlife habitat.	• The degree of existing development in Zone 2, limited opportunities to identify, preserve and enhance natural environmental features or mitigate detrimental environmental conditions on a large scale
	Zones 1A / 2A	• Preserve remaining natural features as much as possible, and maintain their links with external natural areas	• The degree of existing development in Zones 1A and 2A, limited opportunities to identify, preserve and enhance natural environmental features or to mitigate detrimental environmental conditions on a large scale.
	Zone 3	• Take advantage of the current low level of development and the potential for future development to provide a source of wildlife habitat by establishing dedicated parks and natural covenants • Conserve riparian corridors and improve vegetation through riparian planting	• The preponderance of privately held land, which would require significant land purchases by City or donations of private land for green space preservation and establishment of natural covenants
	Zone 4	• Work with farm owners to identify opportunities for habitat protection (e.g., preservation or restoration of riparian vegetation) in the relatively undisturbed farmland • Continue to support preservation of agricultural zoning	• The preponderance of privately held land, which would require significant land purchases by City or donations of private land for green space preservation and establishment of natural covenants

Discipline	Applicability	Opportunities	Constraints
Hydrogeology	Entire Watershed	• Investigate stormwater infiltration on a lot-by-lot basis in upland areas	• High level of development in watershed limits areas for infiltration • Community scale stormwater infiltration is not feasible due to surficial geology • Infiltration capacity limited because of high groundwater levels in low areas around creeks, although soil is most suitable (coarse-grained) • Finer grained soils in upland areas
	Zone 1	• None	• Low permeability of soils in surface layers
	Zone 2	• Assess potential for large cemetery, parks and schools to provide opportunities for stormwater infiltration where surficial geology permits	• Extent of existing development • Low permeability of soils in surface layers, except for areas near Hyland Creek
	Zones 1A / 2A	• None	• Low permeability of soils in surface layers • Potential risk of groundwater contamination related to industrial and commercial uses
Hydrogeology	Zone 3	• Low current development levels enable investigation of alternative infiltration strategies • Investigate potential for stormwater infiltration (Cb geologic unit) in some areas, on a lot by lot basis	• Low permeability of soils in surface layers limits infiltration to a lot-by-lot basis • High groundwater table in the area, limits infiltration capacity
	Zone 4	• None	• Low permeability of soils in surface layers • High groundwater table present
Land Use / Planning / Parks and Recreation	Entire Watershed	• Consider amending or adopting various bylaws and policies to be more supportive of stormwater management/environmental protection (see Table 7.1), for example, pollution prevention regulations, erosion and sediment control bylaw	• The high level of existing or planned development in the watershed, which limits the City's ability to change future land use • The considerable development pressure • Difficulty enforcing new regulations
	Zone 1	• Consider imposing new regulations as redevelopment occurs (see Table 7.1).	• The high level of existing or planned development in the watershed, which limits the City's ability to change future land use • Reluctance to convert existing active park spaces to more natural areas.
	Zone 2	• Consider imposing new regulations as redevelopment occurs (see Table 7.1).	• Limited ability to change land use because most of the area is already developed

Discipline	Applicability	Opportunities	Constraints
Land Use / Planning / Parks and Recreation	Zones 1A / 2A	• Consider introducing a Development Permit Area that focuses on pollution prevention in non-residential areas	• Limited ability to change land use because most of the area is already developed
	Zone 3	• Discuss with landowners options for optimizing stormwater BMPs and environmental values in this relatively undeveloped area of the watershed • Assess potential for cluster development to protect Hyland Creek tributaries • Parks and riparian setbacks are included in the NCP	• Planning at the NCP level makes it difficult to significantly change land use • Private ownership limits the ability to protect park land and riparian areas
	Zone 4	• The City can adhere to stormwater management provisions in NCP • Work with Agricultural Land Commission to educate farming community on impacts of fertilizer and pesticide use on agricultural lands to water quality in Hyland Creek	• Land use plans are already in place for a portion of this area

8.0 WATER QUALITY ASSESSMENT

Water quality is a concern in Hyland Creek as in many urban watersheds, and is influenced by activities on the land. Physical parameters (temperature, conductivity, pH, dissolved oxygen, turbidity) can provide evidence of degraded water quality due to human influences. The presence of coliform bacteria can indicate contamination with fecal material. Other substances, such as metals, pesticides, nitrate, ammonia and phosphate, reflect vehicle use and commercial, residential and agricultural practices and can be transported to the stream via runoff. If unmitigated, future development will increase stormwater runoff and pollutant loads entering Hyland Creek.

Water quality guidelines have been developed in British Columbia to protect various water uses, such as drinking water, primary contact for recreation, irrigation and freshwater aquatic life [Ministry of Environment 2006]. For this assessment, the most applicable (and typically the most stringent) guidelines are used. For example, the most likely risk of exposure to coliforms is through recreation / primary contact (e.g. children playing in the creek), rather than through drinking the water, and the organisms most sensitive to exposure to metals are aquatic organisms (fish and benthic invertebrates).

8.1 Historic Data

Hyland Creek has a history of water quality problems, including discharge of organic waste from a food processing plant [Visser 1991] and chemical spills (vinegar, paint and diesel) resulting in fish kills [DFO 2006]. Specific current water quality issues in the watershed are related to construction and a cement and gravel operation [DFO 2006].

In the early 1990s, frequent incidents of sewage fungus growth and soapy water resulted in loss of all aquatic life in upper Hyland Creek [Visser 1991]. Investigations by the District (now City) of Surrey in 1991 identified a food processing plant as the source of nutrients promoting growth of sewage fungus, prompting the company to divert their wastewater into the municipal sanitary sewer system and eliminating the sewage fungus problem [Visser 1991]. While the report narrowed down possible causes of the soapy water, it did not identify the source.

Between 1972 and 2002, the Ministry of Environment monitored water quality data in Hyland Creek at 152 Street (Station E207718). Results for 2002 indicated that fecal coliform, ammonia, suspended solids and dissolved oxygen levels had significantly improved since 1990; however, *E. coli* levels in irrigation water were close to the maximum specified in provincial water quality objectives[(British Columbia Ministry of Water, Land and Air Protection 2002].

8.2 2006 Water Quality Monitoring Program

Water quality was assessed at four sites in 2006 as part of the ISMP, as previously shown on Figure 5.7. Three sites (H1 and H2 on Hyland Creek, A1 on Archibald Creek) correspond with the 2005 benthic invertebrate sampling program conducted by the City of Surrey and a fourth is situated in the upper watershed (H3 on Hyland Creek just downstream of the King George Highway). Samples were collected on May 4, June 5, June 8 and June 28, 2006, reflecting both dry and wet conditions. Four travel blanks (one per trip) and one field duplicate sample were collected. Samples were preserved as required, kept in a cooler at 4ºC and submitted to the ALS Environmental laboratory (Vancouver BC) within five hours of collection.

At each site, *in situ* water quality (temperature, turbidity, pH, dissolved oxygen (DO), and conductivity) was recorded and grab samples were collected for analysis of metals, nutrients and coliforms. Field meters included a Hanna pH meter, YSI 85 Multimeter (for dissolved oxygen, conductivity, salinity, temperature) and Lamott turbidity meter. *In situ* and analytical water quality results are summarized in below and complete analytical reports are contained in Appendix B.

8.2.1 Quality Assurance / Quality Control

Sample quality (QA/QC) was high as indicated by:

- Four travel blanks (no indication of sample contamination on three dates, trace amounts of phosphates on June 28)
- Two laboratory duplicates (analyses within laboratory data quality objectives)
- One field duplicate (close agreement in concentrations for most parameters, 15% to 35% difference for coliform counts, ammonia and nitrate)
- Field vs. laboratory comparisons for conductivity

Field measurements of pH were similar to laboratory measurements on May 4 (7.7 to 8.0), but notably lower on the other three dates (6.0 to 7.0 for field measurements compared to 7.6 to 8.2 for lab measurements). Such differences are often noted, and can be attributed to differences in field and laboratory conditions and lower accuracy of field meters. As a result, the lab values for pH are considered in site comparisons.

8.2.2 In Situ Water Quality

In situ water quality results are presented in Table 8.1. Weather and stream conditions were consistently dry or wet on three dates; however, the June 8 samples were collected at the start of a rainstorm at sites H2, H3 and A1, following several days of dry weather, resulting in varying flow and runoff conditions at the four sites.

Table 8.1
Field Conditions and *In Situ* Water Quality in Hyland Creek, Spring 2006

Parameter	Date	Site			
		H1	H2	H3	A1
Weather	May 4	Sunny and dry for previous week			
	June 5	Overcast, rain in previous days			
	June 8	Overcast, dry	Heavy rain	Heavy rain	Light rain
	June 28	Sunny and dry for several days			
Temperature (°C)	May 4	10.7	9.6	10.8	10.4
	June 5	13.9	13.8	14.5	13.3
	June 8	13.5	13.1	15.1	12.8
	June 28	15.8	15.4	15.2	14.9
Specific Conductivity (µS/cm)	May 4	273	256	238	247
	June 5	236	243	224	271
	June 8	265	256	126	246
	June 28	255	291	111	236
Turbidity (NTU)	May 4	4.1	2.1	2.7	2.8
	June 5	0.7	0.9	0.9	1.0
	June 8	0.8	0.8	69.3	0.8
	June 28	*	*	*	*
pH (field)[1]	May 4	7.8	8.1	8.0	8.0
	June 5	6.5	6.0	6.5	6.5
	June 8	6.5	6.0	6.0	7.0
	June 28	6.5	6.0	6.5	7.0
DO (%)	May 4	99	84	80	90
	June 5	86	80	85	88
	June 8	84	79	89	88
	June 28	107	95	103	109

* meter not available
[1] field readings for June 5, 8 and 28 substantially lower than laboratory measurements and may indicate calibration problems with field meter

Temperature ranged from 9.6 to 15.8ºC, and increased between May 4 and June 28. Temperature generally was similar among the four sites, although it was up to 1ºC lower at A1. Conductivity ranged from 111 to 291 µS/cm and tended to be lower at H3 than at the other sites; it was lowest at H3 during the June 8 rainstorm, suggesting dilution by runoff, and on June 28 during dry weather. Turbidity typically ranged from 0.7 to 4.1 NTU, with one value of 69.3 NTU measured at H3 during the June 8 rainstorm. Values for pH ranged from 7.8 to 8.1 on May 4 and from 6.0 to 7.0 on the other dates, with low values likely related to accuracy of the field meter, as mentioned in the QA/QC section. Dissolved oxygen levels ranged from 79% to 109% (8.6 to 11.0 mg/L).

Results are compared with BC water quality guidelines for protection of aquatic life [Ministry of Environment 2001]. *In situ* parameters were within applicable guidelines with one exception. Turbidity exceeded provincial guidelines (a maximum increase of 8 NTU over background) at site H3 during heavy rainfall on June 8, with a value of 69.3 NTU. The level of total suspended solids was high (107 mg/L, see Table 8.2) and corresponded with the high turbidity measurement.

Also, temperatures recorded during dry weather on June 28 (up to 15.8ºC) suggest that summer temperatures are near or above optimal levels for salmonids (up to 16ºC for rearing coho salmon and cutthroat trout). This result highlights the importance of maintaining streamside vegetation.

8.2.3 Total Suspended Solids

The total suspended solids (TSS) measurement is commonly used to assess sediment loads in a creek, and typically comes from runoff of sand, silt, clay and organic matter, for example from construction sites, stream bank erosion sites and other exposed soils. High levels of TSS can damage the gills of salmonids and other fish and of aquatic invertebrates and degrade instream habitat when the material settles onto gravel and cobble substrates.

The TSS levels at the four sites were low (<3 to 4 mg/L) on the four dates, with the exception of site H3 during heavy rainfall on June 8, where a value of 107 mg/L was measured. TSS levels are summarized in Table 8.2. This maximum corresponds with a high turbidity value (69.3 NTU), and reflects the ability of stormwater to convey large amounts of suspended materials into the stream. This value also exceeds the BC water quality guideline.

Table 8.2
Total Suspended Solids (TSS) in Hyland Creek, Spring 2006

Parameter (mg/L)	Water Quality Guideline[1]	Date	Site			
			H1	H2	H3	A1
TSS	Maximum induced TSS of 25 mg/L when background is <250 mg/L	May 4	<3.0	<3.0	<3.0	<3.0
		June 5	<3.0	<3.0	<3.0	3.2
		June 8	<3.0	<3.0	107	<3.0
		June 28	<3.0	4.0	3.3	<3.0

[1] BC water quality guidelines for recreation / primary contact [Min. Env. 2001]

8.2.4 Coliforms

Coliforms are a group of bacteria that live in soil, water and the intestinal tracts of cold- and warm-blooded animals, with fecal coliforms, including *Escherichia coli*, specific to mammals, including humans. The presence of *E. coli* and other fecal coliforms indicates contamination with fecal material. Results for Hyland and Archibald Creeks are presented in Table 8.3.

Table 8.3
Coliform Levels in Hyland Creek, Spring 2006

Parameter (MPN/100 mL)	Water Quality Guideline[1]	Date	Site			
			H1	H2	H3	A1
Total Coliforms	None	May 4	>2420	>2420	>2420	>2420
		June 5	11,200	13,000	14,100	16,000
		June 8	>2420	>2420	>2420	>2420
		June 28	15,500	12,000	24,200	>24,200
Fecal Coliforms	Geometric mean ≤ 200/100 mL	May 4	146	TNTC	98	92
		June 5	240	300	500	370
		June 8	270	250	TNTC	340
		June 28	510	180	640	270
E. coli	Geometric mean ≤ 77/100 mL	May 4	53	>2420	165	130
		June 5	236	172	172	259
		June 8	114	155	1,730	199
		June 28	866	196	816	194

[1] BC water quality guidelines for recreation / primary contact [Min. Env. 2001]
MPN = Most Probable Number per 100 mL
TNTC = too numerous to count
BOLD numbers are higher than water quality guideline (mean value)

Levels of *E. coli* and fecal coliforms were compared with the BC water quality guidelines for primary contact recreation [Ministry of Environment 2006], as humans are the most sensitive organisms to coliform contamination and there are no provincial guidelines for protection of wildlife or aquatic life. It is noted that these guidelines are designed to assess mean values (five measurements in a 30-day period, triplicate samples), rather than the individual measurements collected for the ISMP program and results should be interpreted with caution. Individual values for *E. coli* and fecal coliforms exceeded the guidelines in most of the samples analyzed (see Table 8.3) and were highest at site H2 on May 4 (dry weather) and H3 on June 8 (storm event). There were no consistent trends evident among sites or for dry vs. wet weather sampling.

In an urban stream, animal feces are the most obvious source of coliforms, although sewer cross-connections may be implicated if there is a consistent trend in coliform data (not evident here).

8.2.5 Nutrients / Fertilizers

Aquatic organisms are sensitive to changes in nutrient levels hence the relevant comparison is to water quality guidelines for protection of aquatic life. Nitrogen and phosphorus are essential elements for aquatic plants (algae); however, high levels of these compounds (e.g. from lawn and garden fertilizers, detergents, organic matter) can lead to excessive algal growth in a stream and degradation of stream habitat for aquatic insects and fish. Results for the various nitrogen and phosphate fractions at the four sites are shown in Table 8.4.

Table 8.4
Nutrient Levels in Hyland Creek, Spring 2006

Parameter	Date	Site			
		H1	H2	H3	A1
Ammonia (mg/L N)	May 4	0.0193	0.0220	0.0133	0.0160
	June 5	0.0473	0.0220	0.0260	0.0370
	June 8	No analysis	No analysis	No analysis	No analysis
	June 28	0.0300	0.0170	0.0070	0.0140
Nitrate (mg/L N)	May 4	1.14	1.61	2.03	1.22
	June 5	1.05	1.35	2.88	1.06
	June 8	1.23	1.45	2.25	1.31
	June 28	0.82	1.68	0.64	0.94
Nitrite (mg/L N)	May 4	0.0084	0.0154	0.0204	0.0079
	June 5	0.0062	0.0072	0.0126	0.0082
	June 8	0.0070	0.0053	0.0972	0.0124
	June 28	0.0067	0.0093	0.0018	0.0060
Phosphate, ortho (mg/L P)	May 4	0.0211	0.0201	0.0520	0.0292
	June 5	0.0257	0.0251	0.0754	0.0377
	June 8	0.0376	0.0278	0.0185	0.0497
	June 28	0.0340	0.0359	0.0096	0.0544
Phosphate, dissolved (mg/L P)	May 4	0.0260	0.0237	0.0554	0.0328
	June 5	0.0301	0.0271	0.0777	0.0416
	June 8	0.0500	0.0315	0.0190	0.0597
	June 28	0.0364	0.0369	0.0141	0.0549
Phosphate, total (mg/L P)	May 4	0.0326	0.0305	0.0657	0.0419
	June 5	0.0399	0.0326	0.0867	0.0532
	June 8	0.0467	0.0381	0.513	0.0605
	June 28	0.0458	0.0465	0.0473	0.0660

Nitrogen cycles through its various forms (ammonia, nitrate, nitrite and organic nitrogen) during uptake by and decomposition of stream algae and bacteria and by chemical processes. Ammonia levels ranged from 0.0070 to 0.0473 mg/L, increasing with distance downstream in Hyland Creek. Nitrate levels ranged from 0.64 to 2.88 mg/L, and were highest at H3, downstream of the King George Highway, decreasing with distance downstream. Nitrite levels ranged from 0.0018 to 0.097 mg/L, highest at the upstream site. All nitrogen compounds were within BC water quality guidelines for protection of aquatic life [Ministry of Environment 2006], which include nitrite (0.3 mg/L at chloride levels of 8 to 20 mg/L), nitrate (200 mg/L) and ammonia (varies with temperature and pH and is 1.59 to 1.78 mg/L for the range measured). They were also within guidelines for drinking water and recreation (10 mg/L nitrate and 1 mg/L nitrite).

Phosphorus in streams occurs in both organic and inorganic forms. Total phosphate ranged from 0.030 to 0.513 mg/L. Ortho phosphate (dissolved inorganic phosphate) and total dissolved (organic and inorganic) fractions were lower, ranging from 0.020 to 0.078 mg/L. These results indicate the effects of urbanization, given that ortho phosphate concentrations for unpolluted streams average approximately 0.01 mg/L and can increase to 0.05 to 0.1 mg/L in areas receiving additional inputs [Wetzel 2001]. Phosphate levels were highest at the upstream site and decreased with distance downstream. Concentrations of all fractions were greatest during the June 8 rainstorm, to be expected as a result of runoff.

The spatial trend of overall decrease in both nitrogen and phosphorus compounds with distance downstream indicates that water draining the King George Highway area is high in nitrate, and levels are diluted downstream with the input of other water sources. The increase in ammonia with distance downstream suggests natural processes of nitrate uptake and organic matter decomposition. Nutrient cycling in streams follows a spiralling pattern of uptake and downstream release [Wetzel 2001].

8.2.6 Metals

Metals such as zinc, molybdenum, copper and cadmium are common components of street runoff and arise from vehicle use (e.g., wear and tear of brakes, tires), house materials (e.g. zinc strips and copper granules used to control moss and algal growth, copper plumbing pipes), lawn treatments (moss control) and other commercial, residential and agricultural practices in the watershed.

Most metal parameters met the BC water quality guidelines for protection of aquatic life [Ministry of Environment 2006; Nagpal et al. 2006]. This is the most sensitive water use, as guideline levels for most metals are at least ten times higher when considering human uses (drinking water, irrigation, recreation), which are less likely to be a risk with regard to Hyland Creek. The full description of analytical results is contained in Appendix B. Metals in samples from Archibald Creek (A1) met applicable water quality criteria on all four dates. Some exceedances were noted for Hyland sites, as shown in Table 8.5, including:

- At H1, iron slightly above its guideline on June 5
- At H2, cadmium slightly above its guideline on June 28
- At H3, several exceedances on June 8, related to the heavy rain (substantial for arsenic, cadmium, copper, iron and zinc, slight for chromium, lead and molybdenum) and a second exceedance of copper on June 28

The samples collected on June 8 were analyzed for dissolved as well as total metals, providing some insight into relative proportions of these fractions and the presence of particulate matter (sediment) during high runoff. The dissolved fraction tends to be more available biologically and more toxic. Dissolved metals accounted for relatively low proportions of the total in those samples (e.g. for site H3 where levels were highest – 4% for iron, 20% for arsenic, 40% for cadmium and copper, 60% for zinc), suggesting that many metals were associated with the particulate fraction.

Table 8.5
Instances in Which Metal Concentrations Exceeded BC Water Quality Guidelines

Parameter (mg/L)	Water Quality Guideline Maximum	Date	Site			
			H1	H2	H3	A1
Arsenic	0.005	May 4	-	-	-	-
		June 5	-	-	-	-
		June 8	-	-	0.086	-
		June 28	-	-	-	-
Cadmium	Hardness dependent	May 4	-	-	-	-
		June 5	-	-	-	-
	0.000012	June 8	-	-	0.00043	-
	0.000030	June 28	-	0.000037	-	-
Chromium	0.009	May 4	-	-	-	-
		June 5	-	-	-	-
		June 8	-	-	0.011	-
		June 28	-	-	-	-

Parameter (mg/L)	Water Quality Guideline Maximum	Date	Site			
			H1	H2	H3	A1
Copper	Hardness dependent 0.0058	May 4	-	-	-	-
		June 5	-	-	-	-
		June 8	-	-	0.294	-
		June 28	-	-	0.0081	-
Iron	0.30	May 4	-	-	-	-
		June 5	0.333	-	-	-
		June 8	-	-	3.06	-
		June 28	-	-	-	-
Lead	Hardness dependent 0.025	May 4	-	-	-	-
		June 5	-	-	-	-
		June 8	-	-	0.0295	-
		June 28	-	-	-	-
Molybdenum	0.0020	May 4	-	-	-	-
		June 5	-	-	-	-
		June 8	-	-	0.0024	-
		June 28	-	-	-	-
Zinc	0.033	May 4	-	-	-	-
		June 5	-	-	-	-
		June 8	-	-	0.443	-
		June 28	-	-	-	-

[1] BC Approved and Working Guidelines for protection of aquatic life [Ministry of Environment 2006; Nagpal *et al.* 2001]

The other metal of interest was dissolved zinc, an emerging issue related to increased use of galvanized materials (e.g. zinc strips on roofs) in the watershed. Dissolved zinc is readily taken up by aquatic organisms, so is the most toxic form. At sites H1, H2 and A1, dissolved and total zinc levels were lower than the method detection limit (0.005 mg/L) in most samples; however, at H3, dissolved and total zinc levels were elevated and dissolved zinc accounted for 61% to 70% of the total zinc measured (lowest proportion on June 8, during heavy rain). Proportions of dissolved to total zinc in lakes and streams vary widely from 20% to 90% [Ministry of Environment 1999], with values for Hyland Creek in the middle of that range. Additional documentation of dissolved and total zinc levels in local streams would be beneficial in interpreting the significance of the results.

8.2.7 Summary

Baseline water quality at three of the four sites in the Hyland Creek watershed (H1, H2, A1) generally was good, and within applicable water quality standards (protection of aquatic life and recreational use) for all but two data points. However, there were several indications of degraded water quality at H3, located on the north branch of Hyland Creek downstream of the King George Highway in the densely populated and commercial/ industrial areas of Zones 1 and 1A. Nitrogen and phosphorus fractions (nutrients or fertilizers), as well as metals, were highest at H3 and decreased at downstream sites, reflecting dilution with better quality water from elsewhere in the watershed.

This screening level assessment indicated that coliform bacteria, including *E. coli*, were present at all sites and dates at levels that would likely exceed standards if the full protocol for sampling was conducted (five weekly samples over a 30-day period, triplicate samples, recreational use standards for primary contact). Given that there are well-known health risks and likelihood of exposure for humans (especially children), a public awareness program regarding the most easily controlled source of fecal material (dog waste) would be useful. The City will also want to investigate and eliminate cross connections between sanitary sewer and stormwater systems.

Impaired water quality was evident during the heavy rainfall event (June 8), with high amounts of total suspended solids, copper, cadmium, copper, iron, zinc and nutrients, most notably at H3, in the most densely populated area of the watershed, and where levels were substantially higher than water quality guidelines for protection of aquatic life.

9.0 INFILTRATION POTENTIAL OF NATIVE SOILS

To identify areas where infiltration of stormwater may be feasible, the distribution of pervious soils and shallow groundwater within the Hyland Creek watershed must be understood. Successful infiltration of stormwater on a large scale requires well-drained (pervious), unsaturated soils of moderate thickness (on the order of 5 to 10m), with minimum pre-development depths to groundwater of approximately 3 to 5m below grade. During wet seasons, infiltration of stormwater from impervious areas (e.g. rooftops and roadways) can supplement the natural infiltration of water through remaining pervious surfaces, such that summer base flow to creeks is not significantly affected. As such, the primary goals of the hydrogeological investigation were to identify and confirm potential areas of pervious soils within the Hyland Creek watershed that may allow for mid- to large-scale infiltration of stormwater and to identify areas where shallow groundwater tables may be influenced by development.

9.1 Infiltration Testing Field Program

To assess the potential for shallow infiltration of stormwater in Zone 3, and to supplement the work conducted by Piteau [1996], a four-day hydrogeologic field investigation was conducted in Zone 3 from June 12th to 15th, 2006. Three properties were selected for test pitting and percolation testing where the desktop study indicated that there may be some potential for the implementation of stormwater infiltration best management practices (BMPs). The properties selected were:

- Site 1 (TP1): 6231 – 142 Street (City of Surrey Right of Way on south side of property)
- Site 2 (TP2): 6122 – 140 Street
- Site 3 (TP3): 14367 – 60 Avenue

The approximate locations of these properties were shown previously on Figure 5.14. According to available geologic mapping, Site 1 was expected to intersect the Cb unit, and Sites 2 and 3 were located in the Cd unit.

The general methodology for the field program was as follows. Three test pits were dug at each site using a rubber-tired backhoe on June 12, 2006. Test pit logs are presented in Appendix C. The first pit at each site (e.g. TP1) was excavated to a depth of approximately 3m for the purposes of logging soil stratigraphy. Based on observations from the first pit, two shallower pits were dug to depths of 0.86 to 1.02m for the purposes of percolation testing. After excavating, the pits were squared up by shovel and pit walls were scraped to remove any material that may

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have intruded during excavation. Scraping pit walls is necessary to ensure that the materials being tested are as close to their native state as possible. At Site 2, only one percolation test was conducted due to uneven fill depths across the site. Following excavation, the shallower pits were filled with water on June 13, 2006 to depths of approximately 0.15m. Water levels in these pits were measured periodically on June 13 and 14, 2006. The following sections provide a detailed discussion of site-specific observations.

9.1.1 Site 1 (6231 – 142 Street)

Site 1 was chosen as it was believed that test pits on this property would intersect the Cb surficial geology. This unit was identified in the desktop assessment as one that may have reasonable potential for artificial stormwater infiltration. Test pit TP1 (log provided in Appendix C) intersected a thin (0.3m) topsoil layer, followed by silty sand to approximately 0.76m, and then weathered glacial till to the end of the test pit at 2.7m. It is difficult to ascertain the origin of the silty sand layer from 0.3 to 0.76m; it may be a gradational transition into the Cb unit, a weathered zone of the Cd unit, or perhaps even imported fill. Regardless of geologic origin, this unit is too thin and too shallow for artificial stormwater infiltration, so it was not considered for further characterization. Test pits TP1.1 and TP1.2 were excavated to depths of 0.91 and 0.86m, respectively. Percolation tests were conducted in these pits to characterize the permeability of the glacial till unit. Results of the percolation testing on these pits are presented in Table 9.1:

Table 9.1
Percolation Test Results for Site 1

Date	Time	Depth of Water (m)	
		TP1.1	TP1.2
June 13, 2006	12:45	0.152	n.m.
	13:10	n.m.	0.152
	13:52	0.152	0.146
	15:40	0.159	0.140
June 14, 2006	8:20	0.171	0.146
	9:25	0.171	0.146
	11:10	0.178	0.140
	11:45	0.181	0.137
	12:55	0.184	0.133

Note: n.m. = not measured

Just prior to commencing the tests, there was approximately 0.11m of water in TP1.1 at the deepest point. The water levels in TP1.1 rose steadily throughout the duration of the test. There were periodic light showers during the entire field program, so some of this water may be attributed to direct surface runoff. An additional source of water may have been perched groundwater flow along the surface of the low permeability till layer. Finally, the rising water level in TP1.1 may have been due to slow equilibration with the surrounding soils. Regardless of the source of water, it is not possible to obtain percolation rates for TP1.1 from this data.

The response in TP1.2 appears to be more like a conventional percolation test, with water levels dropping (albeit slowly) during the test. Between 12:45 and 15:40 on June 13 (approximately 2 hours and 55 minutes), a water level drop of approximately 1.2cm was measured. While the water levels appeared to rise approximately 0.6 cm overnight (perhaps due to rainfall), a similar rate of change was observed on June 14, where a 1.3cm drop was recorded over 4 hours and 35 minutes.

From the data for TP1.2, one can calculate percolation rates of 1.1×10^{-6} and 7.9×10^{-7} m/s on June 13 and June 14, respectively. As percolation rates become steady, they approach the vertical saturated hydraulic conductivity of a soil [Williams *et. al.* 1998]. As such, if one assumes that steady state has been reached, the above percolation rates can be interpreted as the hydraulic conductivity of the Cd unit in the vicinity of Site 1. Values on the order of 10^{-6} m/s are appropriate for a silty sand [Freeze and Cherry 1979], which corresponds to field observations.

9.1.2 Site 2 (6122 – 140 Street)

Available mapping indicates that Site 2 should have been located within the Cd surficial geology unit. Test pit TP2 (log provided in Appendix C) intersected a thin (0.3m) topsoil layer, followed by gravelly silty sand fill to approximately 0.76m (with a 0.075m asphalt layer observed at the bottom), then silty sand fill to 1.98 m, and finally clayey silt till to the bottom of the test pit at 3.0m. An uneven amount of fill was present across the site, and so even though multiple shallow test pits were excavated for the purposes of percolation testing, only one pit (TP2.1, excavated to 1.02m) intersected what was believed to be the native Cd unit. As such, only one percolation test was performed at this site. Results of this test are presented in Table 9.2:

Table 9.2
Percolation Test Results for Site 2

Date	Time	Depth of Water (m)
		TP2.1
June 13, 2006	13:45	0.305
	15:35	0.286
June 14, 2006	7:45	0.286
	9:00	0.286
	10:40	0.286
	11:30	0.286
	13:00	0.286

TP2.1 was dry prior to commencing the tests. After an initial water level drop of approximately 1.9cm in the first 1 hour and 50 minutes of the test, no measurable change was observed over the next 22.5 hours. The initial decline could have been due a result of the water level in the pit rising above the top of the Cd unit, into the coarser fill layer where a faster drainage pathway existed. While analysis of this data is not possible, the conclusion may be drawn that this soil is of low permeability, and would not be amenable to artificial stormwater infiltration.

9.1.3 Site 3 (14367 – 60 Avenue)

Available mapping indicates that Site 3 should have been located within the Cd surficial geology unit. Test pit TP3 (log provided in Appendix C) intersected a thin (0.2m) topsoil layer, followed by a silt layer with some sand, gravel and clay to approximately 0.61m, and then weathered glacial till to the end of the test pit at 2.7m. Test pits TP3.1 and TP3.2 were excavated to depths of 0.91 and 0.86m, respectively. Percolation tests were conducted in these pits to characterize the permeability of the Cd unit. Results of the percolation testing on these pits are presented in Table 9.3:

Table 9.3
Percolation Test Results for Site 3

Date	Time	Depth of Water (m)	
		TP3.1	TP3.2
June 13, 2006	9:03	0.152	n.m.
	10:00	n.m.	0.159
	10:55	0.146	n.m.
	11:45	0.146	0.171
	13:25	0.146	0.178
	15:25	0.146	0.203
June 14, 2006	8:00	0.143	0.216
	9:13	0.143	0.216
	10:55	0.143	0.216
	11:40	0.143	0.216
	12:50	0.143	0.216

Note: n.m. = not measured

Just prior to commencing the tests, there was approximately 4cm and 7.5cm of water in TP3.1 and TP3.2, respectively. After an initial decline (perhaps attributable to drainage into coarser fill materials), the water levels in TP3.1 remained essentially constant for the duration of the observation period. Similarly to TP2.1, the results of this test are most likely an indication of very low permeability sediments intersected by the test pit.

TP3.2 behaved similarly to TP1.1 in that water levels monotonically increased throughout the test. There were periodic light showers during the entire field program, so some of this water may be attributed to direct surface runoff. An additional source of water may have been perched groundwater flow along the surface of the low permeability till layer. Finally, the rising water level in TP3.1 may have been due to slow equilibration with the surrounding soils. Regardless of the source of water, it is not possible to obtain percolation rates for either TP3.1 or TP3.2.

9.2 Conclusions

Conceptually, the hydrogeologic system of the Hyland Creek watershed is comprised of a shallow groundwater flow system in the near surface coarse-grained soils, where present. A perched groundwater table was observed within 2m of the surface over much of the southern catchments in the watershed [Piteau 1996]. This flow system is most likely driven by infiltration of rainwater and snow melt at the surface in the upland regions. It appears likely that the majority of this infiltration occurs in upland areas of Zone 3 with lesser contributions from upland areas in Zones 1, 1A and 2 given their higher levels of development.

Groundwater discharge to Hyland Creek or to springs and seeps is expected to occur primarily in the middle and lower reaches of Zones 2 and 3 where the Cb material unit is exposed at or near surface. Water levels may fluctuate seasonally on the order of about 1m in flatter upland recharge areas (Zones 1 and 1A) and to lesser degrees in more steeply sloped or discharge areas of the watershed. The shallow sand and gravel soils may become unsaturated in many upland areas during the dry season. In sloped areas, this shallow sand and gravel unit is expected to drain quickly to the tributaries of Hyland Creek.

In flatter upland areas (Zones 1, 1A and the upper reaches of Zone 3), the shallow sand and gravel unit is expected to recharge the underlying silts, clays and tills (e.g. VC and Cd units) predominant in the western and southern watershed. However, this material is expected to be too thin in most areas to accept significant quantities of stormwater infiltration through the majority of the year, although locally some opportunities may exist where material thickness is greater than approximately 4m. In sloped areas, when the sand and gravel material becomes too thin or where it disappears, seepage concerns or springs may occur.

The VC and Cd soils and Interbedded Sand and Gravel material identified by Piteau [1996] are expected to form a complex groundwater flow system important to base flows in Zones 1, 1A and 3 of the watershed. Recharge is expected to occur in the upland areas, and ultimately discharge to the various tributaries of Hyland Creek. Groundwater flow in this system may also contribute to seepage concerns where more permeable planes (fractures, sand seams, sand and gravel lenses) are exposed in slope cuts for road work or other developments.

The Va unit present in the northern portion of the watershed (Zone 2) is expected to behave in a similar fashion to the VC and Cd units. However, drainage is generally poorly developed in this portion of the watershed and it is inferred that the majority of recharge occurring in the upland areas, notably the cemetery at the north limit of the watershed, may infiltrate downwards and supply deeper regional aquifers mapped in the area. In southward facing slopes, groundwater from the Va unit likely drains into the Cb unit which discharges to several smaller reaches on the north side of, and/or directly into, Hyland Creek.

Based on the results of the hydrogeologic assessment, there does not appear to be much opportunity for community-scale infiltration of stormwater in the Hyland Creek watershed. The best remaining opportunity for shallow infiltration of stormwater appears to be on a lot-by-lot basis in the southern upland portion of the watershed (e.g. mainly Zone 3). Prior to implementing any form of artificial infiltration system, detailed hydrogeologic and geotechnical studies should be performed to ensure that such activities will not create seepage or stability issues. Piteau conducted a comprehensive hydrogeologic assessment for this area as part of the South Newton Neighbourhood Concept Plan and provided detailed recommendations on infiltration opportunities in this part of the watershed.

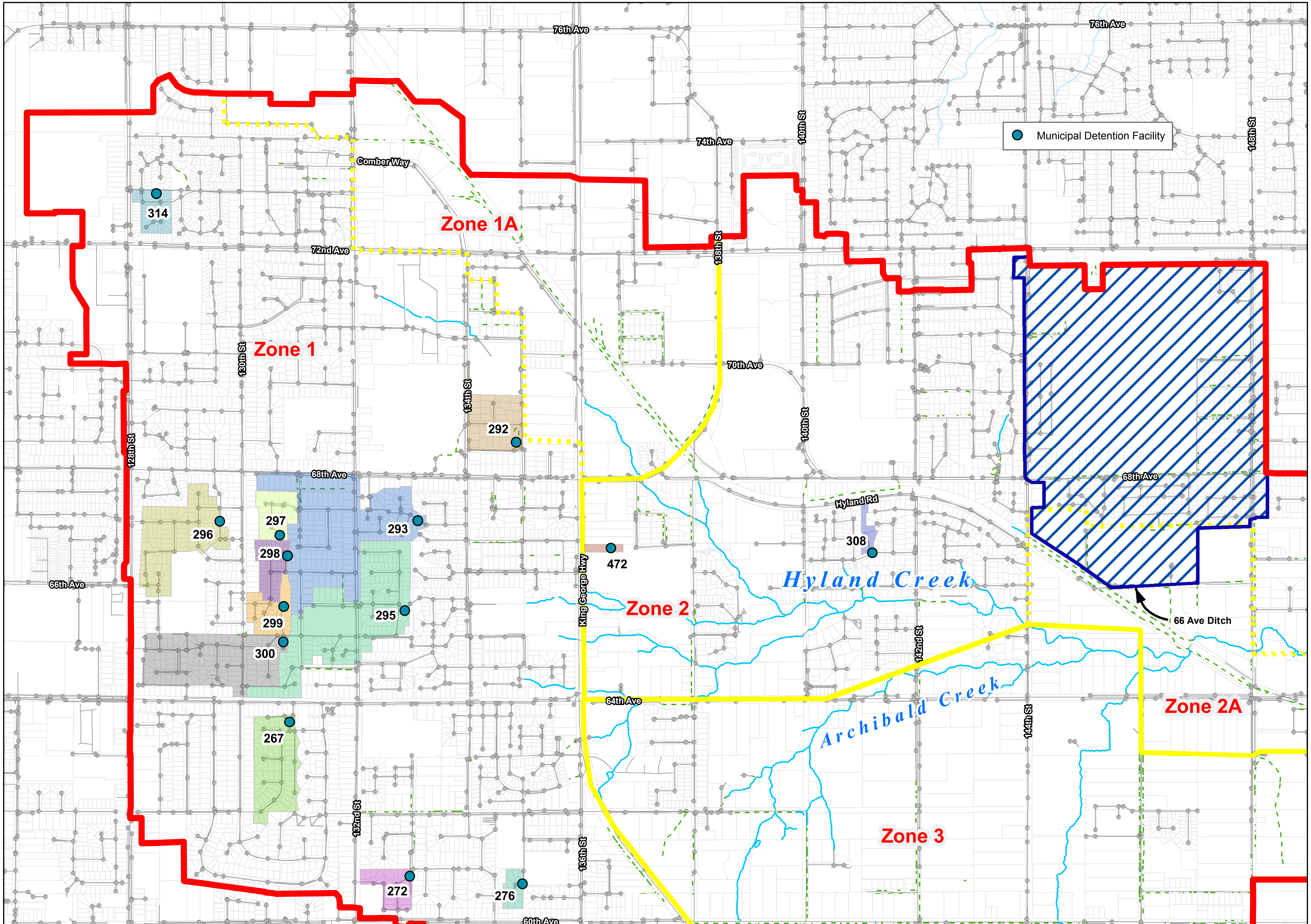
10.0 HYDROLOGIC / HYDRAULIC MODELING AND ANALYSIS

10.1 Existing Municipal Detention Facilities

The City's capital works program includes thirteen existing municipal detention facilities that are labelled as "optimize pond". Eleven of these facilities are located in Zone 1, with the remaining two located in Zone 2, as shown on Figure 10.1. While there is no specific description in the capital works program, optimization could be interpreted as increasing the volume capacity of the pond to provide additional storage, retrofitting the outlet structure to improve the performance of the pond, implementing water quality treatment aspects to the pond, etc. On the other hand, optimization could mean that the pond is not providing a measurable benefit to the area it services or for the Hyland Creek watershed as a whole. Opportunities may exist to remove the facility with minimal impact to the downstream drainage system. Aside from the financial savings of removing a pond (from an operation and maintenance perspective), the City may also be able to sell the land for development and use the funds towards more beneficial enhancements in the watershed. This study has evaluated the existing detention facilities listed in the capital works program with both viewpoints in mind.

To obtain an understanding of the characteristics of each pond in the capital works program under their current configuration, several key parameters were computed. Drainage catchment areas to each pond were delineated based on the storm sewer network configuration, as shown on Figure 10.1. A unit storage volume and unit release rate was then calculated for each pond based on the catchment area size and available information on the pond as-built drawings. These parameters are summarized in Tables 10.1 and 10.2 below.

In three instances, additional ponds exist upstream of the pond being reviewed, resulting in the ponds being linked in series. The cumulative effect of the ponds has not been analysed. Instead, each facility has been assessed independently and in relation to the direct catchment area it services.



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Hyland Creek Integrated Stormwater Management Plan

Figure 10.1

EXISTING MUNICIPAL DETENTION FACILITIES IN CAPITAL WORKS PROGRAM

- Drainage Manhole
- Drainage Main
- Creek
- Ditch
- River
- Sub-Zone Boundary
- Zone Boundary
- 66 Ave Ditch Catchment Area
- Hyland Creek Watershed Area

0 250 500
Metres

Scale 1:12,500

Source: City of Surrey

Prepared By:
URBANSYSTEMS.
1072.0137.01 July 2007

Table 10.1
Unit Storage Volumes for Existing Municipal Detention Facilities

Pond ID	Location		Drainage Area (ha)	Cumulative Drainage Area (ha)	Storage Volume (m^3)	Unit Storage Volume (m^3/ha)
	Street	Zone				
267	63A Ave: west of 131A St	1	5.7	5.7	1,170	206
272	132A St – 61 Ave	1	2.0	2.0	720	360
276	135 St – 60A Ave	1	1.0	1.0	71	71
292	69 Ave – 135 St	1	4.4	4.4	730	166
293	67 Ave – 133 St (Greenbelt)	1	15.5	20.2 [1]	1,410	91
295	65 Ave – 133 St (Greenbelt)	1	14.2	26.0 [1]	860	61
296	129A St – 66B Ave	1	7.5	7.5	1,510	202
298	130A St – 66B Ave	1	2.2	2.2	975	444
299	65A Ave – 130A St	1	2.3	2.3	365	159
300	65 Ave – 130A St	1	9.5	11.8 [1]	860	91
308	66A Ave: east of 141 St	2	0.7	0.7	725	1,036
314	73 Ave – 128B St	1	1.9	1.9	426	224
472	67 Ave – 137 St	2	0.4	0.4	39	98

[1] There are additional ponds within the same cumulative service area which are linked in series to the pond in question. Storage volume shown is that of the pond in question only, not the combined volume of all ponds servicing the cumulative drainage area.

Table 10.2
Unit Release Rates for Existing Municipal Detention Facilities

Pond ID	Location		Drainage Area (ha)	Cumulative Drainage Area (ha)	1:5 Year Design Peak Discharge (m^3/s) [2]	1:5 Year Unit Peak Discharge (L/s/ha)
	Street	Zone				
267	63A Ave: west of 131A St	1	5.7	5.7	*0.080*	14.0
272	132A St – 61 Ave	1	2.0	2.0	0.061	30.5
276	135 St – 60A Ave	1	1.0	1.0	?? [3]	?? [3]
292	69 Ave – 135 St	1	4.4	4.4	0.048	10.9
293	67 Ave – 133 St (Greenbelt)	1	15.5	20.2 [1]	0.257	12.7
295	65 Ave – 133 St (Greenbelt)	1	14.2	26.0 [1]	0.110	4.2
296	129A St – 66B Ave	1	7.5	7.5	0.290	38.7
298	130A St – 66B Ave	1	2.2	2.2	0.059	26.8
299	65A Ave – 130A St	1	2.3	2.3	0.015	6.5
300	65 Ave – 130A St	1	9.5	11.8 [1]	0.210	17.8
308	66A Ave: east of 141 St	2	0.7	0.7	*0.150*	214.3
314	73 Ave – 128B St	1	1.9	1.9	0.049	25.8
472	67 Ave – 137 St	2	0.4	0.4	*0.004*	10

[1] There are additional ponds within the same cumulative service area which are linked in series to the pond in question. Design peak discharge shown is for the pond in question only, not the combined peak flow of all ponds servicing the cumulative drainage area.
[2] Values in italics were calculated based on information provided on the as-built drawings.
[3] For Pond 276, insufficient information existed on the as-built drawings to calculate the design peak discharge.

Specifics of each pond are discussed further in subsequent sections; however, in general all ponds appear to have been designed to meet a 1:5 year post development to 1:5 year pre development criteria for peak flow reduction. Storm events that are less than the 1:5 year do not appear to have been specifically targeted for control. Based on the as-built drawings, all facilities have overflows for the 1:100 year event, either via an overland swale or an overflow riser in the control manhole. As shown in Tables 10.1 and 10.2, the unit storage volumes and release rates are highly variable from pond to pond, even though each pond services the same land use (single family residential). As such, pond performance is also expected to be highly variable.

The detailed analytical review focused on the larger facilities listed in the capital works program (having storage volumes greater than 1,000 m^3). Based on Table 10.1, three facilities met this criterion – Ponds 267, 293 and 296. The basic tasks undertaken for the detailed analysis of these three ponds were as follows:

- An XPSWMM hydrologic / hydraulic model was developed for each pond and its respective catchment area.
- The systems were analysed using Municipal Hall rainfall data for the 1996 – 1997 period, which corresponds to the time frame for which flow data exists for Hyland Creek (140 Street monitoring station).
- The outflow hydrograph from each pond was compared to the flow data to assess the relative benefit the pond provides under its existing configuration.
- The model was then run for an extended series of rainfall data (1996 – 2005) to better evaluate the pond's performance over a longer period of time and under a wider spectrum of rainfall events.

Once the pond's current function and performance level was understood, the analysis looked for opportunities to retrofit the pond to improve its level of service.

As discussed in Section 5.2.4, the mean annual rainfall (MAR) event is often correlated to the "channel forming" or bank full event for creeks and watercourses, and is statistically related to the 2.33 year, 24-hour event. Detention ponds in the Hyland Creek watershed, however, have typically been designed to control flows for the 5-year return period. Thus, post development peak flows resulting from the MAR event are being discharged into Hyland Creek with little to no attenuation. This discharge of uncontrolled MAR flows may be largely attributable to the erosion issues currently being experienced in Hyland Creek. In order to have a more beneficial effect on Hyland Creek, the three larger ponds were reviewed to assess whether they could be practically modified to operate more successfully during a MAR event. The analysis reviewed opportunities to meet this objective by completing the following tasks:

- A representative MAR event was selected from the available rainfall data for the Municipal Hall rain gauge station (as discussed in Section 10.1.2).
- The outlet structure for each of the three larger ponds was modified to activate the pond under the MAR event, with the goal of utilizing the full storage capacity of the pond under the MAR event.
- If needed, the amount of additional storage capacity required to meet the MAR objective was determined.
- The reconfigured pond was then analysed under continuous rainfall data from 1996 to 2005. Hydrographs were compared to those of the existing pond configuration and to those of Hyland Creek, to evaluate whether an improvement in the level of service could be achieved.

Evaluating the larger ponds in this fashion provides an understanding of the contribution each pond makes to the Hyland Creek watershed, and assesses the relative benefit that a retrofit may have on both the individual pond, as well as the watercourse overall.

From the above analysis, an optimal unit storage volume and unit release rate to meet the MAR target was determined and used as the basis for evaluating the relative benefit / opportunity of the remaining ponds listed in the capital works program. These results also formed the basis for the planning of future ponds in the watershed, which is discussed further in Section 10.2.

10.1.1 Significant Historic Rainfall Events

As part of the detailed analysis, the performance of the three ponds were reviewed using rainfall data for the November 1996 to October 1997 period, as this timeframe corresponds to the available flow data for Hyland Creek (as previously discussed in Section 5.2.6). Two significant rainfall events occurred during this time period; May 30/31, 1997, and September 25/26, 1997. Both rainfall events were plotted against the Intensity-Duration-Frequency (IDF) curves for the Municipal Hall rain gauge to establish an approximate return period for these events.

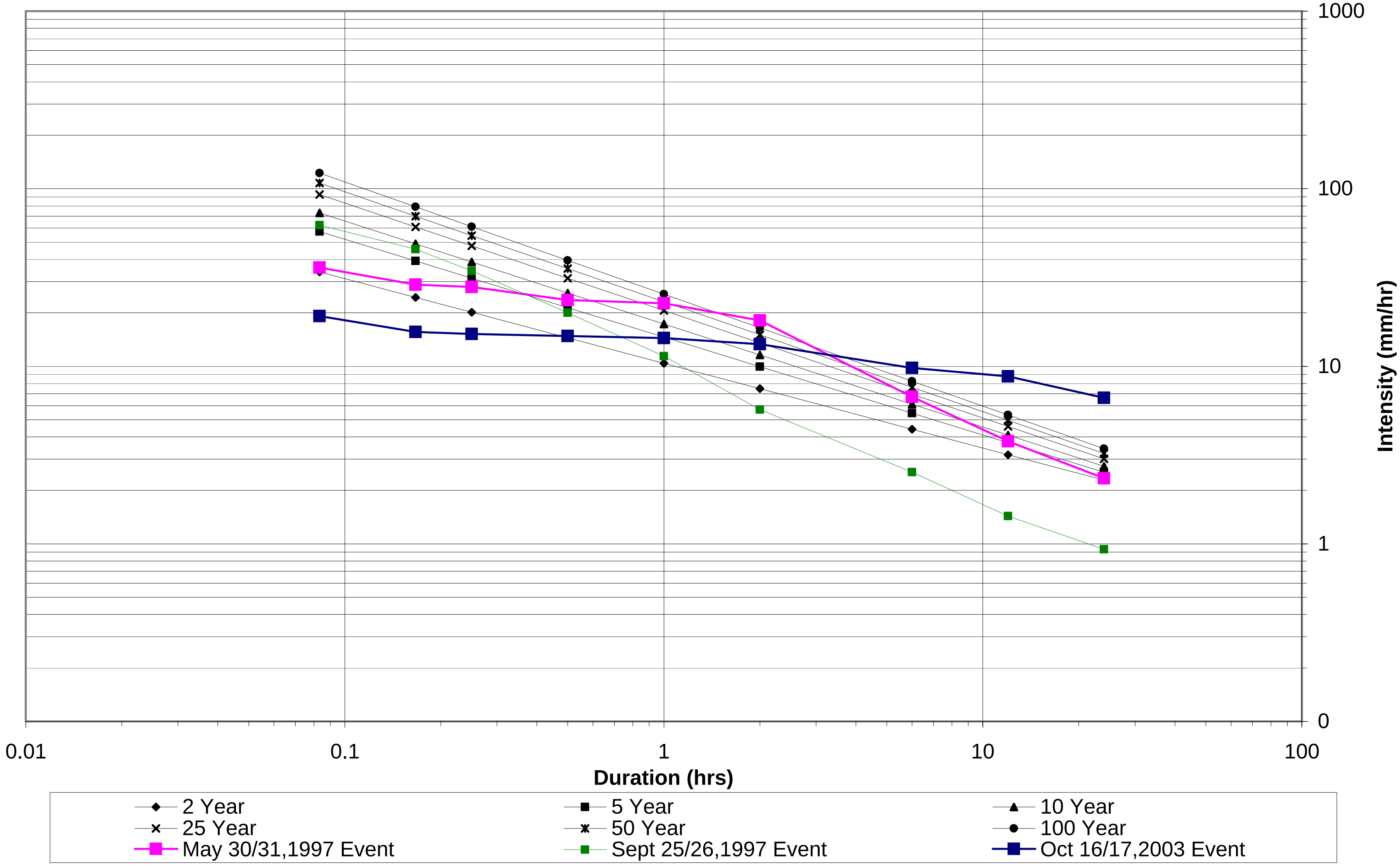
As shown in Figure 10.2, the May 30/31 event was fairly significant and was approximately equivalent to a 50-year, 1-hour storm event. The September 25/26 event was much smaller in magnitude, corresponding to roughly a 2-year, 1-hour event.

For the extended rainfall data up to November 2005, a third significant rainfall event, which occurred on October 16/17, 2003, was captured. Also shown on Figure 10.2, this event was greater than a 100-year, 24-hour event.

10.1.2 Selection of MAR Event

As noted earlier, the recommended method for achieving improved performance under smaller, more frequent storm events is to retrofit the ponds so that their available storage capacities are fully utilized during a MAR event. The concept of designing drainage infrastructure to achieve a volume reduction under a MAR event is in accordance with the 2002 provincial document entitled *Stormwater Planning: A Guidebook for British Columbia*. The GVRD ISMP template recommends using the more stringent criteria outlined in DFO's *Urban Stormwater Guidelines and Best Management Practices for the Protection of Fish and Fish Habitat*, which stipulate volume reduction for the 6-month storm, which roughly equates to 72% of the 2-year storm. However, the City has expressed concern with the DFO document in the past and thus the provincial criteria was adopted for this study.

Figure 10.2 - Surrey Municipal Hall IDF Curves



Rainfall data from the Municipal Hall rain gauge station was reviewed to find an appropriate storm event which approximated the MAR for the Hyland Creek watershed. As noted in Section 5.2.4, the MAR for the Hyland Creek watershed is estimated to be 68 millimetres. Five recorded storm events, as summarized in Table 10.3, were identified in the rainfall data as potential representative MAR events. Hyetographs for each storm event are included in Appendix E.

Table 10.3
Selection of Representative MAR Event

Date	24-Hour Rainfall Depth (mm)
October 27 / 28, 1996	67.6
May 30 / 31, 1997	56.2
October 17, 2003	69.4
November 28, 2003	77.8
November 23 / 24, 2004	61.4

After reviewing the rainfall distribution for each of these events, as well as the rainfall patterns preceding and following the event day(s), the October 27 / 28, 1996 event was selected as the representative MAR event for the analysis. This event closely approximates the total MAR depth, the rainfall pattern over the 24-hour period is fairly evenly distributed, and there was a negligible amount of rainfall on the immediate days preceding or following the storm event. This storm event was specifically used to evaluate pond performance under existing conditions, as well as to evaluate the success of the pond reconfiguration options.

10.1.3 Hydrology

Several hydrologic parameters were evaluated and utilized in the development of the XPSWMM model for each pond catchment area. Parameter values, such as depression storage and Mannings 'n' for impervious and pervious surfaces, were selected based on the data reviewed for the ISMP and professional expertise based on model calibration for similar studies. The Green-Ampt equation was used to compute infiltration losses using the hydraulic conductivity value of the Cd unit, as determined by the percolation test results from the hydrogeological investigation. Table 10.4 summarizes the hydrologic parameters used in the model.

Table 10.4
Hydrologic Parameters for XPSWMM Model

Hydrologic Parameter	Value	Hydrologic Parameter	Value
Impervious Area Depression Storage	0.5mm	Pervious Area Depression Storage	2.0mm
Impervious Manning's n	0.011	Pervious Manning's n	0.2
Average Capillary Suction	200 mm	Initial Moisture Deficit	0.05
Saturated Hydraulic Conductivity	3.6 mm/hr		

The detailed analyses of the three largest ponds (ID's 267, 293 and 296) are presented below. Background data used in the analysis was obtained from the available as-built drawings for each pond. Detailed surveys or field measurements were not conducted to verify this data.

10.1.4 Pond 267

Description

Pond 267 is located on 63A Avenue, just west of 131A Street, as shown on Figure 10.1. The pond services single family development on 130B Street as well as the 62B Avenue, 63 Avenue and 63A Avenue cul-de-sacs. The total catchment area contributing to the pond is 5.7 hectares.

Photo 10.1: Pond 267

The pond consists of a dry, grassed area, as shown in Photo 10.1. A 300mmØ storm sewer from 63A Avenue conveys flows from the upstream catchment area to a manhole in the centre of the pond. A 167mmØ orifice is situated on the outlet pipe from this manhole, which acts as a flow control mechanism. Water backs up behind the orifice control structure and into the pond, providing temporary detention.

The maximum storage capacity of Pond 267 is 1,170 m^3, with a maximum depth of approximately 1.35 metres. At 1.0 metre depth, two catch basins activate as emergency overflows. One catch basin discharges to the storm sewer downstream of the orifice structure, and the other discharges to an overland swale which conveys flows to 64 Avenue.

Pond 267 was designed to activate under a surcharged condition only, i.e. when the flow exceeds the capacity of the orifice. Given the age of the pond, it is likely that it was designed to surcharge only under a 5-year or higher storm event, which was the typical design criteria of the day. Thus under smaller storm events, which the orifice can convey with little to no surcharging, flows completely bypass the pond and receive no attenuation before reaching the downstream drainage system. In addition, the current configuration does not provide any appreciable water quality benefit.

Performance with Existing Configuration

Pond 267 was initially analysed with rainfall data for the November 1996 to October 1997 period, in order to directly compare it with the Hyland Creek flow data. Modeling results and hydrographs for the pond outlet and Hyland Creek can be found in Appendix E.

Based on the modeling results and the hydrographs, Pond 267 activated a total of 20 times during the November 1996 to October 1997 period. However, in most instances the depth of water in the pond was quite low, typically only surcharging to 5 to 10 centimetres above the pond invert. Only in one instance, during the significant May 30/31, 1997 event, did the model show that the water level rose to 0.71 metres above the pond invert. During that event, a peak flow reduction of about 73% is predicted. As such, under its current configuration Pond 267 does not appear to be attenuating peak flows to any appreciable degree during frequent, low-intensity storm events, however, the pond does attenuate flows to some degree under more significant events.

A comparison of the modeled pond hydrograph and the Hyland Creek flow hydrograph clearly indicates that Pond 267 is a very minor contributor to total flows in Hyland Creek. The average pond discharge rate during the 1996 – 1997 period was 1.3 L/s, which represents only 0.8% of the average flow of 166 L/s in Hyland Creek. By comparison, the pond's service area represents about 1.2% of the total area contributing to the Hyland Creek flow station. Furthermore, the maximum pond peak flow rate of 73 L/s is only 0.9% of the maximum peak flow rate in Hyland Creek of 8,353 L/s. These maximum peak flow rates also occurred during different storm events, which likely reflects the difference in time of concentration for the pond catchment area versus the much larger catchment area to the Hyland Creek flow station.

When the model was run for the entire rainfall period (1996 – 2005), the same trend occurs. For instances where the pond activates, water levels typically rose 5 to 10 centimetres above the pond invert. There are only six instances where the water depth exceeded 0.3 metres during the nine years of rainfall data, as shown in Appendix E. The emergency overflow activated in one instance for the storm event in October 2003, during which the pond was again able to achieve about a 73% reduction in peak flow.

In general, the model results indicate that Pond 267 can achieve a reasonable reduction in peak flow during significant storm events, however, flows from frequent, low-intensity storm events are bypassing the pond with little to no flow attenuation. This concurs with the criteria of designing the pond to activate only during a 5-year or higher storm event.

Potential Reconfiguration Opportunities

To evaluate whether Pond 267 could be reconfigured to improve its level of service, the performance of the pond during the October 27 / 28, 1996 MAR event was reviewed. While the model does indicate that the pond activated during this event, the pond was only capable of reducing the incoming peak flow from 68 L/s to 52 L/s, or 24%. Furthermore, only 45 m^3 of the available 1,170 m^3 storage volume was used. Therefore, the pond is being significantly underutilized during a MAR event with its current configuration.

The analysis then reviewed opportunities to reduce the orifice diameter in the control structure to activate the pond under more frequent storm events. By reducing the orifice diameter from 167mmØ to 60mmØ, the existing storage capacity of the pond was maximized under the October 27 / 28, 1996 MAR event.

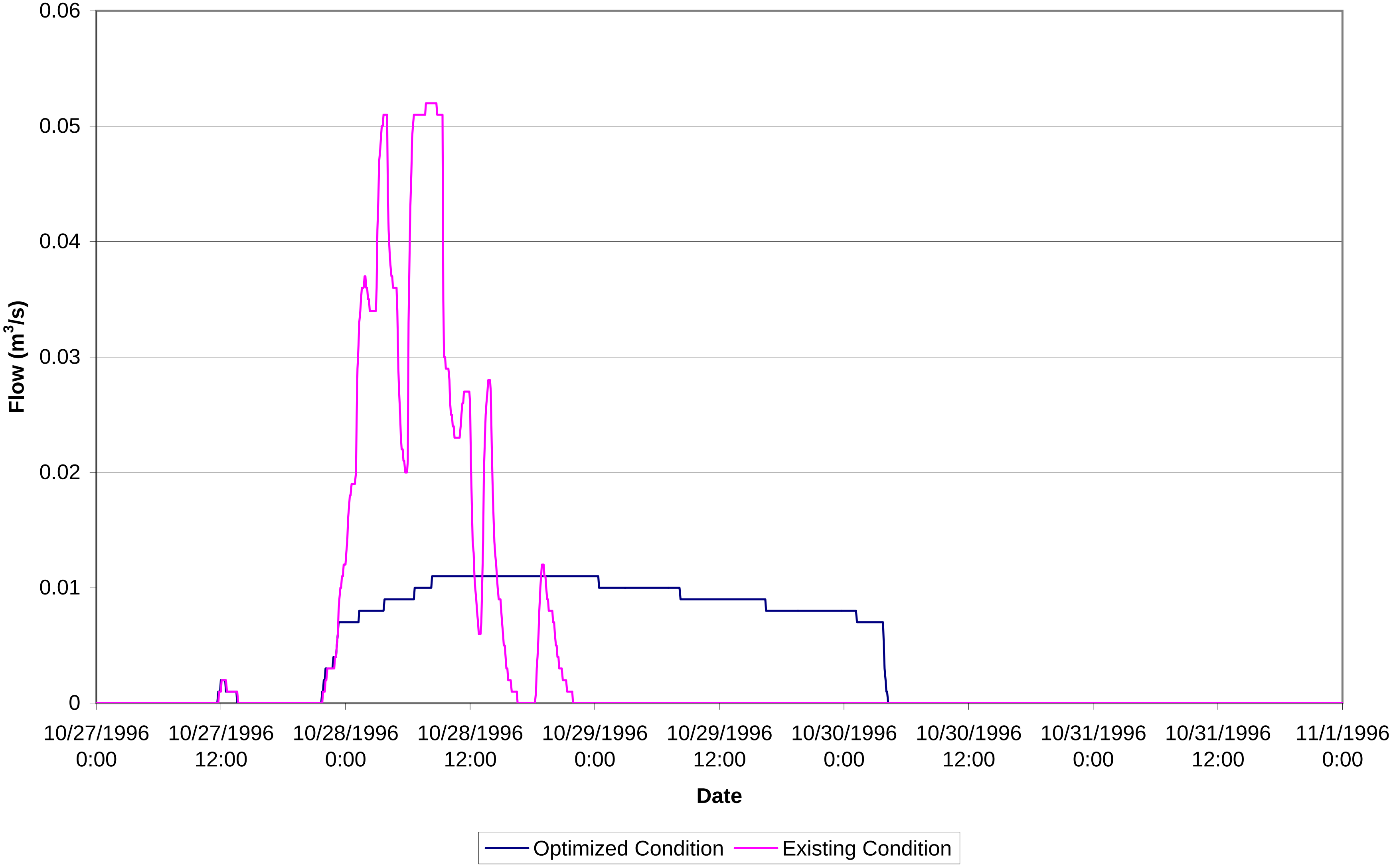
The outflow hydrograph for the pond with and without the pond reconfiguration is shown in Figure 10.3. As shown in the figure, the change in orifice diameter reduced the peak outflow from Pond 267 from 52 L/s to 11 L/s, or 79%.

Performance with Optimized Configuration

With the reconfiguration in place, Pond 267 was analysed with the extended rainfall series from 1996 to 2005. Results are included in Appendix E. Pond 267 activated several times during this period, with water depths in the pond typically ranging from 0.2 to 0.5 metres. The model indicates that the overflow engaged five times, with the largest overflow occurring during the October 16/17, 2003 event. Even for this major storm event, Pond 267 was still able to achieve a 56% reduction in peak flow. Under more frequent, lower-intensity events, Pond 267 would be capable of significantly attenuating flows under the optimized configuration.

If the City decides to proceed with modifying Pond 267 as outlined above, the detailed design should investigate the overflow catch basins in further detail to confirm the nature of their connection to the downstream sewer system, to verify that the anticipated high flows could enter into the catch basins and to verify that the downstream sewer system has capacity to accept this flow.

Figure 10.3: Pond 267 Hydrographs - October 27 / 28, 1996 Rain Event (MAR)



U:\Projects_VAN\1072\0137\01\SWMM\20061101sw pond hydrographs

10.1.5 Pond 293

Description

Pond 293 is located on 67A Avenue just west of 133B Street, as shown on Figure 10.1. The contributing catchment area, which is roughly bounded by 68 Avenue to the north, 133 Street to the east, 65B Avenue to the south and 130A Street to the west, is approximately 20.2 hectares in size. There are four other small detention facilities upstream of this pond (Pond ID's 297, 297 Tank1, 297 Tank2 and 298) which service approximately 4.7 hectares of the 20.2 hectare total. The remaining 15.5 hectares are serviced exclusively by Pond 293. Land use in the catchment area consists of older single family residential development.

Photo 10.2: Pond 293

The pond itself is a dry grassed area situated within an existing greenbelt that is also partially used as park space, as shown on Photo 10.2. Pond 293 is also considered to be a surcharge pond; however, the current configuration uses undersized pipes, rather than an orifice, to control flows. A 600mmØ storm sewer, which conveys runoff from the majority of the catchment, enters the pond area via an easement near 67 Avenue and 133 Street. A 525mmØ storm sewer then conveys stormwater along the western edge of the greenbelt, where it joins a 300mmØ storm sewer that services the remainder of the catchment area. From this point, a 375mmØ storm sewer follows the northern limit of the greenbelt area, where flows are then discharged to the existing 375mmØ storm sewer on 67A Avenue. The 525mmØ storm sewer along the western edge of the greenbelt represents the primary form of flow control for this pond. While the 525mmØ storm sewer is laid at a flat grade (0.10%), it is still capable of conveying up to 0.14 m^3/s before it begins to surcharge. Similarly, the next downstream pipe (375mmØ) can convey up to 0.28 m^3/s before surcharging (at 2.55% grade). Therefore, a significant amount of flow needs to be generated before the system will surcharge to the point of activating the pond. The pond is designed such that the restricted storm sewers force water to surcharge back into the pond via inlet / outlet structures. Once the storm passes, detained water recedes back into the storm sewers through the same inlet / outlet structures.

Photo 10.3: Overflow Structure for Pond 293

If the pond's maximum available storage capacity of 1,410 m^3 is exceeded during a storm event, the overflow structure (see Photo 10.3) conveys flows directly to the existing 375mmØ storm sewer on 67A Avenue. The overflow structure spill elevation is set 0.94 metres above the pond invert elevation, whereas the elevation of the top of the pond is 1.1 metres above the pond invert.

The pond was likely designed to activate under a more extreme event (5-year or larger), thus, like Pond 267, Pond 293 is currently providing little to no benefit for flow attenuation or water quality treatment under its current configuration.

Performance with Existing Configuration

Modeling results and hydrographs for the Pond 293 outlet and Hyland Creek can be found in Appendix E. During the 1996 – 1997 rainfall period, the model indicates that Pond 293 only activated six times. Similar to Pond 267, water levels in the pond were quite shallow, with the exception of the May 30/31 event when the model indicates that water levels activated the emergency overflow structure. With the emergency overflow structure activated, the pond was able to achieve approximately a 54% reduction in peak flow during this storm event. However, the absence of water in the pond during the majority of this time period suggests that most flows bypassed the pond completely. Therefore, the pond appears to have provided no flow attenuation at all for frequent, low-intensity storm events during 1996 and 1997.

Under its current configuration, Pond 293 contributes more flow to Hyland Creek than the other two ponds modeled. This is partially due to the fact that Pond 293 has a larger developed catchment area which generates more runoff, but also because the pond has comparatively low performance. Pond 293 represents 4.5 L/s (or 2.7%) of the average flow and 428 L/s (or 5.1%) of the peak flow in Hyland Creek during the 1996 / 1997 period, which is somewhat significant. Again, the maximum peak flow rates occurred for different events for Pond 293 versus Hyland Creek.

Under the full spectrum of rainfall events from 1996 to 2005, the model indicates that water surcharged to the pond invert approximately 40 times. However, water depths in the pond exceeded 0.3 metres only seven times, and the overflow activated twice. The storage capacity of Pond 293 is not being utilized frequently under the pond's existing configuration, however, when it is, the pond's storage capacity is readily exceeded. This confirms that its unit storage volume of 91 m^3/ha is not sufficient for the catchment area. Given that this pond services a relatively large catchment area, a significant benefit for the catchment area and for Hyland Creek could potentially be achieved by reconfiguring the pond to be more effective in controlling a wider range of flows.

Potential Reconfiguration Opportunities

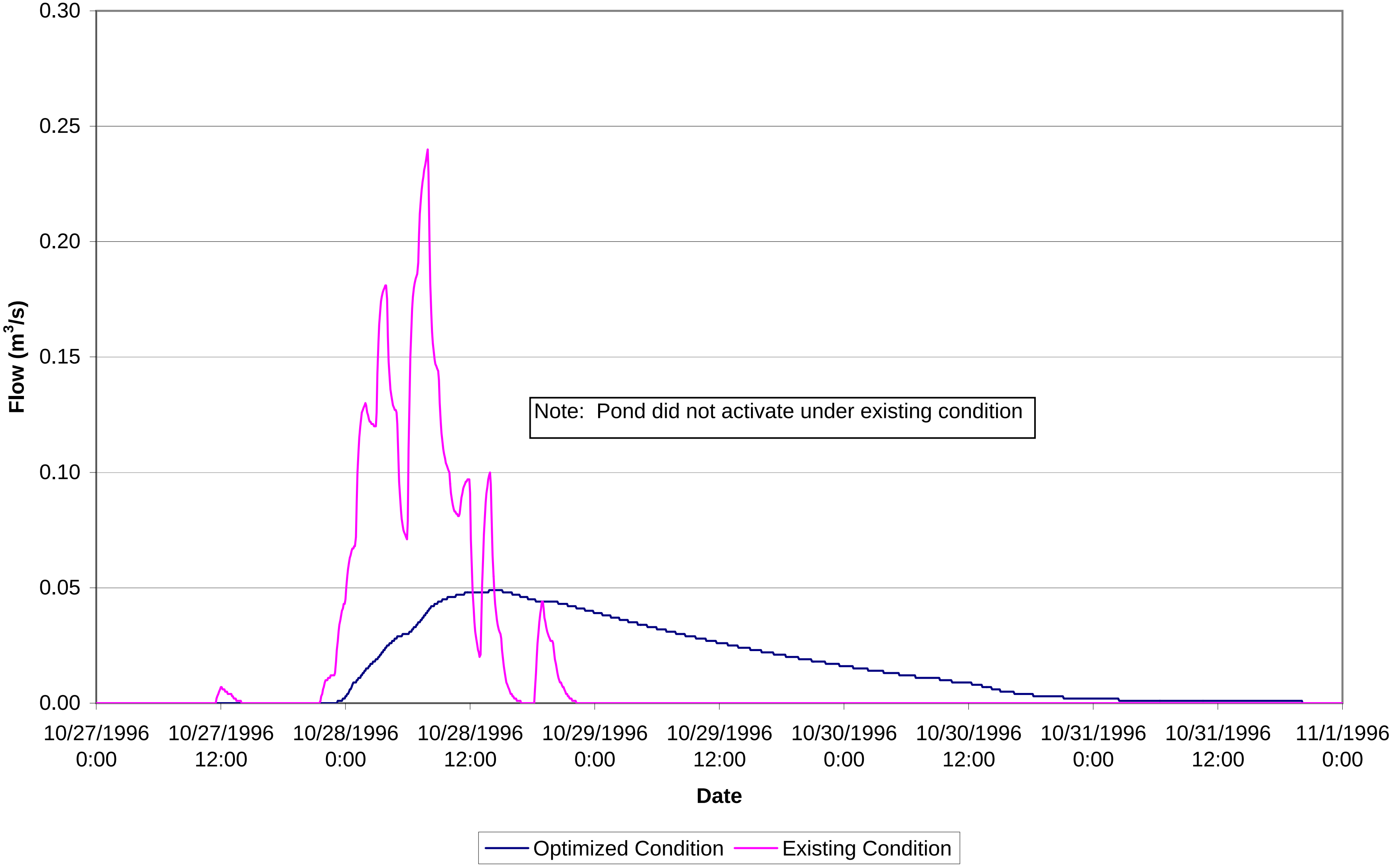
The model indicates that Pond 293 did not activate under the October 27 / 28, 1996 MAR event. This confirms that the current configuration of the pond is allowing most frequent flows to bypass the pond completely. To activate the pond under more frequent events and optimize its performance under the MAR event, a modified flow control structure and additional storage capacity would be required.

To increase the storage capacity of the pond, the pond was deepened from its existing invert elevation of 73.26 m to 72.70 m. By lowering the pond invert, the storage capacity of the pond is increased from 1,410 m^3 to 4,000 m^3. In addition, the pond could now be converted into a flow-through facility (with some minor sewer realignments), which will assist with water quality treatment in addition to quantity control. The existing 525mmØ and 300mmØ storm sewers within the greenbelt would be abandoned and replaced with an orifice plate within the existing overflow structure (see Photo 10.3).

With the revised configuration and additional storage capacity, Pond 293 was capable of reducing the peak flow from the MAR event from 240 L/s (uncontrolled) to 49 L/s. This represents a reduction in peak flow in the order of 80%. The outflow hydrograph for the pond with and without the pond reconfiguration is shown in Figure 10.4.

While significant funding would be required to reconfigure Pond 293, the costs of deepening the facility and retrofitting the overflow structure with an orifice could be partially offset by the removal of four existing ponds in its upstream catchment area (including Pond 297, 297Tank1, 297Tank2, and Pond 298, which is listed in the capital works program) and the sale of the properties where Pond 297 and 298 are currently situated. All four of these ponds are quite small and are providing a limited benefit to their catchment areas.

Figure 10.4: Pond 293 Hydrographs - October 27 / 28, 1996 Rain Event (MAR)



Performance with Optimized Configuration

Pond 293's performance would substantially improve over existing conditions if the retrofits are implemented. When the reconfigured pond was analysed with the 1996 – 2005 rainfall data, the model indicates that water levels in the pond would frequently rise to 0.5 to 0.7 metres above the pond invert, with the overflow activating six times. The pond is capable of attenuating flows by up to 92% during this time period.

10.1.6 Pond 296

Description

Pond 296 is located in a rear yard easement on 129 Street just south of 67A Avenue, as shown on Figure 10.1. The easement can be accessed off of 129 Street, 67A Avenue or 66B Avenue. The pond services an upstream catchment area of 7.5 hectares, which is roughly bounded by 67A Avenue to the north, 129A Street to the east, 66 Avenue to the south, and 128 Street to the west. The catchment area is completely developed with single family residential units. Photo 10.4 shows the pond location, facing west towards the 129 Street access point.

Photo 10.4: Pond 296

Similar to the other two ponds, Pond 296 is a dry, grassed area that is designed to activate under a surcharged condition only. The flow control structure is contained within a manhole on 67A Avenue. Flows from the majority of the catchment area are conveyed to the manhole in a 450mmØ storm sewer. A 316mmØ orifice is situated on the 450mmØ outlet pipe, which acts to surcharge water through a 250mmØ lateral sewer to an inlet / outlet structure located in the centre of the pond. The discharge capacity of the orifice is 0.29 m^3/s when the pond is completely full, which is significantly higher than the 250mmØ sewer capacity (0.06 m^3/s). When the pond does activate, water is temporarily held until it can drain via gravity back through the 250mmØ sewer and orifice once the surcharging subsides. A small portion of the catchment area on 66B Avenue enters the pond via a separate sewer connection from the south; however, this is also controlled ultimately by the flow control structure on 67A Avenue.

The maximum storage capacity of Pond 296 is 1,510 m^3, with a maximum depth of 0.96 metres. If the pond's storage capacity is exceeded, flows are routed via an overland swale to 67A Avenue. The elevation of the overland swale is set at 0.90 metres above the pond invert.

Approximately 1.2 metres of surcharge is required on the orifice before the pond will activate, which roughly corresponds to a peak flow rate of 0.22 m^3/s (assuming that there are no constraints downstream of the orifice). There is also no sump in the flow control manhole on 67A Avenue, so there is currently no method to capture sediments or other water quality pollutants at this location.

Performance with Existing Configuration

The model indicates that Pond 296 only activated four times during the 1996 – 1997 rainfall period, as shown by the figures in Appendix E. The maximum depth in the pond was 0.18 metres, which occurred during the May 30 / 31 rainfall event. This water depth was well below the elevation of the overflow swale. This pond provides an appreciable storage volume at 202 m^3/ha, however it also has the highest unit relate rate at 38.7 L/s/ha, as previously indicated in Tables 10.1 and 10.2. The high unit release rate is due to the fact that the orifice diameter is only slightly smaller than the actual outlet pipe diameter, which allows a significant amount of flow to pass through the orifice before it begins to surcharge. For example, during the May 30 / 31, 1997 storm event, the pond was only able to provide a 30% reduction in peak flow. For the vast majority of rainfall events during 1996 – 1997, it appears that flows bypassed the pond and were discharged directly to the downstream drainage system with no attenuation.

A comparison of the Pond 296 outflow hydrograph versus the Hyland Creek flow station hydrograph indicates that the pond contributes a minor amount of flow to Hyland Creek. The average pond outflow rate during the 1996 – 1997 period was 1.7 L/s, which represents about 1.0% of the average flow in Hyland Creek. The maximum pond peak flow rate was 257 L/s, or 3.1% of the maximum peak flow rate in Hyland Creek.

For the 1996 – 2005 rainfall period, Pond 296 activated 20 times, and only a fraction of the pond's storage capacity was utilized.

Overall, the model indicates that Pond 296 is not very effective in attenuating peak flows under any circumstances with its current configuration. The control device is simply too large to provide appreciable attenuation and does not allow the pond to utilize its storage capacity. A significant improvement in peak flow reduction could likely be achieved if the orifice control structure was modified to maximize the pond's available storage volume.

Potential Reconfiguration Opportunities

Similar to Pond 293, Pond 296 did not activate under the October 27 / 28, 1996 MAR event with its current configuration. A significant improvement to the level of service for this pond could be achieved if the orifice in the flow control structure was reduced from 316mmØ to 60mmØ. In

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conjunction with this, the rim elevation of the control structure would need to be raised slightly to maintain the hydraulic gradeline in this localized area below the ground surface.

When the reconfigured Pond 296 was modeled, the pond was able to reduce the peak outflow from 90 L/s to 12 L/s, or by 87%. The outflow hydrograph for the pond with and without the pond reconfiguration is shown in Figure 10.5.

Performance with Optimized Configuration

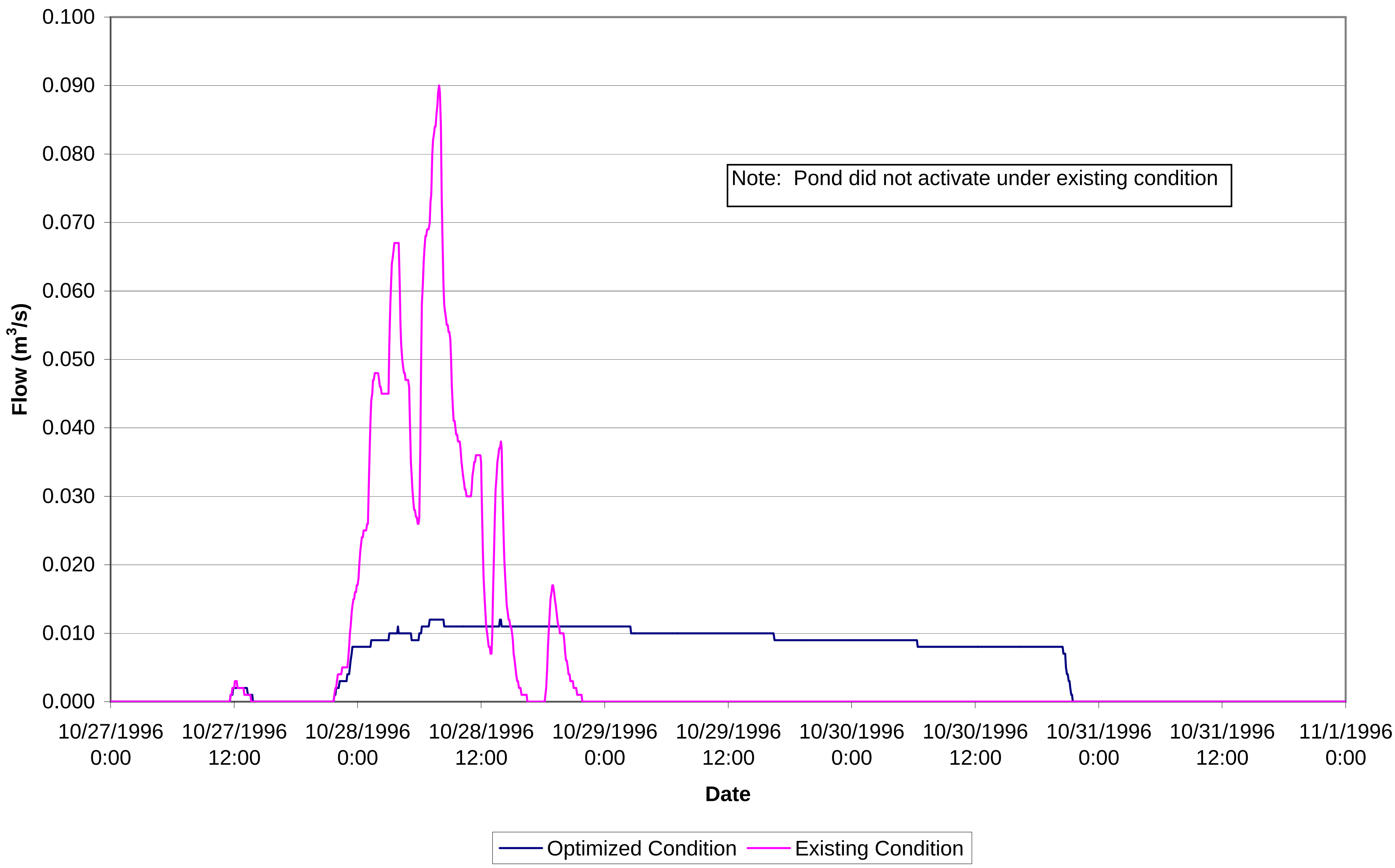
The model also shows that the performance of Pond 296 improves with the reconfiguration in place, with water levels frequently reaching 0.2 to 0.4 metres above the pond invert elevation. While the pond is able to achieve upwards of 97% reduction in peak flow over the 1996 – 2005 rainfall period, the pond overflow did not activate. There is an opportunity to reconfigure Pond 296 into a flow through facility, however, significant removal and replacement of existing storm sewers on 129 Street and 67A Avenue is anticipated. Given the small catchment area, and the significant benefit already possible through decreasing the orifice size in the existing flow control manhole, the costs associated with reconfiguring the storm sewer system seems unjustified at this stage. However, this option could be explored further during detailed design.

Table 10.5 summarizes the recommended reconfiguration for each of the three ponds to optimize their performance under a MAR event.

Table 10.5
Pond Retrofits under MAR Event

Pond ID	Changes to Flow Control Structure	Changes to Storage Volume	Other Modifications or Comments
267	• Reduce orifice diameter from 167mmØ to 60mmØ	None	• Maximum volume used under MAR event = 1,025 m^3 (Volume available = 1,170 m^3)
293	• Abandon existing 525mmØ and 375mmØ storm sewers • Direct 600mmØ and 300mmØ storm sewers into pond facility • Add 138mmØ orifice in overflow structure at 67A Avenue	Increase storage volume to 4,000 m^3	• Remove Ponds 297, 297 Tank1, 297 Tank2, 298 (combined storage volume of 1,556 m^3) in upstream catchment area • Deepen pond and change to a flow through facility to increase storage volume and provide water quality treatment • Raise overflow weir spill elevation from 74.2m to 74.3m
296	• Reduce orifice diameter from 316mmØ to 60mmØ • Raise rim elevation of flow control manhole from 86.83m to 87.1m	None	• Maximum volume used under MAR event = 1,450 m^3 (Volume available = 1,510 m^3)

Figure 10.5: Pond 296 Hydrographs - October 27 / 28, 1996 Rain Event (MAR)



U:\Projects_VAN\1072\0137\01\SWMM\20061101sw pond hydrographs

10.1.7 Optimal Unit Release Rate and Unit Storage Volume

As discussed in the previous sections, the analysis of the existing performance and function of Ponds 267, 293 and 296 indicates that these ponds are providing little to no benefit under smaller, more frequent storm events, and are providing only minimal to moderate benefits for larger storm events. As these ponds were designed to activate under a surcharged condition rather than systems where all flows pass through the facility, the smaller, frequently-occurring flows are bypassing these ponds completely and are being discharged directly into Hyland Creek with no flow attenuation or water quality treatment. Typically, it is the smaller events which are responsible for the majority of erosion and water quality impacts in a watercourse. Therefore it would be beneficial to retrofit these ponds (as outlined in Table 10.5 above) to improve their level of service under smaller storm events.

Tables 10.6 and 10.7 below summarize the changes in peak flow and storage volume during the representative MAR event, as a result of the pond retrofits outlined in the previous section.

Table 10.6
Reduction in Peak Flows under Optimized Condition (MAR Event)

Pond ID	Location		Area (ha)	Existing Conditions		Optimized Conditions	
	Street	Zone		Peak Flow (m^3/s)	Unit Peak Flow (L/s/ha)	Peak Flow (m^3/s)	Unit Peak Flow (L/s/ha)
267	63A Ave: west of 131A St	1	5.7	0.052	9.1	0.0115	2.0
293	67 Ave – 133 St (Greenbelt)	1	20.2	0.240	11.9	0.0489	2.4
296	129A St – 66B Ave	1	7.5	0.090	12.0	0.0118	1.6

Table 10.7
Changes in Storage Volume under Optimized Condition (MAR Event)

Pond ID	Location		Area (ha)	Existing Conditions		Optimized Conditions	
	Street	Zone		Storage Volume (m^3)	Unit Storage Volume (m^3/ha)	Storage Volume (m^3)	Unit Storage Volume (m^3/ha)
267	63A Ave: west of 131A St	1	5.7	1,170	206	No Change	
293	67 Ave – 133 St (Greenbelt)	1	20.2	1,410	91	4,000	198
296	129A St – 66B Ave	1	7.5	1,510	202	No Change	

From the consistent results presented above, it can be concluded that the optimal pond configuration is one that can provide a unit storage volume of approximately 200 m^3/ha, and releases flows at a unit rate of 1.5 to 2.5 L/s/ha during a MAR event. These unit values are applicable to a developed catchment area comprised predominantly of single family residential development, and can be expected to be higher for denser development.

10.1.8 Cumulative Effect of Optimized Ponds on Hyland Creek

As a final step in the analysis, the cumulative flows for Ponds 267, 293 and 296 were superimposed on the Hyland Creek flow station data for the 1996 – 1997 period to gain an understanding of how the pond reconfigurations might reduce overall flows in Hyland Creek. The resultant hydrographs are shown on Figures 10.6 and 10.7.

Figure 10.6 shows the cumulative effect of the recommended reconfigurations on these facilities, whereas Figure 10.7 shows the cumulative effect of these three ponds on the total flow in Hyland Creek. Over the 1996 – 1997 time period, the existing ponds released a maximum cumulative peak flow of 0.72 m^3/s, whereas the maximum peak flow in Hyland Creek over that time was 8.35 m^3/s. Therefore, under existing conditions the three ponds represented 8.6% of the peak flow in Hyland Creek. Under optimized conditions, the cumulative peak flow from the ponds was 0.16 m^3/s (a reduction of 78% from existing conditions). This optimized peak flow represents approximately 1.9% of the peak flow in Hyland Creek (an overall reduction of 6.7% from existing conditions). The average cumulative flow from the ponds does not change between existing and optimized conditions, as the pond reconfigurations only act to redistribute the outflow volume over a longer timeframe. Overall, a significant reduction can be achieved when the ponds are reconfigured, and the potential for appreciable reduction in peak flows in Hyland Creek can be seen.

The combined service area for the three ponds is 33.4 hectares. By reconfiguring these ponds, peak flows in the main stem of Hyland Creek could be reduced by 6.7%. The total drainage area of all of the ponds listed in the capital works program is 67.3 hectares, therefore total flows in the main stem of Hyland Creek could theoretically be reduced by approximately 14% if all of the ponds were retrofitted to meet the target unit release rate (1.5 to 2.5 L/s/ha) and storage volume (200 m^3/ha). The benefit would be most apparent in the upper reaches of the central branch of Hyland Creek (as this branch has 44.1 ha of the 67.3 ha total), however, all three branches of Hyland Creek would benefit to some degree. Overall, a 14% reduction in peak flow is significant for Hyland Creek. However, it may not be economically or practically feasible to reconfigure all of the ponds, as discussed below.

Figure 10.6: Flow Reduction Potential by Optimizing Ponds (Pond ID's 267, 293 and 296)

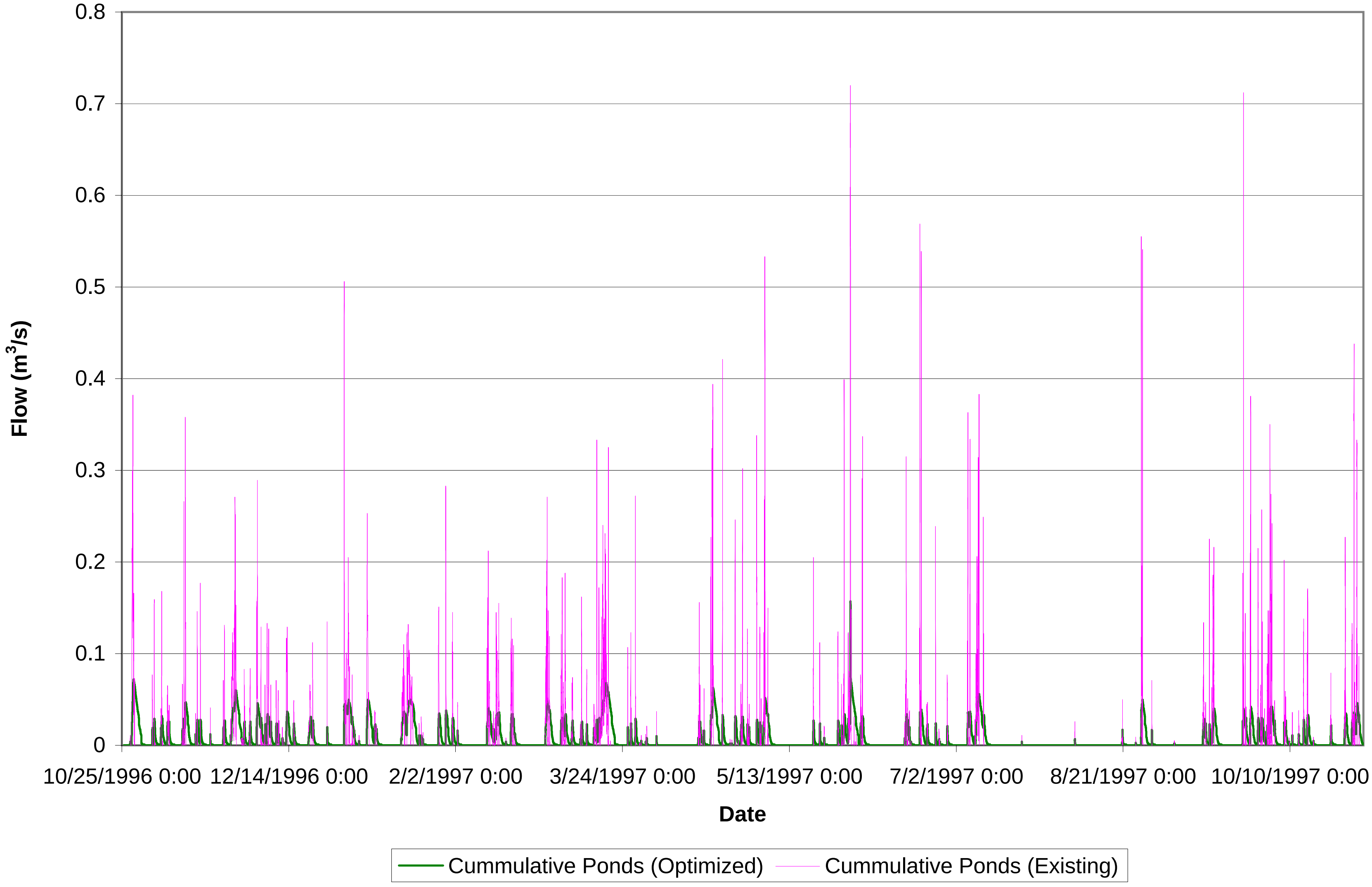


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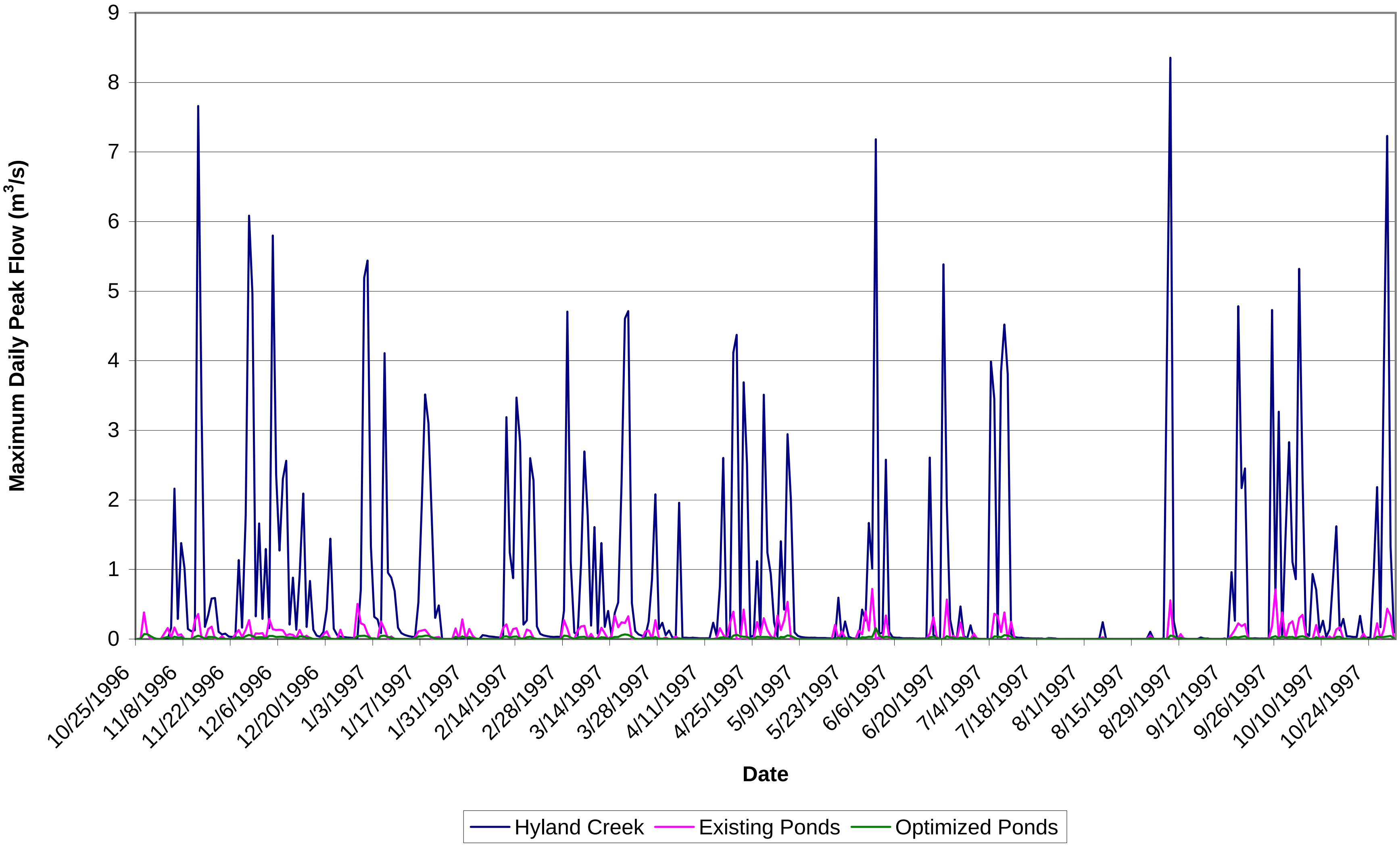
Figure 10.7: Reduction in Daily Peak Flow due to Pond Optimization (Pond ID's 267, 293 and 296)



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10.1.9 Conclusions

Based on the detailed analysis and modeling discussed above for Ponds 267, 293 and 296, it has been demonstrated that a significant improvement in the level of service could be achieved for their respective catchment areas if these ponds were retrofitted as outlined previously in Table 10.5. Furthermore, the analysis indicates that ponds servicing single family residential development should strive for a unit storage volume of 200 m^3/ha and a unit release rate of 1.5 to 2.5 L/s/ha for management of the MAR event. If this is practically achievable with the existing ponds, then strong consideration should be given to maintaining and retrofitting the facility.

The above analysis also suggests that if all of the ponds in the capital works program were retrofitted to meet these targets, an overall peak flow reduction in the order of 14% could theoretically be achieved in Hyland Creek. This represents a significant reduction in peak flows in Hyland Creek over current conditions.

With this in mind, the remaining ponds in the capital works program were reviewed. Table 10.1 previously provided the unit storage volumes of each pond listed in the capital works program. Ponds 267, 272, 296, 308 and 314 have storage volumes greater than 200 m^3/ha, therefore they have adequate storage volumes to service their catchment area under a MAR event. For Ponds 267, 272, 296 and 314, it appears possible to optimize performance simply by decreasing the orifice diameter, therefore these ponds should be retained and modified to meet the target unit release rate of 1.5 to 2.5 L/s/ha under the MAR event. Any detailed design to undertake this work should also evaluate and modify the overflow structure as needed to maintain safe conveyance of flows during extreme storm events.

Pond 308 utilizes a 250mmØ storm sewer, rather than an orifice, as a control mechanism. Modifying an existing manhole for use as a flow control structure or replacing the 250mmØ storm sewer with a smaller pipe are possible retrofits, however, with a service area of only 0.7 hectares the insignificant benefit to Hyland Creek does not justify the costs. Therefore, it would be more cost effective to sell this lot for development and dedicate the funds to other improvements in the watershed. The development potential of this lot would need to be further evaluated by the City's property agents.

Pond 298 also has a storage volume greater than 200 m^3/ha, however, as noted in Section 10.1.5 this pond could be removed since its catchment area could be effectively serviced by reconfiguring and expanding Pond 293.

Ponds 276, 295, 300 and 472 have storage volumes below 100 m^3/ha. Pond 276 consists of a 1350mmØ storm sewer in a drainage easement, which is controlled at its downstream end by an orifice. In order to achieve the 200 m^3/ha target unit volume, the existing sewer would need to be replaced with 2 - 1200mmØ storm sewers or an underground detention vault (e.g. a 3m x 3m x 23m structure). Both of these options would be quite costly and given the small catchment area they are likely not warranted. On the other hand, the drainage easement is essentially integrated with the existing adjacent park, thus the easement containing the sewer could likely not be used for other purposes. Plus, the operation and maintenance costs associated with this sewer are likely minimal. Therefore, it is recommended that Pond 276 remain in place in its current configuration. If desired, opportunities to maximize the available pipe storage by decreasing the orifice diameter in the downstream manhole could be examined, or if the control structure has been problematic in the past from an operations and maintenance perspective, the orifice could be removed altogether.

A portion of the drainage area contributing to Pond 295 is also serviced by Ponds 299 and 300, thus these ponds are linked in series. All three ponds are listed in the capital works program. Pond 299 has a unit storage volume of approximately 160 m^3/ha, whereas both Ponds 295 and 300 are below 100 m^3/ha. Pond 299 is located in a large municipal right-of-way which is accessed by 65A Avenue and 66A Avenue. Part of the right-of-way is currently used as a "tot lot" playground; however, most of the right-of-way is currently passive park space. Given the size of the easement, it appears that Pond 299 could be expanded to achieve a 200 m^3/ha unit storage volume, however, the costs involved may not be warranted given the small catchment area. In this instance the space may be better used as an active park space for the local community. The drainage catchment to Pond 299 could also likely be serviced downstream by retrofitting Pond 295. Thus, the opportunity exists to remove Pond 299, however, further discussion with the Parks department is needed to verify whether an enhanced active park space is desired at this location.

Pond 300 is located within an existing narrow easement and is accessed from 65 Avenue, 65A Avenue and 131 Street. This pond has already maximized its footprint area and cannot be deepened further without the need for additional retaining walls around the pond perimeter, therefore, increasing the storage volume of this pond to meet 200 m^3/ha would be difficult and costly. The pond area is likely not developable as it has limited road access and may not meet acceptable zoning standards. The opportunity to convert this area into active park space could be investigated further by the City Parks department. The pond does have the potential of being converted to a flow-through facility, as there is a 1.4 metre drop in elevation between the manholes immediately upstream and downstream of the pond. Since the pond services an appreciable area (9.5 ha), providing water quality treatment would be beneficial therefore it is recommended that the pond be modified to a flow-through facility. A control structure should also be implemented at the pond outlet to maximize the existing storage capacity of the pond.

Pond 295 is located within an existing greenbelt area that contains pedestrian walking trails and passive space uses. Flow control for the pond currently consists of a 450mmØ storm sewer laid at a 0.05% grade. Given the extent of the greenbelt area, it appears that this pond could be expanded to meet the unit target storage volume of 200 m^3/ha by expanding the pond to the north and deepening the facility. If Pond 299 is removed, Pond 295 would need to account for this additional drainage area. By also reconfiguring the pedestrian trails around the new pond and creating viewpoints or gathering areas (e.g. park benches) around the pond perimeter, usage of the greenbelt may increase as the local residents may view the pond as a community amenity.

Pond 472 services a small commercial site at 6670 King George Highway. While Pond 472 may provide some attenuation, it is likely to be very limited given the small storage capacity of the pond. Furthermore, Pond 472 only controls 0.4 hectares of the total 6.7 hectares draining to Hyland Creek from this catchment area. Therefore, it is recommended that Pond 472 be removed.

Pond 293 also has a storage volume less than 100 m^3/ha, however, as discussed in Section 10.1.5 this pond could be greatly expanded to increase its storage capacity, thereby allowing for the removal of ponds 297, 297 Tank1, 297 Tank2 and 298 upstream.

Pond 292 has a storage volume of 166 m^3/ha, which is only slightly less than the unit target storage volume of 200 m^3/ha. Approximately 150 m^3 of additional storage volume would be required to meet the target, which could be met by deepening the pond by approximately 0.15m. While there is space available for this reconfiguration, the costs associated with the work outweigh the minimal benefit that it would have on peak flows in Hyland Creek. Therefore, Pond 292 should be retained with its current storage capacity. The existing orifice diameter in the flow control structure could be reduced, however, to optimize the pond's performance under the MAR event.

Table 10.8 lists the ponds in the capital works program for Hyland Creek, and indicates whether the ponds should be kept and retrofitted, or removed. The capital works program (discussed in Section 11) has also been updated to include this information.

Table 10.8
Retrofits / Removals of Ponds in Capital Works Program

Pond ID	Location	Retrofit	Remove	Comments
267	63A Ave: west of 131A St	√		Decrease orifice diameter from 167mmØ to 60mmØ
272	132A St – 61 Ave	√		Decrease orifice diameter in control structure
276	135 St – 60A Ave	√		Decrease orifice diameter in control structure
292	69 Ave – 135 St	√		Decrease orifice diameter in control structure
293	67 Ave – 133 St (Greenbelt)	√		Abandon existing 525mmØ and 375mmØ storm sewers; direct 600mmØ and 300mmØ storm sewers into pond facility; add 138mmØ orifice in overflow structure at 67A Avenue
295	65 Ave – 133 St (Greenbelt)	√		Expand to meet 200 m^3/ha unit storage volume
296	129A St – 66B Ave	√		Decrease orifice diameter from 316mmØ to 60mmØ; raise rim elevation of flow control manhole from 86.83m to 87.1m
298	130A St – 66B Ave		√	Service catchment with Pond 293
299	65A Ave – 130A St		√	Service catchment with Pond 295
300	65 Ave – 130A St	√		Retrofit pond to a flow-through facility
308	66A Ave: east of 141 St		√	Costs outweigh benefit to catchment / creek
314	73 Ave – 128B St	√		Decrease orifice diameter in control structure
472	67 Ave – 137 St		√	Too costly to reconfigure to meet unit targets
297*	67A Ave – 130A St		√	Service catchment with Pond 293
297 Tank1*	67A Ave – 130A St		√	Service catchment with Pond 293
297 Tank2*	67A Ave – 130A St		√	Service catchment with Pond 293

* Pond is not specified in the capital works program, however, the analysis indicates that the pond could be removed if its catchment area is serviced by a retrofitted pond that is listed in the capital works program.

The analytical approach taken towards the review of existing detention facilities in the Hyland Creek watershed is somewhat conventional, and is not necessarily the approach that might be taken if evaluating drainage infrastructure in an ISMP for a green field watershed. However, given the watershed conditions and the extent of existing development, this approach was taken in order to make pragmatic decisions about existing drainage infrastructure.

Prior to actually removing a pond, further consideration must be given to how these ponds were designed to function under a major storm event, i.e. the 100-year event. If the pond was designed to overflow under the 100-year event, then modifying the control structure to activate under more frequent events will result in a limited increase in risk to downstream properties. However, if the pond was designed to control the 100-year event, the risk to downstream properties could increase significantly over current conditions as the overflow mechanism for the pond will activate on a more frequent basis. A review of the available as-built drawings suggests that the ponds listed in the capital works program was designed to control a 5-year event only with overflow mechanisms activating for major system events, however, this would need to be confirmed through a detailed hydraulic assessment of the pond.

Finally, removing a pond will likely impact hydraulic gradeline levels in the local downstream storm sewer network. Thus, a detailed hydraulic assessment must also include an evaluation of the potential impacts to local property service connections downstream of the pond.

10.2 New Municipal Detention Facilities in Zones 1 / 1A

A review of the existing municipal detention facilities and storm sewer network suggest that a significant portion of the drainage area contributing to the north branch of Hyland Creek currently drains uncontrolled to the creek. The total area draining to the north branch is 353 hectares and is completely built out with residential, commercial and industrial development in Zones 1 and 1A. These types of development generate a significant amount of stormwater runoff and tend to have a flashy response to rainfall events, particularly for commercial and industrial development as they are directly connected to the municipal drainage system. Water quality is also a concern.

Approximately 115 hectares, or 33%, of this catchment area is currently serviced by municipal detention facilities. The vast majority of these facilities are designed to activate under a surcharged condition only, thus, flows from small, frequent storm events often bypass the existing facilities with no attenuation. Even if these facilities were retrofitted to meet the target unit release rate and unit storage volume discussed in Section 10.1.7, the benefit to Hyland Creek would be limited due to the fact that much of the drainage area is still uncontrolled. The City's GIS database does indicate that there are a few private detention facilities in the catchment area, however, the function and performance of these facilities is not known. Since these facilities service individual developments only, it is anticipated that any localized benefits they have would be negligible by the time flows reached Hyland Creek.

It is evident, given the ongoing instability and erosion degradation outlined in the 2002 and 2006 Ravine Stability Assessment reports for Hyland Creek (see Figure 5.2), that the creek is not capable of withstanding the flows currently conveyed by this catchment area. Thus, additional detention is needed in this catchment area to stabilize the north branch of Hyland Creek. Further, the water quality assessment conducted for this ISMP indicated that water quality was a potential concern along the north branch of Hyland Creek. New municipal detention facilities may assist in improving water quality in this branch.

Consideration was given to implementing disbursed source control detention features in Zones 1 and 1A, however, based on discussions with City staff this approach was not deemed practical.

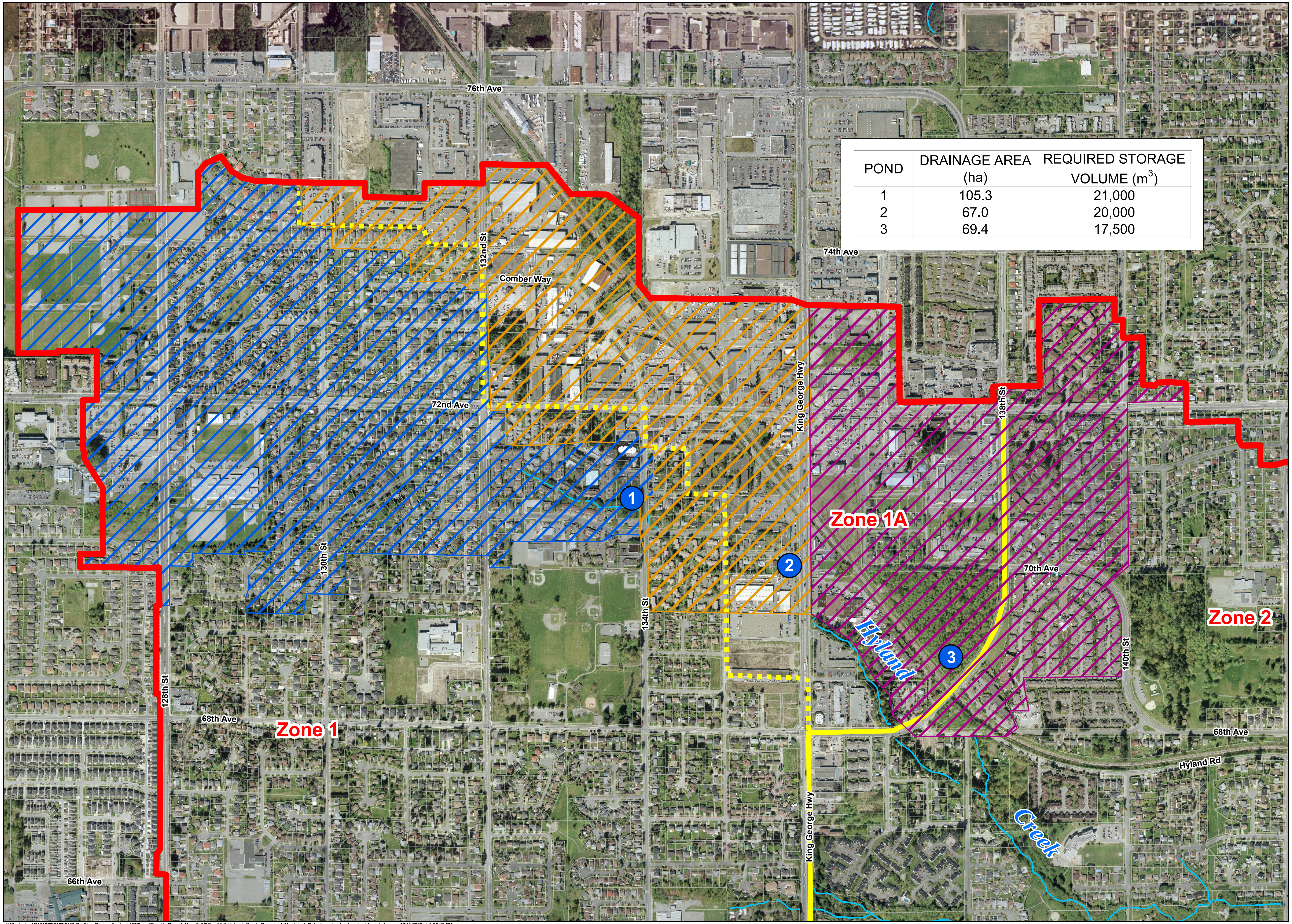
As such a more conventional end-of-pipe solution, using a centralized community-scale approach to stormwater detention, would provide the greatest chance of mitigating issues on the north branch of Hyland Creek in a timely manner.

After reviewing the existing storm sewer network configuration, three sites were identified for proposed municipal detention facilities, as shown on Figure 10.8. Site 1 is located near the intersection of 134 Street and 70B Avenue, whereas Site 2 is located at the intersection of King George Highway and 70A Avenue. Both sites are currently privately owned and the land would need to be acquired by the City. Site 3 is located on the City-owned parcel at 138 Street and 68 Avenue. The 2000 Dillon study previously recommended that a municipal detention facility be constructed at Site 3 (referred to in the capital works program as the Newton Town Centre stormwater detention pond). A breakdown of land use types and drainage areas for each facility is summarized in Table 10.9.

Table 10.9
Land Use and Contributing Drainage Areas to Proposed Ponds in Zones 1 / 1A

Land Use	% Impervious	Contributing Drainage Area (ha)		
		Pond 1	Pond 2	Pond 3
Single Family Residential	55	66.1	8.3	7.1
Multi Family Residential	70	9.2	5.8	27.4
Commercial / Industrial	90	10.1	50.8	22.6
Park / Greenspace / Woodlot	20	19.9	2.1	12.3
Total Drainage Area (ha)		**105.3**	**67.0**	**69.4**

Using the same rationale as the existing pond analysis, a weighted unit storage volume was assigned to the three proposed municipal detention facilities based on the breakdown of land use types in their respective service areas. These unit storage volumes were used to determine the required storage capacity for each facility, such that the facility would be fully optimized under a MAR event. A simplified XPSWMM model was then developed for each facility and its respective service area and analysed under the MAR event to determine the required orifice diameter to maximize the pond's storage capacity. The required storage volumes and orifice diameters for each facility to be optimized under the MAR event are summarized in Table 10.10.



POND	DRAINAGE AREA (ha)	REQUIRED STORAGE VOLUME (m^3)
1	105.3	21,000
2	67.0	20,000
3	69.4	17,500

SURREY
CITY OF PARKS

Hyland Creek Integrated Stormwater Management Plan

Figure 10.8

PROPOSED MUNICIPAL DETENTION FACILITIES IN ZONES 1 / 1A

Hyland Creek Watershed Area
Sub-Zone Boundary
Zone Boundary
Proposed Municipal Detention Facility

0 250 500
Metres
Scale 1:10 000

Source: City of Surrey
2005 Aerial Photography

Prepared By:
URBANSYSTEMS.
1072.0137.01 July 2007

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Table 10.10
Required Storage Volumes for Proposed Ponds in Zones 1 / 1A

Pond	Drainage Area (ha)	Weighted Unit Storage Volume (m^3/ha)	Required Storage Volume (m^3)	Orifice Diameter (mmØ)
1	105.3	200	21,000	375
2	67.0	300	20,000	360
3	69.4	250	17,500 [1]	325

[1] The 2000 Dillon study predicted a storage volume for Pond 3 of 13,300 m^3, thus a slightly higher storage capacity would be required to optimize this pond under a MAR event.

While the storage volumes shown are related to the MAR event, the detailed design of these facilities should also ensure that the City's current servicing objectives for stormwater detention are satisfied. The City's design criteria manual currently requires that 5-year post development flows be controlled to the more stringent of the following two criteria; 50% of the 2-year post-development rate, or to the 5-year pre-development rate. The design will also need to account for safe conveyance for major system flows. Pond storage volumes, as well as outlet control structure size and configuration, may need to be adjusted slightly as part of the detailed design to meet these criteria.

With the optimal configuration in place, the model was used to analyse each facility for the November 1996 to October 1997 time period. The performance of each facility is shown in the hydrographs in Appendix E. During this time period, Ponds 1 and 3 overflowed once during the May 30/31, 1997 event, whereas Pond 2 was capable of attenuating all flows without activating the overflow.

The cumulative impact of the three proposed detention facilities can be seen in Figure 10.9. By implementing the additional detention control in Zones 1 and 1A, a cumulative peak flow reduction of approximately 90% was predicted by the model. When compared to flows in Hyland Creek, as shown in Figure 10.10, the potential reduction of flows to Hyland Creek is also evident.

It should be noted that in Figures 10.9 and 10.10, the maximum peak flow predicted by the model with no ponds in place is slightly higher than actual peak flows measured in Hyland Creek. This is likely due to the simplicity of the model developed for analysing the ponds, in that the time of concentration predicted by the model is much quicker than what actually occurs. For this reason, it would be incorrect to estimate the reduction of peak flows in Hyland Creek using these

Figure 10.9: Flow Reduction Potential of Proposed Ponds in Zones 1 / 1A

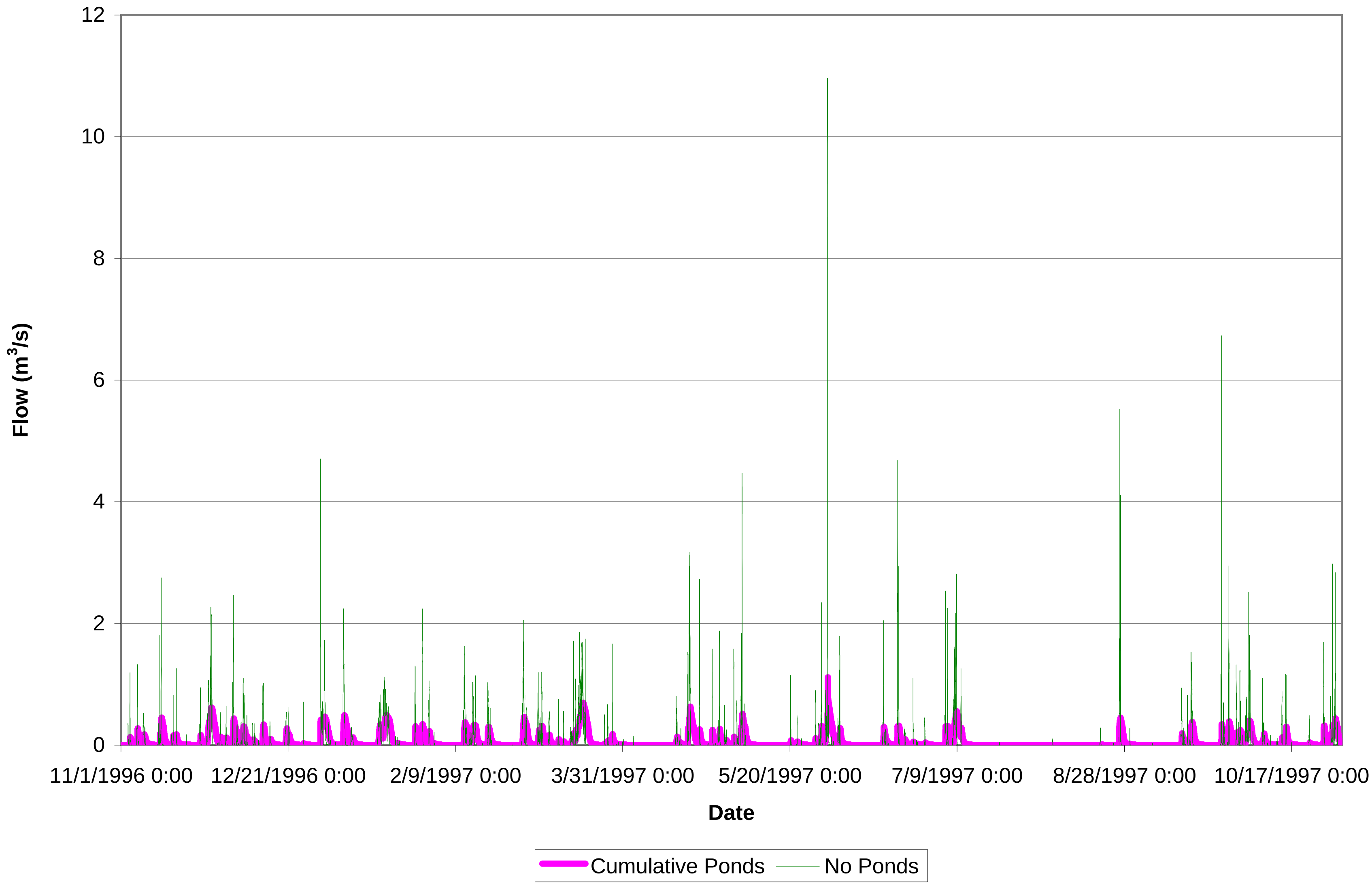

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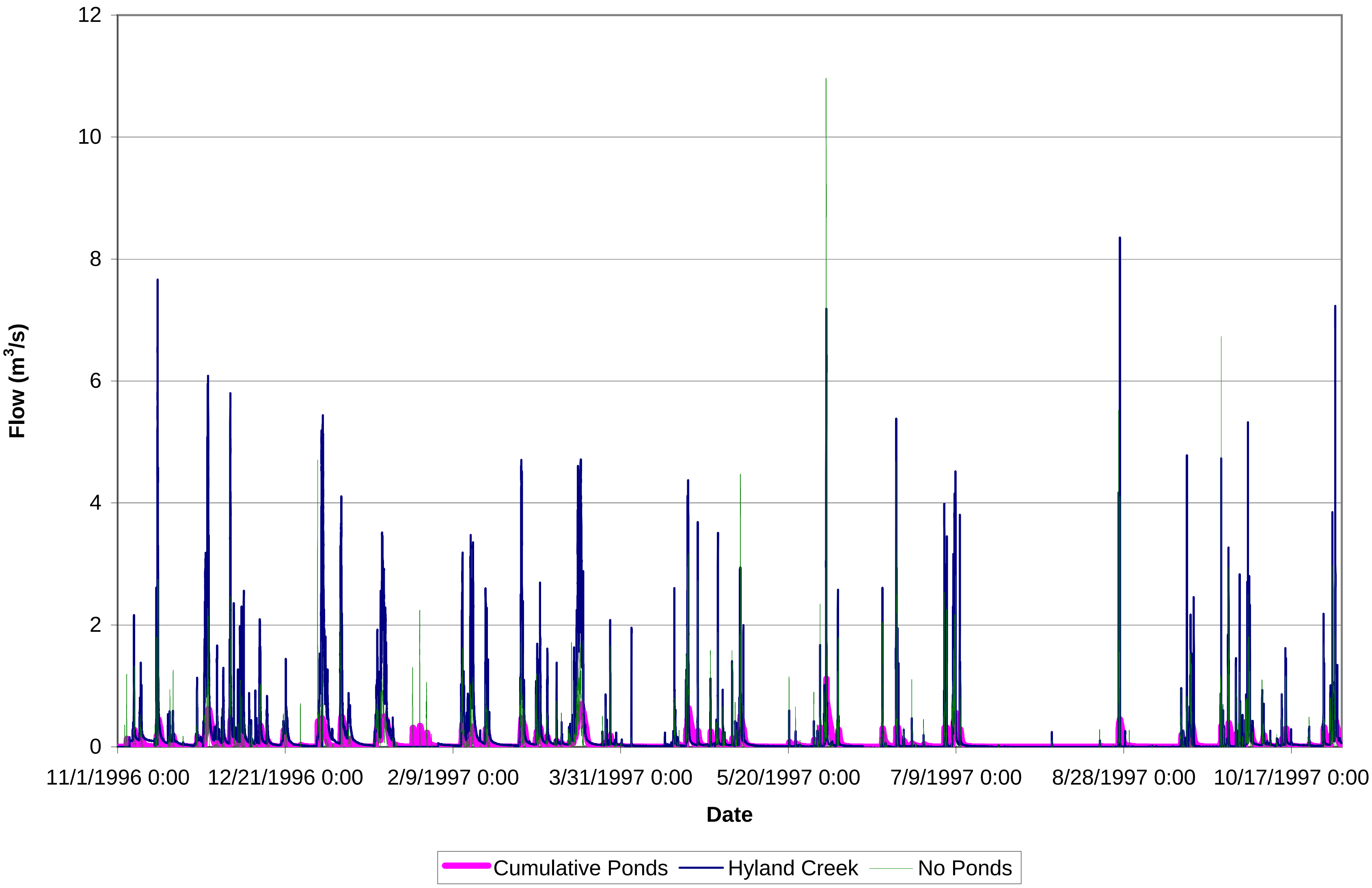
Figure 10.10: Impact of Proposed Ponds in Zones 1 / 1A on Total Flows in Hyland Creek



U:\Projects_VAN\1072\0137\01\D-Drafting-Design-Analysis\D3-Models-Spreadsheets\Spreadsheets\20061125sw zone 1 proposed pond impacts model results. However, the relative reduction in peak flows shown in Figure 10.9 is still valid and confirms that a significant benefit could be achieved in reducing flows to Hyland Creek if the three proposed detention facilities in Zones 1 and 1A were implemented. By attenuating the peak flows generated by this catchment area, further degradation and instability along the north branch of Hyland Creek could be largely reduced and the creek would have an opportunity to stabilize.

Further, the proposed detention facilities could provide an opportunity to significantly improve water quality conditions for this developed area, by allowing suspended solids and other pollutants to settle out in the detention basins. Given that the most notable water quality issues (such as total suspended solids) from the water quality assessment were in relation to sampling site H3 (located at the outlet of the municipal storm sewer network to the north branch of Hyland Creek), the implementation of the three detention facilities could also significantly improve water quality conditions along this reach of the creek if a suitable design was implemented.

10.3 Trunk Drainage System on 66 Avenue


Photo 10.5: 66 Avenue Ditch

A significant portion of stormwater runoff generated in Zone 2 is conveyed through an existing roadside ditch on 66 Avenue, between Upland Road and 148 Street (Photo 10.5). The 66 Avenue ditch services an upstream catchment area of approximately 92 hectares, which is roughly bounded by 72 Avenue to the north, 148 Street to the east, 66 Avenue to the south, and 144 Street to the west, as shown on Figure 10.1.

Single family residential development and industrial development currently exists in the catchment area, along with the Valley View Memorial Gardens cemetery (which comprises approximately 43% of the total catchment area). The City's Parks and Recreation Operations yard is also located within the catchment on 66 Avenue, and borders the north side of the ditch. Aside from some infill and redevelopment of larger single family lots into small lot single family and multi-family development, the catchment area is completely built out.

The City's drainage capital works program currently lists an initiative to infill the 66 Avenue ditch with a storm sewer. However, the City has hesitated to undertake this work, as the ditch currently overtops on a fairly frequent basis and there is concern that infilling the ditch will further reduce the conveyance and storage capacity through this reach of the drainage system. We understand that in instances where the ditch overtops, surface ponding and flooding occurs along 66 Avenue as well as within private property, including the Parks and Recreation Operations yard. Previous drainage improvement works within the ditch were completed by New East Consulting in 2003, however, we understand that the ditch has continued to demonstrate inadequate performance since the upgrades were completed.

Drainage from the upstream catchment area is currently discharged to the 66 Avenue ditch via a 900mmØ storm sewer at Upland Road. The capacity of the 900mmØ storm sewer at the discharge point is 0.81 m^3/s. The ditch conveys flows east on 66 Avenue and connects to an existing 750mmØ pipe system located between 14682 and 14704 66 Avenue. Flows are then conveyed south via the pipe system and are discharged into Hyland Creek near the BC Hydro right-of-way corridor. Based on the available as-built drawings, the 66 Avenue ditch has a 0.5m bottom width, 1.5H:1V side slopes and 0.4% average profile slope (although some reaches of the ditch are at a flatter grade and in some instances are reverse graded, according to the as-built drawings). An average depth of the ditch is estimated to be 1.3m, including a 0.6m freeboard depth. From this information, the capacity of the ditch was calculated to be 4.85 m^3/s (including freeboard). Thus, if the upstream sewer is capable of delivering 0.81 m^3/s under full flow conditions, the ditch itself should have adequate capacity for this flow. We understand that there are no as-built drawings available for the 750mmØ pipe, however, the pipe slope can be roughly determined by estimating the outfall elevation at Hyland Creek using available topography, along with the upstream elevation of the pipe at 66 Avenue and the pipe length. Using this information, a pipe slope of approximately 3.3% was calculated (based on a total length of 175 metres). Thus, the capacity of the 750mmØ pipe is estimated to be 2.0 m^3/s.

The available as-built drawings for the 66 Avenue ditch indicate that there are four culverts situated in the ditch to accommodate driveway crossings to properties on the north side, including the City Parks and Recreation Operations yard. The culverts range in size from 600mmØ to 900mmØ, with three of the four culverts listed as "interim" culverts on the as-built drawings. These culverts will reduce the overall capacity of the 66 Avenue drainage system, as most of these culverts have a lower conveyance capacity than the ditch itself. For example, the 600mmØ culvert has a capacity of 0.72 m^3/s, whereas the 800mmØ culvert is laid on a 0.14% grade and only has a capacity of 0.49 m^3/s under inlet control conditions.


Photo 10.6: Vegetation in 66 Ave Ditch

The site was visited to gain a thorough understanding of the site characteristics and to confirm information provided on the as-built drawings. Heavy, dense vegetation was noted throughout much of the ditch invert, as shown on Photo 10.6. This vegetation appeared to be constricting flow in the ditch in several locations. The culverts noted in the as-built drawings were identified in the field, along with an additional culvert and sand bag headwall located near the midpoint of the 66 Avenue ditch, as shown on Photo 10.7.

The Surrey stream classification system currently lists the 66 Avenue ditch as Class B, meaning that the ditch is believed to provide significant food and nutrient value. However, fish are not likely to be present, given habitat characteristics such as stream gradient, access and proximity to known fish-bearing waters, as well as the length of enclosed 750mmØ pipe between the ditch and Hyland Creek.


Photo 10.7: Additional Culvert / Headwall in Ditch

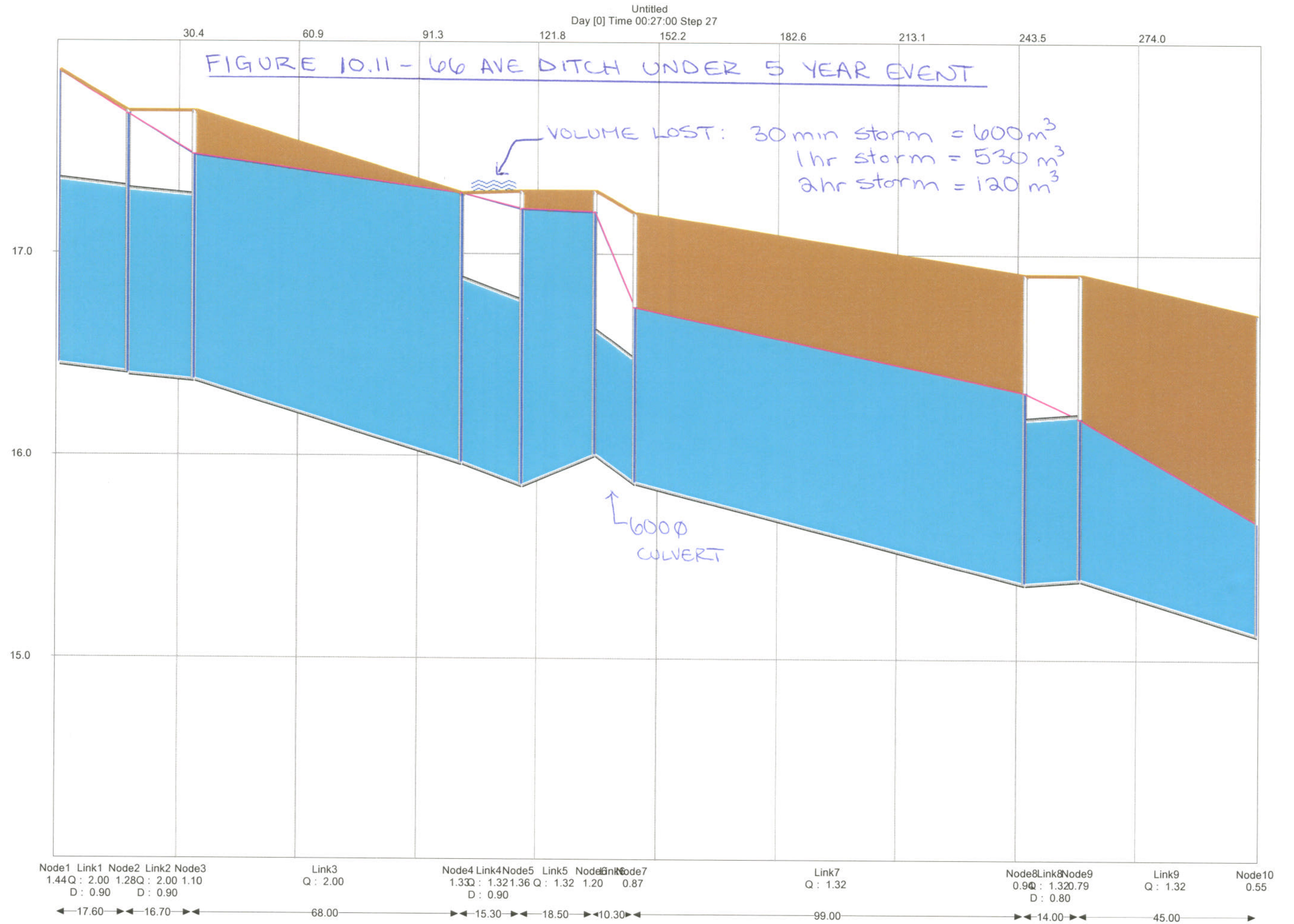
The City's current design criteria states that ditches must be designed to safely convey the 1 in 5-year storm event with a minimum 600mm freeboard depth. The design criteria also states that ditches shall have maximum side slopes of 1.5H:1V, a minimum bottom width of 0.5m, and a minimum profile grade of 0.5%. Aside from a slightly flatter profile grade, the 66 Avenue ditch appears to meet the design criteria for ditch configuration. However, as noted above, the capacity of some of the culverts situated in the ditch may not be capable of conveying the 5-year flow without surcharging and potentially causing upstream reaches of the ditch to overtop. The presence of dense vegetation in the ditch invert may also be reducing the conveyance capacity of the ditch.

Given the extent of the catchment area, a simplified XPSWMM model was developed and used to gain a better understanding of the performance of the 66 Avenue ditch under design storm events as well as under continuous rainfall simulation. A 5-year design storm event was initially run using several time durations (30 min, 1-hour, 2-hour, 6-hour, 12-hour and 24-hour) to evaluate performance and determine peak flows exiting the 66 Avenue ditch into the 750mmØ pipe system. The model indicated that the ditch overtopped for durations less than 2 hours, with a maximum of 600m^3 of water lost. When the model was run under time durations of 6 hours or longer, the ditch was capable of conveying the design flows without overtopping, however, some surcharging of the driveway culverts still occurred. In general, the model indicates that ditch surcharging and flooding appears to be the result of water backing up behind the 600mmØ interim driveway culvert, which has insufficient capacity to convey larger flows as shown on Figure 10.11.

The model was also used to assess the ditch performance under its existing configuration using continuous rainfall simulation (1996 to 2005 period). The model indicated that overtopping and flooding occurred at two locations upstream of the 600mmØ driveway culvert, with a significant volume of water lost from the system over more than 32 hours during the nine years of rainfall data. The ditch and culverts upstream of the 600mmØ driveway culvert remained surcharged for a further 111 hours over the modeled time period.

Upgrading the 600mmØ interim driveway culvert was evaluated to determine whether the surcharging and overtopping in the 66 Avenue ditch could be eliminated under the 5-year event. The model results indicated that, while some surcharging would still occur, overtopping could be eliminated for all storm durations of 1-hour or longer in the 66 Avenue ditch if the 600mmØ driveway culvert was upgraded to 900mmØ. Only minor flooding was predicted for durations less than 1 hour. Furthermore, if all of the driveway culverts were removed overtopping could be eliminated for all storm durations assessed. Under this scenario, the peak flow delivered to the 750mmØ pipe is estimated to be 2.15m^3/s, which is only slightly less than the capacity of the pipe.

In summary, based on the results of the analysis it appears that flooding along the 66 Avenue ditch could be eliminated if all of the driveway culverts were removed. As the removal of all of the driveway culverts is likely not feasible given that access is required to adjacent private properties to the north, these culverts could be replaced with clear span bridge sections as an alternative to maintain the cross sectional area of the ditch. Alternatively, surcharging and flooding conditions could be significantly reduced (although not completely eliminated) by upgrading the 600mmØ driveway culvert to 900mmØ. While an estimated capacity of the 750mmØ pipe was determined using available information, the capacity should be verified through a site survey to confirm the actual pipe properties. It may also be possible that inlet losses at the pipe entrance are preventing some the flow from entering the system. If the driveway culvert upgrade / removal does not fully address the flooding issue on 66 Avenue, further investigation should be undertaken towards reducing inlet losses at the 750mmØ pipe (e.g. provide a tapered inlet).



Untitled
Day [0] Time 00:27:00 Step 27
FIGURE 10.11 - 66 AVE DITCH UNDER 5 YEAR EVENT
VOLUME LOST: 30 min storm = 600 m3
1 hr storm = 530 m3
2 hr storm = 120 m3
600ø CULVERT
30.4
60.9
91.3
121.8
152.2
182.6
213.1
243.5
274.0
17.0
16.0
15.0
Node1 1.44
Link1 Q: 2.00 D: 0.90
Node2 1.28
Link2 Q: 2.00 D: 0.90
Node3 1.10
Link3 Q: 2.00
Node4 1.33
Link4 Q: 1.32 D: 0.90
Node5 1.36
Link5 Q: 1.32
Node6 1.20
Link6
Node7 0.87
Link7 Q: 1.32
Node8 0.94
Link8 Q: 1.32 D: 0.80
Node9 0.79
Link9 Q: 1.32
Node10 0.55
17.60
16.70
68.00
15.30
18.50
10.30
99.00
14.00
45.00

10.4 Stormwater Best Management Practices

From an overall health perspective, the Hyland Creek watershed could be stabilized and potentially greatly improved if stormwater Best Management Practices (BMPs) were implemented as part of new, infill and/or redevelopment in the watershed. Three key ISMP objectives could be met through the implementation of stormwater BMPs, particularly at the site and municipal right-of-way (ROW) level:

- Limit effective impervious area
- Limit total impervious area
- Mimic pre-development hydrology of the watershed in the post development condition

Different scenarios were evaluated to provide an indication of the potential benefits of implementing stormwater BMPs at the site and municipal right-of-way (ROW) level, including disconnection of impervious areas, amended topsoil and on-lot rain gardens. Disconnecting impervious areas from the municipal drainage system can be a successful method to limit the effective impervious area in the watershed. Also, amended topsoil and on-lot rain gardens can provide on-lot retention of stormwater runoff and encourage infiltration of runoff into the native soils, which may act to mimic the pre-development hydrology of the watershed.

The following tasks were undertaken to assess the effectiveness of these stormwater BMPs on flow and/or volume reduction, by comparing stormwater BMPs against conventional drainage techniques:

- A simplified XPSWMM model was developed based on a 100 metre long roadway (20 metre ROW width) with single family small lot development (RF-12 zoning designation) on both sides of the road.
- In the hydrology layer, the catchment area was separated into 4 distinct areas; roof, driveway and patio; private grassed areas; road pavement and sidewalk; and municipal boulevard grassed areas.
- Infiltration files were developed using saturated hydraulic conductivity values estimated from the hydrogeology study
- The model was initially analysed for the November 1996 to October 1997 period to determine the response of the catchment area using conventional drainage techniques (i.e. storm sewers), assuming all impervious surfaces were directly connected. This

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model run was used as the baseline condition for comparison with the stormwater BMP scenarios.

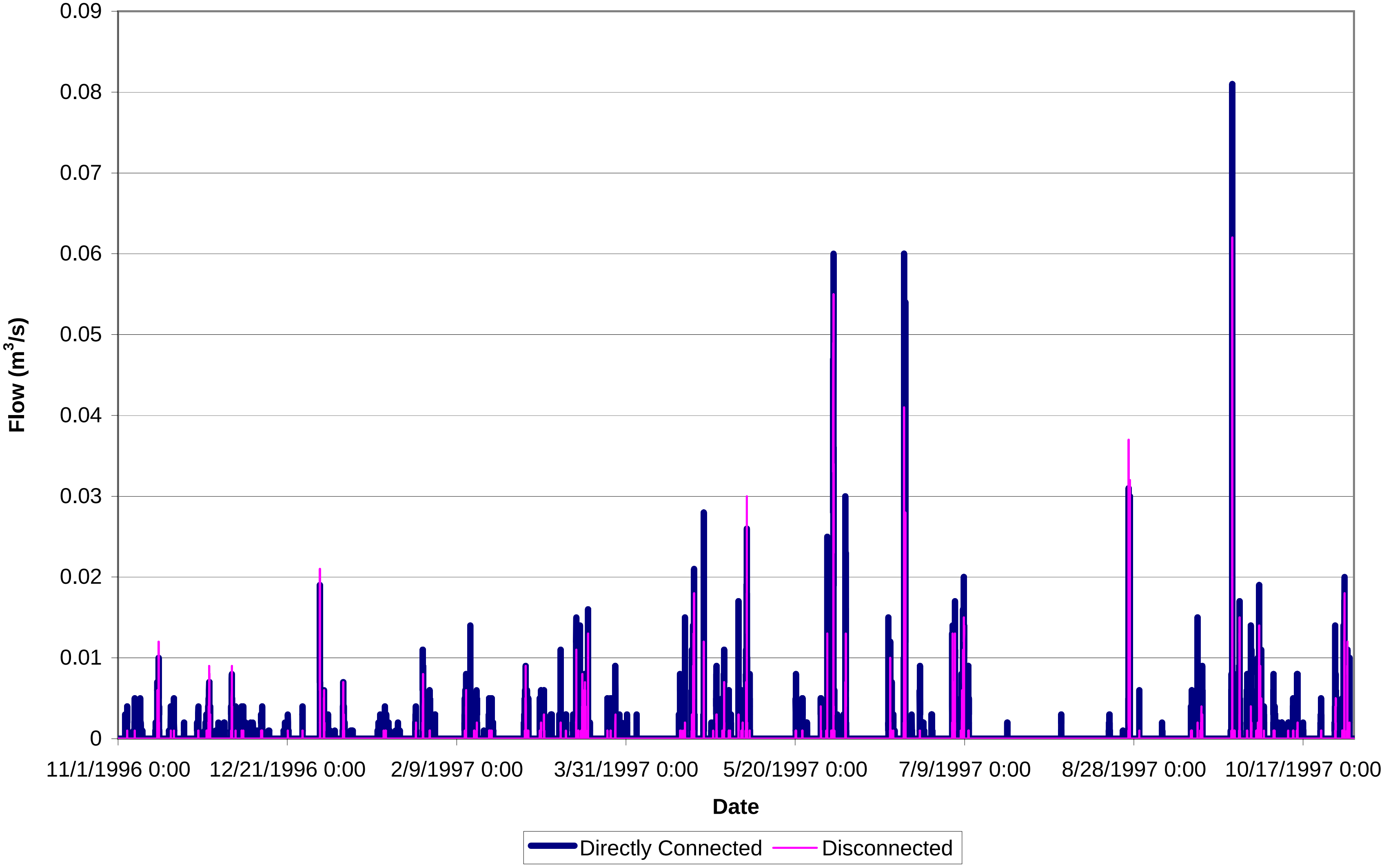
Disconnection of impervious areas was the first scenario to be assessed. For this BMP, stormwater runoff from all impervious surfaces in the model (roof, driveway, patio, road and sidewalk) was redirected to pervious areas (private and municipal boulevard grassed areas). In practical terms, this scenario would essentially equate to disconnecting roof downspouts and using splash pads, as well as directing road, sidewalk, driveway and patio runoff to drain to grassed areas. Figure 10.12 shows the resultant hydrograph for this scenario against the baseline scenario. The figure indicates that a significant reduction in flows could be obtained when impervious areas are disconnected. This is particularly evident for small, frequent storm events, as runoff is predominantly generated by impervious surfaces for these types of events.

With the impervious areas disconnected, these areas cannot efficiently contribute to stormwater runoff leaving the site as runoff is predominantly absorbed by the pervious areas.

One stormwater BMP that has been used successfully for roof leader disconnection in higher density areas in Portland, Oregon, and is gaining momentum in the Lower Mainland, is the planter box. There are two types of planter boxes commonly used – an infiltration planter (Figures 10.13, 10.14) and a flow through planter (Figures 10.15, 10.16, 10.17). In both cases, roof leaders are discharged to a vegetated planter box located adjacent or near to a building. Runoff passes through a growing media, and is then infiltrated into the ground or captured by a perforated overflow pipe which leads to the municipal storm sewer system. The benefits of a planter box include water quality treatment through plant uptake and filtration through the growing media, infiltration (if soil conditions are appropriate) and a significantly longer time of concentration than if the roof leaders were directly connected to the storm sewer system. Recommended plants for the planter box are included in Appendix J.

The hydrogeological assessment indicates that small scale infiltration of stormwater may be feasible, particularly within Zone 3 of the watershed. Further, providing on-site retention of stormwater runoff during frequent, low-intensity events can act to mimic the pre-development hydrology of the watershed by encouraging infiltration, and/or by reducing peak flows and volumes reaching the creek through retention. Therefore, the use of additional topsoil and/or on-lot rain gardens for retention and potential infiltration should be considered for new, infill and redevelopment parcels in the watershed.

Figure 10.12: Stormwater BMP #1 - Disconnect Impervious Areas (RF-12 Zoning, Single Family Residential)



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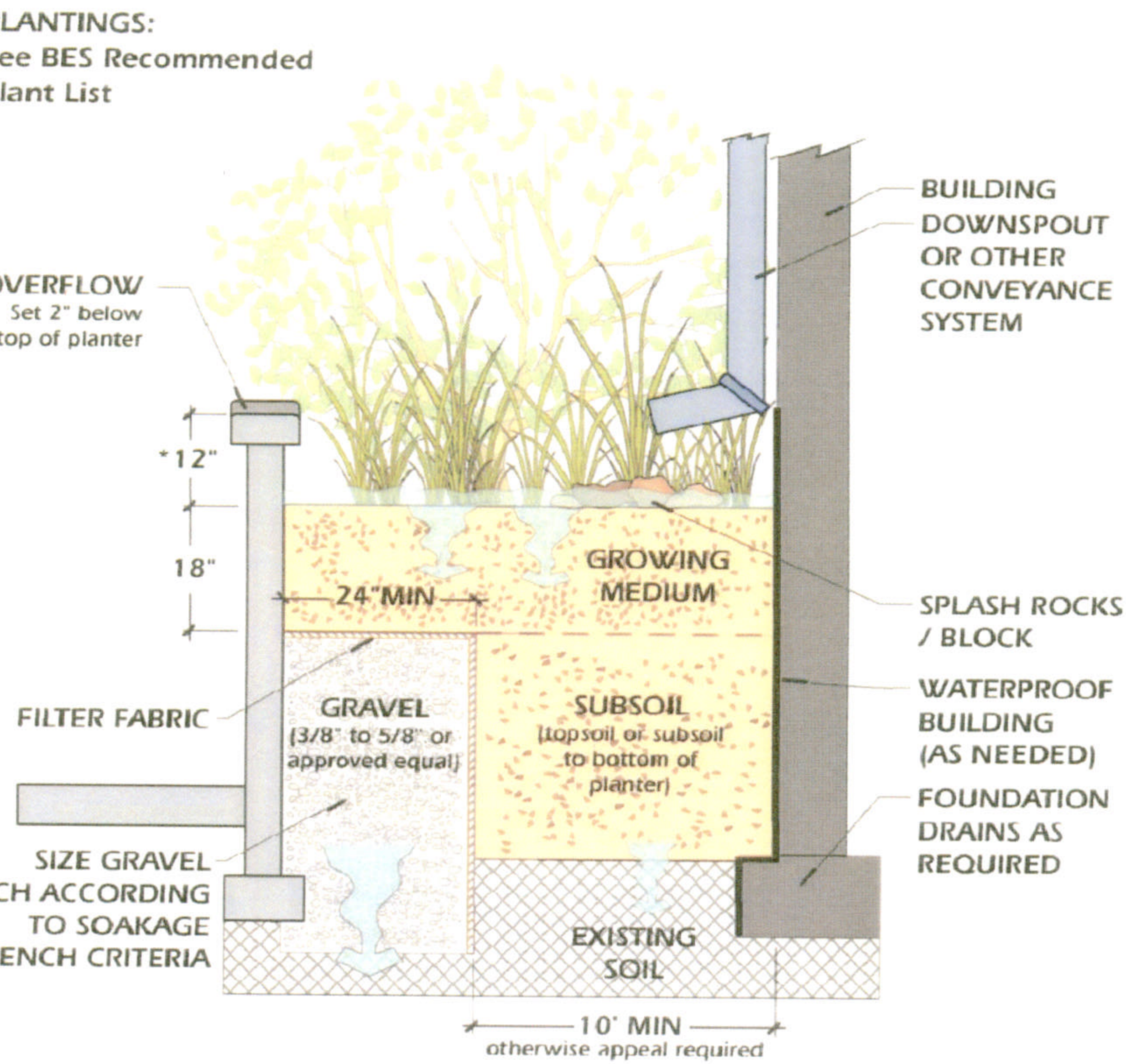
COURTESY OF CITY OF PORTLAND 2004 STORMWATER MANAGEMENT MANUAL



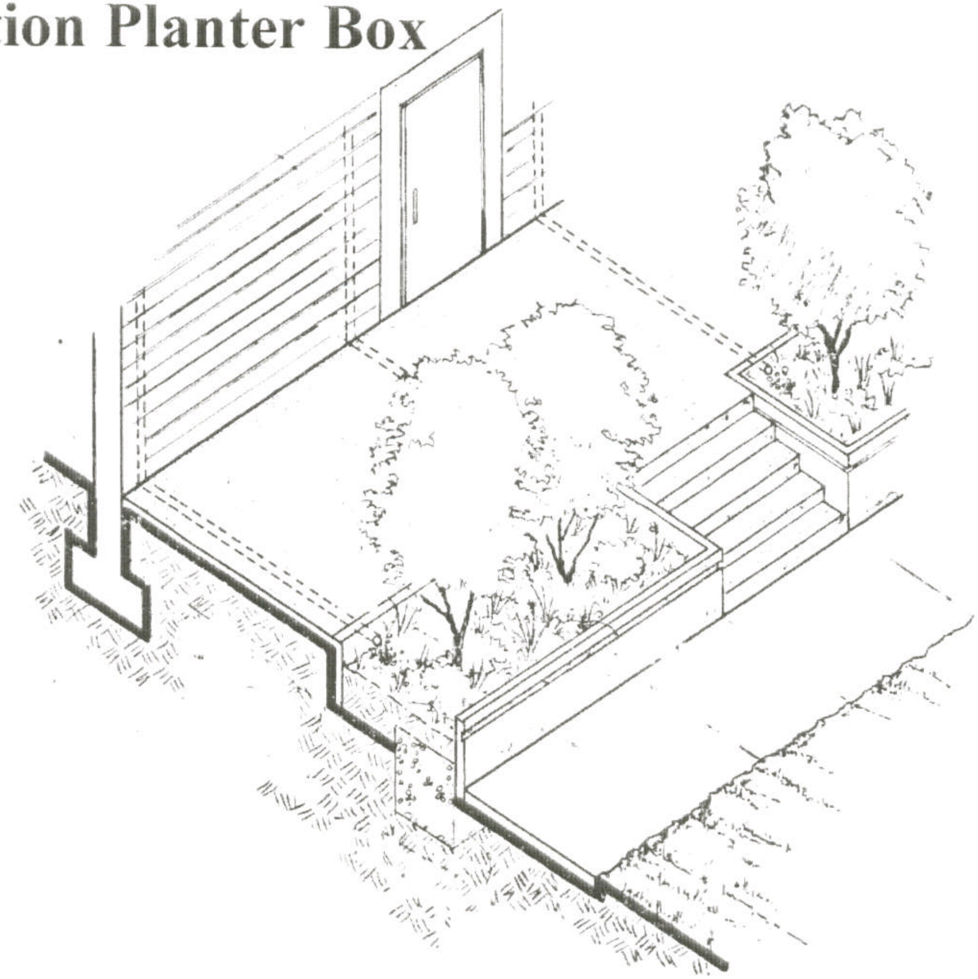
*Water reservoir depth may be reduced if planter surface area is increased.

Infiltration Planter

7/26/02

FIGURE 10.13

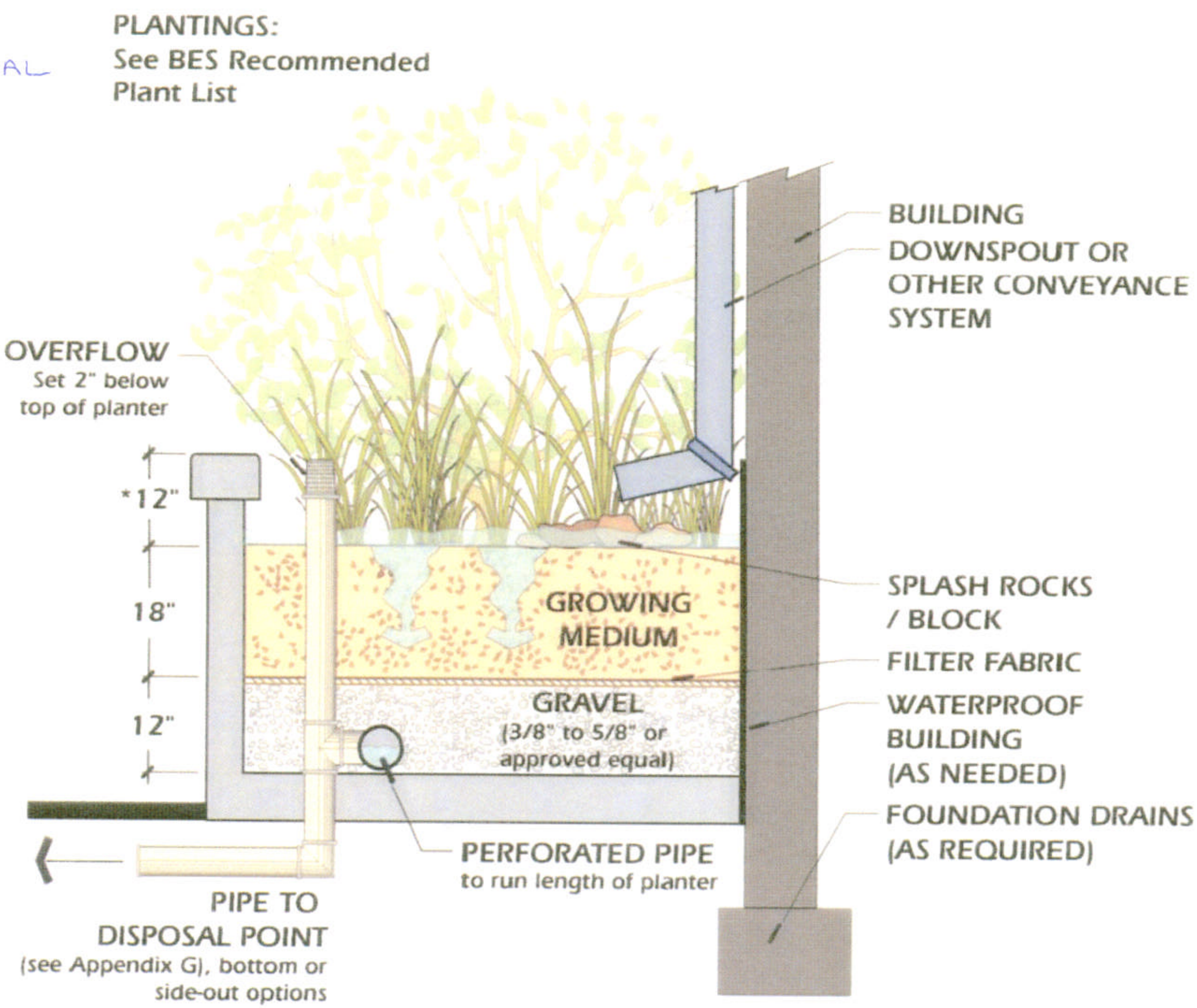
Infiltration Planter Box



COURTESY OF CITY OF PORTLAND, 2004 STORMWATER MANAGEMENT MANUAL

FIGURE 10.14

COURTESY OF CITY OF PORTLAND
2004 STORMWATER
MANAGEMENT MANUAL



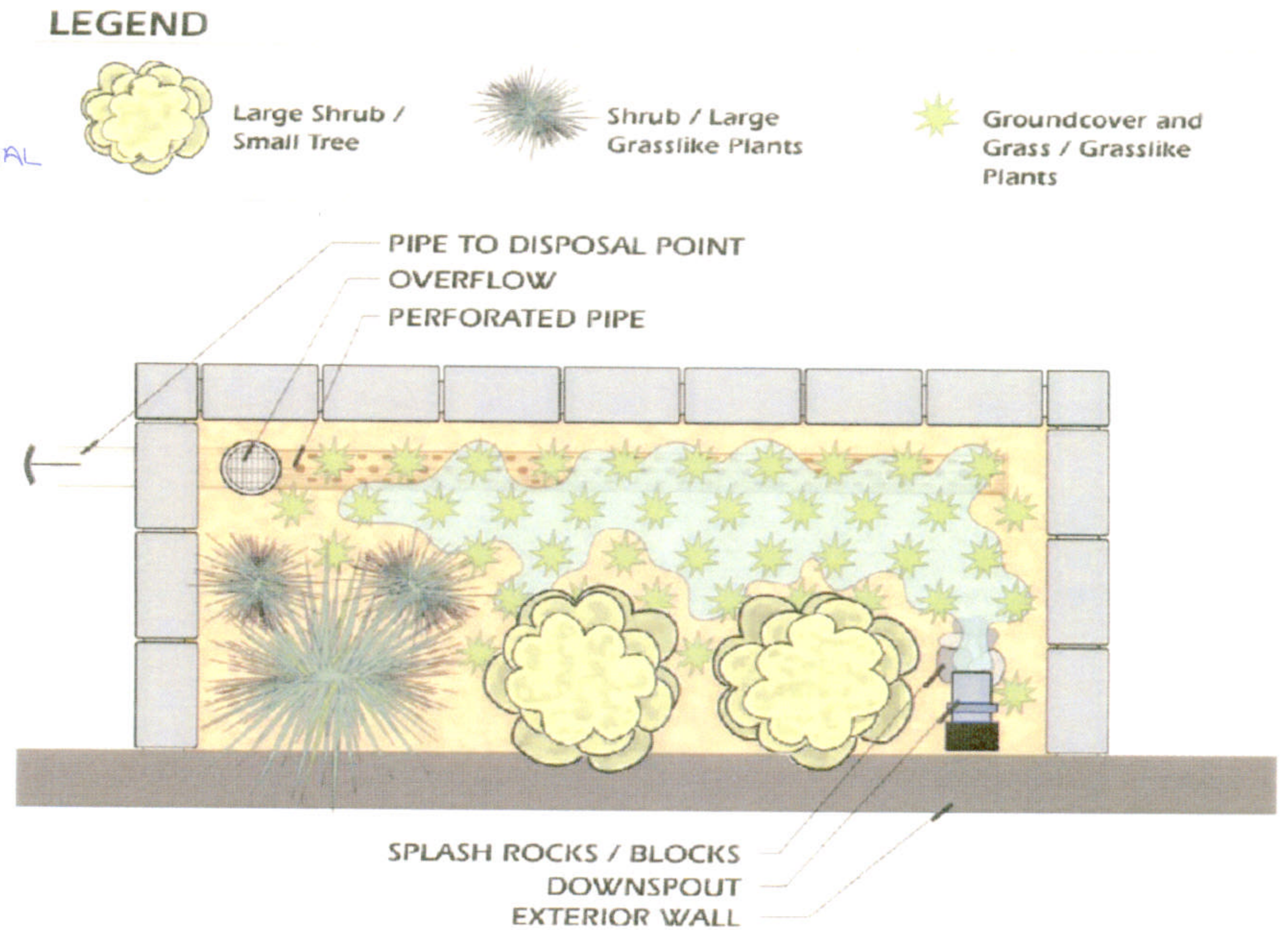
*Water reservoir depth may be reduced if planter surface area is increased.

Flow-Through Planter Box

7/26/02

FIGURE 10.15

COURTESY OF CITY OF PORTLAND 2004 STORMWATER MANAGEMENT MANUAL



Planter Area = Approx. 50 sq. ft.

Not to Scale

Notes:

1. At least 50% of the facility shall be planted with grasses or grass-like plants, primarily in the flow path. Large grass like plants can be considered as shrubs.
2. See BES recommended plant list, and quantity requirements.

Flow-Through Planter - Plan

7/26/02

FIGURE 10.16

Flow-Through Planter Box

COURTESY OF CITY OF
PORTLAND, 2004 STORMWATER
MANAGEMENT MANUAL

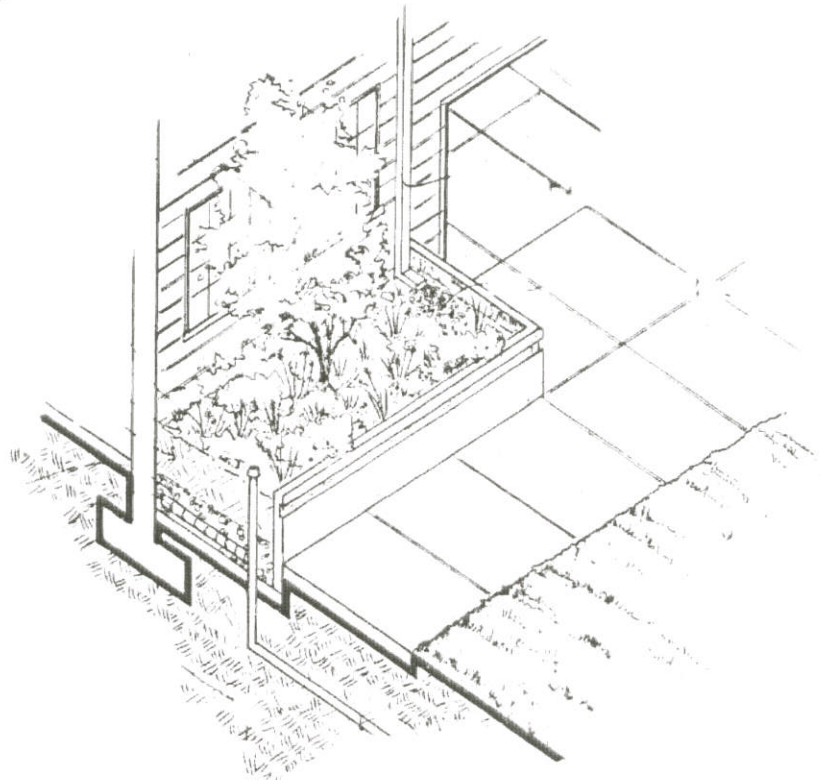


FIGURE 10.17

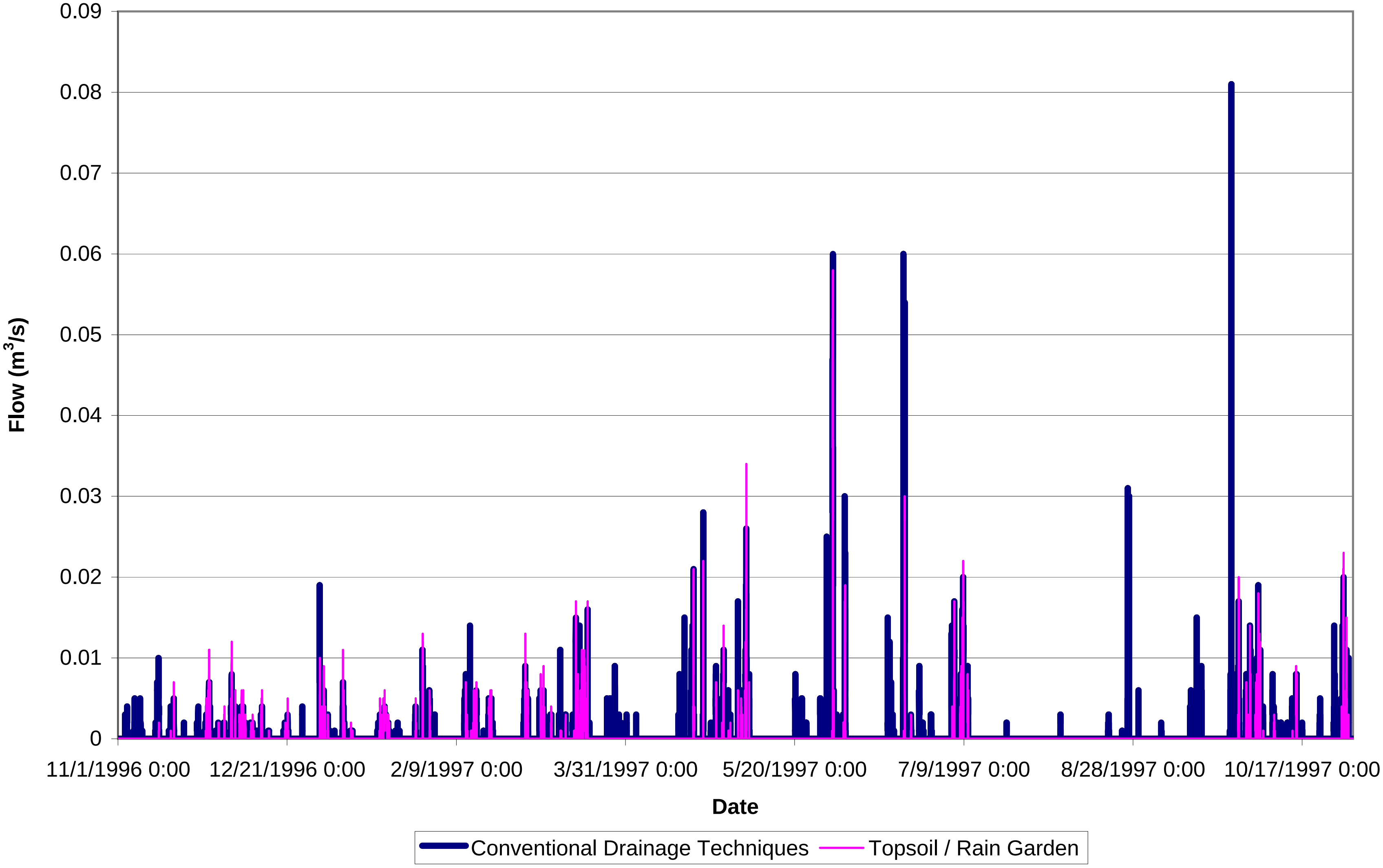
A second BMP scenario examined the potential reduction in flows from adding additional topsoil to pervious areas. To assess these conditions in the model, a depression storage value equal to the 6-month, 24-hour storm was assigned to pervious areas on both the private lots and the municipal road ROW. In practical terms, the depression storage required to retain the 6-month, 24-hour storm event is equivalent to placing 450mm of topsoil in pervious areas for a single family small lot development (RF-12 zoning), as shown in the calculations in Appendix E. All impervious surfaces on the lot and the municipal road ROW were also directed to pervious areas.

Figure 10.18 indicates that a notable reduction in flows could be achieved if 450mm of topsoil was placed in pervious areas. While peak flows during the winter may not be affected to a great extent (due to soil saturation during prolonged rain), in summer peak flows are notably reduced, particularly for storm events which occur after an extended period with no rainfall (due to evaporation and infiltration processes which regenerate available storage capacity). Alternatively, individual rain gardens can be used in place of the additional topsoil to retain the 6-month, 24-hour storm on site. A rain garden scenario would provide similar results, thus the hydrographs shown in Figure 10.18 are valid for this scenario as well.

Some increase in total impervious area due to new, infill or redevelopment in the watershed is unavoidable. However, this increase can be mitigated through the use of porous materials in low traffic areas, such as driveways, patios, sidewalks, on-street parking areas, etc. The use of porous paving materials, such as porous asphalt or porous paver blocks, could be applicable to new development, infill and redevelopment situations in any zone in the watershed, and when used in conjunction with limiting effective impervious area through disconnection, can greatly mitigate the impacts of development on the overall health of Hyland Creek. While this BMP was not specifically modeled, extensive research on its applicability and effectiveness is publicly available. Research on the effectiveness of porous pavements and other stormwater BMPs is summarized in Appendix I.

It is not possible to accurately quantify the reductions in peak flow and volume from the use of stormwater BMPs within the scope of this study. To accurately quantify the benefit of these BMPs, site specific input data for processes such as infiltration, evaporation, groundwater levels, temperature, etc. is required and should be integrated into a comprehensive, calibrated model. However, the assessment completed herein is sufficient to clearly indicate that strong benefits would result through the use of stormwater BMPs.

Figure 10.18: Stormwater BMP #2 - Retain 6 month, 24 hour storm on site through Additional Topsoil or on-lot Rain Gardens (RF-12 Zoning, Single Family Residential)



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11.0 CAPITAL WORKS PROGRAM

This section outlines the need and rationale for undertaking or removing works currently listed in the City's drainage capital works program. Projects currently listed in the capital works program were summarized in Table 5.9. The revised capital works program, based on the findings of the ISMP, is shown in Table 11.1. Project definition reports for the projects listed in Table 11.1 are included in Appendix G.

11.1 Storm Sewer Upgrades

Ten storm sewer upgrade projects were originally listed in the City's drainage capital works program, as shown on Table 5.9. Some of the projects involve upgrading an existing storm sewer to a larger size to improve the level of service to a particular area or to accommodate future development in the catchment. Other projects involve infilling existing roadside ditches with piped systems.

Six of the ten projects were originally recommended by the 2000 Dillon drainage study. That study recommended works based on the results of a detailed and calibrated OTTHYMO hydraulic model of the municipal drainage system. Given that there has been little to no change in the drainage network configuration or land use plan contributing to these sewers since the Dillon study was completed, the calculated peak flows and recommended sewer upgrades from the Dillon study are believed to be still valid. These six projects should remain on the capital works program.

In conjunction with the 148 Street culvert upgrade as recommended by the 2000 Dillon study, the road profile at 148 Street should also be raised at the creek crossing to mitigate the frequent overtopping currently experienced at this location. This could be done in conjunction with the road improvements planned by the City Roads Department in this area between 2012 and 2016. Raising the road profile may result in higher water levels immediately upstream of the new culverts under more extreme events (due to possible culvert surcharge and backwater conditions), however, there is a fairly large floodplain area upstream of the culverts and visual observations suggest that adjacent properties may not face increased risk by creating a higher backwater condition immediately upstream of the culverts. This should be confirmed with a detailed hydraulic study and field survey.

Table 11.1
Hyland Creek Watershed
Drainage Capital Works Program

ID	Project Name	Project Location	Start	Original Priority Level	Report Reference	Revised Priority Level	Zone	Comments
Storm Sewer Upgrades								
3809	500m Pipe Upgrade	65A Ave.: 130 - 132 St.	2016	L	Dillon (2000)	3	1	
6238	1200m Pipe Upgrade	68 Ave.: 130 - KG Hwy	2017	X	Dillon (2000)	3	1	Past drainage complaints on record
6419	900m Pipe Upgrade	64 Ave.: 130 - 134 St.	2011	M	Dillon (2000)	3	1	Long term priority due to recent road upgrade; past drainage complaints on record
7032	195m Pipe Upgrade	67A Ave.: 133 - 134 St.	2017	X	Dillon (2000)	3	1	
6032	Ditch on 66 Avenue	66 Ave: 145A - 147 St	2006	S	USL (2007)	2	2A	Remove / upgrade driveway culverts; further analysis required to confirm adequacy of downstream system to convey flows
6041	1200m - 600m on 144 St.	144 St.: 65 - south of 60 Ave.	2011	N	UMA (1995)	1	3	Short term priority as road improvements planned for 144 St / 60 Ave intersection in 2007
6244	900mm Upgrade Existing Storm	68 Ave.: 141 - 142 St.	2007	S	Dillon (2000)	3	2	
6247	Culvert Crossing Upgrade	Hyland Crk: 148 St.	2007	S	Dillon (2000)	2	2A	Road improvements planned between 2012 - 2016 (widening to arterial standards, 14m pavement width); raise road profile in conjunction with culvert upgrade; past drainage complaints on record
10315	300m - 525mm New Storm Sewer	6165 - 6267 148 St.	2006	N	S. Newton NCP (1999)	2	3	Road improvements planned between 2012 - 2016 (widening to arterial standards, 14m pavement width); past drainage complaints on record
10316	560m - 900mm New Trunk Sewer	148 - 150 St.: 63 Ave.	2006	N	S. Newton NCP (1999)	3	2A	Project 4/5 in NCP
Existing Detention Facility Retrofits								
6234	Pond at 63A Ave.	63A Ave: west of 131A St	2009	S	UMA (1995)	2	1	Pond ID 267 in GIS database
6235	Pond at 132A St.	132A St. - 61 Ave.	2009	S	UMA (1995)	2	1	Pond ID 272 in GIS database
6221	Pond at 73 Ave.	73 Ave: 128B St.	2013	L	UMA (1995)	2	1	Pond ID 314 in GIS database
6224	Pond at 65 Ave.	65 Ave. - 130A St.	2013	L	UMA (1995)	2	1	Pond ID 300 in GIS database
6226	Pond at 129A St.	129A St. - 66B Ave.	2015	L	N/A	2	1	Pond ID 296 in GIS database
6227	Pond at 69 Ave.: 135 St.	69 Ave: 135 St.	2013	L	UMA (1995)	2	1	Pond ID 292 in GIS database; past drainage complaints on record
6228	Pond at 135 St.	135 St.	2014	L	N/A	2	1	Pond ID 276 in GIS database
6256	Existing Dry Pond Upgrade	Greenbelt 67 Ave. 133 St.	2006	S	Dillon (2000)	2	1	Pond ID 293 in GIS database
6257	Existing Dry Pond Upgrade	Greenbelt 65 Ave. 133 St.	2006	S	Dillon (2000)	2	1	Pond ID 295 in GIS database
New Detention Facilities								
6036	Recharge Pond - P4B	141 St. / 62 Ave.	2009	N	S. Newton NCP (1999)	2	3	Design to optimize under a MAR event
6242	Creation of Detention Pond - P4A	140 St.: 62 Ave. - 64 Ave.	2007	N	S. Newton NCP (1999)	2	3	Design to optimize under a MAR event
6243	Creation of Detention Pond - P1C	62 Ave. 138 St. - 140 St.	2009	N	S. Newton NCP (1999)	2	3	Design to optimize under a MAR event
8565	Archibald Detention Pond P1B	138 St. / 62 Ave.	2007	S	S. Newton NCP (1999)	2	3	Design to optimize under a MAR event
6022	Newton Town Centre Stormwater Detention Pond	138 Street: 68 Ave.	2012	M	Dillon (2000)	1	1A	Design to optimize under a MAR event
TBD	Pond 1	134 Street and 70B Avenue	N/A	N/A	USL (2007)	1	1	Design to optimize under a MAR event
TBD	Pond 2	King George Highway and 70A Avenue	N/A	N/A	USL (2007)	1	1A	Design to optimize under a MAR event
Erosion Remediation and Sediment Control								
TBD	1 site (ID=HYLD-12; risk = H)	6702 - 138 Street	N/A	N/A	Associated (2006)	2	2	Clear site of debris / beaver dam first and monitor for one year
10314	Sediment Control Device (2 Req)	6191 148 St.	2006	N	S. Newton Pond 8 Review (2002)	3	3	
10317	Sediment Control Device (2 Req)	6315 150 St.	2008	N	S. Newton Pond 8 Review (2002)	3	3	

Notes:

1 Based on City's capital works program as of September 2006.
2 Original Priority Level: S = Short Term (1-3 yrs), M = Medium Term (4 - 7 yrs), L = Long Term (8 - 10 Yrs), X = Very Long Term (+10 yrs), N = Identified in NCP
3 Revised Priority Level: Refer to main document for description.
4 N/A = Not Available, TBD = To Be Determined
5 Road improvement schedule based on correspondence with J. Boan, Surrey Transportation Manager, June 24, 2006.
6 Drainage complaints based on summaries provided by City listing resident complaints from November 2003, October 2003, 1997 and active files; compaints listed in above table are capacity related only (maintenance related complaints are not included).

Two of the remaining sewer upgrade projects listed in the capital works program were recommended by the South Newton NCP to convey flows from new development in Zone 3 to proposed detention facilities at the base of the watershed. As the ISMP stormwater servicing strategy for Zone 3 (as discussed in Section 12.1.5) will still require trunk storm sewers to convey higher peak flows to the proposed detention facilities in Zone 3, these sewer upgrades are still valid and should remain in the capital works program. The storm sewer installation on 144 Street (ID 6041) should also remain as it is part of the Zone 3 servicing concept.

The storm sewer upgrade works currently listed in the capital works program involves infilling the existing ditch on 66 Avenue with a storm sewer. Based on the discussion in Section 10.3, it is not recommended that the 66 Avenue ditch be replaced with a storm sewer as the ditch provides appreciable storage capacity for the upstream catchment area. A stable, well vegetated ditch also provides superior water quality treatment over a storm sewer, which is a key objective of the ISMP. Opportunities to remove or upgrade existing driveway culverts situated within the ditch should be considered first. Ideally, driveway culverts should be removed completely, however, if this is not possible the 600mmØ interim culvert should be upsized to 900mmØ, or alternatively the driveway culverts should be removed and replaced with clear span crossings to maximize the storage volume and conveyance capacity of the ditch. Thus, the project to infill the 66 Avenue ditch can be removed from the capital works program and replaced with the driveway culvert upgrade (to 900mmØ).

A frequent inspection and maintenance program should be established for the 66 Avenue ditch to remove accumulated sediment in any culvert crossings that remain, as well as to monitor vegetation that may represent a conveyance and storage restriction to the ditch. Vegetation should only be removed if it presents a significant restriction. Confirmation of the capacity of the 750mmØ pipe downstream of the 66 Avenue ditch should also be undertaken through a field survey.

11.2 Existing Detention Facility Retrofits or Removals

Table 10.8 previously summarized whether the existing detention facilities listed in the capital works program should be removed or retrofitted, based on the analysis in Section 10.1. The existing detention facilities to be retrofitted have been listed in Table 11.1.

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11.3 New Detention Facilities

Several new municipal detention facilities are currently listed in the capital works program. Most of these facilities were originally recommended by the South Newton NCP and are located within Zone 3. As the proposed stormwater management strategy for Zone 3 will incorporate these facilities, they should remain in the capital works program. However, these facilities should be designed to meet the required performance targets discussed in Section 12.1.5.

As discussed in Section 10.2, three new detention facilities are proposed for Zones 1 and 1A, including the Newton Town Centre facility which is currently listed in the capital works program. These detention facilities have been added to Table 11.1.

11.4 Erosion Remediation and Sediment Control

There are seven erosion remediation sites and three sediment control facilities currently listed in the City's capital works program in Table 5.9. The findings of the recent Ravine Stability Assessment Update report by Associated Engineering [2006] supersede the erosion works currently listed.

As noted in Table 5.6, the 2006 report identified a total of thirty-one erosion sites on Hyland Creek and six sites on Archibald Creek. Of these identified sites, only one site on Hyland Creek was identified as a high risk site, with the remaining sites being classified as medium risk (15 sites) or low risk (21 sites). The high risk site on Hyland Creek was initially identified as low risk in the first Ravine Stability Assessment conducted by Urban Systems in 2002, thus it appears that this site has continued to degrade over time. The site, located on the north branch of Hyland Creek near 138 Street, consists of an undermined bank where flows have eroded the toe of the bank to create a near vertical exposed face. The ongoing erosion of the toe has begun to destabilize the soils supporting a gabion wall structure located on the upper bank slope. The gabion wall was constructed to create a yard area for an adjacent residential home, which is situated approximately 15 metres from the top of the creek bank. The creek bank itself is approximately 5 metres high in this location. The 2006 report recommends that the site be initially cleared of vegetative debris (fallen trees, foliage, etc) as well as a beaver dam, and monitored for a year. If erosion degradation continues, the report recommends that a rip-rap berm be constructed along the toe of the bank slope.

The erosion remediation sites currently listed on the City's capital works program should be removed and replaced by the high risk erosion site on Hyland Creek as identified by the 2006 Ravine Stability Assessment Update report, as indicated in Table 11.1. The remaining medium and low risk erosion sites identified in the 2006 report should be monitored annually to assess whether conditions stabilize or continue to degrade over time. If the additional stormwater detention facilities in Zones 1 and 1A are implemented as discussed in Section 10.2, erosive flows to the north branch of Hyland Creek will be significantly reduced and it is possible that the remaining medium and low risk sites will stabilize.

The sediment control facilities currently identified in the capital works program should remain on the list, as they appear to be associated with specific developments under the South Newton NCP (Zone 3). Priority levels for these facilities remain unchanged from their current levels.

12.0 RECOMMENDATIONS

Previous studies for the Hyland Creek watershed have reviewed stormwater issues from strictly a hydraulic perspective. Integrated stormwater management plans represent an advancement in watershed management planning, through the integration of traditional stormwater management analysis with other valuable considerations, including land use planning, aquatic habitat, wildlife and terrestrial habitat, hydrogeology, and parks and recreation needs. The integration of these disciplines allows for the development of a comprehensive strategy to stabilize and potentially improve the overall health of the Hyland Creek watershed.

Section 12 outlines our recommendations for the Hyland Creek watershed, based on the assessment and analysis conducted for the ISMP. Priority levels have also been assigned to each recommendation, as discussed further in Section 13.

12.1 Stormwater Management

12.1.1 Watershed Level

Adopt Performance Targets for New, Infill and Redevelopment Areas

<u>Performance Target # 1</u> – Meet a no net runoff target for rainfall events up to the 6-month, 24-hour post development storm event

We recommend that the City adopt a performance target requiring all new development, infill development and redevelopment areas in the Hyland Creek watershed to meet a no net runoff target (i.e. runoff is not permitted to be discharged offsite) for rainfall events up to the 6-month, 24-hour post development storm event. The intent of this performance target is to encourage the development community to use stormwater best management practices (BMPs) to meet the ISMP objective of approximating pre-development hydrologic characteristics under a post development condition. This performance target should apply to all land use types, including single and multi-family residential, commercial, industrial, institutional, etc. A possible exception may be agricultural lands, given the low amount of impervious area typically associated with this land use type.

Through the adoption of this performance target, each development would need to retain all of the stormwater runoff generated by impervious surfaces (roofs, driveways, patios, parking lots, etc), plus the rainfall volume captured by pervious areas, on the site. In Zone 3, where the hydrogeological investigation determined that stormwater infiltration may be feasible, the City should also require that the developer retain a hydrogeological engineer to quantify the anticipated infiltration rates for the existing soils. This information can then be taken into account when sizing stormwater BMPs to meet the no net runoff target.

Amended topsoil should be the primary stormwater BMP to use to meet the no net runoff target. For example, to achieve the no net runoff target for a single family small lot (RF 12, 10 units per acre) development, a topsoil depth of 450mm would be required for all pervious areas, as shown by the calculations in Appendix E. This topsoil depth could potentially be decreased to 300mm if porous pavement were used instead for low traffic surfaces, such as the driveway and patio areas. Roof leaders and overland runoff from other impervious surfaces on site should be directed to topsoil areas. Amended topsoil should have a minimum 8% organic content for lawn areas, and 15% organic content for landscaped areas. If existing onsite topsoil is to be reused (see below), the topsoil may need to be amended with organic material to meet these minimum requirements.

The developer may choose, at their discretion, one of the following procedures for topsoil retention and amendment:

- Retain existing topsoil onsite by sectioning off pervious areas (thus preventing disturbance of such areas by construction activities) and adding an additional amount of topsoil (as needed) to meet the no net runoff criteria and distribute on the lot;
- Strip existing topsoil and stockpile onsite, then add topsoil and organics as necessary to meet the no net runoff criteria and redistribute on the lot; or
- Strip existing topsoil and dispose offsite, then import new topsoil to meet the no net runoff criteria and redistribute on the lot.

Given the higher densities and additional impervious areas typically associated with multi-family, commercial, industrial or institutional developments, it may not be practical or feasible to utilize amended topsoil alone to meet the no net runoff target. In such cases, supplemental stormwater BMPs, such as rain gardens, planter boxes, porous pavements, rooftop and parking lot storage, bioswales, etc., could be incorporated into the site design in conjunction with amended topsoil to meet the no net runoff target. Examples of supplemental stormwater BMPs are listed in Appendix I.

It would be the responsibility of the developer's engineer to prove that the onsite systems could meet the no net runoff target for the 6-month, 24-hour post development storm.

<u>Performance Target # 2</u> – Adopt water quality targets

We recommend that the City adopt performance targets related to water quality for all land use types in the Hyland Creek watershed. These performance targets are already outlined in the City's recently adopted Erosion and Sediment Control (ESC) bylaw, and relate to turbidity levels in discharge water during construction. Further, we also recommend that the City require higher density developments, including multi-family residential, commercial, industrial and institutional uses, to reduce concentrations of oil and grease discharged offsite to less than 10 mg/l via the use of on-lot water quality BMPs, such as oil/grit separators, bioswales, etc. This requirement would typically be applied during the building permit process, with the goal of also capturing developments that are not subject to the rezoning or subdivision process.

The intent of imposing water quality performance targets in the Hyland Creek watershed is to mitigate water quality degradation in existing developed areas (particularly for the catchment area draining to the north branch of Hyland Creek, based on the water quality measurements taken at site H3), and to prevent similar water quality degradation from occurring in future development areas (predominantly in Zone 3). Improving water quality in the Hyland Creek watershed is a key objective of this ISMP.

Implement Capital Works Program

We recommend that the City undertake the capital works projects outlined in Section 11 and listed in Table 11.1. Capital works include new detention facilities, retrofits and upgrades to existing detention facilities and storm sewers, and erosion and sediment control works. The need for these works has been discussed in previous sections and verified through the analysis conducted as part of this ISMP.

Develop and Implement a Public Education Program

There are several things that the City can do to educate the general public and local businesses on integrated stormwater management issues and initiatives. Many residents have a sense of the detrimental impacts that people and development can have on a watershed, but are often unaware about what they can do as individuals to help out. The main intent of the public education program is to raise awareness about the stormwater and environmental issues in the Hyland Creek watershed, and to encourage involvement by local residents and businesses.

We recommend that the City continue to work with local schools, SHARP and SNAP on planting, cleanup and instream activities in the Hyland Creek watershed. In addition to this, we recommend that the City prepare a brochure or newsletter to inform local residents and businesses of such activities being conducted in the Hyland Creek watershed. The brochure could be posted on the City's website, mailed out to residents and businesses, and/or be available in hard copy at the front desk at the municipal hall. The brochure could also outline measures that could be undertaken by individual homeowners or businesses on their property to improve the impacts of stormwater runoff quantity and quality, such as:

- Water conservation techniques (for example, capturing water from roof downspouts in a rain barrel and using for irrigation of on-lot landscaping and grassed areas)
- Implementing on-lot water quality treatment units (mainly for commercial and industrial business) to target water quality pollutants of concern, as identified by the ISMP water quality assessment (including TSS, metals)
- Retaining as much native vegetation as possible on private property and removing exotic plant species that have high irrigation demands
- Amending soils in landscaped areas with additional organics and topsoil to encourage retention of water
- Providing a list of local composting facilities and encouraging residents and businesses to obtain amended soils and organic materials from these facilities
- Fencing off riparian areas on private property
- Cleaning up garbage and debris from the roadside ditch or curb / gutter in front of their home or business
- Avoiding disposal of yard waste in riparian areas
- Picking up and disposing of animal (dog) feces appropriately in private and public areas (the City could also provide bags and disposal containers at all local park entrances)
- Highlighting the detrimental impacts of herbicides and pesticides on water quality and encouraging the reduction or elimination of these on private grassed and landscaped areas
- Highlighting the detrimental impacts of galvanized materials, and copper granules and zinc strips in roofing materials on water quality and encouraging the reduction or elimination of these materials on private property

We also recommend that the City prepare a brochure for developers, builders and new home owners which outlines how to install and maintain stormwater and environmental BMPs that are constructed on private property. This brochure should be provided with all building, zoning and development permit applications. While this brochure would be mainly applicable to Zone 3, some infill and redevelopment areas in other zones could utilize the brochure if BMPs are implemented. We understand that the City is currently developing this type of brochure for the East Clayton Neighbourhood.

Other City led activities, such as painting fish symbols on catch basin and manhole lids, are also an effective public education tool therefore we recommend that the City continue these education initiatives. The City should post periodic bulletins on their website or in local newspapers to update the public on the implementation of any of the ISMP recommendations and/or future stormwater-related works in the watershed.

We also recommend that the City work with the local residents and businesses to encourage the formation of a stewardship group for the watershed. This could be initiated by asking for volunteers through the brochures noted above. The City could provide assistance to the group as needed in organizing and advertising events, such as creek clean-ups or riparian planting activities. Information regarding specific events and general stewardship activities could be advertised through the City's website, local newspapers and/or through stewardship newsletters to the community. The stewardship group may also consider going door-to-door once a year in selected neighbourhoods in the watershed to outline their proposed activities for the coming year and to encourage residents to volunteer.

From a development perspective, we recommend that the City initiate a developer recognition award. The purpose of the award would be to acknowledge developers who recognize the importance of stormwater management and environmental issues in the watershed and who implement innovative methods to meet the desired objectives and performance targets. Developers who exert a high level of effort to mitigate the impacts of development on stormwater runoff, either through excellent erosion and sediment control practices during construction or through the implementation of stormwater and environmental BMPs, should be recognized publicly by the City. Market trends for residential development are continuing to move towards "green", sustainable development, thus having a developer recognition award may encourage more of these types of developers to the watershed. Public recognition may also provide an incentive for developers to work with the City on testing new stormwater methodologies or to enter into partnerships with the City for the design and construction of pilot projects, as outlined below.

Undertake Pilot Projects

Pilot projects are intended to test out different stormwater and environmental BMPs and confirm that they can meet the ISMP performance targets before they are required throughout the watershed. Ideally, the City should investigate the opportunity to work with the development community to implement pilot projects in Zone 3, as future development (and thus the opportunity to incorporate BMPs) is anticipated to be concentrated in this zone and financial contributions from the development community may be available. However, opportunities to undertake pilot projects in other zones should also be considered. Selection of an appropriate site for a pilot project will depend on soil conditions, location in the watershed, type of land use, level of support from adjacent landowners and the presence of existing municipal drainage infrastructure and underground utilities.

We recommend that the City identify opportunities to implement the following types of pilot projects in the Hyland Creek watershed:

- *Alternate Road* (BMPs could include porous pavement, perforated pipe galleries, vegetated swales, amended topsoil, narrowed road widths, reduced on-street and off-street parking, etc; project could include a local road, lane, etc with less than 5% profile grade)
- *Porous Pavement* (construct new or retrofit existing parking lot, on-street parking areas, sidewalks, driveways, etc; partner with a developer or local residents, or implement as part of an existing park or municipal building)
- *Rain Garden* (within private or public property, such as an existing park space or municipal building; accept runoff from roof downspouts, impervious surfaces, etc)
- *Groundwater Recharge* (BMPs could include perforated pipe galleries, rain gardens, etc; a hydrogeological engineer should be retained for the design to quantify potential infiltration rates for the soils and to confirm that there would be no detrimental impacts downslope, for instance, introducing a greater risk of slope instability, seeps or springs)
- *Planter Box* (as a roof leader disconnection method for commercial and industrial developments)

Monitoring pre and post construction conditions for these pilot projects is essential for quantifying the benefits of the BMPs on the overall watershed. Peak flows, volumes and water quality should all be considered in the monitoring program. In some instances, constructed works may need to be refined or even replaced over time in order for them to be completely successful, however, once any issues are worked out, pilot projects can provide great benefits and represent a definitive step towards approximating the natural hydrologic and hydraulic response of the watershed under developed conditions.

Update Design Criteria Manual to Require Disconnected Roof Leaders for All Land Uses

Currently, Section 5.4(L) of the City's Design Criteria manual specifies that all roof leaders for lots zoned for detached residential use be discharged to splash pads rather than be directly connected to the municipal drainage system. This is the preferred condition as it minimizes effective impervious area by directing runoff to pervious surfaces, where water has an opportunity to naturally infiltrate back into the ground and vegetation can remove any gross pollutants. Based on the analysis in Section 10.4, a significant benefit to the overall health of the Hyland Creek watershed could be achieved through the use of this BMP.

For all other types of land uses, including multi-family residential, institutional, commercial and industrial properties, the City's design criteria manual stipulates that roof leaders be directly connected to the municipal drainage system. As these land uses contribute a significant amount of stormwater runoff, disconnecting impervious surfaces associated with these land uses could have a significant benefit on Hyland Creek.

To meet the ISMP objectives of limiting effective impervious area and improving water quality in the watershed, we recommend that the City continue its policy of requiring and enforcing disconnected roof leaders for single family residential lots. We also recommend that the City amend Section 5.4 (L) of the Design Criteria manual to require disconnection of roof leaders and other impervious surfaces for multi-family residential, institutional, commercial and industrial developments. This policy should apply to new, infill and redevelopment areas within the watershed. While it is recognized that disconnecting roof leaders in higher density areas may be challenging, there are several BMPs which could be used to meet this objective, including planter boxes, rain gardens, bioretention areas, underground storage / retention chambers, etc.

12.1.2 Zone 1

Construct New Municipal Detention Facilities

We recommend that the City construct three new municipal detention facilities in Zones 1 and 1A, at the locations previously shown on Figure 10.8. The intent of implementing these facilities is to control peak flows reaching the north branch of Hyland Creek and to improve water quality conditions. Currently, runoff from much of the contributing area to the north branch of Hyland Creek is uncontrolled, leading to ongoing erosion degradation and water quality issues, as evident by the 2006 Ravine Stability Assessment report and the water quality assessment conducted as part of this ISMP (site H3).

Storage volumes and outlet structure requirements for these three facilities were previously summarized in Table 10.10. These facilities are also listed in the capital works program in Table 11.1.

12.1.3 Zone 2

Beyond addressing the high risk erosion site on the north branch of Hyland Creek (discussed in Section 11.4), there are no other unique stormwater management recommendations for Zone 2. Watershed level recommendations should be followed.

12.1.4 Zone 1A / 2A

Aside from the proposed municipal detention facility in Zone 1A (discussed in Section 12.1.2) and public education initiatives with commercial and industrial businesses (discussed in Section 12.1.1), there are no unique stormwater management recommendations for Zones 1A and 2A. Watershed level recommendations should be followed.

12.1.5 Zone 3

Adopt Additional Performance Targets

In addition to the performance targets outlined in Section 12.1.1 for the entire watershed, we recommend that the City adopt the following performance targets specific to Zone 3. The intent of these additional performance targets are to maintain seasonal base flows to Archibald Creek and the 144 Street tributary, to approximate the pre-development hydrological and hydraulic characteristics of the area, and to ensure adequate detention of peak flows during the full spectrum of rainfall events, all of which are key objectives of the ISMP.

Performance Target # 3 – Capture and Direct Flows up to the 2-Year Pre-Development Flow to Archibald Creek or the 144 Street Tributary

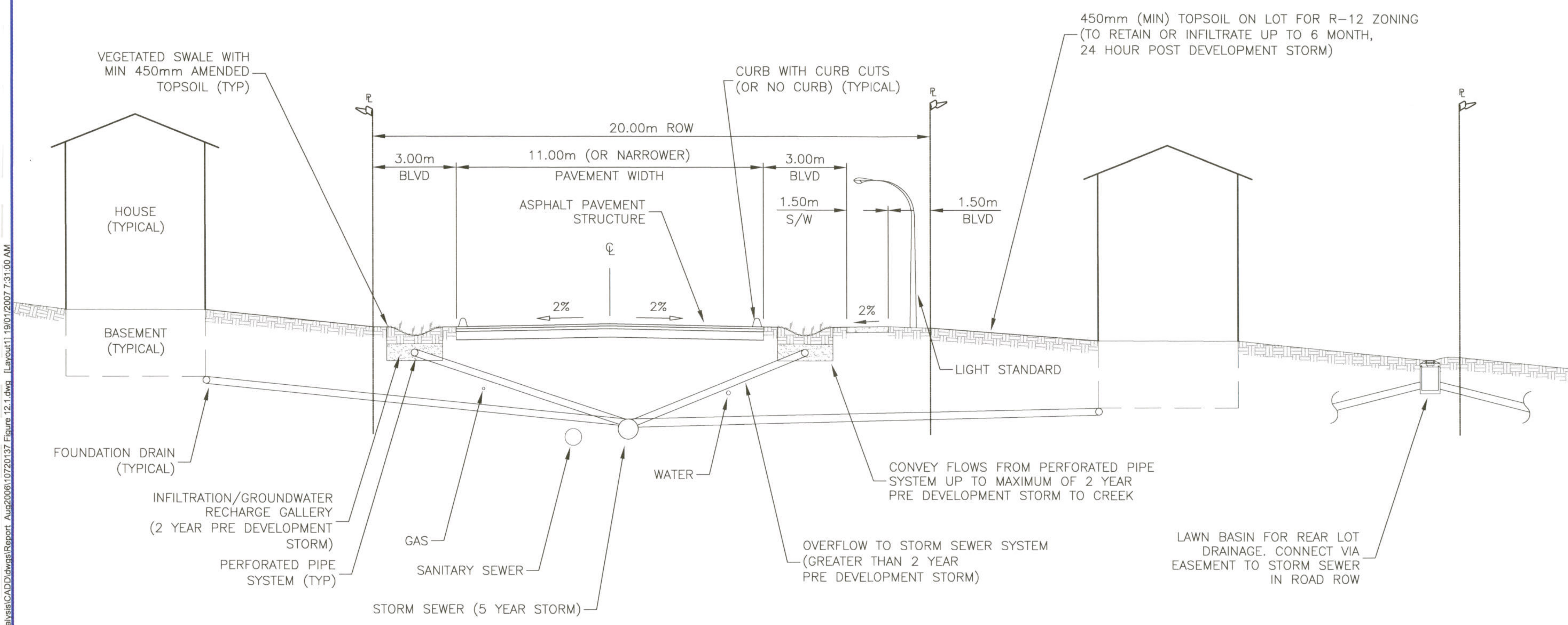
For storm events greater than the 6-month, 24-hour post development event, onsite retention of runoff (via amended topsoil or other means) will be exceeded, therefore a method of conveying and managing stormwater runoff must be provided. Base flows to Archibald Creek and the 144 Street Tributary must also be maintained, as this is a key goal of the ISMP. To meet both of these objectives, we recommend that perforated pipe galleries be installed within the municipal road right-of-way (ROW) to capture and direct flows up to the 2-year pre-development flow to the creeks. These galleries, situated within the municipal road ROW, would run parallel to the road and accept overland runoff from both the road ROW and adjacent private properties.

Galleries would essentially consist of a trench filled with clean drain rock to store the stormwater runoff volume generated from events greater than the 6-month but less than the 2-year event. The gallery would encourage infiltration of stormwater runoff where feasible and appropriate, and would also incorporate a perforated pipe overflow system to direct runoff that was not infiltrated (up to the 2-year pre-development flow) to the creeks. The pipes should be oriented in the gallery with their perforations downwards and the gallery should be wrapped in geotextile to ensure that surrounding soils do not clog the drain rock or the perforated pipe. These overflow systems would respect the natural drainage divide between the Archibald Creek and the 144 Street Tributary as much as possible. Erosion control measures may also be required at the outfall of the overflow systems to the creeks. Galleries would be overlain by a vegetated swale, which could be used to meet the water quality targets noted in Section 12.1.1.

In Zone 3, galleries would typically be situated on roads running east-west (or roughly parallel to the contours) and on roads with less than 5% profile grade. It is anticipated that most north-south oriented roads in Zone 3 will be too steep to incorporate the galleries, given the existing topographical conditions. A typical cross section for a single family residential development (RF-12 zoning) is shown in Figure 12.1.

Given the low infiltration characteristics noted in the hydrogeology field investigation, it is anticipated that the galleries would work in two ways, depending on the time of year. In the summer when weather conditions are typically dry, the galleries would encourage infiltration of stormwater runoff into the underlying soils to recharge the groundwater table. In the winter when the water table is high and saturated soil conditions are common, the galleries would likely act as an alternate conveyance system for groundwater to reach the creeks. This system may also assist in alleviating some of the seepage issues noted in the area in wintertime by capturing this water and conveying it to the creek. We recommend that the City require the developer to retain a hydrogeological engineer during the design of the galleries, to ensure that the galleries will not introduce slope instabilities in steeper areas of Zone 3.

Maintenance tasks associated with the perforated pipe galleries would include flushing the perforated pipes and checking for blockages once a year and replanting vegetation or adding topsoil in the swales as required.



NOTE:

1. R.O.W. AND PAVEMENT WIDTH DIMENSIONS WILL VARY BASED ON ZONING DESIGNATION. OPPORTUNITIES TO MINIMIZE PAVEMENT WIDTH AND ON-STREET PARKING SHOULD BE REVIEWED.
2. APPLICABLE FOR ROADS UP TO 5% PROFILE GRADE.

SURREY
CITY OF PARKS

HYLAND CREEK INTEGRATED STORMWATER MANAGEMENT PLAN

Figure 12.1

CONCEPTUAL DRAINAGE SERVICING SCHEME FOR FUTURE DEVELOPMENT IN ZONE 3

DATE: JANUARY, 2007
PROJECT No. 1072.0137.01
SCALE: N.T.S.

URBANSYSTEMS.

Performance Target # 4 – Capture and Convey Flows in excess of the 2 Year Pre-Development Flow via Conventional Drainage Techniques

Beyond the 2-year pre development storm event, the capacity of the perforated pipe galleries will be exceeded. We recommend that the galleries overflow to the conventional drainage system outlined in the South Newton NCP. As per the NCP, this system would convey flows to detention facilities located at the base of the watershed. The system would also accept foundation drain service connections (i.e. basements) from adjacent properties, which would likely be too deep to be serviced by the perforated pipe galleries. The drainage system would also need to account for safe conveyance of major system flows.

Performance Target # 5 – Design South Newton NCP Detention Facilities for a MAR Event

The South Newton NCP recommended that several municipal detention facilities be constructed at the base of the watershed within Zone 3 to service future development. These facilities were to be designed as flow-through facilities and sized to control the 5-year post development peak flow to pre development levels. However, based on the analysis and discussion in Section 10.1 for existing detention facilities in the watershed, it was found that detention facilities can provide a significant benefit to the watershed if they are designed to control the Mean Annual Rainfall (MAR) event. For example, a detention facility servicing a single family residential catchment area can control the MAR event by providing a unit storage volume of 200 m^3/ha, and a unit release rate of 1.5 to 2.5 L/s/ha. These unit values should be modified as needed to reflect varying land uses in the contributing area to each detention facility.

We recommend that the design of the South Newton NCP detention facilities focus primarily on controlling the MAR event, with strong consideration given to also controlling the 5-year post development peak flow to satisfy the City's current servicing objectives for stormwater detention. Beyond the design event, the capacity of the detention facilities would be exceeded and safe conveyance routes for flows (likely via the creeks themselves) would need to be provided in the design.

Retain Flow Monitoring Station on Archibald Creek

A flow monitoring station has been in place on Archibald Creek at the 142 Street crossing since 1996. The station captures flows from Zone 3 and the extreme southern portion of Zone 1. As discussed in Section 5.2.6, the data indicates that this catchment is a significant contributor to seasonal base flows in Archibald Creek, and to Hyland Creek overall. The data also indicates that seasonal base flows in Archibald Creek have recently begun to decline, which may be associated with recent development in Zone 3.

Given the importance of understanding and maintaining the seasonal base flow regime in the Archibald Creek tributary, particularly as development proceeds in Zone 3 of the watershed, we recommend that the flow monitoring station on Archibald Creek be retained. Data from this station can be used to monitor the performance and impact of stormwater and environmental BMPs that are implemented as part of new development in Zone 3 from a peak rate and volume perspective. The data can also be used as an indicator for refining stormwater and environmental approaches in Zone 3, if the data indicates that base flows in Archibald Creek are continuing to decline despite the implementation of BMPs intended to mimic natural base flow characteristics.

Designate Zone 3 as a Unique Area in the Design Criteria Manual

We recommend that the City designate Zone 3 as a Unique Area in the City's Design Criteria Manual, such that certain design criteria can be applied to this zone to meet the ISMP objectives of limiting effective and total impervious area for new development. To limit effective impervious area, the City should require that roof leaders from all new development be disconnected from the municipal drainage system regardless of land use type, as previously discussed in Section 12.1.1. Roof leaders could be discharged to pervious areas via splash pads, planter boxes, bioswales or other appropriate BMPs.

To limit the amount of total impervious area associated with new development, the design criteria should also stipulate that porous paving materials be used for all low-traffic areas, such as driveways, patios, parking stalls and sidewalks. Alternatively, the City could limit or set a maximum on the number of off-street parking areas that are constructed of impervious materials, as discussed in Section 12.5.1.

An amendment to the City's Building Bylaw would also likely be required to permit and enforce the Unique Area design standards on private lots during construction.

Support a Topsoil Stockpile Site

Given the extent of future development planned for Zone 3 and the anticipated demand for topsoil to meet the ISMP performance targets, we recommend that the City support a central site in the watershed for use by the development community for topsoil stockpiling, screening and recycling. This site could be used by several developers to store stripped topsoil for later use during final lot grading. The benefits of having a site within the watershed include short haul distances to store stripped topsoil, gained developable area by not needing to store topsoil on site, and the fact that native topsoil is returned to the same watershed.

12.1.6 Zone 4

We recommend that the City continue to work with the agricultural community to encourage the use of agricultural BMPs, such as screening irrigation intake pipes. Agricultural BMPs are included in publicly available literature by the provincial Ministry of Agriculture and the Ministry of Environment. We understand that the City also has an Environmental Farm initiative underway to support the use of BMPs by the agricultural community.

12.2 Aquatic Habitat

12.2.1 Watershed Level

The aquatic habitat studies conducted for the ISMP indicate that most watercourses in the Hyland Creek watershed are Class A (Figure 5.8) and that most barriers to fish passage occur in the headwater areas (Table 5.13), i.e., much of Hyland Creek and its tributaries are fish bearing and there are relatively few concerns about access to habitat. Consequently, removal of migration barriers is of relatively low priority. Of higher priority are addressing water quality, riparian vegetation and flow regime issues, based on increasing incidence of erosion, exceedance of some water quality guidelines for protection of aquatic life during storm events, and the importance of determining the amount of riparian protection through setbacks that adequately protect for fish, geotechnical, wildlife and other values.

Establish Adequate Riparian Setbacks

The City of Surrey currently requires a 15 metre to 30 meter riparian setback for fish-bearing streams (30 metre setback for residential areas with more than six units per acre, 15 m setback for less than 6 units per acre).

The importance of adequate setbacks for maintenance of watershed health, protection of fish habitat, wildlife corridors, access for maintenance, geotechnical and floodplain concerns, as well as for protection of property cannot be overemphasized. Historically, encroachment along the creeks (houses and other structures, landscaped areas) has contributed to erosion problems because the ability of the creek to meander naturally has been restricted. Encroachment has also led to loss of riparian vegetation (Section 6.2), with associated degradation of fish habitat and loss of wildlife habitat and migration corridors. The increase in the number and risk status of erosion sites along Hyland Creek and Archibald Creek (see Figure 5.2 and Table 5.6) indicates stress on the streams. Many of these sites are in areas where development occurred before current setbacks were established: the riparian corridors are less than 5 metres from top of bank and there is poor or no stormwater management measures in place. Although erosion is a natural process in a watershed, it is accelerated by human activities. Setbacks should be determined based on geotechnical and geomorphological values, in conjunction with existing and proposed flow regimes, as well as fisheries and wildlife values.

Specific wildlife considerations as they relate to riparian setbacks are discussed in Section 12.3.1. The federal *Species at Risk Act* and the anticipated implementation of the provincial *Wildlife Amendment Act* should be considered when species of conservation concern are present. In effect, lands considered "critical habitat" for rare, threatened or endangered species will need to be highlighted and considered. It should be noted that the *Species at Risk Act* only applies to federal lands at this time. The *Wildlife Amendment Act* lists species of concern, but at this time the list is limited. It may change in the future in which case this Act should be tracked, and setbacks altered to meet its requirements when applicable.

In urbanized watersheds, riparian areas often provide significant amounts of wildlife habitat. This applies to both fish bearing (Class A and AO) and non-fish bearing (Class B) streams. As discussed in Sections 12.3.1 and 12.3.5, setbacks of 15 or even 30 metres will not be enough to provide migration corridors and habitat for large mammals such as deer or for other species or for species of conservation concern. Setbacks recommended for the protection of critical preferred habitat of the red-listed Pacific water shrew are currently 100 metres (Ministry of Environment 2005). For habitat of blue-listed red-legged frog and other amphibians (slow flowing, marsh, wetland and pool areas), recommended setbacks are at least 30 metres on each side of a stream or wetland, with adequate connectivity with other habitat areas [Ministry of Environment 2004].

The Riparian Areas Regulation (RAR) of the *Fish Protection Act* came into effect on March 31, 2006; however, the City has not formally adopted it yet, as discussions continue between the Department of Fisheries and Oceans (DFO), the Ministry of Environment (MoE) and the Union of BC Municipalities (UBCM). The City currently uses setbacks outlined in the Land Development Guidelines for the Protection of Aquatic Habitat as its standard. When the tri-party agreement is signed between DFO, MoE and UBCM in the future, the City will then look at implementing RAR with additional setback requirements to address other concerns in creek and ravine areas.

In the proposed City setback determination, the City will allow the detailed and simple assessments described in the RAR and will require the developer to consider other factors, such as slope stability, drainage access and maintenance, floodplain, hazard trees, property protection, trails and wildlife if legislation dictates. Under the RAR, a qualified environmental professional conducts a simple or detailed assessment of fish habitat values within a 30 metre assessment area along Class A, AO or B watercourses (see Figure 5.8) and determines the appropriate setback. Setbacks may range from 5 metres to 30 metres. RAR setbacks are widest for permanent, fish-bearing streams (Class A, such as Hyland and Archibald Creeks and several tributaries) with at least a 15 metre width of existing or potential riparian vegetation, and smallest for non-permanent, non fish-bearing streams (Class B or C) with minimal riparian vegetation. According to the RAR, areas within the setbacks are to be maintained as Streamside Protection and Enhancement Areas (SPEAs). Proposed stormwater detention facilities and recreational facilities should be situated outside the riparian area, and access should be restricted to minimize disturbance and discourage encroachment by auxiliary structures (e.g. sheds, fencing, landscaping, swimming pools, garages).

We recommend that the setbacks defined in the recently completed Neighbourhood Concept Plans (NCP), such as the South Newton NCP in Zone 3, be used for applicable areas. For planning purposes, the City is now using the simple RAR assessment methodology to assign setbacks for creeks at the NCP level, which will typically result in setbacks of 15 metres or 30 metres for Archibald Creek and other Hyland Creek tributaries in Zone 3 (depending on the width of existing riparian vegetation and proposed density of housing). In some cases, wider setbacks will be needed to fully protect all environmental and property values discussed above, and will need to be assessed on a site-by-site basis.

The riparian setback widths will need to be assessed carefully for developments proposed along Hyland Creek and its tributaries, considering the impacts to structural stability (erosion, bank repairs), habitat loss for fish and wildlife, protection of adjacent properties (hazard trees) and providing adequate access for maintenance along the creek corridor. Zones 1, 1A, 2 and 2A show evidence of impacts of these physical changes, as well as of water quality and flow regime changes associated with the loss of impervious cover. These should be considered when planning future developments in Zone 3. It is strongly recommended that these setbacks not be relaxed in the Hyland Creek watershed, particularly in Zone 3. Riparian setbacks should be the widest provided in existing municipal and provincial legislation to protect fisheries, wildlife, geotechnical and property values.

Fencing and planting of native vegetation within riparian areas are discussed in Section 12.3, in relation to terrestrial habitat.

Continue Water Quality Monitoring Program

The water quality assessment (Section 8 and Appendix B) indicates that several parameters, including turbidity, total suspended solids (TSS), fecal coliform, *E.coli* and some metals, exceeded the provincial water quality guidelines for protection of aquatic life on some or all of the four sampling dates. The assessment followed recommendations of the GVRD ISMP template to sample during base flows, although it is noted that this is not a comprehensive water quality program and does not indicate water quality throughout the year or the extent to which exceedences indicate significant issues for the watershed.

We recommend that the City continue its water and benthic invertebrate monitoring program, both to further assess conditions in the streams and to evaluate the effectiveness of any stormwater management improvements the City undertakes (for example, the detention facilities recommended in Zones 1 and 1A, upstream of water quality site H3). The program conducted in 2006 for this ISMP provides a basis for future monitoring programs, with the same four sampling sites, list of parameters, and sampling during dry weather. Given the high variability in water quality due to dry versus wet weather sampling, differences from start to end of a rain event, ephemeral changes related to spills and discharges changes, it would be expensive to design a comprehensive water quality sampling program to more fully assess conditions. A more cost-effective and environmentally relevant approach to assessing trends over time is to augment the benthic invertebrate monitoring program with an additional site at H3, as discussed below.

Continue Benthic Invertebrate Sampling Program

The City began its benthic invertebrate sampling program on Hyland Creek and Archibald Creek in 2005 and intends to repeat the program in future years. Benthic sampling provides a biologically based indicator of stream and watershed health, and is well correlated with physical indicators of watershed use, such as EIA and RFI. The benthic program and sampling sites are described in Section 6.3.

In addition to the sites currently assessed (H1 and H2 on Hyland Creek in Zone 2, and A1 on Archibald Creek in Zone 3), we recommend that a fourth site be added (H3 on Hyland Creek, downstream of King George Highway in Zone 1A). These sites were previously shown on Figure 5.7. Similar to continuing water quality monitoring program at this site, establishing a benthic monitoring site at H3 would enable an assessment of the effectiveness of any stormwater treatment facilities installed in the upper watershed.

Remove Fish Migration Barriers

Several fish migration barriers were identified in Table 5.13, including culverts at 138 Street, 148 Street, 64 Avenue and 68 Avenue. Among these, none are assigned a high priority for removal as they are located in the upper watershed, where their removal will result in access to only a limited amount of fish habitat (up to 350 m). Before considering barrier removal on these tributaries, it will be important to address concerns about poor water quality in the upper watershed (site H3) so that fish and benthic communities can be sustained in any newly accessible habitat. With that said, passability for fish should be considered whenever culvert replacements and road works are planned.

SHIM mapping conducted in the spring of 2006 [MarLim 2006] also indicated the presence of beaver dams, log jams and debris in several locations. Beaver dams and debris jams are often left in place as they are not complete barriers to fish movement and provide increased habitat complexity for fish. However, we recommend that the City monitor beaver dams and debris jams as they may result in flooding of roads or properties. Materials from log jams and debris jams should be reused in the creek to provide fish habitat, and anchored to prevent movement downstream. Yard waste deposited along a tributary near 148 Street (SHIM feature 100.0, [MarLim 2006]) may also pose a barrier and should be removed.

Stream habitat quality generally appeared to be good during the 2006 assessments, with areas of spawning gravel, large woody debris and riparian vegetation noted. The City has also undertaken restoration work as part of the SHARP program. As a result, no specific restoration initiatives have been identified at this stage, although efforts on an individual site or reach basis (e.g. protection or enhancement of riparian vegetation, avoidance of bank channelization, erosion repair) continue to be important in all zones of the watershed.

We also recommend that garbage and foreign objects specifically identified during the site reconnaissance be removed. Particular areas of accumulation are discussed below for specific zones.

12.2.2 Zone 1

No specific recommendations are made for aquatic habitat in Zone 1 at this time, as addressing water quality issues is of greater benefit and priority than daylighting enclosed sections of the creek or removing migration barriers to allow for the possibility of fish migration west of King George Highway. Garbage and other litter were noted at most of the storm sewer outfalls to Hyland Creek at King George Highway. We recommend that the City, local stewardship groups or service organizations conduct periodic clean-up campaigns at these storm sewer outfalls.

12.2.3 Zone 2

In addition to the erosion remediation works recommended in the 2006 Ravine Stability Assessment Update, we recommend that the City consider removing foreign objects in some areas of Hyland Creek. During the 2006 field reconnaissance, it was noted that a creosote-coated telephone pole is situated within the channel bed immediately downstream from benthic monitoring site H2. We recommend that this pole be replaced with a non-creosote pole outside the top of bank of the channel. Remnants of an abandoned vehicle (age unknown) were also identified within the main channel approximately 70 m upstream of site H2, and may be a source of hydrocarbons to the creek. We recommend that the City investigate this area, which is on private property, for potential contamination and suitability of removing the vehicle, if doing so will not disturb stream habitat extensively. Further discussion with DFO will likely be required.

12.2.4 Zones 1A and 2A

Recommendations to improve the aquatic habitat in Zones 1A and 2A include retrofitting existing commercial and industrial areas with onsite water quality treatment devices and discouraging the use of cosmetic pesticides and herbicides on private property (as discussed in Section 12.1.1). Both initiatives will assist in improving water quality conditions and aquatic habitat in Hyland Creek.

12.2.5 Zone 3

Given the amount of development planned for Zone 3, protection of riparian areas along Archibald Creek and the 144 Street Tributary will be a concern. General guidance for the entire watershed is provided in Section 12.2.1. It is important for the City to provide clear guidance on setbacks in Zone 3, based on information in the South Newton NCP, City policies, Riparian Areas Regulation, and environmental and geotechnical considerations. The NCP recommends a 30 metre setback for residential areas with more than six units per acre and a 15 m setback for less than 6 units per acre. Physical stability of the streams (cf. evidence of increasing erosion in Archibald Creek), wildlife species of conservation concern and overall watershed health should be considered in determining setback widths. The likelihood of the blue-listed red legged frog in the Archibald Creek corridor indicates that in areas of preferred habitat (slow flowing, marsh, wetland and pool areas), the setbacks recommended by the Ministry of Environment [2004], at least 30 metres on each side of a stream or wetland, with adequate connectivity with other habitat areas, should be employed.

We recommend that the City work with landowners and developers around Archibald Creek to protect the appropriate riparian areas, making sure all factors are considered when determining setback width. In addition to their value as fish habitat, riparian areas provide important wildlife habitat and often are the major migration corridors, as discussed in Section 12.3.1. Efforts made to protect and maintain watershed health in Zone 3 will be well spent, given current habitat quality and low level of growth, anticipated future development in this zone, and status of the watershed as a whole.

12.2.6 Zone 4

In addition to reviewing agricultural BMPs with the farming community and undertaking educational initiatives for water quality improvement (as discussed in 12.1.6), the City should consider the following aquatic habitat recommendations unique to Zone 4. Hyland Creek has been channelized and dyked in Zone 4 for agricultural purposes, from 152 Street east to the creek's discharge into the Serpentine River. Conserving the remaining riparian area, as well as enhancing the area through planting a continuous corridor of native trees and shrubs along the banks, is recommended, as this will improve water quality and habitat, as well as provide or improve wildlife migration corridors. The City should also consider placing boulders and large woody debris along the channel to provide fish cover and to increase channel complexity.

Properly screened irrigation water intakes along the creek and agricultural ditches are required under law (DFO end of pipe regulations) to ensure fish are not harmed by the intakes. Although these intakes are licensed under provincial regulation, we recommend that the City, in conjunction with DFO, the Ministries of Environment and of Agriculture and Lands, continue developing education campaigns for farmers and monitor the status of the intakes.

12.3 Wildlife and Terrestrial Habitat

Establish and Maintain Wildlife Migration Corridors

Protection of riparian habitat for wildlife species of conservation concern and for migration corridors is also discussed in Section 12.2.1.

We recommend that the City focus their effort on establishing recreation/wildlife corridors that will connect, or better connect, areas within the Hyland Creek watershed to those outside it, such as:

- Hyland Creek and Archibald Creek to the Serpentine River and Nicomekl River (south and east-west links);
- Hyland Creek and Archibald Creek to Bear Creek (north); and
- The Hyland Creek watershed to Surrey Lake Park and Fleetwood Park (north link).

These corridors are shown in Figure 5.10 and discussed in Section 5.4.3. Protecting these corridors would be the most effective, given the built up nature of the watershed and the expense of purchasing and restoring land for new wildlife corridors. As evident in the figure, these corridors are easily lost unless they are protected or restored.

Due to the financial restrictions of restoring developed land to its natural state, conservation efforts to maintain wildlife movement connectivity should focus on the two alternatives to wildlife corridors introduced by Simberloff et al. [1992]: the step stone and the landscape matrix conservation strategy. For the step stone strategy, existing patches of wildlife habitat could be enhanced by, for example, removing all exotic vegetation, planting native vegetation that is attractive to a cross section of wildlife species, creating wetland habitat and buffering habitat patches from human disturbance. On the landscape matrix scale, community stakeholders should be informed about the contribution that they could make to improve the wildlife capacity of the community. For example, residents could take ownership of a nest box and bat house program and encourage residents to landscape with native vegetation. These would be small but meaningful contributions to the Hyland watershed, and could be incorporated into the public education brochure discussed in Section 12.1.1.

We also recommend that the City of Surrey consider removing existing wildlife movement barriers or mitigating for the presence of these barriers (e.g., impassable streets, perched culverts). Many of these corridor linkages may be reflected in existing park zoning, but more and wider corridors will give wildlife species a secure area to migrate from one natural area to another. With the creation of new corridors or enhancement of existing corridors, appropriate management measures will be required to ensure that wildlife-human conflicts do not occur in areas of shared wildlife-human use.

Fence Riparian Corridors to Conserve and Restore Native Riparian Habitat

Riparian habitat along many reaches of Hyland Creek, Archibald Creek and their tributaries provide the main migration corridors for wildlife within the watershed. Municipal parks also provide larger areas of undeveloped habitat for wildlife. Unfortunately, much of the riparian habitat in the Hyland Creek watershed has been disturbed to varying extents through development encroachment and human-related activities. Protection of riparian habitat from incursion (landscaping, structures) is essential in maintaining healthy riparian areas and all the watershed health benefits this provides. Fencing is one of the most effective means of identifying and protecting riparian habitat, and it will also act as a visual reminder to people to not encroach on the riparian area.

We recommend that the City continue to require fencing of riparian areas for all new developments and that the City, through public education initiatives, encourage fencing on existing properties and use of native vegetation. The style of fencing should consider wildlife needs (tall fencing may discourage migration outside the riparian area) and habitat protection (low fencing is easily jumped, removed or ignored, as in disposal of garden wastes).

Encourage Native Landscaping in Developed Areas

Section 12.1.1 discusses various public education initiatives the City could implement to assist in achieving the goals and objectives of the Hyland Creek ISMP. One is to prepare a brochure encouraging local residents and developers to plant native vegetation on private property and to obtain native plants and topsoil from local sources. There are many benefits to using native species, including provision of a diversity of food supplies (seeds, berries at various times of year) and habitats for birds and other wildlife, adaptation to local climate conditions (wet winters, dry summers), and low maintenance requirements (watering, disease resistance). The brochure should also encourage removal of exotic species on private property and replanting with native species.

We recommend that the City encourage and support the use of native plants in landscape areas for new developments as part of the building permit application process. We also recommend that the City adopt a policy of using native plants in passive park spaces, preservation / natural areas, riparian areas and green spaces.

12.3.1 Zone 1

Wildlife and terrestrial habitat opportunities and recommendations for Zone 1 are included in the watershed-level recommendations discussed above.

12.3.2 Zone 2

Wildlife and terrestrial habitat opportunities and recommendations for Zone 2 are included in the watershed-level recommendations discussed above.

12.3.3 Zones 1A and 2A

Wildlife and terrestrial habitat opportunities and recommendations for Zones 1A and 2A are included in the watershed-level recommendations discussed above.

12.3.4 Zone 3

Most of the wildlife migration in Zone 3 will occur along the main stream corridors and may extend into parks proposed as part of the South Newton NCP. Based on a review of available aerial photography and knowledge of wildlife migration characteristics, there is one proposed park space in Zone 3 (near 148 Street, just south of 64 Avenue) that is heavily vegetated and could potentially provide suitable habitat for wildlife and/or act as a migration corridor. However, we understand that the property is currently under development application and the proposed layout has not included a sufficient width of green space to function as an adequate wildlife corridor. Thus, the opportunity to connect this green space to the 144 Street Tributary corridor was not examined further. This example illustrates the fragility of such corridors and emphasizes the importance of maintaining riparian corridors to the fullest width possible under municipal and provincial legislation.

General guidance on desirable right of way width is often based on protection of identified sensitive habitat and species of conservation concern [Ministry of Environment 2004]. The GVRD Biodiversity Conservation Strategy[5] also provides general guidance on habitat connectivity.

12.3.5 Zone 4

As discussed further in Section 12.5.6, the City's continued support of the agricultural land reserve (ALR) designation in Zone 4 will allow for the protection and restoration of riparian habitat, as well as provide corridor linkage opportunities for wildlife to migrate through the watershed.

12.4 Hydrogeology

Stormwater infiltration is an important component of watershed management planning, and is essential for maintaining base flows (summer low flows) and reducing peak flows and floods. Infiltration options include maintaining natural pervious surfaces by limiting the amount of development, or to mitigate the impacts of development by improving the thickness of soil layers on remaining lands or by developing artificial means of infiltration (e.g., use of perforated pipes, rain gardens, rock pits or underground infiltration galleries on a site or larger scale, or deepwater infiltration on a community scale).

While there may conceivably be some potential for deeper stormwater injection, it is not believed that such a practice would be effective in maintaining base flows in Hyland Creek or Archibald Creek. In addition, deep stormwater injection is a developing technique, and many questions remain on the effects of mixing two physically and chemically dissimilar waters such as surface stormwater and deep groundwater, and of means of preventing introduction of contaminants into aquifers. Thus, deepwater infiltration of stormwater runoff is not recommended for the Hyland Creek watershed.

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5 www.gvrd.bc.ca/growth/biodiversity.htm

12.4.1 Watershed Level

Ensure Basements are Properly Designed and Protected against High Water Table

Basements are a geotechnical as well as a hydrogeological concern, and site-specific development plans should be reviewed by qualified professionals prior to granting permits. In general, however, three cases can be considered:

1. *Basement foundation is completed above the natural high water table elevation* – The structure should not affect the groundwater flow regime aside from the effects associated with the reduction in permeable area available for recharge due to the building footprint.

2. *Basement is constructed as a tanked (i.e. impermeable) structure below the natural high water table* – This type of construction results in a reduction in cross-sectional area to support groundwater flow. This can cause a rise in ambient groundwater levels possibly leading to increased seepage concerns in adjacent areas. Effects may be mitigated by groundwater diversion or interception systems, but such systems would need to be carefully designed by a qualified professional on a lot-by-lot or development-by-development basis. See discussion in (3) below.

3. *Basement is constructed below the natural high water table and groundwater is diverted and/or intercepted to control water levels* – Groundwater levels may be locally controlled by perimeter interception drains, trenches, or other diversion systems. Intercepted groundwater is typically either returned to the hydrogeologic system downgradient of the structure of concern, or discharged to the local storm sewer system.

    - If diverted water is returned to the hydrogeologic system, there may be seasonal effects on groundwater levels in the area (e.g. additional seepage problems, soft ground, etc), as well as possible effects on stream base flows and water quality depending on the type and scale of works and their proximity to creeks.

    - If intercepted groundwater is discharged to the storm sewer system, base flows in nearby creeks would be affected.

Regardless of the type of system used, careful design and assessment by a qualified professional will be essential to avoid net negative effects on surrounding properties and the creeks. In addition, regular maintenance, inspections and performance monitoring will be necessary to ensure adequate system performance and prevent seepage and/or flooding issues.

In general, given the undeveloped permeable area remaining in the watershed for recharge and the low bulk hydraulic conductivity of the Capilano Sediments (Cd unit), we recommend that basements in areas with high water tables be properly designed to protect groundwater resources. Use of diversions or drains should be carefully considered by a qualified professional, and the effect of the drain or diversion on the local hydrogeologic system should be suitably quantified.

Minimize Alteration of Natural Surfaces

In light of the findings of the hydrogeological investigation, we recommend that when considering future development in the Hyland Creek watershed, every effort should be made to minimize, to the maximum extent possible, the alteration of natural surfaces and vegetation. Protection of natural surfaces will also assist in approximating the natural hydrologic characteristics of the watershed, which is a key objective of the ISMP. Where possible, preference should be given to the use of permeable pavements and other technologies that allow precipitation to infiltrate to the ground. In addition, the footprints of impermeable structures should be minimized to maintain as much natural land cover as possible and to limit the amount of total impervious area.

12.4.2 Zone 1

There are no unique hydrogeology recommendations for Zone 1. Watershed level recommendations should be followed.

12.4.3 Zone 2

There are no unique hydrogeology recommendations for Zone 2. Watershed level recommendations should be followed.

12.4.4 Zones 1A and 2A

There are no unique hydrogeology recommendations for Zones 1A and 2A. Watershed level recommendations should be followed.

12.4.5 Zone 3

Monitor Impacts of Local Seeps and Springs on the Northern Slope of Zone 3 as BMPs are Implemented

Infiltrating stormwater to surficial soils could raise the groundwater table to or near the surface, potentially resulting in soft ground conditions, seepage, or reduced structural integrity of the soil. As development in the watershed proceeds and stormwater BMPs are implemented, we recommend that the City carefully review the impacts on local seeps and springs on the northern slope, as well as monitor changes in seasonal base flows in Archibald Creek (using flow monitoring data), to ensure that existing seeps and springs do not worsen and that additional seeps and springs are not created.

Require New Developments to Investigate Potential of Small-Scale Stormwater Infiltration as part of Achieving On-Lot Performance Targets

From the results of the infiltration testing program described in Section 9, the hydraulic conductivity of the native surficial soils at the three test locations in Zone 3 is estimated to be less than 10^{-6} m/s, and is most likely on the order of 10^{-8} m/s. As a result, the hydrogeologic conditions encountered at the sites tested are not considered suitable for artificial stormwater infiltration to surficial soils at any scale larger than possibly the individual lot-scale. However, the possibility for stormwater infiltration at the lot-scale should still be explored as a method of achieving the ISMP objectives of maintaining seasonal base flows to Archibald Creek and the 144 Street Tributary, approximating the pre-development hydrology of the catchment area and achieving the ISMP performance targets.

Based on the available surficial geology mapping, the Capilano Sediments (Cb unit) appear to possess suitable hydraulic properties to support community-scale infiltration of stormwater (see Figure 5.12). Unfortunately, the infiltration test targeting that soil unit did not appear to intersect the Cb material type, so it was not possible to assess infiltration potential in Cb soils. Based on the results of the desktop hydrogeology study, it is considered likely that groundwater elevations in the majority of the Cb unit will preclude the infiltration of stormwater, particularly during the winter wet season. However, this has not been specifically assessed as part of this ISMP. As such, we recommend that infiltration capacity and suitability for artificial stormwater infiltration BMP's be assessed on a lot-by-lot or development-by-development basis (and incorporated where appropriate) in Zone 3 to maintain seasonal base flows to the creeks and to approximate the pre-development hydrology of the watershed. The suitability of a given site for artificial stormwater infiltration should be evaluated by qualified hydrogeologists and geotechnical engineers, in order to prevent seepage problems or soil instabilities from occurring at the site or further downslope of the proposed development.

12.4.6 Zone 4

There are no unique hydrogeology recommendations for Zone 4. Watershed level recommendations should be followed.

12.5 Land Use / Parks and Recreation

This section provides a number of suggested implementation strategies that could be used to promote stormwater management and environmental objectives in the Hyland Creek watershed. As several of these recommendations involve adopting bylaws according to either the *Local Government Act* or the *Community Charter*, we recommend that the City seek legal counsel to ensure any new regulations are consistent with the City's existing bylaws and to confirm legality.

While this report focuses on the Hyland Creek watershed, many of the policies identified in this section could theoretically be applied City-wide.

12.5.1 Watershed Level

Identify Opportunities to Enhance Existing Park Space

There are several existing parks within the Hyland Creek watershed and future parks are proposed for Zone 3. Unwin Park and the Newton Athletic Park (both in Zone 1) are the largest parks in the watershed, however, there are also several local parks associated with neighbourhoods and schools that are distributed throughout the watershed. These parks contain a mix of active (baseball diamonds, soccer fields, etc) and passive (treed areas, nature trails, etc) park uses.

Park space, whether active or passive, can potentially represent a significant portion of pervious surface within a developed area. However, from a stormwater management standpoint, passive park space is much more effective than active park space for addressing stormwater runoff. Passive park space tends to retain native vegetation and topsoil, thus promoting evaporation, transpiration and infiltration processes. Disturbance is kept to a minimum and the land is left in as close to a natural state as possible. In contrast, active park space tends to include fewer natural features and often the ground is disturbed and compacted during construction, thus potentially limiting the amount of infiltration that can occur. While parking lots can be associated with both types of park uses, activities that take place in active space areas tend to result in higher parking demands. Thus, although active park space is in high demand in the watershed, the City should ideally aim to balance these demands with stormwater management and environmental goals.

We recommend that the City review the existing parks in the Hyland Creek watershed and look for opportunities to enhance these parks by:

- Maximizing passive space areas

- Adding amended topsoil and planting native vegetation in passive space areas
- Retaining existing native vegetation to the maximum extent possible
- Minimizing onsite parking and/or using permeable pavement for parking areas
- Modifying active space areas to incorporate rain gardens, underground retention / infiltration systems, etc.

Implement Erosion and Sediment Control Bylaw

We understand that the City has recently adopted an Erosion and Sediment Control Bylaw, and is moving forward with implementation. We recommend that the Erosion and Sediment Control Bylaw be applied to land development as well as municipal capital projects within the Hyland Creek watershed, with the intent of reducing the amount of total suspended solids (TSS) entering the watercourse (TSS was identified as a pollutant of concern in the ISMP water quality assessment). The City is already held training sessions for contractors, consultants and builders on the bylaw, and has begun to retain and train additional staff for implementing and enforcing the bylaw.

Finalize and Adopt Stormwater Drainage Regulation and Charges Bylaw

We recommend that the City also adopt regulations to prevent pollutants from entering the municipal drainage system, such as those described in the Draft Surrey Stormwater Drainage Regulation and Charges Bylaw, which was prepared by Urban Systems in 2004. We recommend that the City work towards adopting this bylaw. The Draft Bylaw regulates what is permitted to enter the drainage system, provides clear lists of prohibited and restricted wastes, and sets out inspection and monitoring requirements. Adoption of these types of regulations will help protect and/or improve water quality in the watershed which should, in turn, better support aquatic and stormwater objectives.

Require Retention and Planting of Native Vegetation for New, Infill and Redevelopment Areas

To manage stormwater most effectively, the City should establish regulations that can be applied to both small-scale infill or redevelopment projects in established areas, and large-scale greenfield developments. One regulation that can help minimize changes in the natural water balance by promoting evapotranspiration and infiltration, and can be applied to both small- and large-scale developments, is a requirement to retain and/or plant native vegetation. This requirement would also assist in minimizing total impervious area in the watershed.

The City could use a variety of regulatory tools to ensure that adequate vegetation is planted on-lot, including:

- Development Permit Areas
- Landscaping Bylaw
- Restrictive Covenants

As a first step, the City should prepare an education brochure on the importance of retaining native vegetation and trees, which would be distributed to developers, builders, home owners, commercial businesses, and industrial businesses as discussed previously in Section 12.1.1. The education program may be sufficient to encourage the preservation and/or provision of native vegetation and trees on a voluntary basis.

For future ISMPs and land use planning, we recommend that the City consider introducing a Development Permit Area to ensure guidelines are met. A Development Permit Area would give the City the most flexibility in terms of the requirements that can be imposed on new development. As per section 920 (7) of the *Local Government Act*, municipalities can impose Development Permit Areas for the protection of the environment, and can specifically require planting or retention of native vegetation and trees to protect riparian areas, control drainage, or control erosion. Development permits for the protection of the environment must be obtained prior to subdivision, construction, or alteration of the land; therefore this type of development permit would be applicable not only to greenfield areas, but also to any areas that may redevelop.

Impose Minimum Topsoil Regulations

Similar to the requirement to retain or plant native vegetation, minimum topsoil depth requirements are also applicable to both small- and large-scale development and redevelopment areas. Topsoil is important because it can reduce the volume and rate of stormwater runoff from developed areas. To ensure that all new, infill and redevelopment lots can meet the performance targets stated in Section 12.1.1, the City could impose minimum topsoil regulations through the introduction of new provisions in the following bylaws:

- Subdivision and Development Bylaw

- Building Bylaw
- Soil Removal and Soil Depositing Regulation Bylaw

The City could also consider introducing new Development Permit Areas and restrictive covenants to ensure a minimum depth of topsoil is retained or deposited on each lot. The education brochure regarding native vegetation (as noted above) should also include information on the importance of topsoil retention.

Revise Taxation Schedule for Drainage Parcel Tax

The City currently levies a stormwater utility in the form of a drainage parcel tax for the construction and operation of the City's storm drainage system. The 2006 drainage parcel tax rates are as follows:

- $154 per parcel for all property classes except Class 9 (agricultural)
- $102 per parcel for Class 9 (agricultural) properties

While the collection of funds specifically for drainage infrastructure and maintenance is preferable to the reliance on general revenues, we recommend that the City revise the taxation schedule to better reflect the impacts that development may have on the drainage system and the environment. For example, instead of differentiating between only agricultural and non-agricultural uses, the City could levy a tax that differentiates between commercial, industrial, and residential users.

Implement a Stormwater Utility Fee

To create incentive to adopt on-site BMPs and raise revenue fairly, we recommend that the City introduce a more detailed stormwater utility fee, which levies charges based on the user-pay principle (i.e. charges reflect use of the stormwater system). The utility fee should be based on parcel size, intensity of development, land uses, or any other factor that relates to the use of drainage infrastructure. The stormwater utility should provide financial incentives to homeowners to adopt BMPs by giving credit to homeowners that can demonstrate that they contribute significantly less stormwater runoff per property. The 1998 report entitled *Assessing the Applicability of a Stormwater Utility to Local Governments in British Columbia*, which was prepared for Surrey, Abbotsford, and Kamloops by Urban Systems, discusses many of the recommendations noted above. It should be noted that the legislation pertaining to the creation of a stormwater utility has changed since 1998. Municipalities now have the power to create a user charge (i.e. stormwater utility) that can vary according to any factor specified in the stormwater utility bylaw.

Lower Development Cost Charges for Implementation of BMPs

To provide developers with a further incentive to implement BMPs, we recommend that the City consider charging lower stormwater DCCs for developments that incorporate on-site BMPs. Theoretically, the use of on-site BMPs should mean less drainage infrastructure is needed to serve those parcels, which would mean infrastructure costs and resultant DCCs would fall. As these special DCC rates would likely result in the most significant changes in Zone 3, which have yet to be fully developed, the new DCC rates could be limited to Zone 3, but could also be applied throughout the watershed.

Adopt Impervious Area Regulations

As per section 9.7 (2) of the *Local Government Act*, municipalities can adopt a bylaw that establishes the maximum percentage of the area of land that can be covered by impermeable material, thus limiting total impervious area. While most zones in Surrey's current Zoning Bylaw include a provision regarding maximum lot coverage, the definition of "lot coverage" does not relate to impervious surfaces. We recommend that the City consider amending the definition of "lot coverage" to include impervious surfaces such as paved driveways and patios, to encourage the use of pervious materials such as porous pavements. Certain zones, such as the RF-12, RF-9 and RM-23 Zones, include maximum non-porous or paved area regulations; these types of stipulations should be extended to all zones.

We recommend that the City also set a maximum on the number of off-street parking spaces constructed of impervious paving materials that could be provided on each lot to further minimize total impervious area, which is a key objective of the ISMP. Over time, the City should aim for all off-street parking spaces to be constructed of pervious materials. This policy would be applicable even in high parking demand neighbourhoods, because only the surface material would change while the number of available off-street parking spaces would remain constant. These types of parking regulations would encourage homeowners to make more efficient use of impervious surfaces that already exist in the community (i.e. public roadways), and reduce the need for additional impervious surfaces.

Educate the Public and Industry Regarding the Use of Copper / Zinc Roofing Materials and Galvanized Materials

The City should educate the public and industry regarding the negative impacts of using galvanized materials and roofing containing copper granules or zinc strips. This could easily be done through the brochure discussed in Section 12.1.1. These materials leach and contribute to water quality concerns in the watershed (copper granules and zinc are used in roofing materials to prevent the growth of moss). Elevated levels of copper and zinc were measured in the ISMP water quality program. The education program should encourage homeowners to manually remove moss instead of using roofing materials containing copper granules or zinc strips (pesticide use would not be recommended given the related environmental concerns). The education program should also encourage industry to minimize the use of galvanized materials where possible.

Update the Operation and Maintenance Program to Include Stormwater and Environmental BMPs

The City's current operation and maintenance program does not include procedures for maintaining some of the stormwater and environmental BMPs outlined in the ISMP. Therefore, we recommend that the program be updated to reflect these BMPs. The program should outline the frequency of inspection as well as provide instructions on long-term maintenance and upkeep of BMP components. Additional training of City staff will likely be required.

12.5.2 Zone 1

Aside from the watershed level initiatives discussed above, there are no other regulations or policies that could be implemented which are unique to Zone 1.

12.5.3 Zone 2

Aside from the watershed level initiatives discussed above, there are no other regulations or policies that could be implemented which are unique to Zone 2.

12.5.4 Zone 1A / 2A

Aside from adopting a Stormwater Drainage Regulation and Charges Bylaw to address water quality issues related to commercial and industrial development in Zones 1A and 2A (Section 12.5.1), the City could also consider the following:

Ensure City-owned Parcel Preserves Significant Greenspace

The existing City-owned property in Zone 1A at 13720 70 Ave (70 Avenue and 138 Street) is currently zoned for industrial use. The terrestrial investigation conducted for the ISMP noted that this site presently contains deciduous forest with minimal amounts of conifers and a well developed, dense understory. This forest provides good habitat for songbirds and small mammals, and is the last remaining large parcel of natural habitat in Zones 1A or 2A. Thus, conservation and protection of natural greenspace within this parcel in the context of future development would benefit the watershed.

As the property is already owned by the City, land acquisition to preserve portions of this parcel is not required. This parcel currently falls within the Light Impact Industrial Zone, but we understand that the site is designated for Multiple Residential uses in the Official Community Plan. The Newton Town Centre Study identifies this parcel for future multi-family development and includes a stormwater detention facility (as discussed in Section 12.1.2) and surrounding park space (or a suitable alternative) as a central focal point. The City should continue to support the development of a central focal point, but should ensure that this focal point preserves significant areas of natural greenspace for the benefit of the watershed.

12.5.5 Zone 3

Amend Subdivision and Development Bylaw to Require BMPs

As Zone 3 has yet to be fully developed, the City has an opportunity to require stormwater BMPs through its Subdivision and Development Bylaw. The City could amend the Subdivision and Development Bylaw to set new standards for future development in Zone 3 (the application of these new standards need not be limited to only Zone 3, but could be applied City-wide if desired). We recommend that the City consider an amendment to its Subdivision and Development Bylaw to require the use of stormwater BMPs to meet the performance targets outlined in Section 12.1.1 and 12.1.5. The bylaw amendment could also require a reduction in minimum pavement width on road ROW's.

Given that the South Newton NCP currently calls for the installation of a conventional stormwater management system, an amendment to the NCP may be required to implement the suggested changes to the Subdivision and Development Bylaw.

The City may also consider allowing developers to forego certain works and servicing requirements if they install on-site BMPs. For example, the City may consider permitting developers to install rain gardens instead of requiring landscaped medians. This arrangement would give the developers flexibility and, depending on the trade-offs permitted, an incentive to install on-site BMPs.

12.5.6 Zone 4

Continue to Support ALR Designation

Zone 4 has limited future development potential, as most of the zone is within the Agricultural Land Reserve (ALR), with the exception of the extreme northern portion of this Zone which falls within the East Newton Business Park Neighbourhood Concept Plan. As described in Section 12.5.5, the City could amend its Subdivision and Development Bylaw to require the use of stormwater BMPs within the business park portion of Zone 4.

The City's continued support of the ALR designation and the agricultural community will further stormwater management and environmental protection objectives.

13.0 PRIORITIZATION OF RECOMMENDATIONS

All of the recommendations discussed in Section 12 for the Hyland Creek watershed are summarized and prioritized in Table 13.1.

Priority levels were assigned to each recommendation based on the following:

Priority Level 1	The recommendation will considerably improve the overall health of the Hyland Creek watershed by meeting one or more of the key objectives of the ISMP. The City should implement the recommendation within the next 3 to 5 years.
Priority Level 2	The recommendation will somewhat improve the overall health of the Hyland Creek watershed by partially meeting one or more objectives of the ISMP. The City should consider implementing the recommendation within the next 5 to 10 years.
Priority Level 3	The recommendation will have a limited affect on the overall health of the Hyland Creek watershed. The City should consider implementing the recommendation over the next 10 years or longer.

Table 13.1
Hyland Creek Watershed Recommended Works

Recommendation	Zone	Section Reference	Priority Level 1	2	3
Construct 3 new municipal detention facilities in Zones 1 / 1A	1 / 1A	10.2, 12.1.2	♦		
Retain flow monitoring station on Archibald Creek and use data to evaluate BMPs and seasonal base flow levels	3	12.1.5	♦		
Adopt performance targets for new, infill and redevelopment areas	All	12.1.1	♦		
Adopt additional performance targets for Zone 3	3	12.1.5	♦		
Undertake pilot projects in the watershed	All	12.1.1	♦		
Establish adequate riparian setbacks on Archibald Creek and 144 Street tributary	3	12.2.1, 12.2.5	♦		
Continue water quality monitoring and benthic invertebrate sampling programs (3 sites) and add 4th site on the north branch of Hyland Creek	All	12.2.1	♦		
Continue practice of requiring riparian areas to be fenced for new developments	All	12.3.1	♦		
Require new developments to investigate potential of small-scale stormwater infiltration as part of achieving on-lot performance targets	3	12.4.5	♦		
Implement Erosion and Sediment Control bylaw to land development and City capital works projects	All	12.5.1	♦		
Finalize and adopt the Stormwater Drainage Regulation and Charges bylaw	All	12.5.1	♦		
Revise taxation schedule for the Drainage Parcel Tax to reflect impacts of different land uses	All	12.5.1	♦		
Designate Zone 3 as a "Unique Area" in the City's Design Criteria Manual	3	12.1.5	♦		
Update Subdivision and Development Bylaw to enforce Zone 3 EIA / TIA requirements under "Unique Area" Designation	3	12.1.5	♦		
Update Design Criteria Manual to require disconnected roof leaders for all land uses	All	12.1.1	♦		
Undertake erosion remediation works at high risk site on the north branch of Hyland Creek	2	11.4, 12.1.3		♦	
Retrofit or remove existing municipal detention facilities	1, 2	10.1, 11.2, 12.1.1		♦	
Construct new municipal detention facilities in Zone 3 at locations shown in South Newton NCP; size facilities to achieve ISMP performance targets	3	11.3, 12.1.5		♦	
Upgrade culvert crossing on Hyland Creek at 148 Street and raise road profile	2A	11.1, 12.1.1		♦	
Remove or upgrade 600mmØ interim culvert in 66 Avenue ditch	2A	10.3, 11.1, 12.1.1		♦	
Develop and implement a public education program for residents, commercial businesses, industrial operations, developers, and builders	All	12.1.1		♦	

Recommendation	Zone	Section Reference	Priority Level		
			1	2	3
Prepare a brochure for developers, builders and new home owners in Zone 3 on how to install and maintain stormwater and environmental BMPs	3	12.1.1		♦	
Continue to work with local schools, SHARP and SNAP on planting, cleanup and in-stream activities	All	12.1.1		♦	
Initiate a developer recognition award for developers who demonstrate a commitment to achieving stormwater and environmental ISMP objectives	All	12.1.1		♦	
Support a designated site for developers to use for topsoil stockpiling and screening within the watershed	3	12.1.5		♦	
Establish and maintain wildlife migration corridor connections between the watershed and external areas	All	12.3.1		♦	
Adopt City policy of using native plants in passive park spaces, preservation/natural areas and green spaces	All	12.3.1		♦	
Monitor impacts of local seeps and springs on the northern slope of Zone 3 as BMPs are implemented	3	12.4.5		♦	
Ensure basements are properly designed and protected against high water table	All	12.4.1		♦	
Minimize alteration of natural surfaces during development	All	12.4.1		♦	
Require retention and planting of native vegetation for new, infill and redevelopment areas	All	12.5.1		♦	
Review opportunities to enhance existing park space to achieve stormwater and environmental objectives	All	12.5.1		♦	
Amend definition of "lot coverage" in Zoning bylaw to include driveways, patios and other impervious surfaces	All	12.5.1		♦	
Impose minimum topsoil regulations	All	12.5.1		♦	
Set maximum limits on amount of off-street parking that can be constructed of impervious materials	All	12.5.1		♦	
Implement a stormwater utility fee	All	12.5.1		♦	
Update operation and maintenance program to include stormwater and environmental BMPs	All	12.5.1		♦	
Continue to support ALR designation	4	12.3.6, 12.5.6		♦	
Continue to encourage the agricultural community to implement agricultural BMPs	4	12.1.6, 12.2.6			♦
Encourage the formation of a watershed stewardship group	All	12.1.1			♦
Undertake storm sewer upgrade projects listed in capital works program; coordinate with road improvement projects where applicable	All	11.1, 12.1.1			♦
Monitor and track medium and low risk erosion sites identified by 2006 Ravine Stability Assessment report	All	11.4			♦
Remove fish migration barriers at culvert crossings as part of road upgrade projects	All	12.2.1			♦
Continue to monitor beaver dams and partial debris jams, and assess risk of flooding	2, 2A, 4	12.2.1			♦
Remove yard waste barrier along tributary reach near 148 Street	2A	12.2.1			♦

Recommendation	Zone	Section Reference	Priority Level		
			1	2	3
Remove foreign objects (car, hydro pole) in creek near benthic monitoring site H2	2	12.2.3			♦
Conduct periodic cleanup campaigns at storm sewer outfalls to creek	1	12.2.2			♦
Encourage farming community to plant continuous corridor of native trees / shrubs along creek banks	4	12.2.6			♦
Retain sufficient green space in City-owned parcel in Newton Town Centre area	1A	12.5.4			♦
Amend Subdivision and Development bylaw to require use of stormwater and environmental BMPs to meet performance targets	3	12.5.5			♦
Lower development cost charges for developments that incorporate stormwater and environmental BMPs	All	12.5.1			♦

14.0 COST ESTIMATES

Cost estimates have been developed for the municipal capital works projects listed in Table 11.1. The revised cost estimates listed in the tables below are representative of a Class D cost estimate and include 5% for mobilization/demobilization, a 35% contingency, a 15% engineering allowance, a 10% administration allowance, and 6% GST. Details on the cost estimates can be found in Appendix H.

14.1 Storm Sewer Upgrades

Cost estimates were originally provided for some of the storm sewer upgrade works listed in the capital works program as part of drainage studies prepared by Dillon [2000] and UMA [1995], as well as for the South Newton NCP, prepared by the City of Surrey and Reid Crowther [1999]. As these projects will remain in the capital works program, the original cost estimates (listed in Table 14.1 below) were reduced to a base price (without contingencies or allowances) and a unit escalation factor was applied to arrive at an equivalent base price in June 2007 dollars. Allowances were then added, as outlined above, to obtain the revised cost estimate. Details on the unit escalation factors that were applied to each project are given in Appendix H.

Table 14.1 itemizes the costs associated with the storm sewer upgrades listed in the capital works program.

Table 14.1
Storm Sewer Upgrade Costs

ID	Project Name	Project Location	Report Reference	Original Cost Estimate	Revised Cost Estimate
3809	500m Pipe Upgrade	65A Ave: 130 – 132 St	Dillon [2000][1]	$3,000,000	$5,976,000
6238	1,200m Pipe Upgrade	68 Ave: 130 St – KG Hwy	Dillon [2000]		
6419	900m Pipe Upgrade	64 Ave: 130 – 134 St	Dillon [2000])		
7032	195m Pipe Upgrade	67A Ave: 133 – 134 St	Dillon [2000]		
6244	900mmØ Upgrade Existing Storm	68 Ave: 141 – 142 St	Dillon [2000]		
6032	Ditch on 66 Avenue	66 Ave: 145A – 147 St	USL [2007]	N/A	$10,000
6041	1200m – 600mmØ on 144 Street	144 St: 60 – 65 Ave	UMA [1995][2]	$300,000	$1,126,900
6247	Culvert Crossing Upgrade	Hyland Cr at 148 St	Dillon [2000]	$100,000	$199,200
10315	300m – 525mmØ New Storm Sewer	6165 – 6267 148 St	S. Newton NCP [1999][3]	$190,000	$535,300
10316	560m – 900mmØ New Trunk Sewer	63 Ave: 148 – 150 St	S. Newton NCP [1999]	$300,000	$845,200
				Total Cost for Storm Sewer Upgrades	**$ 8,692,600**

[1] The original cost estimates listed above for projects recommended by Dillon [2000] included a 15% contingency, 10% engineering allowance and 7% GST.

[2] The UMA [1995] drainage study only provided a per linear meter cost for storm sewer installation, and did not appear to account for other costs, such as pipe connections, bedding and backfill or surface restoration. Thus, a higher unit escalation factor was applied to this project to reflect these other costs.

[3] The South Newton NCP [1995] noted that all of the projects in the NCP were potentially 100% recoverable through Development Cost Charges (DCC) to the development community.

14.2 Existing Municipal Detention Facility Retrofits

The extent of the retrofits required for existing municipal detention facilities listed in the capital works program were previously outlined in Table 10.8. Table 14.2 below itemizes the costs associated with these retrofits. Appendix H provides a detailed breakdown of costs for the more complex retrofit works.

Table 14.2
Existing Municipal Detention Facility Retrofit Costs

ID	Project Name	Project Location	Cost Estimate
6221	Pond at 73 Ave	73 Ave: 128B St	$ 1,000
6224	Pond at 65 Ave	65 Ave – 130A St	$ 106,700
6226	Pond at 129A St	129A St – 66B Ave	$ 7,500
6227	Pond at 69 Ave: 135 St	69 Ave: 135 St	$ 1,000
6228	Pond at 135 St	135 St	$ 1,000
6234	Pond at 63A Ave	63A Ave: west of 131A St	$ 1,000
6235	Pond at 132A St	132A St – 61 Ave	$ 1,000
6256	Existing Dry Pond Upgrade	Greenbelt 67 Ave – 133 St	$ 382,400
6257	Existing Dry Pond Upgrade	Greenbelt 65 Ave – 133 St	$ 483,800
Total Cost for Municipal Detention Facility Retrofits			**$ 985,400**

Table 10.8 also highlighted existing municipal detention facilities that could be removed, based on the analysis conducted for the ISMP. Upon review of the available aerial photography, the total developable land area associated with these detention facilities is approximately 0.68 hectares. Based on the current land value provided by the City, the removal of these ponds could translate into approximately $ 1,262,300 if the land were sold for development, which could be used towards the capital works projects or other ISMP initiatives in the watershed. It is anticipated that a minor portion of these funds would be needed to decommission the existing detention facilities (e.g. to remove control structures, emergency overflows, etc).

14.3 New Municipal Detention Facilities

New municipal detention facilities have been recommended as part of the Dillon [2000] drainage study, South Newton NCP, and this ISMP. Unit escalation factors have been applied to costs from previous studies, as outlined in Appendix H. Table 14.3 itemizes the costs associated with new municipal detention facilities listed in the capital works program.

Table 14.3
New Municipal Detention Facility Costs

ID	Project Name	Project Location	Report Reference	Original Cost Estimate	Revised Cost Estimate
6242	Detention Pond P4A	140 St: 62 – 64 Ave	S. Newton [1] NCP [1999]	$ 939,000	$ 2,645,400
6036	Recharge Pond P4B	141 St: 62 Ave	S. Newton NCP [1999]		
6243	Detention Pond P1C	62 Ave: 138 – 140 St	S. Newton NCP [1999]	$ 1,046,700	$ 2,948,900
8565	Detention Pond P1B	138 St: 62 Ave	S. Newton NCP [1999]		
6022	Newton Town Centre Pond	138 St: 68 Ave	Dillon [2000][2]	$ 1,200,000	$ 2,281,400
N/A	Pond 1	134 St: 70B Ave	USL [2007][3]	N/A	$ 6,605,300
N/A	Pond 2	KG Hwy: 70A Ave	USL [2007] [3]	N/A	$ 6,284,700
Total Cost for New Municipal Detention Facilities					**$20,765,700**

[1] The South Newton NCP [1995] noted that all of the projects in the NCP were potentially 100% recoverable through Development Cost Charges (DCC) to the development community.

[2] The original cost estimate listed for the Newton Town Centre pond recommended by Dillon [2000] included City engineering costs, a 10% consultant payment allowance, tender estimate, a 15% contract contingency, test holes and legal survey, plus 6% overhead and 7% GST. The original cost estimate was reduced to a base price, then increased slightly to account for the revised storage volume determined by the ISMP analysis.

[3] The revised cost estimates for facilities recommended by this ISMP report include costs for land acquisition. See detailed cost estimate in Appendix H.

14.4 Erosion Remediation and Sediment Control

Table 14.4 itemizes the costs associated with the erosion remediation and sediment control devices listed in the capital works program.

Table 14.4
Erosion Remediation and Sediment Control Costs

ID	Project Name	Project Location	Report Reference	Original Cost Estimate	Revised Cost Estimate
N/A	Erosion Site HYLD-12	6702 – 138 St	Associated [2006]	$ 75,000	$ 148,000
10314	Sediment Device (2 Required)	6191 148 St	Pond 8 Review [2002]	$ 110,000	$ 247,900
10317	Sediment Device (2 Required)	6315 150 St	Pond 8 Review [2002]	$ 110,000	$ 247,900
Total Cost for Erosion Remediation and Sediment Control					**$ 643,800**

The total cost to complete all of the projects listed in the capital works program is $ 31,087,500 including all contingencies and GST. If all NCP related works (total value of $ 6,974,800) were 100% recoverable through DCC charges, and the additional $ 1,262,300 (from removing existing detention facilities and selling the land) was used to offset costs, the total cost to complete the projects listed in the capital works program could be reduced to $ 22,850,400.

Priority levels for works listed in the capital works program were previously summarized in Table 13.1. Based on these priority levels, the City should focus on implementing the capital works in the following order:

Table 14.5
Costs for Capital Works (by Priority Level)

Priority Level	Project	Costs
1	Pond 1, Pond 2 and Newton Town Centre Pond	$ 15,171,400
2	Erosion Site HYLD-12	$ 148,000
	Existing Detention Facility Retrofits	$ 985,400
	New Municipal Detention Facilities in Zone 3	$ 5,594,300
	66 Avenue Ditch – Culvert Upgrade	$ 10,000
	Culvert Upgrade (Hyland Creek at 148 Street)	$ 199,200
3	Remaining Storm Sewer Upgrades	$ 8,483,400
	Sediment Control Facilities	$ 495,800
	TOTAL	**$ 31,087,500**

15.0 IMPLEMENTATION, EVALUATION AND ADAPTATION

15.1 Long-Term Monitoring and Performance Evaluation

Long-term monitoring and evaluation of the performance of particular stormwater management recommendations is essential in verifying that the ISMP goals and objectives are being met with the proposed implementation strategy. This is particularly true for Zone 3 of the watershed where the majority of future development, and thus the greatest potential risk of watershed health degradation, is anticipated. However, performance evaluation should also extend to other zones in the watershed.

The City should conduct a detailed post-construction monitoring program for any pilot projects conducted in the watershed to quantify the benefits of these projects from peak flow, volume and water quality perspectives. Ideally, results from the monitoring program should be compared to a similar site in the watershed that uses conventional drainage techniques, or the City could establish a pre-construction monitoring program at the pilot project site if the project schedule allows. Comparing pre and post construction data will allow the City to quantify the benefits of stormwater BMPs, weigh the benefits against any increase in costs over a conventional design, and provide a sound rationale for requiring BMPs in other areas of the watershed.

The flow monitoring data from the Archibald Creek flow monitoring station should be reviewed as stormwater and environmental BMPs are implemented in Zone 3, to ensure that seasonal base flows to Archibald Creek are not being negatively impacted by development activities. Base flow trends, particularly during low flows in the summer, should be plotted and compared on a year-to-year basis. If the yearly trends indicate a similar pattern and distribution to historical flow data, then the City could conclude that the BMPs are operating as designed. However, if the data indicates that seasonal base flows are declining, or that the distribution pattern of flows has changed (e.g. lower summer flows, higher winter flows) then the types and function of the BMPs being implemented could be changed to mitigate this. Climate change should also be considered in this evaluation.

In existing developed areas, the City should rely on the water quality and benthic invertebrate sampling programs to evaluate the performance of ISMP recommendations. In particular, water quality results from site H3 (north branch of Hyland Creek) could be used to quantify the benefits of implementing the three new municipal detention facilities in Zones 1 and 1A from a water quality perspective (e.g. decrease in TSS levels). Further, both the water quality and benthic sampling programs could be used to evaluate the success of public education initiatives in the watershed, as discussed below.

15.2 Environmental Monitoring Program

The environmental monitoring program recommended for the Hyland Creek watershed incorporates the benthic invertebrate and water quality assessments described in Sections 6.3 and 8.0, respectively, and recommended in Section 12.2.1. These programs, particularly the benthic invertebrate monitoring, will assist in verifying the effectiveness of proposed drainage infrastructure, stormwater and environmental BMPs, and educational initiatives in protecting the aquatic resources of the watershed.

15.3 Financing Strategy

The City could recover capital costs associated with recommended works in the following ways:

- On-site works and services, and those works and services to be provided up to the centre line of the road fronting new development, could be provided directly by the developer as part of the works and services required under the Subdivision and Development Bylaw (provided that the bylaw is amended to require BMPs).
- For those items that cannot be classified as works and services under the Subdivision and Development Bylaw, capital costs could be recovered through:
    - *Rezoning* – the City could negotiate off-site works at the re-zoning stage
    - *Drainage parcel tax / stormwater utility fee* – the City could amend the drainage parcel tax or develop a stormwater utility fee (as discussed in Section 12.5.1) to account for these new costs
    - *Development Cost Charge Bylaw* – the City could update its DCC Bylaw to include new drainage projects
    - Other cost recovery tools – the City could also make use of other cost-recovery tools such as Local Service Taxes (in conjunction with long-term borrowing) and Development Works Agreements to recover costs. However, given that the City already has a drainage parcel tax in place, these additional tools may not be required.
- Operation and maintenance costs associated with new drainage infrastructure could be recovered through the drainage parcel tax.
- Revenue generated from the removal of existing municipal detention facilities (as listed in Table 10.8) and sale of the associated land could fund a variety of other ISMP initiatives.

We suggest that the Engineering Department work with the City's Finance Manager to determine how the disposition of land might be handled, and how the resulting funds might be allocated.

15.4 When Would an ISMP Update Be Required?

The GVRD ISMP template currently recommends that an ISMP be updated every 12 years, however, given the high development demand in the Hyland Creek watershed, an update may be required earlier if future watershed conditions significantly deviate from those assumed in this ISMP. An update to the Hyland Creek ISMP may be required if one or more of the following conditions occur:

- The City's OCP, Zoning bylaw, or a local NCP is amended to significantly change future land uses and/or densities, to allow significant infill and densification in existing developed areas, or to permit encroachment into green space and riparian areas;
- The City undertakes extensive updates to their Parks and Recreation Master Plan;
- Flow data for Archibald Creek indicates a decrease in base flows despite the implementation of stormwater and environmental BMPs in the watershed; or
- Water quality and benthic invertebrate monitoring programs show continued stress and degradation in Hyland Creek and Archibald Creek despite the implementation of ISMP recommendations.

15.5 Future Work

15.5.1 Audit of Regulatory Tools

To implement the recommendations of this and any other ISMP, the City will require a comprehensive understanding of its regulatory powers pertaining to stormwater management and environmental protection. The GVRD ISMP Template provides a framework for developing ISMPs, but does not specifically include implementation details (the GVRD ISMP Template does reference the Options for Municipal Stormwater Management Report completed in 1997, which investigates regulatory options; however this report has not been updated to reflect current practices and legislation). To fill this gap, we recommend that the City:

1. Develop an inventory of relevant powers under the *Local Government Act* and *Community Charter*.

   This ISMP describes various powers available to the City, but should not be considered to be a comprehensive summary of all of the regulatory powers available. A full inventory of all of the powers would help the City identify further opportunities for meeting stormwater management and environmental objectives. The outcome of this step could be a master table that lists each available regulatory tool, the issues that can be addressed by each tool, and the advantages and disadvantages of each tool.

2. Conduct an audit of the City's current regulations.

   The City should also consider conducting a more thorough audit of its current regulations (i.e. bylaws and policies) to identify any regulatory gaps. A "report card" could be developed to show how well City policies align with stormwater management and environmental objectives. The City could then consider addressing any policy gaps by referencing the inventory of regulatory powers from Step # 1 above to choose the most appropriate regulatory tool.

The completion of the inventory and audit would result in efficiencies for the City. As subsequent ISMPs are completed, the City would be able to reference the inventory and audit to quickly identify policy gaps, and choose appropriate regulatory tools to address the gaps.

15.5.2 Development of a Decision-Making Framework

The Hyland Creek ISMP document outlines various recommendations that the City could implement to improve stormwater management, aquatic habitat, and wildlife and terrestrial habitat in the Hyland Creek watershed. While the introduction of all of these measures would be optimal from a watershed health perspective, it is recognized that the City operates within a number of policy constraints that may limit the City's ability to implement the full set of recommendations. Therefore, the City will need to prioritize and choose among the various policy recommendations outlined previously. Unlike the design of a detention facility or culvert, deciding among these types of policy recommendations is not a technical exercise; rather, these decisions are highly subjective as they are based on objectives and values.

A decision-making framework would help ensure that the technical information gathered through an ISMP is presented in a form that can be used by decision-makers (i.e. Council) in the decision-making process. The decision-making framework would provide Council and Staff with a relatively straightforward and defensible way of making decisions based on ISMP findings. Once developed, the decision-making framework could be applied to all subsequent ISMPs in the City.

To enable the City to make well-informed and reasoned decisions, we recommend that the City establish a decision-making framework. The development of a decision-making framework would involve:

- Problem definition based on the ISMP
- A visioning session with Council to identify the City's long and short-term economic, environmental, and social objectives related to the watershed (i.e. more fully develop the objectives outlined in the Request for Proposals)
- Characterizing trade-offs among objectives
- Evaluating each recommendation with respect to the City's objectives – this would entail completing assessments of the costs and benefits associated with each of the suggested regulatory changes (a multiple account evaluation approach could be used to promote transparency and understanding of tradeoffs)
- Prioritizing recommendations based on the evaluation
- Developing a timeline for introducing identified recommendations

APPENDIX A

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APPENDIX B

WATER QUALITY ANALYSIS RESULTS

(In Electronic Version on CD-ROM only)

APPENDIX C

HYDROGEOLOGICAL ASSESSMENT

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APPENDIX D

MAR AND BASE FLOW CALCULATIONS

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APPENDIX E

HYDROLOGIC / HYDRAULIC MODELING RESULTS

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DRAINAGE COMPLAINT SUMMARY

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PROJECT DEFINITION REPORTS FOR CAPITAL WORKS

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COST ESTIMATES

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APPENDIX I

STORMWATER BEST MANAGEMENT PRACTICES RESEARCH

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APPENDIX J

LIST OF PLANTS (COMMON AND SCIENTIFIC NAMES)

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APPENDIX K

PHOTO INVENTORY

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APPENDIX L

HYLAND CREEK ISMP TERMS OF REFERENCE

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