Retrofitting Suburbia in an Urban Watershed: Sustainable Growth in the Beecher Creek Subbasin

by

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ABSTRACT

It is estimated that 3.3 million people will inhabit the Vancouver Region within the next 25 years. Traditionally, constructing low-density suburbs well into the Fraser Valley was the method to accommodate this regional growth. However, the detrimental impacts of urban sprawl are now well documented and are having an impact on how Vancouver envisions the growth boundary. Traffic congestion, auto dependency, and long commutes from isolated suburbs are the noticeable effects of sprawl for many people living in the Lower Mainland yet another important impact is the threatened local and regional ecosystems. Urban sprawl is consuming arable land and endangering the natural ecosystems.

In response to these social and ecological problems, the Greater Vancouver Regional District has developed the Livable Region Strategic Plan which intends to manage growth through the promotion of more compact communities, to increase transportation choice, and to protect the green zone within the GVRD's twenty municipalities. Instead of building upon unused and undeveloped land outside the metropolitan areas, the plan looks for opportunities within existing communities. The goal is to alleviate sprawl on a regional scale and maintain the ecological integrity of the hinterlands. However, how can the intensification within the growth concentration areas be managed to maintain the integrity of our urban ecosystems?

The Beecher Creek subbasin is a typical example of a highly urbanized watershed within the Burnaby growth concentration area. The upper two-thirds of the watershed is mainly single family residential. This area has the potential to accommodate the current high demand for ground oriented, low cost housing in the region. However, measures must be taken to mitigate the impacts that increased density will have on the watershed and the community.

This thesis examines a sustainable growth strategy for the region using a watershed approach and is based on sensitive infill practices, Best Management Practices (BMP's) and sustainable design. The result is the Beecher Creek Urban Watershed Retrofit Plan. The watershed components such as the block, dwelling unit, yard, lane, street, cul de sac, driveway, sidewalk, open space and stream corridors are examined and retro-fitted to accommodate density while improving the ecological, social and experiential functioning of the whole. Retrofitting is the term used to describe "the process where communities incrementally add or alter the built environment to accommodate the needs that are shaped by changing social and economic realities" (Lee 1999, 12). Each component speaks to a denser, greener more livable watershed.

The result is a comprehensive design of a retro-fitted Neighbourhood that has accommodated density while also improving the ecological, social and experiential function of the site. The design addresses the relationship of the site to its watershed context and its surrounding community. As a comprehensive document it also serves as a model for similar urban residential watersheds.
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1.0 INTRODUCTION

It is estimated that 3.3 million people will inhabit the Vancouver Region within the next 25 years. Traditionally, constructing low-density suburbs well into the Fraser Valley was the method to accommodate this regional growth. However, the detrimental impacts of urban sprawl are now well documented and are having an impact on how Vancouver envisions the growth boundary. Traffic congestion, auto dependency, and long commutes from isolated suburbs are the noticeable effects of sprawl for many people living in the Lower Mainland yet another important impact are the threatened local and regional ecosystems. Urban sprawl is consuming arable land and endangering the natural ecosystems in our region.

In response to these social and ecological problems, the Greater Vancouver Regional District (GVRD) has developed the Livable Region Strategic Plan which intends to manage growth through the promotion of more compact communities, to increase transportation choice, and to protect the green zone within the GVRD's twenty municipalities. Instead of building upon unused and undeveloped land outside the metropolitan areas, the plan looks for opportunities within existing communities. The goal is to alleviate sprawl on a regional scale and maintain the ecological integrity of the hinterlands. However, how can the intensification within the growth concentration areas be managed to maintain the integrity of our urban ecosystems?

We must seek new ways of retrofitting neighbourhoods to accommodate our growing population and to restore and heal urban ecosystem functions. This thesis examines a sustainable growth strategy for the region from a watershed perspective and uses sustainable principles such as sensitive infill, pedestrian friendly streets, land use mix, and a healthy urban ecosystem. The result is the Beecher Creek Urban Watershed Retrofit Plan. The watershed components such as the block, dwelling unit, yard, lane, street, cul de sac, driveway, sidewalk, open space and stream corridors are examined and retro-fitted to accommodate density while improving the ecological, social and experiential functioning of the whole. Each component speaks to a denser, greener more livable watershed.

The Beecher Creek subbasin is a typical example of a highly urbanized watershed within the Burnaby growth concentration area. The upper two-thirds of the watershed is mainly single family residential with few Neighbourhood amenities. This area has the potential to accommodate the current high demand for ground oriented, low cost housing in the region. However, measures must be taken to mitigate the impacts that increased density will have on the watershed and the community.

Sensitive infill is one approach to accommodate density in a fine grained, incremental way that allows the retention of existing homes and favours a more considerate response to place (Murphy 1994). The Beecher Creek Retrofit Plan explores various dwelling and lot types that fit into the single family Neighbourhood character and that encourage social diversity within a single community.
The Retrofit Plan also provides greener, narrower, pedestrian friendly streets to promote social interaction and safe walkable environments. Narrowing the width of the streets in the watershed will allow the remaining land to be given over to more functional purposes. Streets are a readily available and often neglected resource that can be reclaimed to increase the permeability, enhance wildlife habitat and enrich the social interactions between blocks. In addition, as the density of the watershed increases streets could become wildlife corridors, recreational spaces and provide an important social milieu.

Watersheds are an important part of the hydrological system. Watersheds capture precipitation, filter and store the water and then release it into lakes, streams, estuaries and oceans. Preserving the natural environment and promoting natural drainage systems within an urban watershed can mitigate the impacts of density on the watershed, the community and the region. The Beecher Creek Retrofit Plan uses the natural topographic feature of the watershed boundary to provide a natural edge to the community and a shared resource within the community. A watershed approach is an ecological system perspective that can be used to measure and monitor change and specifically what affects the changes (Brown et al. 1997). It is also an integrative strategy that can be used to explore the interactions between the users, stakeholders, land and water efficiently (Ibid.). In addition, it is easier to understand processes, interrelationships, thresholds and system responses within the natural boundary of the watershed (Ibid.). The watershed is also a natural unit to base landscape history and allows us to develop possible future scenarios (Ibid.).

In addition, identified indicators can be used to determine the ecosystem health for given set of land use activities and allows us to set limits on the rates of changes that are desirable and tolerable. In an urban watershed the land use is highly correlated to the health of the watershed. Human activities and infrastructure have a negative impact on urban watersheds by altering the chemistry, hydrology and geometry of the water system and by decreasing the riparian habitat (Zandbergen 1998). The health of urban watersheds has been closely linked to seven indicators including imperviousness, riparian forest cover, pollutant loading, water quality, sediment quality, fish health, and public health (Ibid.). From these seven measures, imperviousness and riparian forest cover are found to be the most effective to illustrate the general physical state of a watershed (Ibid.). In fact, the GVS&DD classification of watershed health is based on the percentage of the watershed area covered by impervious surfaces and the percentage of a 30-metre wide riparian strip on both stream banks in forested land cover. A riparian forest cover/imperviousness analysis will be conducted to measure the ability of sensitive infill, Best Management Practice’s (structural and non-structural strategies that are used to restore the natural hydrological regime) and sustainable principles to create a healthier urban watershed. In addition, a functional element analysis will be performed on the residential block to illustrate in detail how the individual site contributes to the health of the whole watershed.
The Beecher Creek Retro-fit Plan seeks to illustrate the potential of a more compact community within a healthier urban ecosystem thus providing an example of a more environmentally sensitive way of managing growth within our cities. The emergence of healthy urban ecosystems can take the pressure off our regional resources and thus reduce our ecological footprint (Rees 1992).
1.1 Statement of Intent

I propose that it is possible to retrofit the Beecher Creek subbasin to accommodate growth while enhancing the ecological functioning of the watershed.

2.0 RATIONALE FOR THE STUDY

The rationale for altering the existing form of the Beecher Creek neighbourhood to accommodate growth with the intention of improving the health of the watershed is based on the following issues:

Accommodating Growth:
- Burnaby as a growth concentration area was expected to accommodate 119,600 housing units by 2021 according to the regional plan however the City's official community plan states that only 77,700 dwelling units will be built by 2021, thus there is a deficit of 42,000 units (Tomalty 1997, 55)
- The GVRD estimates that land suitable for single family housing will be exhausted in 15yrs thus there is a limited supply of land (Tomalty 1997, 33)
- The land along Lougheed Highway in Burnaby will be intensified as a rapid transit corridor (Tomalty 1997, 48)

Environment:
- Concern over the loss of habitat and of recreational and conservation areas including the Agricultural Land Reserve (ALR)
- Motor vehicles are the largest source of air pollution in the region (Tomalty 1997)
- Poor quality of local urban ecosystems that have been degraded by infrastructure and human activities
- Between 1985 and 1992 the trip distances increased by 12%, trip time by 20%, and proportion of trips on transit fell by 11% (GVRD 1993)
- The pollutant loadings in the Brunette water system are the result of non point source pollution (Brown et al. 1997)
- The overall degree of imperviousness is high in the Brunette watershed and therefore poses a problem for maintaining and enhancing stream health (Brown et al. 1997)
- Urban infrastructure in the Brunette watershed has contributed to the loss of 40% of the original stream networks and consequently riparian corridors (Brown et al. 1997)

Economic:
- Low density development is a fiscal stress that consumes up to 18% of the property tax towards growth related services such as water, sewage and roads (Tomalty 1997, 32)
- Employment in the periphery municipalities has increased by 30-50% having a major influence on regional travel behavior (Tomalty 1997, 33)
• High land prices in the Region (Tomalty 1997, 33)

Social:
• Commuting time has increased and air quality is deteriorating (Tomalty 1997, 33)
• A mismatch of housing needs and housing supply (Tomalty 1997, 33)
• Social structure is moving toward an increase in the aging population, youth and lower income residents (Tomalty 1997, 33)
• In 1989 only 17% of Canadian households were considered to be traditional families (CMHC 1991, 9)
• The fastest growing household are single parent families and non-family households, consequently, the average household size is expected to declined from 2.6 in 1991 to 2.4 in 2021 and the demand for smaller units will increase (Tomalty 1997, 34)
• Housing costs have risen more than real income (Tomalty 1997, 34)

In response to these issues and trends, intensification is a feasible and rational response to provide affordable housing and to mitigate the impacts of urban sprawl. It is also important to consider the impacts of increased density on existing communities and to integrate intensification with the restoration of urban ecosystems.

3.0 PROJECT GOALS

The goal of the thesis is to demonstrate what the Beecher Creek Subbasin could look like if it were retrofitted in order to accommodate growth with the intention of increasing the ecological functioning of the urban watershed based on the following sustainable principles:

• conserve land and energy by designing compact walkable communities that provide services such as transit, shops, parks etc. within a five minute walking distance
• increase the density of the watershed through a wide range of lot and sensitive infill types
• provide greener, narrower, pedestrian friendly streets to promote social interaction and safe walkable environments
• preserve the natural environment and promote natural drainage systems

4.0 PROJECT OBJECTIVES

• To illustrate through design how sensitive infill, pedestrian friendly streets, land use mix and a restored natural drainage system can be integrated into an existing community to produce a more complete, compact community within a healthier urban ecosystem
• To illuminate the connection between sustainable design and liveability
• To quantify the design and determine if it is possible to increase the density and maintain (or enhance) the health of the watershed through an impervious/riparian forest cover analysis and functional element analysis

• To produce an urban watershed retrofit plan that may provide patterns, processes and prototypes for other growth concentration areas in the Greater Vancouver Regional District

5.0 METHODOLOGY

The research methodology primarily consists of a review of the literature on sensitive infill, Best Management Practices (BMP's), sustainability principles, urban watershed management and policies that support the goal of a more compact community within a healthier urban ecosystem.

A literature review was conducted of:

- current policy and zoning supporting sustainable development
- urban watershed management and urban watershed health indicators
- sustainable development principles and best management practices (BMP's)
- Intensification and sensitive infill development types
- past precedent

From the literature available case studies of sensitive infill strategies, BMP's and sustainable design were selected. The selected practices were applied to the Beecher Creek Sub watershed components including the individual lot, dwelling unit, block, street, lane, cul de sac, parks and stream corridor to produce design solutions that improve the health of the urban watershed.

An impervious/riparian forest cover analysis of the watershed was conducted before and after to determine if it is possible to increase the density and maintain (or enhance) the ecological health of the watershed. A functional element analysis was also performed on residential block types to determine the success of the retro-fit design to reduce imperviousness.

5.1 Impervious/Riparian Forest Cover Analysis

In order to improve the health of the urban watershed, indicators are required to establish benchmarks against which the impacts and our progress in reducing them can be assessed. This section will discuss the main issues of cumulative effects and specifically identify watershed indicators that can be used to examine the cumulative effects of non-point source pollution from urban land use activities.

Cumulative effects refer to a variety of pollutants that are released into a watershed from a variety of sources that are nebulous thus the term non-point source pollutants (Brown et al. 1997). Pollution concentrations can alter over time (e.g. seasonal variation in rainfall) and in space such as different slope variations and flow characteristics in stream reaches (Ibid.). Each pollutant added will have an uncertain
effect on the water system as a whole. Interactions that take place between pollutants will have either a synergistic or an antagonistic effect when they interact. Interaction between pollutants are also effected by water quality factors (alkalinity, pH, dissolved organic matter, hardness) and sediment quality (organic matter content, presence of iron and manganese oxides, particle size) (Ibid). These factors also play a part in determining how the pollutants will affect aquatic biota.

Watershed indicators are tools that can be measured to understand the cumulative effects of non-point source pollution caused by urban land use activities. Zandbergen (1998) states that indicators should encompass a comprehensive and integrated approach, balance between scientific complexity and the demand of management, conceptually relate to each other, provide some description of ecosystem health and provide direction for management. As well, different indicators are needed for different types of watersheds. There are many indicators that validate urban impacts on watersheds including: impervious areas, as a percentage of the total area; riparian habitat referring to the amount of forest cover in a 30m buffer zone around stream; pollutant loadings expressed in a land use type and intensity indicator (traffic density, urban land use, industrial/commercial land use and density of industrial operations); water quality, conditions expressed in a Water Quality Index based on exceedances of objectives; sediment quality, expressed in a Sediment Quality Index based on exceedances of sediment quality criteria; threats to public health based on the presence of bacterial contamination in surface waters; and fish health, as measured by total fish population, species composition and fish habitat (Ibid.).

However, several studies have proved that due to their quantitative and integrative character the two most comprehensive indicators of watershed health are impervious surfaces and the riparian forest cover. High permeability and substantial riparian forest cover are inclusive for a healthy urban stream. Even a large buffer cannot mitigate the effects of urban runoff if a watershed has a high degree of imperviousness. This thesis will use the physical indicators of imperviousness and riparian forest cover to compare existing conditions and the proposed retrofit design on a landscape level planning scale. The initial assessment will help to focus stream conservation and restoration efforts and will also illustrate impervious components of the watershed that can be reduced. The final analysis intends to illustrate and support the chosen strategies for the retrofit design.

### 5.1.1 Imperviousness Indicator

Imperviousness refers to the ratio of area on a developed parcel that prevents infiltration into the soil including paved roads, parking lots, driveways, rooftops, sidewalks, patios and compacted soil. This indicator is most accurate when the impervious area directly draining into the stormwater system or into the streams (referred to as effective impervious area) is measured to illustrate the impact of urbanization (Zandbergen 1998). The United States Environmental Protection Agency (1998) states that:
Studies have linked the amount of imperviousness to changes in the hydrology, habitat structure, water quality and biodiversity of aquatic ecosystems. Increased imperviousness can change the hydrology of a receiving stream, increasing runoff volume and rate and decreasing the receiving streams capacity to handle floods.

In the Brunette River Watershed imperviousness was "positively correlated with Cu and Pb in sediments, and conductivity and fecal coliform counts in streamwater" proving that it is an integrative indicator of watershed health (Zandbergen 1998). In addition, a threshold between 5 and 15% imperviousness has been identified. Below this threshold watershed impacts are relatively minor or not measurable, while higher imperviousness is linked to poor watershed health.

5.1.2 Riparian Forest Cover Indicator

Riparian forest cover is another key indicator of cumulative effects from non-point source pollution from urban land use activities due to its quantitative and integrative character. The riparian forest around streams provide: erosion control; pollutant removal; large organic debris recruitment; microclimate modification and wildlife diversity and distribution. However, the standard 30m buffer often used in urban watershed development guidelines and municipal bylaws is insufficient to perform these functions (Zandbergen 1998). Furthermore, the ability of the buffer to achieve the aforementioned benefits relies on the quality, including the complexity and structure, of the forest cover (Ibid.).

Impervious area and riparian forest cover are quantitative, integrative and easily derived using digital ortho-photos in combination with ArcView GIS (Zandbergen 1998). Once the percentage of imperviousness and riparian forest cover have been calculated the watershed can be rated on the riparian forest cover/imperviousness graph. The graph classifies watershed health in 5 categories from excellent to very poor. This classification can be used to quantify the success of the retro-fit design at a landscape level and to determine if it is possible to increase the density and maintain (or enhance) the health of the watershed.

5.2 Functional Element Analysis

On a site specific scale a functional element analysis can be used to identify in detail the contribution of the various components of the watershed to the total imperviousness. In the mainly residential Beecher Creek Watershed the functional elements include: streets, sidewalks, parking and driveways, roofs and lawns, landscaping and open space.

In this study, the functional element analysis is used to compare the existing block patterns to the retro-fitted block design to illustrate the possibility of increasing density and decreasing imperviousness.
One block was identified that is representative of the various forms of residential development present in the watershed. The functional elements were mapped and analyzed using a digital orthophoto and AutoCAD.

6.0 INTENDED OUTCOME

The intended outcome of this thesis is a design that illustrates how the ecological health of the urban watershed is dependent on the health of its individual elements including the: individual lot, dwelling, street, lane, cul de sac, parks and stream corridors. The design intends to show how these elements can be retrofitted to accommodate density, green street systems, walkable and interconnected neighbourhoods, greener infrastructure and natural drainage systems. The synthesis of the retro-fitted elements will result in a comprehensive design that has accommodated density and enhanced the ecological functioning of the watershed. As a comprehensive document it will also serve as a model for similar residential sites in the Greater Vancouver Regional District growth concentration areas.

7.0 SITE CONTEXT

The project site is the suburban area within the Beecher Creek Subbasin of the Brunette watershed, located in Burnaby, BC.

7.1 Burnaby

7.1.1 Setting

Burnaby has a population of 179,209 making it the third most populated urban centre in British Columbia. It covers 93 square kilometres on the Burrard Peninsula and is the geographic centre of the Greater Vancouver Regional District (GVRD). Burnaby, along with several other municipalities on the Burrard Peninsula, is identified as a growth concentration area that will accommodate the largest share of the region’s projected growth over the next twenty-five years (Liveable Region Strategic Plan). The city occupies approximately 4 percent of the land area of the GVRD yet accommodates 10 percent of the Region’s population thus it has approximately three times the average density of the metropolitan region as a whole (Burnaby OCP 1998).

7.1.2 Physiography

Burnaby has an interesting physical landscape of ridges, hills, valleys and an alluvial plain that influence the city form. Three watersheds are located within Burnaby. The Burrard Inlet Watershed and its fourteen creeks drain into the Burrard Inlet and occupy the steep northern slopes of Burnaby Mountain and Capitol Hill. The study area is located within the Central Valley Watershed or the Brunette Watershed and is
situated between Hastings and Kingsway Ridges. The watershed includes the southern slopes of Burnaby Mountain, Burnaby Lake, Deer Lake, Still Creek and the Brunette River, which drain into the Fraser River. The 10 creeks of the Fraser River Watershed flow down the southern slopes of Burnaby in deep ravines that are protected as conservation parks.

7.1.3 Growth

The GVRD has identified Burnaby as a Growth Concentration Area, currently approximately 175,000 people live in this watershed and over the next 25 years it will accommodate the largest share of the regions projected population growth (Burnaby OCP 1998). The residential goals outlined in the OCP are:

- To provide a varied range and choice of living opportunities within the City
- To establish increased opportunities for ground oriented housing
- To maintain and improve Neighbourhood liveability and stability

One of the City's directions to achieve the goals is to "amend zoning bylaw regulations in single and two family residential areas to better reflect contemporary and changing standards" (Ibid).

Single and two family residential neighbourhoods occupy the largest land use of any category of Burnaby's developed land area comprising 49.7 in 1996 (Burnaby OCP 1998). Single family suburban generally have R1, R2, and R3 zoning but have recently been associated with R10 and R11 rezoning which allow for "low-scale forms of development in mature single family areas consistent with the Neighbourhood character" (Ibid.). Single and two family urban areas have R4 and R5 zoning and provide for the development of single family dwellings, duplexes, and semi-detached family dwellings depending on lot size (Ibid.).

Between the years 1996 and 2021 the City of Burnaby is expected to absorb 80,791 to 110,791 people (Burnaby OCP 1998). The average population density of Burnaby is increasing from 8.3 persons per acre to approximately 12.4 persons per acre in 2021 (Ibid.). To accommodate this increase an additional 16,400 units will be developed between 1996 and 2006 (Ibid.). Out of the 16,400 units 12,850 will be new ground oriented units and 4000 will be located within the single family suburban and single and two family urban Neighbourhood areas (Ibid.).

7.1.4 Directions and Policies

The City has recognised that an "appropriate relationship between the built environment and air, land and water will need to be considered" (Burnaby OCP 1998). Towards this goal the city council approved an integrated stormwater management approach to watershed management issues in 1996. Initiatives to achieve this include undertaking planning from a watershed and ecosystem perspective, adoption of the
Burnaby Watercourse Bylaw which focuses on reducing contamination of storm water and local waterways, and the adoption of an Open Creeks and Watercourse Policy. Ecological infrastructure is part of a strategy to restore the health of watershed and is included in the following Burnaby initiatives: "the urban trial program; the State of the Environment Report for Burnaby (SOER); the establishment of design guidelines for Environmentally Sensitive Areas (ESA's); the Parks and Recreation Master Plan (City of Burnaby 1998); the Local Improvement Program; and land management tools including land swapping and density bonus incentives, comprehensive development zones and ongoing public acquisition of all significant stream corridors" (Golden 1999, 80). Burnaby City also intends to: incorporate environmental issues as part of the assessment of growth management options and land use plans; preserve and enhance ecological systems within the city; encourage stewardship; and provide, maintain and protect a comprehensive mix of park and open space (Burnaby OCP 1998).

7.1.5 Town and Village Centres

One of the proposed Town Centres in the Liveable Region Strategic Plan is Burnaby's Brentwood Town Centre. The development plan for the area proposes the addition of approximately 9300 new dwelling units and over a million square feet of new office and commercial space. In addition a new transit system is anticipated to support the intensification of the area and to provide alternative transportation to the conventional auto travel. The centre will provide thousands of nearby residents with jobs and services. The site is also recognised as one of the most polluted subbasins in the Brunette River Watershed.

The Brentwood District of Burnaby was the focus of the UBC sponsored charrette focusing on sustainable urban landscapes. The Brentwood Town Centre site was selected due to the "supportive political climate, a well developed policy framework, and the presence of diverse physical and socio-cultural landscape characteristics common to many other communities in British Columbia and beyond, ensuring the solutions are transferable" (Condon and Proft 1999, 10). The charrette produced four redevelopment plans illustrating what the Brentwood Town Centre could look like if it were designed to "accommodate the projected housing demand and commercial capacity in such a way to establish transit oriented, identifiable neighbourhoods while maintaining (or potentially enhancing) existing ecological systems" (Condon and Proft 1999, 11). The concept plans transformed the 590-acre medium-density, first ring, suburban commercial strip landscape into a sustainable community that provided 9,300 new dwelling units accommodating 16,500 persons. The designs also provided light rail along the Broadway/Lougheed corridor and the placement of a major transit node as well as connectors via other modes of transportation to the light rail node. Furthermore, the restoration of the Still Creek corridor was a major focus in all four of the design concepts. The goal was to establish BMP's to reduce the water contamination and to mitigate the impacts of urbanization on the stream corridor ecology. All of the Charrette performance objectives were based on emerging local, provincial and federal policies that support the goal of sustainable neighbourhoods and communities.
The possibility of sustainable redevelopment of the Brentwood town centre provided the impetus for this thesis which looks at the possibility of retrofitting the suburban land within the Beecher Creek subbasin (just to the north of the Proposed Town Centre) to accommodate growth while maintaining (or potentially enhancing) the health of the subbasin. The retrofitted suburb would be placed in a sustainable context within proximity to jobs and services and rapid transit.

In addition to the Brentwood Town Centre the Burnaby OCP indicates two village centres and one Service Commercial Centre just outside of the study area. The Hastings/Holdom village centre, Holdom/Lougheed Station Area Village Centre and the Hastings Service Commercial Area. These areas are intended to “provide a focal point for convenient, close to home access to commercial facilities and services that can meet the day to day shopping needs of surrounding residential Neighbourhood areas” (Burnaby OCP 1998, 5).

7.2 The Brunette Watershed

The site was chosen within the Brunette Watershed due to: the wealth of existing information and ongoing studies monitoring the watershed health; the interest of Burnaby City to achieve a zero net increase in stormwater run-off and the existence of a Brunette Basin Watershed Management Plan (Burnaby OCP 1998).

The Brunette Watershed is a 72 square kilometre highly urban drainage area where most of the natural systems have been replaced by development or lost to underground infrastructure. Stormwater runoff from heavy traffic, dense residential areas and road networks containing lead, copper, mercury, grease, oil and other contaminants drain into Deer Lake, Burnaby Lake, the Brunette River and then into the Fraser River resulting in significant disturbances of the water resource. These pollutants have a harmful
effect on habitat for coho salmon and cutthroat trout and over 200 species of birds and 23 species of mammals (BBTG 1998).

7.2.1 The Westwater Research Centre

The Westwater Research Centre at the University of British Columbia has been collecting data on the Brunette River watershed since the 1970s. It includes extensive monitoring of water quality, sediment quality and biota, and analysis of land use changes with a Geographic Information System. Zandbergen (1998) has further developed an assessment methodology to link watershed health indicators to management in urban watersheds. The assessment consists of a set of key watershed indicators, which can be used for developing watershed management plans.

The major findings to date indicate: the pollutant loadings into the water system are the result of non point source pollution; the overall degree of imperviousness is high and therefore poses a problem for maintaining and enhancing stream health; and urban infrastructure has contributed to the loss of 40% of the original stream network and consequently riparian corridors. As explained in the methodology, this thesis uses the imperviousness/riparian forest cover analysis to measure the success of the retro-fit design.

7.2.2 Brunette Watershed Management Plan

The Brunette Basin Task Group (BBTG) is developing and implementing a watershed management plan for the watershed. The BBTG is spearheaded by the Greater Vancouver Regional District (GVRD) and consists of representatives of the City of Burnaby, City of Vancouver, City of Coquitlam, City of New Westminster, the BC Ministry of Environment Lands and Parks (BCMOELP), the Department of Fisheries and Oceans (DFO), British Columbia Institute of Technology (BCIT), UBC Westwater Research Centre, and the Sapperton Fish and Game Club.

The proposed objectives of the Brunette Watershed Management Plan (1998) are:

- Environmental: to protect or enhance aquatic habitat, terrestrial habitat and biodiversity
- Social: to enhance recreational opportunities and minimise health and safety impacts related to flooding and poor water quality
- Financial: to minimize the cost of carrying out the plan and minimize property damage due to flooding
- Learning: to increase the understanding of natural systems and the impact of the plan on these systems and human health
8.0 BEECHER CREEK SUBBASIN – SITE ANALYSIS

8.1 Site Location

The Beecher Creek sub-watershed is approximately 228 ha and is one of the smaller creeks in the Brunette River Watershed. The area is bounded by Hastings Street and Kingsland Drive in the north-south direction and Gamma Avenue and Fell Avenue in the east-west direction. The study site includes the residential portion of the subwatershed that drains into Beecher Creek and is approximately 166 ha.

Figure 2: Site Context of Burnaby and the Beecher Creek Watershed
Source: Burnaby OCP 1998.

8.2 Existing Land Use

The upper and middle reaches of the watershed are predominantly residential while the lower area flows through commercial and industrial areas then into the lower reaches of Still Creek. Within the upper catchment area residential use makes up 91% of the land area, 3% is school grounds and 6% is park area (Chang 1998). There are approximately 1225 residential lots and an estimated 3063 people (assuming an average 2.5 people per dwelling unit).

Currently the total park and school ground area within the Watershed is 176 375m$^2$ for a population of 3063 which translates to 57.6m$^2$ of total open space per person.

The Hastings Service Commercial Centre, Hastings/Holdom Village Centre, Holdom/Lougheed Station Area Village Centre and the previously mentioned Brentwood Town Centre are located just outside the watershed boundary and are a ten to fifteen minute walk for most residents.
8.2.1 Zoning

(Drawing 2)

The areas of interest in this study are the existing single family dwelling properties that could accommodate ground oriented infill as well as the existing recreational park and school ground areas that could also serve to function as wildlife habitat and stormwater management areas.

The R9 residential district provides for single family residential development on small lots in areas of 0.81 or more hectares (2 or more acres) that are undergoing comprehensive development or redevelopment. The uses permitted are single family dwellings, home occupations and accessory buildings and uses (Burnaby OCP 1998).

The R5 residential district provides for the use and development of two-family dwellings on larger lots in medium density residential areas (Burnaby OCP 1998). Uses permitted include: single family dwellings; two family dwellings; group homes; boarding, lodging or rooming houses for not more than 5 persons when situated in a single family dwelling on a lot with an area of not less than 668.88m² (7,200 sq.ft); home occupations; and accessory buildings and uses (Ibid).

The Residential District R4 provides for the use and development of two-family dwellings on larger lots in medium density residential areas (Burnaby OCP 1998). The uses permitted include: single family dwellings; two family dwellings; group homes; home occupations; and accessory buildings and uses (Ibid).

Residential District R3 preserves the basic minimum density of development in the mature single family areas of the Municipality (Burnaby OCP 1998). The uses permitted include: single family dwellings; home occupations; accessory buildings and uses; and group homes (Ibid).

Residential District R2 provides for medium density urban-type residential areas (Burnaby OCP 1998). The uses permitted include: single family dwellings; home occupations; accessory buildings and uses; and group homes (Ibid).

The Park and Public Use District (P3) provides for the location, preservation and development of public land to serve the educational, park and recreational needs of the Municipality (Burnaby OCP 1998). The uses permitted include: assembly, cultural and recreational facilities, including: arenas, auditoriums, band shells, bowling greens, community centres, curling rinks, gymnasiuums, riding academies, skating rinks, stadiums, swimming pools and tennis courts; arboreta, botanical gardens, planetaria, zoological gardens and aquaria; public parks; public golf courses; public libraries; public playfields and playgrounds; public schools; a dwelling or dwelling unit for a caretaker, watchman or other persons similarly employed, when considered to be essential to the operation of the facility; and accessory buildings and uses (Ibid). The
conditions of use in these areas shall be oriented to pedestrian needs and be so located and designed as to avoid vehicular interference with pedestrian movement (Ibid).

### 8.2.2 Parcel Layout

(Drawing 3)

In general the continuous built form in the Beecher Creek Urban Watershed is the single-family residential block within a grid pattern. Basically, the block consists of the lane, streets, houses, and yards. It is this block unit and its variations that are examined to determine the overall character of an area as well as its potential to accommodate growth and enhance the ecological integrity of the watershed (Vidners and Luxton 1981 34).

![Figure 3: From left to right - Typical Residential Street, Collector Street, Lane, Cul de Sac, Boulevard](image)

The size and shape of block is determined by lane, street and road allowances. The existing right of ways are generally oversized for the amount of traffic in the residential area. Collector street right of ways are 11 metres wide while residential streets are 8.5 metres, paved lanes are 5-6 metres and cul de sacs are 8.5 metres. These wide swaths of pavement add up to dominate 212 988.5 m² of the watershed. With few trees and wide streets that promote high vehicle speeds, the existing streetscape is not pedestrian friendly.

The collector street, residential street, lane and cul de sac are predominant features throughout the watershed and are currently underutilized space that could be more valuable if used as building lots and for stormwater management.
8.3 Soils

The study area is mainly made up of till at the base with some sand and gravel on top (Chang 1998).

8.4 Topography and Drainage

(Drawing 1)

The study site is within the natural topographic boundary of the Beecher Creek Subwatershed. The major feature of the site is Beecher Creek which flows south into the lower reaches of Still Creek. The watershed’s south facing continuous slope into the river valley allows potential for channelling, capturing, and treating stormwater runoff.

Stormwater is collected via a curb-gutter-sewer system, however, a few remnants of surface drainage remains along lane ways and a few open ditches parallel major collectors and through local roads.

![Figure 4: Existing drainage consists of curb and gutter, culverted streams and remnant swales](image)

Although the watershed is highly developed a large amount of the stream corridor is open. However, one-third of the original stream network has been covered by pavement or diverted into culverts. No large outfalls empty into the stream but there are approximately 7 small outfalls which have not been mapped.

8.5 Hydrology

Urban development changes the natural stream morphology through grading and man-made stormwater conveyance systems and changes in infiltration, interception, and evapotranspiration capacities due to reduced vegetative cover and increased impervious surfaces. These often drastic changes lead to: a significant increase in storm runoff volume; increases in overland flow concentration during storm events, resulting in higher in-stream flow velocities and peakflows; an increase in the runoff erosive and pollutant carrying capacities; and limited subsurface recharge, resulting in reduced stream baseflow due to loss of interception, infiltration, and depression storage (Brown et al. 1997). Thus, the predevelopment
hydrologic regime's channel morphology, baseflow, currents, pools and riffles, streambed substrate, bank stability, and in-stream and riparian vegetation are often destroyed or severely disrupted. In turn, the urban watershed no longer has the capacity or ability to control flooding, erosion, sedimentation, rate of discharge, water temperature or the baseflow which all impair the aquatic ecosystems.

The main hydrological issue in the Beecher Creek Watershed is flow variation. Specifically the problems that occur during the winter high flows that flush fish species and their eggs out of Beecher Creek (Chang 1998). To improve the hydrologic regime and mitigate the changes to the stream system a strategy to mitigate flood and erosion damage resulting from peak flows during major storm events is necessary. This would involve developing runoff management and a reduction of impervious areas.

8.6 Water Quality

Traditional urban development often results in poor water quality. In fact, water quality, specifically the runoff pollutant loading, is directly proportional to watershed imperviousness (Zandbergen 1998). Urban runoff can carry pollutants such as sediments, nitrogen and phosphorus, metals and trace elements, oil and grease, organic contaminants, bacteria and viruses, oxygen demanding substances, toxic chemicals and floatable materials to the receiving stream (GVS&DD 1999). In addition, the reduction of vegetation around a stream leads to an increase in water temperature causing stress to cold water fish such as salmon and trout (Zandbergen 1998).

Sedimentation, caused by the removal of vegetation and increased volume of runoff, can result in: increased turbidity, reduced light penetration, reduced prey capture for sight feeding predation, clogging...
of gills and filters of fish and aquatic invertebrates, and in slow moving waters changes in the composition of bottom substrate (reducing available spawning gravel beds)” (Zandbergen 1998). Urban watersheds are also sources of high levels of phosphorous and nitrogen from fertilizers and animal waste can lead to alga blooms causing eutrophication. Parking lots, roads and service stations result in the highest concentrations of vehicle pollutant runoff such as crankcase oil, grease and other lubricating agents (Ibid.). Fecal coliforms in the receiving stream from domestic sewage and animal droppings usually indicates the presence of other disease causing bacteria and viruses (GVS&DD 1999). Toxic chemicals, such as polycyclic aromatic hydrocarbons (PAH's), pesticides, PCB's, dioxins etc. resulting from atmospheric deposition are usually low but the concern is accumulation (Zandbergen 1998). In addition, oxygen demanding substances, including all organic material which undergoes bacterial decomposition in receiving waters, have a negative effect on aquatic species.

Zandbergen's (1998) research in the Brunette River Watershed showed that sediment contamination is extensive and the results of water quality conditions are poor showing exceedances in fecal coliforms, copper and dissolved oxygen. In addition, Zandbergen (1998) found that the pollutant loading indicator was indeed linked to imperviousness based on traffic density and land use type and intensity. In this study, the Beecher Creek Sub watershed had a fair final pollutant loading (stream health) score based on a traffic density of 200-300 km/ha/day and a relatively low industrial/commercial land use (10-20%) and a relatively high amount of open space (10-20%).

However, water quality can be improved further through riparian corridor protection, a reduction of impervious areas, controlled stormwater runoff and community participation and awareness.

8.7 Imperviousness

The subwatershed has a high degree of imperviousness and has increased from 46% in 1973 to 49% in 1993. This high degree of imperviousness in the Beecher Creek watershed has had a negative impact on hydrology, water quality, riparian corridors and aquatic habitat. Given the contribution of residential housing to overall imperviousness in the watershed, a functional element analysis was performed to determine which elements contributed most to residential imperviousness. Functional elements include streets, sidewalks, parking/driveways, roofs, and lawns/landscaping/open space in residential areas. One block was chosen within the Beecher Creek Subwatershed, indicative of the high density single family housing with 3.5 units per acre within a grid road network that dominates the suburban part of the watershed. The study showed in detail how each element contributed to the overall imperviousness of the watershed. The total imperviousness was found to be 49%. Of the total impervious area, approximately 8% was attributed to the lane, 7% to sidewalks, 13% to parking, 22% to roofs and 51% to lawns and open space based on a 30 unit block on 7.93 acres (Zandbergen 1998).
The two approaches generally used to reduce impervious surfaces include reducing the effective imperviousness of urban development and reducing the total imperviousness by modifying the patterns of development. Reducing the effective imperviousness involves increasing rainfall infiltration into the soil instead of diverting it into the storm sewers and drainage ditches. The second approach involves modifying the existing residential development pattern involving narrowing roads and shortening driveways to landscape level planning that could involve modifying road network layout and connections between various land uses.

The goal of the retrofit plan is to reduce the effective and total imperviousness of individual lots, dwellings, streets, lanes, and cul de sacs.

8.8 Forest Cover and Riparian Plant Communities

The forest cover and the riparian plant community are a significant part of the watershed and play a large role in its overall health and functioning. Vegetation has the ability to: filter sediment, pollutants and nutrients; regulate stream flow; modify temperature; provide diverse fish and wildlife habitat; stabilize stream banks and reduce erosion (Brown et al. 1997). In addition, these zones provide green and aesthetic places for public recreational opportunities.

Riparian buffer zones can influence stream flow by slowing the path of water down through its vegetative material thereby allowing overland flow to infiltrate into the ground. By absorbing most of the surface water the riparian strip acts as a storage area and releases the water at a slower rate thus controlling the stream flow and decreasing erosive forces. Another example of riparian system importance is its ability to abate water pollution. The vegetation acts as a physical, biological and chemical pollution filter (Brown et al. 1997). Physically the vegetation removes suspended solids by its filtering capacity. The factors that influence the ability to filter include: the amount, size and type of suspended solids; pore space in riparian material; pathways within riparian material; and also the altering wetting and drying cycles which play an important role in maintaining filter capacity (Ibid.). Chemically the vegetative filter, through organic and inorganic processes, breakdown the solids. The vegetation, water and solids react in a variety of ways such as ion exchange, adsorption, precipitation, oxidation and reduction which are further influenced by pH, temperature, aeration, moisture, and biological activity (Ibid.). Biologically the riparian zone is rich with micro and macro soil organisms, fungi, algae, and plants that act to filter nutrients, solids, and contaminants (Ibid.). The microbial activity in the soil is determined by moisture, temperature (15°C
optimal), aeration (BOD), pH (6-7), a balanced nutrient supply, a carbon/nitrogen ratio (C/N 25:1 optimum), and the presence of active keystone species (Ibid.).

However, development in a watershed generally leads to a decrease in total forest cover as well as the riparian forest cover paralleling streams. This reduces its natural ability to control erosion and filter and absorb pollutants. In addition, urbanization typically results in fragmented corridors and loss of ecosystem integrity and thereby reduces ecosystem stability and biological diversity. Road crossings and stormwater drainage systems can further add to the deterioration of the riparian buffer functions. Road crossings are a substantial barrier, break the continuity of the forest cover, and can result in an increase in erosion and sedimentation problems (Zandbergen 1998). In addition, underground stormwater drainage systems can bypass the riparian buffer zone thereby reducing the capacity of buffers to filter out pollutants from runoff (Ibid.)

In the 30 m buffer zone drawn around the Beecher Creek on each side (5.2% of the total subwatershed area) forest cover comprised 50% of the buffer, open and green space was 11.1%, residential took up 18.1%, commercial/industrial/institutional 14.3% and roads and paved areas 6.6% (Zandbergen 1998). Zandbergen (1998) notes that given the high degree of development, the forest cover is reasonable. The hypothetical 100m buffer (16.9% of total subwatershed areas) drawn around the stream consisted of 25.2% forest cover, 8.8% open and green space, 36.6% residential, 19.9% commercial/industrial/institutional and 9.5% roads and paved areas (Ibid.). Road crossings occur at 2 points in the residential area and four points in the lower part of the stream (should be less than 2 per km to maintain buffer integrity). There are also approximately 7 small storm water outfalls along the corridor that further impair the natural function of the buffer zone. The existing riparian vegetation is comprised mainly of red alder and salmon berry with black cottonwood, big leaf maple and hemlock dispersed throughout (Bily and Swanepoel Eds. 1999).

Indeed, it is evident that forest cover and riparian plant communities play a significant role in determining the condition of the watershed. The functions and benefits of the riparian corridor can be extended throughout the watershed by improving the total forest cover and ecological functioning in yards, streets and open spaces.

Thus, the protection of the hydrology and terrestrial and aquatic habitat of a stream system may involve: restoring the ecological functioning of yards, streets and open spaces; maintaining or enhancing the effective width of the riparian buffer zone (which may include land acquisition); revegetation; and decreasing road crossings and stormwater outfalls.

8.9 Wildlife

Although this list of wildlife is a fairly comprehensive definitive identification some groups of species will require consulting more technical references.
8.9.1 Mammals
Mammals that are likely to be found and are suited for the Beecher Creek Corridor include: red fox (Vulpes fulva); Coyote (Canis latrans); Raccoon (Procyon lotor); Spotted Skunk (Spilogale gracilis); Douglas Squirrel (Tamiasciuus douglasi); Northern Flying Squirrel (Gloucomys sabrinus); Meadow Mole (Scapanus townsendi); Townsend’s Vole (Microtus townsendi); Deer Mouse (Peromyscus maniculatus); Shrew (Sorex sp.); Brown Bats (Eptesicus fuscus); Wood Rats (Neotoma cinerea) (Bily and Swanepoel Eds.). Currently there is insufficient habitat to support the: Douglas Squirrel (Tamiasciuus douglasi); Northern Flying Squirrel (Gloucomys sabrinus); Deer Mouse (Peromyscus maniculatus); Shrew (Sorex sp.); and the Brown Bat (Eptesicus fuscus) (Ibid.)

8.9.2 Amphibians
Amphibians that were identified within the Beecher Creek Corridor include: Pacific Tree Frog (Hyla regilla); Rough Skinned Newt (Taricha granulosa); North Western Toad (Bufo boreas); Red Legged Frog (Rana aurora); Spotted Frog (Rana pretiosa); Western Red-backed Salamander (Plethodon vehiculum) (Bily and Swanepoel Eds. 1999). All of the aforementioned amphibians require habitat restoration (Ibid.).

8.9.3 Fish
Currently, Beecher Creek contains coho, cutthroat, steelhead/rainbow trout, peamouth chub, and crayfish which are all native (Zandbergen 1998). Due to the moderate amount of industry in the Beecher Creek watershed it has been identified as having a high fish habitat potential (Ibid.). However, the upper sections of the stream have been lost, a number of road crossings disrupt the channel, changes to the stream morphology, and moderate to poor vegetative and poor substrate all contribute to a poor fish habitat, fish population, species composition, indicator species, and very poor returns of coho/trout (Ibid.). To protect and restore the aquatic habitat it is necessary to: reduce turbidity and sedimentation; minimize oxygen demand; decrease low base flows; minimize water level fluctuations; conserve and restore native vegetative cover for food (aquatic bacteria, plants and invertebrates) and shading; and improve water quality.

8.9.4 Birds
The following insect gleaning birds that have been identified within the Beecher Creek corridor include: Orange-crowned Warbler (Vermivora celata); American Goldfinch (Carduelis tristis); Western Tanager (Piranga ludoviciana); Bewick’s Wren (Thryomanes bewickii); Wilson’s Warbler (Wilsonia pusilla); Warbling Vireo (Vireo gilvus); Red-eyed Vireo (Vireo olivaceus); Ruby-crowned Kinglet (Regulus calendula); and the Black-capped Chickadee (Parus atricapillus) (Bily and Swanepoel Eds. 1999). Within this guild the Chestnut-backed Chickadee (Parus rufescens) and the Brown Creeper (Certhia americana) require habitat restoration(Ibid.). The Pacific-slope Fycatcher (Empidonax difficilis), Willow Flycatcher (Empidonax traillii), and the Tree Swallow (Tachycineta bicolor) from the Hawkers guild are also present
in the corridor (Ibid.). Chiseling birds also known as woodpeckers such as the Downy Woodpecker (Picoides pubescens); Pileated Woodpecker (Dryocopus pileatus); and the Northern Flicker (Colaptes auratus) exist within the riparian zone (Ibid.). In addition, leaf-tossers or ground foragers that have been identified include the Spotted towhee, the Bushtit (Psaltriparus miniumus), Winter Wren (Troglodytes troglodytes), Fox Sparrow (Passerella iliaca), and the Song Sparrow (Melospiza melodia) (Ibid.). However, the Dark-eyed Junco (Junco hyemalis) and the White-crowned Sparrow (Zonotrichia leucophrys) require habitat enhancement (Ibid.). From the swooping guild the Cooper’s Hawk (Accipiter cooperii), Red tailed Hawk (Buteo jamaicensis), and the Western Screech Owl (Otus kennicottii) all need further habitat augmentation (Ibid.). Likewise goes for the Wood duck (Aix sponsa) from the dabbling guild (Ibid.). The Cedar Waxwing (Bombycilla cedrorum) and the Stellar Jay (Cyanocitta stelleri) dwell in the corridor however the Swainson’s thrush (Catharus ustulatus) from this frugivorous guild requires better habitat (Ibid.). Finally, the House Finch (Carpodacus mexicanus) and the Pine Siskin (Carduelis pinus) from the granivores guild have sufficient habitat but the Red Crossbill (Loxia curvirostra) need improved habitat within the corridor (Ibid.).

According to the above analysis of plants and wildlife within the Beecher Creek Corridor, it is evident that the riparian corridor requires additional structure and diversity and an improved in-stream habitat to support the aforementioned animal species.

![Figure 8: The existing stream corridor lacks diversity and layers that would support resident species](image)

Best Management Practice’s and sustainable design principles can be applied to parks, stream corridors and streets to improve the connectivity and biodiversity of green spaces thus increasing the integrity of urban ecosystems and providing a rich and diverse web of movement for humans and wildlife. These connections that weave throughout the community may also promote an awareness of natural systems within the watershed.
9.0 INTENSIFICATION

Goal 1:

Increase the density of the watershed through sensitive infill and a wide range of dwelling types

Decentralised urban growth and the sprawling low-density residential suburbs we see today are coming under increasing scrutiny. Issues such as the ecological implications of sprawl (Van der Ryn and Calthorpe 1986), the decline of cities and communities (Jacobs 1961), the inefficient use of land and public services, and the social homogeneity and social segregation (Calthorpe 1992) found in these areas are well documented and inspire the notion of infill. Indeed, Lynch (1981, 264) maintains "the density of housing is always a fundamental decision in city design. It sets the framework for all the other features and has far reaching implications".

The intensification of the single family residential area in the Beecher Creek Subwatershed is viewed as a way to use existing housing stock and existing residential land more effectively and to alleviate the detrimental impact of sprawl. Infill is one alternative to address the social, demographic and economic changes that are creating a demand for ground oriented, affordable housing. It is also a way to generate income to restore urban ecosystems. Nonetheless, the notion of infill is faced with several constraints such as the current regulatory situation and neighbourhood resistance. Thus, the major challenge of intensification is to illustrate how growth can be integrated to enhance the community. As Tomalty states "the future of the complete communities movement will depend on building support for the notion within suburban communities" (1997, 67).

The following section builds on the rationale for promoting sensitive infill as well as the common barriers to higher residential densities in single family neighbourhoods. The intent of the Beecher Creek retrofit plan is to achieve a variety of lot types within each block that will provide diverse and affordable residential housing, more services closer to home and an increase in overall density through sustainable infill.

9.1 Benefits

9.1.1 Social

Intensification in an existing single family Neighbourhood provides a choice of housing types and tenures which meet the needs of the increasing number of smaller households such as single-parent families, and low- and moderate-income households, and the elderly (Douglas 1994, 5). In addition, CMHC (1981) states that intensification encourages social diversity in that it includes a mix of age groups, income levels, occupations and activity interests within a single community. At the same time the Neighbourhood is able to "maintain existing households while providing opportunities for new families who wish to move
into stable neighbourhoods” (Vidners and Luxton 1981). This social diversity also tends to strengthen the communities identity by permitting different and changing housing needs to be met within the Neighbourhood fabric and provides an interesting and diverse living environment (CMHC 1981).

Higher densities also increase the tax base which can facilitate environmental restoration of the area as well as contribute to improving community services and amenities. For instance public transportation is more viable in higher density areas and provides a higher quality of life for those who depend on it. In addition increased density supports more activities and services, as Van Der Ryn states, “from the point of view of sociability it is a density that is too low to support corner stores, cafes and all the kinds of places that we associate with conviviality” (1986, 40). As well, an increased diversity of services and an enriched environment provides a visually stimulating walking environment which encourages people to walk instead of drive (Rapoport 1991). This behavior reduces the dependency on the vehicle and in turn frees up land taken by the automobile and helps to increase air quality. More people in a Neighbourhood also provide more “eyes on the street” and create a safer environment for walking (Jacobs 1961).

9.1.2 Economic

Economically higher density and a variety of dwelling types within the community “stabilizes long term demand for community services by attracting a variety of residents with different needs that change in a variety of ways over time (CMHC 1981). Increased density also provides the numbers necessary to support service and retail areas and will attract additional businesses. The city becomes more spatially, economically and energy efficient as higher densities require less land and thus reduce the “per capita cost of building and maintaining services such as roads, utilities and any form of transportation” as well as reducing building costs, services and amenities (Van der Ryn 1986). As stated above, an increase in population means an increased tax base which can facilitate environmental restoration of the area as well as contribute to improving community services and amenities. In addition, low cost infill housing can increase the economic feasibility of single-parent families, low and moderate income households, and the elderly living and staying in a single family area in ground oriented housing.

9.1.3 Environmental

Complete and compact communities reduce the impact of sprawl on the hinterlands and can also facilitate environmental restoration of our urban air, water, fauna, and flora systems through an increased tax base and Neighbourhood endowment funds. In addition, new sensitive infill units can be built using sustainable technology to reduce land, energy and water use thus decreasing its ecological footprint.

Mixed use, high density areas generally lead to improved air quality through increased transit use and reduced car trips thus decreasing pollution from vehicle exhausts by reducing the number of kilometers per trip. In fact Calthorpe (1992) states that denser land use coupled with mixed uses reduce travel
distances and number of trips by 40 to 50 percent. High density also offers more opportunities to walk or ride a bicycle to work, service, and entertainment facilities.

9.2 Constraints

Constraints such as existing building codes, zoning bylaws and official plans as well as residential attitudes are common barriers to higher residential densities.

9.2.1 Residents Attitudes

Regardless of the aforementioned benefits of intensification “many studies have shown that the idea of intensification in many suburban areas is controversial and in some areas outright rejected” (Tomalty 1997, 64). The studies indicated that residents were concerned about: increased traffic through the Neighbourhood; overuse of local amenities such as parks; poor site design; loss of green space through infill; loss of surrounding property values; obstruction of views; fears that the general livability of the area will be reduced; stress on schools and daycare’s; affect on property values; and possible crime and social problems (Ibid.). However, a study conducted by the Vancouver City Planning Department (1986) found that residents in single-family areas were more willing to accept new infill high-density housing if it was clearly family housing, if it was an improvement over previous land uses, if it was accompanied by a community facility such as a park, and if it was located in areas that were already heterogeneous. In a recent community attitude survey of Burnaby 78 percent of residents surveyed supported legalization of secondary suites with controls such as provision of on-site parking, owner occupancy of the main unit or the secondary suite, and appropriate fees being charged (GVRD 1996).

It would seem rationale therefore to assume that if these amenities are provided and infill is used as a tool to improve a community and its environment, infill would be accepted. In fact, the City of Vancouver is considering that funding for Neighbourhood amenities such as parks, daycare and libraries in neighbourhoods be linked to an acceptance of increased densities (Tomalty 1997, 65).

9.2.2 Zoning

Urban infill is an important strategy for maximizing land use within existing municipal boundaries however zoning is often a constraint to infill in low-density residential areas. Tomalty found that “zoning bylaws set maximum density limits without specifying minimum density requirements” and “subdivision and development control bylaws set minimum road and servicing requirements that make intensification difficult” (1997, 50).
Currently, Burnaby’s Zoning and Development By-law states that:

6.1(1) No residential use building shall be located on the same lot as any other residential use building, except as otherwise provided for in this By-law

This specification would mean that to the lot would have to be subdivided for an additional infill unit and would further be subjected to municipal frontage and size requirements, and would have to front onto a public street (Tomalty 1997). Therefore, it is necessary to review zoning and development by-laws and to investigate intensification options. Vidners and Luxton 1981 suggests that “zoning can be a tool and viewed as an opportunity for the development of new building forms” (39). Selected sections of the zoning by-law could be amended, and architectural and site development criteria could be established. This process should involve community input for developing guidelines and acceptable performance criteria for infill housing (CMHC 1998).

Small-scale intensification can be encouraged through permitting the subdivision of residential lots and allowing new development to use zero lot lines. Zoning can also be a tool to increase environmental protection. Performance zoning can be used to allow flexibility in where or how development is designed, as long as the impact of the development is kept within specified acceptable limits. For instance, lot imperviousness ratios, shared driveways, reduction of on-street parking, flexible road right-of-ways and road widths, reductions in side yard restrictions and increases in overall unit-lot densities and zero-lot-line development practices could all encourage innovative site layout options and can be part of flexible zoning requirements.

It is important to note that each lot is unique within the watershed in terms of its context in relation to topography, streams and city infrastructure such as proximity to traffic arteries, retail districts, and availability of services (Vidners and Luxton 1981). Thus, intensification strategies should be examined on a lot by lot basis according to its context and the requirements of the community.

9.3 The Beecher Creek Retrofit Plan – Increasing Population Density

A denser, greener and more livable community is the intent of the proposed residential land use plan. The retrofit plan offers a variety of household types and tenures and accommodates a diversity of people from different family types and ages. The proposed sensitive infill housing can also provide affordable housing and mortgage aids to younger families. Intensification methods appropriate for retro-fitting the Beecher Creek Subwatershed single family Neighbourhood are conversion and sensitive infill.
9.3.1 Sensitive Infill

Sensitive infill is a fine grained, incremental approach that allows the retention of existing homes and favours a more considerate response to place (Murphy 1994). Infill can take on many forms however it is generally associated with:

low rise development on small scale sites requiring little or no demolition of residential units and capable of being built by small builders. Such development conforms in all other respects to the existing scale and character of the Neighbourhood (Peter Barnard Associates 1981, 11).

Furthermore, sensitive infill blends into the social, economic, historical and cultural context of the existing Neighbourhood (CMHC 1982, 2).

9.3.2 Conversion

Burnaby allows secondary suites in single family attached homes if the suite is to be occupied by a member of the primary occupant’s immediate family (Tomalty 1997, 48). Conversion, otherwise known as a secondary suite or an accessory apartment, is further described as:

Altering an existing dwelling to create an additional dwelling unit. The accessory apartment is the most common conversion. A basement, attic, or guestroom in a single family home can be converted into an accessory apartment. Conversion provides a rental income for the owner and/or accommodation for members of the owner’s family or extended family (Lee 1999, 43-44)

Internal unit densification is a viable alternative to increase the efficient utilisation of the residential area. These accommodations tend to be more affordable compared to other rental units and add to a neighbourhoods diversity in areas which may not otherwise have sufficient supplies of affordable housing (Douglas 1994, 5).

9.3.3 Proposed Lot Types

(Drawing 4)

The Beecher Creek Retrofit Plan proposes diverse infill lot types to accommodate a wide range of housing demands in the region. In the Beecher Creek residential area, backyards adjacent to lanes are the most suitable source of land for infill. The individual lot infill is a lane house built off the lane in the rear yard as an individual private development. This form would build on the existing garage type pattern set off the rear lane with the existing setbacks or a proposed zero lot line, and are possible on lots as narrow as 33’ (Vidners and Luxton 1981 33). The vacant lot redevelopment is used in the Beecher Creek Retrofit plan as an opportunity to build Neighbourhood commercial centres with residential units above.
Additionally, the narrow street infill lot involves narrowing streets that are currently 66' to 33' on right of ways that run north/south. This would create a 33' lot that could be sold or leased for new infill housing (Demarco and Sebastian 1997). The revenue generated from the development could initiate a Neighbourhood endowment fund to be used for improvements within the watershed (Ibid). The proposed Beecher Creek Retrofit Plan has created an additional 25 lots for this purpose. Demarco and Sebastian's (1997) 'Thin Streets' proposal is also sensitive to present and future infrastructure and services and excludes North/South streets with existing water or sewer lines from development. They suggest respecting or relocating small gas or underground telephone lines into the remaining right of way (Ibid).

Figure 9: Proposed narrow house site on Dellawn Drive. Once the road has been narrowed a 30' lot can be created.
Other infill lot types include the corner lot subdivision, rear lot continuous infill (zero lot line configuration allowed along the entire lane), redundant lane infill and redundant street redevelopment.
9.3.4 Proposed Dwelling Types

(Drawing 5)
The Beecher Creek Retrofit Plan also includes various dwelling types such as the lane house, multiplex, townhouse with lane house, single family house with rentable suite, live/work units and the zero lot line house with rentable suite and lane house.

Figure 11: Examples of dwelling types. From left to right single family house with rentable basement suite on a 33’ lot; townhouse on privately owned 6.5 metre lot. Source: Condon 1998.

Lane House (79m2-85m2)
The ‘Healthy Housing Design Competition’ organized by the Canadian Mortgage and Housing Corporation in 1991 demonstrated the feasibility of a environmentally sustainable, affordable infill housing designs (CMHC 1993). The Vancouver winning entry in the urban infill category was energy efficient, resource efficient, environmentally responsible, economically viable, and provided a healthy indoor environment. The design was a two storey one bedroom frame house with a footprint of 85m2 designed to fit a typical Vancouver 10m by 37m lot. The lane house was constructed to consume half the energy of a R-2000 home and was built in 1993 in the commercial Drive area of Vancouver. A Toronto winning entry was a 79m2, two bedroom lane house designed to be completely self sufficient. In this design the house electricity is provided by a “photovoltaic array and a thermopile which converts heat from the woodstove into electricity” (Lee 1999). Additionally, rainwater is collected and purified by reverse osmosis and food wastes and sewage are composted (Lee 1999).

Figure 12: Lane house unit in the Mount Pleasant Area of the City of Vancouver
The Beecher Creek Retrofit Plan proposes the construction of 691 self sufficient Lane House Units. These units can be built above a two car garage and can be accessed from the street and the lane. In addition, each unit has its own private garden (Condon 1998).

**Townhouse with Lane House (6.5 by 25m)**

The proposed townhouse units are built on their own lots and share only the party wall that separates one property from the next which allows easy management and land efficiency versus a commonly owned parcel (Condon 1998). A two car garage is located off the lane with a rentable lane house above on the second and third floor. The lane house is as described above.

An additional approach to sensitive infill are Thin Houses. Andrew Crosse built 7 thin houses on Vancouver's West Side at 905 sq ft. which fits on a 33' by 17' parcel (Lee 1999, 32).

**Single Family House With Rentable Suite (10m by 25m)**

This particular single family house with a rentable suite fits on a 33' lot and is a ground oriented design with the master bedroom located on the main floor which is ideal for the elderly. A full basement can be converted into a suite and could act as a mortgage helper to first time home buyers.

**Zero Lot Line House With Rentable Suite And Lane House (10m by 28m)**

This structure can also be located on a 33' lot and has up to 4 floors (3200 sq.ft) with a developed basement and attic. The zero lot line house has a party wall on only one side of the structure and a rentable lane house as described above.

**Live/Work Units**

The retrofit Plan proposes Live/Work units along the lane between Hastings Street and Frances Street. The concept of these units is to allow home based work such as "types of craft, office retail, and selected wholesale uses as well as consultant businesses" (Condon 2000). The residential component in this type of housing is tied in tenure to the business component and is a transition from the commercial area along Hastings (Condon 2000).

Figure 13: Example of Live/Work type development that would run along the laneway behind Hastings Street
The Multiplex units in the Retrofit plan imply fee simple row houses, stacked townhomes or apartments and apartments above street oriented commercial units. The Retrofit plan accommodates three commercial multiplexes and one apartment building as shown on the proposed dwelling types drawing.

The number of dwellings added in the retrofit plan equals 847 units housing an additional 2117.5 people. These intensification strategies utilize the often-underused lane system and the overgenerous right of ways and are least disruptive to the existing Neighbourhood fabric. Areas that should be not be intensified include lots identified within the 30m riparian zone and instead can be replanted to contribute to the health of the urban stream system.
10.0 PEDESTRIAN FRIENDLY STREETS

Goal 2:
*Provide greener, narrower, pedestrian friendly streets to promote social interaction and safe walkable environments*

The following section generally describes the concept of pedestrian friendly streets and presents the proposed right-of-way goals of the Beecher Creek retrofit plan.

“Street reclamation can capture portions of territory from automotive dominance and offer new configurations of activity and experience”

(Girling and Helphand 1994, 220)

Narrowing the width of the streets in the watershed will allow the remaining land to be given over to more functional purposes. Streets are a readily available and often neglected resource that can be reclaimed to increase the permeability, enhance wildlife habitat and enrich the social interactions between blocks. In addition, as the density of the watershed increases streets could become wildlife corridors, recreational spaces and provide an important social milieu. As Morrish states:

Roadways can be great linear hallways with permeable walls shaped by the natural and built features along a road. Often passers-by assess a place by the character of its roadway; people use roadway features to orient themselves. Corridors become richly layered cultural and environmental spaces which help define and connect sectors of the community (1996, 80).

Donald Appleyard (1981) suggests that the street should be regarded as an organic entity with a multitude of functions and possibilities. The street, he states, should be an extension of the home a safe sanctuary; a place for play and learning; a neighbourly territory; a community; a livable healthy environment; a green and pleasant land; and a unique and historical place (Appleyard, 1981).

The safety of the street is an important factor in the livability of a Neighbourhood (Jacobs 1993; Appleyard 1981; Francis 1991). Helphand and Girling (1994) and Donald Appleyard (1981) document narrowing streets and using the woonerf principle to achieve safe residential streets and to reduce auto hazards of children in Western Europe. Traffic management is a consequential component to one’s connection to the street and it is found that less traffic at reduced speeds increases social contact among residents (Appleyard and Lintel 1977). Jacobs (1993) concurs that every fine street is associated with places for people to walk leisurely and are safe primarily from vehicles (272). As Moore states “urban streets can be humanized; the balance between the needs of people and the needs of motor vehicles can be redressed”(1991, 60).
The street should provide opportunities for play and learning. For instance, Mark Francis (1991) notes that an element of risk and discovery contribute to the individual development and environmental competence of children. It is well documented that an important part of a child's learning occurs close to the home and depends on safe access to street spaces (Ibid.). Streets can be appealing places to play as Moore reports "when traffic density is low and streetscape diversity high children are drawn to an environment that is extremely well adapted to their needs" (1991, 51). A network of roadside swales, tall grasses and street trees tied into greenways provides a rich educational environment as well as recreation and green space close to home. Streets also provide an important gathering place where all age groups can communicate about life and learn about their neighbours. For example Jacobs states that "it's on foot that you see peoples faces and statures and that you meet and experience them" (1993, 271).

A neighbourly territory and sense of community involves love and stewardship over the street. Successful streets hold memories and meaning that recall the history of the place and the people and reveal the larger social, economic and environmental context (Francis 1991). A street according to Mark Francis (1991) is democratic when people take ownership of them which can be either real if the residents up keep the sidewalk or street trees or symbolic if the residents feel their property extends into the public realm. A great street brings people together and involves participation and responsibility (Jacobs, 1993).

A livable healthy environment implies that the street is comfortable. Busy streets diminish street life and move people and social activities inside or to the backyard (Appleyard 1981; Hepland and Girling 1994). By improving the liveability of the street social activities and recreation can occur in the front yard thus making more efficient use of this under-utilised space and leaving the backyard space for the rear lot infill dwellings. As well, livability of the street improves if there is adequate solar access and shading accordingly, and protection from the rain and wind (Francis 1991; Jacobs 1993). Alexander states that "on a hot summer day the air over the grass surface is 10 to 14 degrees cooler than the air over an asphalt road" (1977, 267-268)

A healthy street involves the re-introduction of trees which can provide benefits such as: energy conservation, better air quality, wind protection, cooling, water conservation, erosion control, noise reduction, increased recreation opportunities, wildlife habitat, pollution control and improved soil quality. A green street is also psychologically healing and adds visual quality and diversity. Research by Appleyard (1981) documents that trees are rated as the most desired element on a street. Deciduous trees are the most appropriate to provide shade and solar access when needed and also movement and shadows which contribute to the life of the street (Jacobs 1993). Trees can also protect the stream by controlling soil erosion and storm water runoff volumes by 17 percent (Schueler 1997b). Vegetation also
adds diversity for children who can play "along the ecotone of gutter rivers, down 'bottomless' storm drains, among insect life of sidewalk verges, in jungles of front fence vegetation" (Moore 1991, 53).

Narrow streets have also been associated with an increased market value. Many older residential areas that have thin streets are "characterized by high income home values with more Neighbourhood feeling" (Oregon Department of Transportation and the Department of Land Conservation and Development 1996). In addition, Scheuler (1997) states that property values are increased by an average of 6% to 15% when homes are surrounded by large trees or are located on well-shaded avenues. In addition trees located near the home can reduce heating and cooling bills by 20% to 25% (Schueler 1997a). On a larger scale mowing costs can be reduced by $1000 to $2400 per ha when open space is managed as natural buffers (Schueler 1997a).

Within the Beecher Creek community the existing lanes, fourteen cul de sacs and residential and collector streets are excessively wide and void of cultural expression and serve no ecological function except for a few street trees lining the odd street. This requires redesigning streets to balance vehicle and pedestrian activity as well as ecological functions.
10.1 The Beecher Creek Retrofit Plan – Right-of-Ways
(Drawings 6 and 7)

10.1.1 Collector Streets - Parkways
The existing collector street width is narrowed from 11m to two 5m lanes separated by a 2m wide concave median swale planted with street trees and shrubs. The 5 metre lanes are lined by a 2m grass boulevard strip which accommodates a swale, and existing utility and light posts. The 1.5m sidewalk on both sides provides ample pedestrian space which is buffered from the road by the grassy swale. The narrow 0.5 metre strip lining the outside of the sidewalks accommodates street trees and tall grasses. The collector street now provides bio-remediation and functions as a green link to the surrounding open space system.

Collectors include part of Hasting Street, Parker Street, Delta Avenue, and Holdom Avenue. Springer Avenue has been changed into a residential street and the section crossing Beecher Creek has been removed. A change in paving pattern marks the section where the daylighted stream crosses under Parker Street.
10.1.2 Residential Streets – Thin Streets

The residential street is narrowed from 8.5 metres to 6 metres. The street is lined on both sides by a 4 metre strip that accommodates a 2 metre gravel parking shoulder, street trees, swale and existing utility poles. The 1.5 metre sidewalk is lined with a 1 metre strip accommodating another row of street trees, tall grasses and shrubs.

A few residential streets running North South, Gamma and Howard Avenue, and Dellawn Drive running East West are narrowed and extra lots have been added to the blocks. As well, a redundant section of Ellesmere Avenue has been closed to accommodate additional lots. A section of Howard Avenue has been removed as well as the Venebles Cul de Sac to accommodate the daylighted stream.

Dead end residential streets within the 100 metre riparian zone have been further narrowed to 3.5 metres to decrease impervious surfaces and increase the land area for riparian plantings. These include Braelawn Drive and Heathdale Drive.

Intersections between residential blocks are marked with a change of pavement treatment and larger street trees and benches on each corner providing a gateway to each block and creating a distinct gathering place for social interaction.
10.1.3 Lanes - Mews

Lanes are narrowed from 5-6 metres to 3.5 metres with a 1.25 metre strip which accommodates a swale, lane trees and walkway. All redundant laneways are removed to create additional lots.

Figure 19: Existing Lane and Proposed Mew
10.1.4 Cul de Sacs - Woonerfs

Cul de sacs are an ideal place to incorporate the woonerf, "a Dutch concept that combines pedestrian and vehicular spaces to create a hybrid yard space" (Helphand and Girling 1994, 222). The design can turn the street over to community activities and ecological functions such as playgrounds, gardens, bike storage and wet ponds thus giving life to the street. Helphand and Girling (1994) suggest that the yardscape feel of the cul de sac already is ambiguous in terms of ownership, territoriality and function and would benefit from the multipurpose concept of the woonerf where cars are woven into the design, but do not dominate it.

In this example of a redesigned cul de sac the 15 metre right of way is transformed into two 3.5 metre roads lining a community green. This space can be used as community gardens to accommodate the increased density or perhaps developed with sustainable infill units. The next 27 metre section of the woonerf is a full sized basketball court surfaced with permeable pavement and lined with two 3.5 metre strips of changed pavement colour to denote vehicle through zones. The end of the woonerf, in this design, functions as a community amphitheatre and stormwater detention. Street trees provide a buffer between the houses and the street activities.
11.0 WALKABLE COMMUNITY

**Goal 3:**

*conserve land and energy by designing compact walkable communities that provide services such as shops, parks etc. within a five minute walking distance*

As noted previously, problems associated with the existing suburbs are exclusionary zoning that promote vast tracts of single land uses and consequently a dependency on the automobile. However, existing suburbs can be retrofitted to provide services, shops and parks nearby that support the pedestrian. Town planners such as Duany and Plater-Zyberk's (DPZ) and Peter Calthorpe have developed concepts called Traditional Neighbourhood Design (TND) and Pedestrian Pocket or Transit Oriented Development (TOD) respectively. These concepts are based on traditional American towns and an environmental ethic and promote "small scale, mixed use, environmental sensitivity, internally consistent hierarchy of architectural, building and street types, finite geometry with legible edges and a centre, walkability, and alleys with accessory units and reliance on succinct graphic guidelines in lieu of traditional zoning codes" (Kelbaugh 1997 130).

The Beecher Creek Retrofit plan incorporates these principles and promotes a diversity of land use, activities and building types, pedestrian oriented streets that accommodate easy, direct access to parks, shopping and work and Neighbourhood centres that are distinctive and finite in size and can be easily traversed on foot. This change in land use of the Beecher Creek Watershed community can reduce the number of automobile trips by 40 to 50 percent and thus improve social life (Kelbaugh 1997, Girling and Helphand 1994).

11.1 The Beecher Creek Retrofit Plan – Walkable Community

(Drawing 8 and 9)

The Beecher Creek Retrofit plan increases the population by 2118 people within the watershed boundary and provides 40.6m$^2$ of open space per person. Green streets provide a network of green links to the stream corridors, parks and schools and the existing cul de sacs are transformed into Neighbourhood parks that are based on the pedestrian oriented woonerf concept.

In addition to the four planned commercial centres mentioned earlier, the Retrofit plan proposes three additional neighbourhood commercial centres within a five-minute walking distance from every residential unit. This provides a working and shopping place for nearby residents as well as a civic focal point. Residential units are also incorporated above the street oriented commercial units.
Furthermore, a network of trails, paths, pedestrian friendly streets and natural systems offer an alternative from vehicle travel and create a hierarchical web of movement between the home, work, marketplace, parks, transit stations, and neighbourhood schools. The improved connections and street enhancement between various land uses provide a visually stimulating and more comfortable environment for pedestrians and bicycles.
12.0 HEALTHY URBAN ECOSYSTEM

Goal 4:

*Enhance and preserve the natural environment and restore natural drainage systems*

Restoring the ecological function of the urban watershed is the main focus of the Beecher Creek Retrofit. An undisturbed watershed performs many functions that are virtually impossible to restore in an urban setting. However, Best Management Practices (BMP's) can be used to enhance the natural environment and restore natural drainage systems and thus provide a better habitat for humans and wildlife on individual lots, right-of-ways, parks and stream corridors. This ecological infrastructure can be woven throughout the watershed to satisfy social and recreational demands as well as storm water management, stream protection and habitat enhancement. The following section describes several BMP's that can be implemented to restore the individual lot, right-of-ways, parks and stream corridors.

12.1 Best Management Practices

The watersheds existing conventional stormwater system is highly impervious and is physically separated from natural processes through a series of impervious gutters, catch basins and subsurface pipes. These man-made systems neglect the potential cultural, social and ecological functions that ecological infrastructure can fulfill. Best Management Practices (BMP's) are tools that provide an alternative strategy to controlling and mitigating the impacts of stormwater runoff and can improve the ecological functioning of the urban watershed. There are three types of BMP's including non-structural, structural and operational and maintenance. Non-structural BMP's are preventative strategies that can stop negative impacts to begin with. Structural BMP's, on the other hand, are methods to mitigate the existing adverse impacts of urbanization. Finally, operational and maintenance BMP's include the upkeep of structural BMP's and also include preventative measures.

As noted before high permeability and substantial riparian forest cover are inclusive for a healthy urban stream. Even a large buffer cannot mitigate the effects of urban runoff from roads, parking lots, housing, stormwater drainage systems if a watershed has a high degree of imperviousness. In fact, because urban areas are highly diverse and have a high rate of polluted runoff, usually non point source pollution, buffer strips can only treat approximately 10% of the runoff, therefore, the remaining 90% of the runoff should be addressed through BMP's that will treat urban runoff before it reaches the streams (USDA 1998).

12.1.1 Benefits

There are several social benefits associated with BMP's including an enriched human/nature interaction, enhanced air quality, and improved visual aesthetics and recreational opportunities. Morrish refers to
alternative stormwater methods as "beautiful infrastructure, which responds to the physical and
topographical features of the locale, [and] is primary to creating community identity and a personal sense
of orientation" (1995, 80). By integrating these natural processes into the urban residential landscape it
can enrich human interaction with nature and provide and awareness of natural systems in the
watershed.

BMP’s can also enhance the ecological function of the watershed by providing: improved microclimate
(shading, wind protection, noise abatement), increased habitat, decreased imperviousness, control of
peak discharges and removal of sediments and pollutants. Methods such as wet and dry detention
ponds, vegetated filter strips, swales, wetlands and riparian buffer strategies create a complex,
multifunctional environment that not only restores the natural hydrological regime but also provides
habitat connectivity.

In contrast, the economic benefits are difficult to measure and often the "reluctance to change an older
system is due to an inadequate user density to rationalise the cost of changing older systems" (Golden
1999). In a greenfield project research shows that if BMP’s are implemented, there are lower
infrastructure and maintenance costs and improved property values (Condon 1998). However, the
previous chapter illustrates how to intensify a watershed through sensitive infill and how this may provide
an adequate "user density" to rationalize changing the existing conventional stormwater system to a more
ecological infrastructure. Hence, the costs of implementing BMP’s may be offset by an increase in
population density.

12.1.2 BMP Selection

BMP’s are chosen according to the watershed goals, objectives and priorities which may include:
protection of life and property such as flood control, streambank stability, prevention of drainage
obstruction, and worker/public safety; protection of fish habitat to improve water temperature, turbidity and
sedimentation, dissolved oxygen, stream structure, groundwater recharge, water level fluctuations,
vegetation/food supply and water quality; protection of water quality to decrease sediment, nitrogen and
phosphorous, metals and trace elements, oil and grease/ harmful organics, oxygen demand, bacteria and
viruses and floatable material; and community support and acceptance which considers parks and
greenspace, fish and wildlife habitat, aesthetics and public safety (GVS&DD 1999).

The Greater Vancouver Sewage and Drainage District (GVS&DD) (1999) has developed a guide to select
BMP’s according to the level of development and land-use activity. Because this thesis explores retro­
fitting the level of development falls between developed land and redeveloping land to accommodate
BMP’s. In terms of land use activity the area of study deals with residential land-use. According to the
GVS&DD (1999), non-structural BMP’s that are suitable include: buffer zones and preservation of natural
areas and drainage systems; impervious area reduction/restriction/disconnection; construction
design/review/inspection enforcement; consultant and contractor education; and public education and participation. Structural BMP’s appropriate for the residential watershed are the: water quality inlet; manhole sediment trap; dry vault and wet vault; dry pond; wet pond; engineered wetlands; vegetated swale or grassed channel; vegetated filter strip; off-line infiltration basin; roof downspout system; porous pavement (concrete grid and modular pavers); bioretention (dry swale with underdrains); and sand filter or organic filter (GVS&DD 1999). Operational and Maintenance BMP’s include: maintenance of structural BMP’s; detection/removal/prevention of illicit connections; spill and complaint reporting and response; street cleaning; maintenance of runoff conveyance systems and hillslopes; catch basin cleaning; roadway and bridge maintenance (Ibid.).

The BMP’s chosen for the retro-fit design of the Beecher Creek Subwatershed were based on the following criteria: suitability to a particular site; promotes infiltration and reduces imperviousness; provides wildlife habitat; and provides aesthetic value and recreational opportunities. Infiltration strategies are the most effective as they can: reduce the peak flow rate; reduce the overall volume of stormwater; increase groundwater recharge; allow the deposition of pollutants through filtration and settling; and recycle nutrients through cation exchange, plant uptake, nitrification and denitrification before reaching the ground water table (Herson-Jones et al. 1995).

The non-structural BMP’s that were chosen are riparian restoration and the reduction/disconnection of impervious areas. Structural BMP’s appropriate to the watershed include: wet basins, wetlands, swales, filter strips, porous pavement, roof downspout, and bio-retention. To maximize the success and benefits of these BMP’s, education and proper maintenance needs to be incorporated along with the retro-fit design. Limitations such as depth to the impermeable layer, depth to the water table, and soil type of the catchment area may serve as constraints to the aforementioned BMP’s and are beyond the scope of this thesis. Detailed design of the aforementioned BMP’s can be found in the manual referenced in the bibliography.

12.1.3 Description of Proposed BMP’s

Riparian Restoration

Riparian areas are an integral part of the stream corridor and form the backbone of the watershed. In addition to being a highly aesthetic part of the landscape, these areas serve many environmental functions such as stabilizing the streambank, controlling water temperature, providing nutrients to organisms, creating diverse habitats, trapping sediment, filtering pollution, and helping to dissipate erosion energy and reducing runoff volume (Munro and Taccogna, 1994). Vegetative buffer zones around streams allow river processes to occur without the need for expensive engineering solutions and can also provide important greenway connections. In addition, it has been found that homes near
restored streams are valued 3% to 13% higher than homes situated by unrestored streams (Schueler, 1997a)

Streambank Stabilization

Bioremedial methods can be used to stabilize stream banks allowing habitat to be recreated with live systems that are more durable, effective, visually appealing and involve less maintenance then conventional engineering practices. By using rock, timber, soil, and plants to emulate the conditions of a natural stream, the banks can become hydrologically stable.

Streambank protection requires re-grading in most circumstances to a 2H:1V slope or flatter so that vegetation can be established. The most effective plants to use in bioremediation are those that are propagated by cuttings and layers. The basic prerequisite for bioremedial materials is native vegetation and easy propagation.

Stream Bank Vegetation

After a slope is stabilized vegetation should be established to further reinforce the bank and provide a diverse and aesthetic landscape. Biodiversity is essential in riparian planting in order to emulate a natural streamside ecosystem. In an undisturbed environment there is a series of edges: emergent plants, herbaceous plants and low shrubs; taller shrubs; and trees (Menashe 1993). Once the vegetation has established itself the riparian zone will provide opportunities for human and wildlife corridors.

There are many factors that influence vegetative types along a stream course. The steepness of a slope is an important indicator of what plant species should be utilized to stabilize a slope. Soil types are also an important component that influences plant growth, vigor, rooting depth and available moisture (Menashe 1993). Soil conditions are further defined by dry or saturated soil conditions. Furthermore, the aspect of a stream bank changes throughout its course and will effect plant communities.

By using bioremedial methods and planting native vegetation, the impacts of urban related activities can be mitigated along the creek. The result is an enhanced urban landscape with improved fish and wildlife habitat. The riparian corridor also provides an opportunity to improve human interaction with nature within the city.

Riparian Buffer Zone Width

There are many factors influencing the minimum corridor width. It is suggested by the USDA (1998) that “the widest and most contiguous stream corridor, which achieves habitat, conduit, filter, and other
functions, should be an ecologically derived goal of restoration". In addition, Brown et al. (1997) suggest that the optimum size of a buffer zone is dependent on the functional value of the resource, intensity of adjacent use, buffer zone characteristics, specific buffer requirements, and the size of the stream. However, in general a width of 5 metres to 10 metres "is too little", 15 metres to 30 metres "is a minimum", and 30 metres to 100 metres "is a realistic compromise" (Brown et al. 1997). Zandbergen (1998) states that "the standard 30 metre buffer often used in urban watershed development guidelines and municipal bylaws is insufficient to achieve benefits such as large organic debris recruitment, floodplain process, benthic invertebrates, moderation of microclimate and wildlife diversity and distribution".

Indeed, the ideal restoration would result in a corridor that emulates the natural stream system, however, due to urban land constraints, infrastructure and activities disrupting and destroying the streams natural structure and function, this is often not feasible. When restoring riparian buffer zones it is important to conduct a watershed analysis to understand disturbances both inside and outside the stream corridor and to look at a reference riparian corridor and the predevelopment riparian plant community (Brown et al. 1997).

The USDA (1998) has designed an urban stream buffer that consists of the following 3 lateral zones:

... stream side, middle core, and outer zone. Each zone performs a different function, and has a different width, vegetative target and management scheme. The stream side zone protects the physical and ecological integrity of the stream ecosystem. The vegetative target is mature riparian forest that can provide shade, leaf litter, woody debris and erosion protection to the stream. The middle zone extends from the outward boundary of the stream side zone, and varies in width, depending on stream order, the extent of the 100-yr. floodplain, adjacent steep slopes, and protected wetland areas. Its key functions are to provide further distance between upland development and the stream. The vegetative target for this zone is also mature forest, but some clearing may be allowed for storm water management, access, and recreational uses. The outer zone is the buffer's "buffer," an additional 25-ft setback from the outward edge of the middle zone to the nearest permanent structure. In most instances, it is a residential backyard. The vegetative target for the outer zone is usually turf or lawn, although the property owner is encouraged to plant trees and shrubs, and thus increase the total width of the buffer. Very few uses are restricted in this zone. Indeed, gardening, compost piles, yard wastes, and other common residential activities often will occur in the outer zone.

This design allows for flexibility that is essential in an urban setting. Boundaries that are agreed upon should be adequately marked describing allowable uses within the riparian zone.
Acceptable Land Uses

Acceptable land uses within the buffer zone are activities that are compatible with the conservation and protection of the riparian vegetation. Through sensitive planning and good design, activities such as: walking, jogging, and hiking; ecological interpretation; wildlife viewing; promotion of environmental awareness; and photography and painting can occur within the riparian area (FRAP 1997).

There is usually controversy between science, policy and legislation regarding buffer zones. In most cases, buffer zones are determined by a compromise between public acceptability and political agendas. In addition to these pressures, the riparian zone is further compromised by its high economic and aesthetic values. This often leads to high resource use including water based recreation, wildlife viewing, transportation access, and residential and recreation development (Brown et al. 1997). Science is often left out of the formula because the buffer zone widths that are recommended for stream corridor integrity are seen as taking up too much of the land base and real estate tax base. However, the Beecher Creek Retrofit Plan increases density outside the buffer zone and increases forest cover throughout the watershed.

Buffer zones are a vital part of watershed management and perform critical functions that relate to the overall health of the watershed. Successful examples of achieving urban watershed health, cited throughout the literature, are corridors that function as linear open space managed for conservation, provide habitat protection, serve as filters for air, noise, and water pollution and also promote walking, jogging, bicycling.

Forest Cover

It is estimated that forest cover can reduce storm runoff volumes by 17% (Schueler 1997b). Forest cover also provides a natural buffer and can also take the place of turf on public lands reducing mowing costs by up to $1000 to $2400 per ha (Schueler 1997a). In addition forests on residential and commercial land can increase property values by 6% to 15% and can decrease cooling and heating bills by 20% to 25% (Schueler 1997b).

Reduction/Disconnection of Impervious Areas

Impervious surface reduction can be incorporated into policies and regulations. For instance, changing lot layouts can reduce impervious surfaces. Lot layout determines the total road length required to serve each dwelling unit through lot setback restrictions, thereby influencing road imperviousness. Lot setback restrictions such as lot area, and front, side and back yard setbacks, lead to requirements for driveway and sidewalk design. Flexibility in zoning and regulations such as "zero-lot-line" development can reduce overall site imperviousness by placing new development closer to the street or lane thereby reducing
required disturbance area and driveway lengths. In addition, an impervious surface tax can be implemented to encourage a reduction of impervious surfaces on private properties.

Public transportation can also play a large role in the reduction of impervious areas by reducing the need for parking and wide street corridors catering to the vehicle. Impervious parking areas can be replaced by under building parking, porous pavement and shared parking. Incorporating open drainage systems not only improves the infiltration capacity of the watershed but also replaces the impervious curb and gutter system. Other reduction methods include decreasing road widths which creates a more comfortable pedestrian environment.

The disconnection of impervious areas implies diverting runoff from impervious surfaces into filtration and infiltration systems such as the roof downspout system, porous pavement, bioretention and swales (GVS&DD 1999). On a regional scale building complete compact communities within growth concentration areas reduces urban sprawl and its consequent impervious surfaces.
Wet Pond/Wetland System

The pond/wetland system has been found to be the best combination for contaminant removal (Schueler, 1994). This combined system detains collected runoff temporarily and provides flood control, streambank erosion protection, and water quality improvements (GVS&DD 1999). This system maintains a permanent pool of water between storms and during the storm events the wet pond controls the turbulence of runoff which enhances the settlement of particles and minimizes scour and resuspension of sediments (Ibid.). Flocculation and settling of fine particles occurs between runoff events (Ibid.). Soluble contaminants and particles that do not settle in the pond and can be removed or are "converted to less harmful forms through chemical transformations and biological action by bacteria and vegetation that develop in the permanent pool" (Ibid.).

The wetland portion of the system has a higher ability to remove particulate, colloidal and dissolved contaminants due to its greater structural complexity (GVS&DD 1999). It is recommended that the minimum surface area of the wetland system is 1% to 2% of the contributing area with an overall total land area of 3% to 5% including buffers (Ibid.). Additionally, wetlands provide fish and wildlife habitat, recreational and aesthetic benefits and can increase surrounding property values.
Swales

Swales are shallow vegetated conveyance channels that allow stormwater to infiltrate and sediment and particulates to be filtered and degraded through biological activity. These channels can be retrofitted to existing development along the edges of roads, lanes and parking lots and can take the place of conventional stormwater curb, gutter and pipe systems to collect street runoff. Hydrologically, swales can decrease storm water flow velocities, increase the time of concentration, reduce peak flow rates and decrease flooding and stream bank erosion (GVS&DD 1999). The swales capacity to remove contaminants is a function of its length and they can provide primary treatment of storm water by capturing suspended solids, oils and particulate metals before it reaches other BMP's such as a wetland system (Ibid).

The recommended minimum effective bottom width of a swale is 0.6m with a parabolic or trapezoidal cross section (GVS&DD 1999). The swale should be constructed with a sandy loam topsoil layer with an organic matter content of 10% to 20% and less than 20% clay content and planted with water-tolerant native plants (Ibid.).

Swales can be designed as a drainage channel, a grassed channel, a dry swale or a wet swale. The drainage channel is designed only to convey water during peak flows for large storms, minimize erosion, trap course sediment, and allow water to infiltrate into soils (GVS&DD 1999). These swales can be designed as french drains underlain with crushed gravel drain trenches. Grassed channels, otherwise known as bio-retention swales or bio-filters, are planted with grass or native vegetation. These channels are usually dry between storm events and can be designed to convey the 10 year event but more frequently provide water quality treatment and infiltration of water for smaller 6 month events (Ibid). The dry swale is completely dry between storm events and allows the greatest infiltration of water and highest water removal rate of all the channel systems. The runoff is stored in a 50% sand, 50% loam swale soil with an under drain that removes excess water to a secondary system. This swale is able to store water underground until it can infiltrate naturally into the soil. Alternatively, the wet swale stores standing water between storm events and is usually saturated due to a high groundwater table or a high baseflow. Shallow ponding areas along the swale can be established by using check dams and may “reduce flow velocity, promote infiltration, enhance settling of particles, and result in increased infiltration and evapotranpiration for the water quality storm” (Ibid.).
Figure 25: Types of swales – For details see the GVS&DD Stormwater Guidelines referenced in the bibliography.

Dry Swale
(source: CWP, 1997)

Wet Swale
(source: CWP et al, 1997)
Vegetated Filter Strips

Filter strips are broad areas of vegetation that intercept and slow an even flow of stormwater runoff until it infiltrates into the soil. The filter strip can be designed to collect sheet flow from streets, driveways and as infiltration systems for roof downspouts. Soil content should contain 50mm of compost if the native soil has less than 10% organic content and should be able to absorb 1.15 to 4.3 mm/hr (GVS&DD 1999). The filter strip contaminant removal capacity is comparable to vegetated swales and also provides wildlife habitat (Ibid.).

Porous Pavement

Porous pavements include permeable paving material that allows water to infiltrate to a gravel filter layer or structural materials such as pre-cast concrete grids, modular unit pavers interspersed with permeable voids such as grass or crushed gravel to allow infiltration.
These pervious pavement types can be used as an alternative to asphalt and are appropriate to retrofit human use areas and light vehicle use such as driveways, parking areas, storage yards, bike paths, walkways, recreational vehicle pads, service roads, fire lanes etc. (GVS&DD 1999).

**Roof Downspout**

Disconnecting the rooftop runoff through infiltration practices helps to reduce the impacts of rooftop imperviousness. The infiltration can be through sub-surface sand filters (if contaminated); infiltration trenches filled with drain rock, dry wells, subsurface perforated infiltration tanks for storage and infiltration; dispersion (open top) trenches (including rock pockets and trench drains) or surface dispersion (over vegetated filters)” (GVS&DD 1999). These systems can achieve groundwater recharge, reduced contaminants and reduced peak flow rates and volume of stormwater runoff (Ibid.).

![Figure 28: Roof downspout system. For details see the GVS&DD Stormwater Guidelines referenced in the bibliography. (source: WSDOE, 1992)](image)

The ideal system allows maximum infiltration in the form of infiltration trenches, surface dispersion trenches, and surface dispersion systems (see GVS&DD Guide for Stormwater for design details). The surface dispersion uses a splash block to drain the rooftop runoff away from the building into an infiltration area such as a vegetated filter strip, swale or infiltration trench. This system has the highest infiltration capacity and the lowest labour and material cost requiring only weeding, replacement of the splash rock and loosening of the soil over time (Ibid).

**Bioretention**

Bioretention is a filtering system that stores runoff in a shallow depression temporarily and then gradually allows the water to percolate through a constructed filter bed of plants and soil to an underlying drain system (GVS&DD 1999). Bioretention involves a "flow regulation structure/level spreader with a
vegetated filter strip or grass channel leading to a shallow ponding area consisting of a surface layer of organic mulch, underlain by a planting soil bed that supports turf, shrubs, trees underlain in turn by a sand bed and then and underdrain system" (Ibid). It is recommended that the system has a minimum width of 3m, a minimum length of 5m with a maximum ponding depth of 0.15m and a minimum soil bed depth of 1.2m (Ibid). The planting soil should be a "sandy loam or a sand/loam mix with 35% to 60% sand and more than 25% clay by volume" (Ibid). Contaminant removal includes filtration, adsorption, volatilisation, ion exchange, microbial action and plant uptake (Ibid). This system is complex to construct but provides wildlife habitat and mimics the natural hydrological system.

12.2 Individual Lot

The following examines how best to increase the contribution that each lot makes to a more sustainable urban watershed. The goal on the individual lot is to reduce impervious surfaces, manage stormwater and increase the habitat value on each lot. In addition, building sustainability into new development as well as attempting to retrofit existing development is an essential part of moving towards sustainability. Thus, existing houses should be upgraded to become more energy efficient, resource efficient, environmentally responsible and economically viable. New development consumes natural resources thus the proposed infill units should minimize the use of non renewable materials, use recycled materials, maximize the use of renewable materials and minimize energy consumption. New infill units can achieve a high level of land and energy conservation by optimising the use, reuse and recycling of renewable resources of wind, water, sun and the land. The new households can demonstrate the use of passive strategies and renewable energies for heating, cooling and ventilation, on site water retention, and recycling of water and wastes. This design strategy for infill units will reduce the ecological footprint of added density within the watershed. In essence, changing the existing building dominance over the landscape to dwelling sustainably with nature.
In the total block area the existing typical lot consists of the roof 22%, sidewalk/patio 7%, lane 8%, and parking 13% and green areas make up 50%. Impervious areas on each lot typically include the roof, parking, sidewalks and patios. The retrofit block area is 23% roof, 6% sidewalk, 4% lane, 67% green space and parking has been reduced to zero. The following illustrates how an individual lot with a rear lot infill unit can achieve only 33% impervious surfaces.

Figure 30: Individual lot with rear lot infill unit can achieve 35% impervious surfaces.

Roof-Downspout System
Rooftop runoff from the infill unit and the south side existing house roof is directed into a cistern in the backyard. The overflow from the cistern is then directed through a vegetated swale and then into a bioretention system. The runoff from the north side of the existing house roof drains into a vegetated swale in the front yard.

Pavement Removal
Removing pavement and planting trees, shrubs, and vines helps to create a more comfortable environment and creates an opportunity to design more useful outdoor spaces. The common walkway from the front street to the infill units serves 4 dwelling units and reduces the pavement significantly. This sidewalk is also covered with a trellis and vines to reduce the ambient air temperature and humanize the pavement. Individual driveways are replaced by parking areas provided on the front street on a 2m wide
gravel parking verge. In addition two parking stalls are located under the infill unit off the back lane. If required, further parking areas can be incorporated into the lawn areas in the form of grasscrete or thin ribbons of concrete or stones for under the tires of vehicles to allow infiltration, a stable surface and improved aesthetics (Alexander 1977). Common driveways can also reduce the amount of pavement needed.

Porous Pavement
Sidewalks and patios in the retrofit plan are constructed with pervious materials such as pavers, stones, crushed gravel and wood decking to allow infiltration.

On-site Retention/Detention and Soil Infiltration
The cistern in the backyard captures rainfall and rooftop runoff for reuse to later irrigate the lawn and vegetated areas. The rain water that by-passes the cistern is directed through a vegetated swale and collected into a bioretention system to be absorbed into the soil below.

The front yard also captures rainfall and rooftop runoff into a vegetated swale. Berms are built up around the swale to increase the water storage capacity. The site will not be able to handle all storm events due to limited space and in these instances the excess flow is diverted into the roadside and lane swales

Planting Native Vegetation
A diverse palette of native plant species not only provides food, cover and nesting sites to indigenous wildlife but are also best suited to the local climate. Using native vegetation conserves water, reduces maintenance, and celebrates the natural regional landscape. Trees can also intercept rainfall and reduce energy costs by providing shade and insulation.

These options can "significantly reduce peak runoff flow rates and runoff volumes and recharge groundwater if extensively used in residential areas" (GVS&DD 1999).

12.3 Right of Ways

Swales
To address stormwater runoff from right of ways swales that incorporate infiltration devices run along the residential streets and lanes and feed into the collector parkway swales. This is a primary treatment and infiltration strategy for surface water flow before it reaches the wetlands then finally into beecher creek. The parkway is separated by a 2m wide concave median swale planted with street trees and shrubs in addition to two swales that run along each sidewalk. Vegetated swales also run along every residential street and lane and collect runoff from the roadway as well as excess runoff from individual lots.
Pavement removal
The existing collector street width is narrowed from 11m to two 5m lanes. The residential street is narrowed from 8.5 metres to 6 metres and dead end residential streets within the 100 metre riparian zone have been further narrowed to 3.5 metres to decrease impervious surfaces and increase the land area for riparian plantings. Lanes are narrowed from 5 or 6 metres to 3.5 metres. Cul de sac pavement is reduced to two 3.5 metre roads lining a community green.

Street Trees
The parkway has 3 rows of street trees that run along the sides and down the centre. The residential street has four rows of trees that line both sides of the sidewalks. Laneways and cul de sacs accommodate two rows of street trees.

Figure 31: Swales, pavement removal and street trees improve the pedestrian street environment and create green corridors along parkways, thin streets and mews.

12.4 Parks/Schools
Aubrey Elementary School is planted with native trees and shrubs. Kensington Park now accommodates a wetland and a riparian buffer along the Beecher Creek tributary and the culverted section is daylighted. Alpha Secondary School is planted with native vegetation and has a recreation/detention field. Beecher Creek Park accommodates a large wetland and is planted with native vegetation.

12.5 Stream Corridors
(Drawing 10 and 11)
Over the years, the upper stream sections of Beecher Creek have been lost due to urban development and the remaining stream corridor deals with the encroachment of impervious houses, roads, lanes, and
yards. In fact, within the 30 m buffer zone drawn around the stream on each side (5.2% of the total subwatershed area) forest cover comprised 50% of the buffer, open and green space was 11.1%, residential took up 18.1%, commercial/industrial/institutional 14.3% and roads and paved areas 6.6%. Zandbergen (1998) notes that given the high degree of development the forest cover is reasonable. The hypothetical 100m buffer (16.9% of total subwatershed areas) consisted of 25.2% forest cover, 8.8% open and green space, 36.6% residential, 19.9% commercial/industrial/institutional and 9.5% roads and paved areas (Ibid.). Road crossings occur at 2 points in the residential area and four points in the lower part of the stream (should be less than 2 per km to maintain buffer integrity).

The health of the open stream system relies on the ability to restore the natural structure and function of the riparian corridor and to reduce the amount of impervious surfaces within and outside the corridor. Thus, the restoration of the riparian corridor involves: streambank stabilization; revegetation (including residential yards); maintaining and enhancing the effective width of the riparian buffer zone (which includes land acquisition); instream restoration; reduction of road crossings; minimization of stormwater outfalls; and a reduction of impervious surfaces. In addition, the aforementioned BMP's that extend beyond the corridor are implemented to mitigate stormwater runoff, erosion and pollutant loading at the source before reaching the stream corridor (Herson-Jones et al. 1995).

A 30m riparian zone is established along the daylighted tributary and the existing stream system. The upper open stream section running through Kensington Park is revegetated with riparian plantings. The culverted section of this reach is daylighted and follows its original drainage pattern through Venebles Cul de Sac, down Howard Avenue, across Parker Street and behind Cedardale, Brookdale, and Beridale cul de sacs and across Meadedale Drive into the open Beecher Creek. Residential lots within the 30m riparian zone are planted with riparian vegetation and are not intensified. Right of ways and other paved

![Figure 32: Daylighted section of the Beecher Creek Tributary](image-url)
surfaces within this zone are significantly reduced. Additionally, a trail system is established along the stream corridors.
13.0 PERFORMANCE STANDARDS SUMMARY

13.1 Watershed Elements and Sustainable Alternatives

There is a need to examine every element of the watershed to explore how the parts can contribute to the health of the whole. The continuous elements in the Beecher Creek Urban Watershed are the single-family residential lot; the street, lane and cul de sac; open spaces and riparian corridors. Changes can be made incrementally to these elements to move the urban watershed towards sustainability. As Christopher Alexander states, “every increment of construction must be made in such a way as to heal the city” (1987, 22). Creating sustainable environments on every scale from single family lots to blocks to the community watershed allows people to find meaning in their lives through a connection with nature.

An important component to the success of a more sustainable landscape is the need for understanding. As Thayer states:

> people who are able to comprehend how and why a sustainable landscape functions will respond differently to that landscape than those who are uninformed or unable to ‘read’ the landscape...environmental knowing heightens landscape experience” (Thayer 106).

As noted before, within a watershed boundary it is possible to arrive at a better understanding of processes, interrelationships, thresholds and system responses. Thus, if people understand that ‘every increment of construction’ affects the health of their community watershed we may begin to change the paradigm of human dominance over nature and begin to accept living with natural systems.

The following provides a summary of performance objectives and sustainable design alternatives required to increase the density and improve the ecological, economic, social and experiential functioning of the urban watershed. Through denser, mixed use block patterns; sustainable infill units; alternative street, lane and cul de sac design; and by restoring the ecology of yards and open spaces, a more functional and experiential urban environment can be realized.

13.2 Intensification Performance Objectives

To identify lots conducive to intensification and modify zoning and configurations to accommodate increased density and diversity of the watershed. Lots within the riparian leave areas are not intensified and it is recommended that these areas adopt the use of native plant species to significantly enhance the health of the stream corridors.

Proposed Infill Lot Types:
Individual Lot Infill – 691 Units
Vacant Lot Redevelopment – 7 Lots
Narrow Street Infill – 21 Lots
Corner Lot Subdivision – 7 Lots
Rear Lot Continuous Infill – 62 Units
Redundant Lane Infill – 1 Lot
Redundant Street Infill – 4 Lots

**Housing Density**

Average Residential Density: 12.5 units per hectare (upha)
Total average increase in population: 2117.5
Number of lots added: 25
Neighbourhood Endowment Fund = $6 500 000.00

**13.3 Land Use Mix Performance Objectives**

The Beecher Creek Retrofit Plan accommodates a diversity in lot types and dwelling types and tenures within each block to achieve a complete, mixed-use community.

**Dwelling Types:**

Lane House – 691 Units
Commercial/Residential Units – 20
Narrow House With Lane House – 56 Units
Single Family House With Rentable Suite – 10 Units
Live/Work Units – 62 Units
Zero Lot Line House With Rentable Suite And Lane House – 18 Units

**Dwelling Objectives**

- To retrofit the existing houses in the watershed to be more energy efficient, resource efficient, and environmentally responsible
- To consider the character of the existing Neighbourhood such as window types, roof styles, materials and texture, colours, geometry, and aesthetics when creating design standards for infill units (Vidners and Luxton 1981)
- To consider circulation with respect to streets and lanes for infill units
- To consider location, massing and height of infill units with respect to topography (views), sunlight and privacy of existing houses
- New infill units will be energy efficient, resource efficient, environmentally responsible and economically viable.
- To plan outdoor space efficiently to address issues of privacy and access to sunlight, as higher site density means that each person will have less outdoor space (Murphy 1988)
- All infill units will be zero lot line development to reduce driveway and sidewalk lengths.
Commercial

- There are 3 proposed mixed-use Neighbourhood Commercial/Residential Centres located throughout the watershed.
- There are 4 planned Commercial Centres surrounding the Beecher Creek Watershed that place it in a sustainable context. These include the Brentwood Town Centre, the Hastings/Holdom Village centre, the Holdom/Lougheed Station Area Village Centre and the Hastings Service Commercial Area. These areas are intended to “provide a focal point for convenient, close to home access to commercial facilities and services that can meet the day to day shopping needs of surrounding residential Neighbourhood areas” (Burnaby OCP 1998, 5).
- The proposed Neighbourhood commercial centres are all located within a 5 minute walking distance of every resident within the watershed boundary.

Right of ways and accessibility

- Every Street is bicycle and pedestrian friendly.

Parks and Greenways

- A Greenway Corridor is located along Beecher Creek.
- Small Neighbourhood parks are distributed throughout the watershed within walking distance to all residents.
- Parks, school grounds and riparian corridors provide recreational amenities in addition to serving as part of the ecological infrastructure system.

13.4 Right-of-Way Performance Objectives

To enhance the ecological functioning of streets and to achieve pedestrian friendly streets by narrowing the right-of-way, planting street trees, and providing a natural drainage system to reduce the impact of increased density in the watershed.

- Maximum infiltration from roadside infiltration devices is 2.0 mm/hr (48 mm/day) and during saturated and winter conditions 0.5 to 1.0 mm/hr (24 mm/day) (Condon 2000).
- Swales along roads are designed to address surface flow for a 5 year storm with no road flooding; and a 100 year storm with a maximum of 250 mm depth of flooding on road surfaces (Condon 2000).
- Water is routed to an open drainage system for infiltration and water quality.
- The proposed Right-of-ways have reduced the pavement area by 95 004 m².
- Street trees and native shrubs are planted on every street to enhance the street climate and native species habitat.

13.5 Ecological Infrastructure Performance Objectives:

(Drawings 12 and 13)
13.5.1 Individual lot
• Each lot has no more than 35% covered with impermeable surfaces (roofs, patios, sidewalks, parking).
• All impermeable surfaces are to drain first through vegetated filters and then into infiltration systems to reduce the siltation and maintenance.
• All overflow from detention facilities is to be directed through subsurface sand filters (if contaminated); infiltration trenches filled with drain rock, dry wells, subsurface perforated infiltration tanks for storage and infiltration; dispersion (open top) trenches (including rock pockets and French drains) or surface dispersion (over vegetated filters)" (GVS&DD 1999).
• Infiltration systems should be located at least 1 metre from the foundation of the dwelling unit (Condon 2000).
• Each lot is to have an infiltration capacity of 24 millimetres per day times the total area of the parcel (Condon 2000).
• Indigenous and drought tolerant plants should be chosen for landscapes that increase biodiversity and provide habitat for local and regional species and requires less water.
• Lots within the 30m riparian buffer zone are encouraged to contribute to maintaining stream hydrology, water quality and riparian habitat by combining backyards and planting riparian vegetation to provide a contiguous and effective riparian zone.
• Individual lots are part of the forest cover strategy for the Beecher Creek Retrofit Plan. Trees are to cover at least 40% of the lot when mature and are to be located at least 3 metres from the outside edge of infiltration devices (Condon 2000).
• Any site topsoil removed for infill building purposes is to be stockpiled, amended (if necessary) and reused to absorb more rainfall and to provide a better growing medium.
• Any excess rainfall that is not absorbed on site will be diverted into the right-of-way swales.

13.5.2 Open Space
The parks, school grounds and stream corridors in the retrofit plan incorporate ecological infrastructure and serve as a network of green recreational links that serve the watershed community. These areas also play a large role in increasing forest cover and biodiversity and serving as wildlife corridors for the aforementioned resident species.

Parks and School Grounds
• All impermeable surfaces are to drain into infiltration systems.
• Permeable surfaces are to infiltrate at rates not less than 36 millimetres per day during winter conditions (Condon 2000).
• The proposed wetlands for Alpha Secondary School, Kensington Park and Beecher Park are to be designed as per the GVS&DD 1999 Stormwater Guidelines.
• Beecher Creek park is designed to accommodate flood waters for the 100 year storm up to a maximum depth of 1 metre (Condon 2000).
The forest cover in park and school sites is 40 to 50 percent
Native vegetation is planted where ever possible

13.5.3 Right of Way
- All existing road, lane and cul de sac widths are reduced and redundant roads and lanes are eliminated to decrease site imperviousness and to create additional residential lots
- All right of ways provide a safe, interesting and comfortable environment for pedestrians and bicycles
- The retrofit plan creates an interconnected web of circulation patterns for a variety of travel modes
- Ecological infrastructure is incorporated within these right of ways to mitigate stormwater runoff and protect fish habitat
- Street trees along streets, lanes and cul de sacs are increased on average by 248 percent per block
- Canopies of street trees are intended to cover 60 percent of these right-of-ways.

13.5.4 Stream Corridors
- Impervious road surfaces are reduced by 7.4% within the riparian zone
- The width of the riparian corridors is increased by enhancing forest cover along the stream corridor and on individual lots within the 100m riparian zone
- Forest cover has increased by 10.7% in the riparian zone
- The retrofit plan proposes to daylight the lost North East tributary of Beecher Creek
- The Springer Avenue stream crossing has been removed
- Runoff management that integrates natural drainage features is implemented wherever possible throughout the watershed
- The time of concentration in the retrofit plan is lengthen by longer flow paths and by routing flow over vegetated surfaces (e.g. swales, filter strips) (GVS&DD 1999)
- The retrofit plan proposes a riparian boardwalk along the main tributary of the Beecher Creek corridor for walking only. Multi-use pathways are provided along right of ways adjacent to the stream.

14.0 CONCLUSION

Due to urban sprawl and deteriorating regional and local ecosystems, it is necessary to explore retrofitting existing urban space to accommodate growth and to preserve the hinterlands. Sustainable principles such as sensitive infill, pedestrian friendly streets, land use mix, and a healthy urban ecosystem are tools that can be applied to any watershed in numerous ways to achieve this goal.

Implementation of the Beecher Creek Retrofit Plan has the potential to realize environmental and social benefits as well as environmental enhancement. The Plan can be applied incrementally to each of the watershed components such as the yard, street, open space and stream corridors to accommodate density while improving the ecological, social and experiential functioning of the whole. Each component speaks to a denser, greener more livable watershed.
Sensitive infill is one approach to accommodate density in a fine grained, incremental way that allows the retention of existing homes and favours a more considerate response to place (Murphy 1994). The Beecher Creek Retrofit Plan explores various dwelling and lot types that fit into the single family Neighbourhood character and that encourage social diversity within a single community.

The Retrofit Plan also provides greener, narrower, pedestrian friendly streets to promote social interaction and safe walkable environments. Narrowing the width of the streets in the watershed will allow the remaining land to be given over to more functional purposes. Streets are a readily available and often neglected resource that can be reclaimed to increase the permeability, enhance wildlife habitat and enrich the social interactions between blocks. In addition, as the density of the watershed increases streets can become wildlife corridors, recreational spaces and provide an important social milieu.

Preserving the natural environment and promoting natural drainage systems within an urban watershed can mitigate the impacts of density on the watershed, the community and the region. The Beecher Creek Retrofit Plan uses the natural topographic feature of the watershed boundary to provide a natural edge to the community and a shared resource within the community. In addition, riparian forest cover and imperviousness are integrative indicators that can be used to determine ecosystem health in the watershed. According to the Watershed Classification System, the Beecher Creek Retrofit Plan has moved the urban watershed from a fair ecosystem health rating to a good ecosystem health rating (Zandbergen 1998).

The Beecher Creek Retro-fit Plan seeks to illustrate the potential of a more compact community within a healthier urban ecosystem thus providing an example of a more environmentally sensitive way of managing growth within our cities. The emergence of healthy urban ecosystems can take the pressure off our regional resources and thus reduce our ecological footprint (Rees 1992).


**DWELLING UNIT COMPARISON**

Area of Watershed = 166 ha

**Existing:**
Existing number of residential lots = 1225  
Existing Density:  
1225 lots / 166 ha = 7.4 units per hectare (upha)

**Proposed:**
Proposed number of residential lots added = 847  
Total number of residential lots = 1225 + 847 = 2072 lots  
Proposed Density:  
2072 lots / 166 ha = 12.5 upha

**POPULATION COMPARISON**

Existing Population (approximate count):  
1225 residential lots @ average 2.5 people per dwelling unit = 3063 people

Proposed Population:  
847 dwelling units added @ average 2.5 people per dwelling unit = 2117.5 people

Proposed Total Population:  
3063 + 2117.5 = 5180.5

**IMPERVIOUS SURFACE COMPARISON**

**PAVED ROAD SURFACES**

Existing total road pavement = 212,988.5 m² (21.3 ha)

Proposed total road pavement = 117,984.5 m² (11.8 ha)

Total Pavement Area Reduction:  
212,988.5 m² – 117,984.5 m² = 95,004 m² (9.5 ha)

**FUNCTIONAL ELEMENT ANALYSIS ON A TYPICAL BLOCK**

Total Area of Block = 23,966.5 m² (2.4 ha)

<table>
<thead>
<tr>
<th>Element</th>
<th>existing block (%)</th>
<th>retrofit block (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roof</td>
<td>22</td>
<td>23</td>
</tr>
<tr>
<td>Sidewalk</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>Lane</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>Parking</td>
<td>13</td>
<td>0</td>
</tr>
<tr>
<td>Lawn</td>
<td>51</td>
<td>67</td>
</tr>
</tbody>
</table>
OPEN SPACE COMPARISON

<table>
<thead>
<tr>
<th>Open Space Areas</th>
<th>Existing Area (hectares)</th>
<th>Proposed Area (hectares)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neighbourhood Parks</td>
<td>0</td>
<td>2.35</td>
</tr>
<tr>
<td>School/Park</td>
<td>17.6</td>
<td>18.6</td>
</tr>
</tbody>
</table>

RIPARIAN FOREST COVER/IMPERVIOUSNESS ANALYSIS

Note: Riparian Forest cover / Imperviousness analysis is based on a 100 metre buffer around Beecher Creek and a 30 metre buffer around the Beecher Creek Tributary.

<table>
<thead>
<tr>
<th></th>
<th>Existing (%)</th>
<th>Proposed (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roads</td>
<td>9.7</td>
<td>2.3</td>
</tr>
<tr>
<td>Residential</td>
<td>62</td>
<td>62</td>
</tr>
<tr>
<td>Forest</td>
<td>22.3</td>
<td>33</td>
</tr>
<tr>
<td>Open Space</td>
<td>6</td>
<td>2.7</td>
</tr>
</tbody>
</table>

Total Area of Analysis = 378,024m2
SWALE INFILTRATION CAPACITY CALCULATION

NOTE: The natural infiltration capacity of the soil is taken from the East Clayton Neighbourhood Concept Plan (2000) due to similar soil characteristics.

Assume:
- natural infiltration capacity of the soil is 24mm/day
- half of 2 year 24 hour rainfall = 40mm

Roadway Swales:

Total Road Area = 117985 m$^2$
Total Swale Area = 40385 m$^2$

Natural Infiltration = 24mm/day
Rainfall = 40mm/day @ 0.5 of 2 year 24 hour rainfall

Needs to Infiltrate:
40mm + 40mm (117985m$^2$/40385m$^2$) = 157mm + lot overflow

Can Infiltrate:
24mm/d

Runoff Before Development:
16mm(117985m$^2$+40385m$^2$) = 2434m$^2$

Runoff After Development:
157mm-24mm=133mm
133mm x 40385m$^2$ = 5371m$^2$

Detention Required:
5371m$^2$-2534m$^2$ = 2831m$^2$
APPENDIX 3: POTENTIAL NEIGHBOURHOOD ENDOWMENT FUND
REAL ESTATE VALUES

Approximate cost for average residential lot in the Beecher Creek Watershed area = $260,000

Beecher Creek Retrofit Plan has added 25 lots to watershed

Potential Neighbourhood Endowment Fund:

25 lots + $260,000 = $6,500,000

The revenue generated from the sale of these lots can be used towards retrofitting the Beecher Creek Watershed to achieve a denser, greener, more livable environment.
Individual Lot Infill (691 units)
Vacant Lot Redevelopment (7 lots)
Narrow Street Infill (20 lots added)
Corner Lot Subdivision (7 lots)
Rear Lot Continuous Infill (62 units)
Redundant Lane Infill (1 lot added)
Redundant Street Redevelopment (4 lots added)

Number of Lots Added = 25
Potential Neighbourhood Endowment Fund = $6,500,000.00
Number of Dwellings Added = 847
© Average 2.5 people/dwelling unit = 2117.5 people
Total Open Space = 236,623 m²

Total Open Space / Person = 77.23 m²
Total Road Area = 11,796.5 m²
Total Swale Area = 40,385.2 m²
Natural Infiltration = 24 mm/day
Rainfall = 40 mm/day @ 0.5 of 2 year 24 hour rainfall
Needs to Infiltrate: 40 + 40(17,985/40,385) = 157 mm
Can Infiltrate: 24 mm/day
Detention Required = 2,831 m²